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Update on Cotton
Production Research

Contents

Introduction

Ethiopia is not a big producer of cotton, but the government recently assigned cotton as a high priority crop for the country. A number of initiatives have been undertaken by the government to improve cotton production. The cotton area is scattered among small scale farmers as well as commercial growers but the Awash valley is the most productive and dominant cotton zone in the country. Cotton production can easily be extended to more areas, both irrigated and rainfed. The local textile industry has enough capacity to consume all cotton produced in the country. Ethiopia does not have its own breeding program and relies on germplasm received from other countries. Varieties developed in other countries are imported and adopted after a lengthy and cumbersome testing procedure which takes over 10 years. 57% of farms are fully mechanized, and animal traction is still used on 41% of farms. Inputs are available in abundance, and farming operations are well organized. Farmers suffer due to a lack of good varieties and proper advice for growing cotton successfully. The second article provides an analysis of the cotton situation in Ethiopia and also provides suggestions on how to improve cotton production.

Mali is the largest cotton producing country by area on the African continent. In 2004/05 only Egypt produced more cotton than Mali in Africa. Yields in Mali are less than half of what is achieved in Egypt. Yields in Mali are also lower than many other countries in the region. Cotton production is very important for Mali as almost one-third of the population directly or indirectly relies on income from cotton production. The variety development program is very strong. The Compagnie Malienne de Développement des Textiles –CMDT (Malian Company for the Development of Textiles) is the most important player in the country, responsible for the supply of inputs, transfer of technology, purchase of seedcotton from farmers and exports. Over 95% of cotton produced is exported. The first article reviews all aspects of cotton production in Mali and analyses reasons for low yields.

Helicoverpa armigera is the most wide spread pest on cotton. It is found in all major cotton producing countries and is notorious for developing resistance to insecticides, particularly pyrethroids. The resistance problem and its consequences are known in Australia and China (Mainland) where it became almost impossible to control the pest with an economical number of sprays. Following the serious problem of resistance in China (Mainland), the pest also seemed to become a problem in India and Pakistan. China (Mainland), India and Pakistan together planted half of the world cotton area in 1991/92 when *H. armigera* was becoming a major threat to cotton production in the region. The ICAC initiated a project in the region to deal with the problem. The project was managed and executed by the Natural Resources International Ltd., UK. The Common Fund for Commodities provided funding for this project with additional support from national governments in project countries. The third article describes the work undertaken in Pakistan under this project. The project also made significant achievements in India, China (Mainland) and the UK which will be discussed in one of the up-coming issues of the *ICAC RECORDER*.

The Technical Information Section of the ICAC has published a bibliographic search of the Agricola and CABI databases for many years. Searches on key words like stickiness, a quality character, insect, etc., were usually published in June and December issues each year. However, a search will not be published any more because the National Agriculture Library of the USDA has decided to provide Agricola free of cost on-line. The database is available free on-line at the National Agricultural Library web page at http://www.nal.usda.gov/index.html.

The 10th ALIDA meeting was held in Ibagué, Colombia from June 8-10, 2005. Close to 300 researchers from Argentina, Brazil, Bolivia, Colombia, Mexico, Paraguay, Peru, USA and Venezuela attended the meeting. Representatives from Delta and Pine Land Company Ltd., Plato Industries Ltd., International Cotton Advisory Committee and many private companies in

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Colombia also attended the meeting. The meeting discussed all aspects of production research and cotton situation in the region. The increasing population of whitefly in Colombia and high cost of production in the region were of special interest to many researchers.

The meeting elected new President of ALIDA until the next meeting. The new President of ALIDA is

Dr. Jorge Cadena Torres
Subdirección de Desarrollo Tecnológico Ecorregional
Corporación Colombiana de Investigación Agropecuaria
CORPOICA
Bogotá
Colombia
Phone: (57-91) 422-7347
Fax: (57-91) 422-7300
Email: <jcadena12000@yahoo.com.mx>

The next meeting of ALIDA will be held in two years either in Mexico or Venezuela. Researchers from both countries wanted to host the meeting but they needed to talk to their governments before making a firm commitment. ICAC will contact government authorities in both countries and host country for the next meeting will be announced at the ALIDA web page at <http://www.alida-algodon.org/>.

Cotton Production in Ethiopia

Ethiopia has 14 administrative states, and cotton is grown in 12 states in varying amounts. Most cotton is grown in the Awash River Basin of the Afar state. Climatic conditions are ideal for high cotton yield and good fiber quality. State-owned 'commercial growers grow most cotton although some small-scale growers have also survived and continue to grow cotton. The Awash River Basin has an annual evaporation/transpiration rate of 2,700 mm against an annual rainfall of 500-600 mm, thus requiring irrigation. All the agricultural lands in the Awash River Basin are irrigated. The Awash River Basin is divided into three areas: the Upper Awash River Basin, the Middle Awash River Basin and the Lower Awash River Basin. Vegetable and fruit crops outnumber cotton plantations in the Upper Awash River Basin where cotton is just getting established. The middle and lower regions are devoted entirely to cotton.

The Awash valley accounts for over 64% of the country's total cotton production. Other potential cotton areas include the Humera-Metema plains, Gambela, the Wabe Shebele River Basin and the Omo Valley. The main production areas for rainfed cotton, which accounts for more than 50% of total production, are located in the northwestern plains along the Sudanese border. Additional production areas are scattered in pockets all over the country, but the southern part is the most significant.

The state of Amhara planted as much as 50,000 hectares to cotton just a few years ago. Small growers in this state produce cotton without irrigation. Rainfed cotton is also grown in the Southern state. This region normally plants 30,000 hectares to cotton, and state farms run only one-tenth of the area. Currently, no cotton is grown in Somali state, although land is suitable for cotton production. Soil conditions and irrigation are ready and cotton is expected to gain ground in this state. Similarly, the Tigray state is also preparing to devote more land to cotton under rainfed conditions. Currently, cotton may occupy up to 5,000 hectares in this state.

There are 11 spinning plants, 11 gins and an unknown number of small oil expeller units in the country. The processing industries are working below capacity because of a shortage of raw material. According to the Ministry of Agriculture and Rural Development, the local textile industry had a consumption capability of over 40,000 tons of lint in 2003. However, due to lack of supply, it operated about 30% below capacity.

Planting Seed

The Seed Enterprise, a government institution responsible for input supplies and seed production for all crops, is in charge of producing quality seed and selling it to farmers. The Seed Enterprise has been producing certified seed for cereal crops (mainly wheat, sorghum and maize) but not for cotton. The Seed Enterprise began producing cottonseed on a limited scale in 2004. Farmers continue to rely on the seed available in the market, but no one knows the origin, purity and germination characteristics of this seed. The only planting seed that has at least some reliability and guarantee is the seed supplied by commercial growers. Commercial growers do not do any rouging to eliminate offtypes but they do decide, on the basis of field appearance, which fields look uniform enough for seed production purposes. Seedcotton from those fields is harvested, stored and ginned separately. The seed production industry was never established in Ethiopia, and although the Seed Enterprise seems to be seriously intent on producing cottonseed, it will probably be many years before Ethiopian farmers have access to quality seed.

Planting Cotton

Commercial growers cultivate their land while the soil is dry. Dry plowing is followed by disc plowing and land leveling before the furrows are made. Fields are pre-irrigated and when weeds germinate, a Lilliston cultivator is used to remove weeds from the tops of ridges. Commercial growers use 12-16 kg/ha of delinted seed for machine planted cotton. Small growers in regions where irrigation water is not available wait for the rains to come before starting land preparation for cotton planting. Most of the time the seed they use is not delinted and they plant by broadcasting seed. Some farmers, however, delint the seed themselves. When using delinted seed, farmers consume at least 16 kg/ha; if it is not delinted, the recommended amount is 35 kg/ha, which most farmers follow. The first irrigation is recommended at 21 days after emergence. Ridges are made and furrows opened before the first irrigation.

Almost 2% of all farms use only manual labor to cultivate fields and produce cotton, 41% use animal traction and the remaining 57% are fully mechanized. Some farmers intercrop cotton with food crops: beans, sorghum, maize and peas. Growers in Ethiopia do not follow long-term crop rotation protocols, and the one-year rotation followed on a limited scale is cotton-sorghum/sesame. Cotton is also rotated with maize and sweet potato but only on a small scale. There is also a tradition of growing cotton as a perennial crop in high altitude areas.

Cotton Research

Systematic research on cotton started with the establishment of the Werer Research Center in 1966 in the Middle Awash Valley. It started with screening of varieties, sowing date trials, irrigation regimes, crop rotations and studies related to pest attacks. However, research facilities, especially for fiber testing, were not available for a long time. Cotton research has passed through different organizational schemes and responsibilities. Currently, the Werer Research Center is the leading cotton research facility in the country. The Center has a mandate to work on fiber crops and over 90% of its activities are focused on cotton. The program is run under the Crop Research Directorate of the Ethiopian Agricultural Research Organization under the aegis of the Ministry of Agriculture. The Ethiopian Agricultural Research Organization is the highest autonomous government body and the largest specialized agency in charge of coordinating agricultural research activities in the country. The Ethiopian Agricultural Research Organization is primarily responsible for generating, improving and adapting technologies and coordinating, encouraging and assisting research activities with a view to fulfilling the country's current and long-term agricultural requirements. The program follows a multidisciplinary approach based on the integration of agro-ecology and cotton demand. Work has recently begun on facilities at the Werer Research Center to install a fiber quality lab, and some of the equipment has already been acquired. Currently, the core disciplines include breeding, agronomy, entomology and pathology. The most significant research achievements are: release of varieties for irrigated and rainfed conditions, determination of agronomic requirements, and the identification and description of bollworms, aphids, whitefly, leaf worms, jassids, flea beetle, stainers, leaf miner, seed bug and red spider mite. The biology of these insects has been studied to develop recommendations for appropriate insect control measures. Studies have been undertaken to identify various diseases and to recommend the relevant cultural and biological control measures.

Breeding

Ethiopia has no program of its own for the development of new varieties. All varieties currently grown have been imported from other countries. Ethiopia used to have a separate Ministry of State Farm Development, and as the key agency in cotton production it officially imported germplasm from other countries. The purchases were done government-to-government and a great deal of germplasm was imported during that period. In the absence of any formal method of importing germplasm from other countries, cotton breeders are now importing new germplasm exclusively through personal contacts. Once a variety is imported, breeders evaluate it at the Werer Research Center to determine its agronomic performance. Selected varieties proceed to preliminary yield trials followed by pre-national trials, each for one year, after which they are further tested for three years in national variety trials. Usually, no more than three varieties are selected for the national trials. Selections from previous years plus the three new varieties add up to no more than 10-12 varieties, including standards. Varieties selected from the national variety trials go on to one-year variety verification trials. Imported varieties are tested only for yield performance or, at most, for staple length. The data from the national variety trials is sent to the National Variety Release Committee and committee members visit the variety verification trials. The chairman of the Ethiopian Inputs Authority heads the National Variety Release Committee, and its members include experts in various fields of expertise.

It takes about 10-12 years to release a variety but the Ethiopian Agricultural Research Organization is considering how to shorten that period by 3-4 years. The appearance of certain fungal and bacterial diseases is related to weather conditions, and researchers do not want to take the risk of releasing varieties that are susceptible to fungal or bacterial diseases. Breeders are looking for short cycle varieties for two reasons: the crop does not require irrigation after September when the rains end; and crop maturity does not extend into cold weather conditions. The potential for insect pest resistance is continuously monitored throughout testing. All varieties are susceptible to wilt in flood-irrigated conditions. An Israeli variety, Gedera-236, has also been found to be susceptible under furrow irrigated conditions. Gedera-236 was imported directly from Israel, without testing, for commercial production in 2004/05. The Government of Ethiopia imported 240 tons of seed and a large area was planted to this variety, including some rainfed areas. The variety

Cotton Varieties Grown in Ethiopia

Variety	Ginning Outturn (%)	Length (mm)	Micronaire	Strength (tppsi)
Acala SJ2	34.1	28.6	3.2	79.3
DPL 90	34.8	27.7	3.7	77.3
Çukurova 1518	39.5	27.0	3.8	74.6
Arba	40.6	30.3	3.5	79.7

proved sensitive to water stress, as it had been developed for use under irrigation. The variety required irrigation at frequent intervals of 6-8 days, which was not possible, and farmers were disappointed.

Single plant selection from among introduced varieties has been tried without success so far. Most Turkish varieties perform well under Ethiopian conditions, except that they grow tall and lodging becomes a problem. States also have their own small-scale research programs but most of their work is limited to the implementation of trials directed by the Werer Research Center.

Insect Pests

All cotton in Ethiopia is sprayed with insecticides. The American bollworm *Helicoverpa armigera* is a major pest and affects cotton in all states. Out of a total of 8-9 sprays per season, 4-5 target the American cotton bollworm. Under typical crop conditions, two sprays are directed against whitefly and 2-3 sprays against aphids. Whitefly may appear early in the season or in the latter part of the crop cycle. Insecticide applications may also be required against spider mites, but only if they come early in the season. Efforts are made to control mites by spraying only patches affected by the pest. Insecticides use is avoided when mites appear late in the cycle, closer to maturity. While the American bollworm is a permanent pest throughout the cotton areas of Ethiopia, there is a lot of seasonal variation with regard to all other pests. Occasionally, thrips (*Caliothrips* spp) becomes a problem in the early stages and when it does, the crop has to be sprayed. Whitefly rarely becomes a problem in the rainfed areas but aphids do appear more frequently. Another less severe but common pest in rainfed areas is the flea beetle (*Podagrica* spp).

Excessive rains also lead to bacterial blight problems in the Southern State, in Gambela and in some parts of Amhara. Verticillium and fusarium wilts exist but do not cause significant losses in any of the production areas. The Lower Awash Basin areas have experienced a wilt-like disease for many years. Efforts have been made by local researchers on their own and in collaboration with the Natural Resources Institute of the United Kingdom to identify the organism responsible for this disease, but so far they have not been successful. No control measures have been taken but luckily the disease is not spreading to other areas. Wilting symptoms appear at squaring through to the boll formation stage and plants show symptoms similar to verticillium disease. Only individual plants are affected by this wilt-like disease instead of patches in the field. Incidence is usually high, averaging 76%, but research has shown that the average loss in yield in still less than 1%. Field observations have shown that plants may recover, but if the attack is more severe the plant may die.

Weeds are a big problem in Ethiopia. Herbicides are not used most of the time and manual or cultural operations are not enough to keep cotton fields clean. Weeds grow rapidly due to frequent rains during the cotton season, 500-600 mm of rain. A variety of weeds show up in the fields and some of the commonly occurring weeds are the following:

Narrow Leaf Weed	Broad Leaf Weeds
Eriocula fatumansis	*Xanthium strumarium*
Sorghum arundlaceium	*Chorchurus spp.*
Cyperus rotundus	*Portulaca Oleracea*
Cyprus esculantus	*Borehavia erecta*
Echinocloa colona	*Abutilon* spp.
Bracharia spp.	

Soil Fertility and Irrigation

The Afar state has chromic vertisols and alluvial soils which are good for cotton. Most soils used for cotton production in Ethiopia are naturally rich in nitrogen, phosphorous and potassium. Fertilizer is not recommended for cotton in spite of the mono-cropping system employed for many years, particularly in the Awash River Basin. Some reports claim that research has not detected any impact stemming form fertilizer application. Fertilizer used to be applied at the rate of 50 kilograms of nitrogen until the early 1990s, but not any more. Field performance indicates that yields are declining in general, and that it could be due to nutrient imbalance stemming from a macronutrient deficiency, but no serious analysis has been undertaken. It is believed that irrigation water carries some nutrients, but no data are available to support the claim.

Estimates suggest that 88% of the cotton area does not get any synthetic fertilizers. The remaining 12% of the area, if fertilized at all, gets only 46 kg/ha of nitrogen and 16 kg/ha of phosphorous. Fertilizers, when applied, are usually split into 2-3 doses. Fertilizers are available through the public sector but they may also be acquired in the open market. The Agriculture Bureau has offices throughout the country and plenty of fertilizer is available both in the open market and through Bureau outlets. The Agriculture Bureau is willing to sell fertilizer on credit just to move its stocks. The Agriculture Bureau is responsible for the transfer of technology and thus has direct contact with growers. It uses its relationships to sell fertilizers. The price of fertilizers is fixed and remains almost the same wherever farmers choose to buy them.

Furrow and flood methods are used to irrigate cotton where water is available for irrigation. Furrow irrigation is used in the Upper Awash River Basin and the two water quantities recommended are 75 mm every two weeks or 125 mm every three weeks, depending upon the availability of water. Pre-planting irrigation is recommended at the rate of 120 mm of water. The Lower Awash River Basin is flood irrigated and there are no quantity recommendations. On average cotton is irrigated five times a season.

Ginning

All ginning is done on saw gins, most of which are old. There are 11 ginneries owned by commercial growers and private companies. Small growers sell their seedcotton to private ginners but commercial growers usually opt for custom ginning. The average cost of ginning 100 kg of seedcotton is approximately US$4. Most gin stands employ 132-140 saws and have a ginning capacity of 75 tons of seedcotton/day when operating around the clock. The ginning season lasts almost six months or even longer at some gins. Many gins perform a stickiness test to make sure that cotton is not highly sticky.

One pre-cleaning is used to get rid of trash, which averages about 4%. All cotton is hand picked in Ethiopia and this would appear to be the reason why trash content is so low. Cotton is manual classed into six different grades: Strict Low Middling, Middling, Middling to Strict Middling, Strict Middling, Strict Middling to Good Middling and Good Middling. Most cotton falls in the category of Middling and Middling to Strict Middling. Lower micronaire is a common problem related to low maturity. Acala and DPL measure about 4.0. Bales display no classing information but carry instead a bale number, lot number, farm name, bale weight and year of production. A few ginneries may add a grade tag. Pre-classification of cotton starts at the farm level where clean cotton is separated from the rest.

Cost of Production

There is wide variation in the cost of production among growers. Commercial growers have a greater number of mechanized farming operations, use better quality seed, are better informed about production technology and have the financial resources needed to buy inputs. Average yields are always higher at commercial farms as compared to small growers. The following is the average cost of production for irrigated commercial farms in Ethiopia.

Average Cost of Production in Ethiopia

Operation/Item	Cost in US$/ha
Land rent	295.0
Ploughing	30.9
Planking	15.1
Land preparation for sowing	28.9
Seed @18 kg/ha	14.6
Drilling	15.4
Labor	19.7
Thinning	1.5
Manual weeding	26.1
Hoeing	41.7
Irrigation	26.6
Insecticides	66.5
Picking	69.4
Stick cutting	3.9
Transportation to gin factory	52.1
Ginning	131.9
Fiber testing	3.5
Management and administration	153.7
Repairs	19.3
Fixed costs (Irrigation, power, machinery)	18.3
Others	135.7
Total	1,169.6

Issues for Consideration

The soil is rich and climate conditions are suitable for growing cotton. In spite of this, cotton production has not expanded in Ethiopia. The Government of Ethiopia has recently categorized cotton as a strategic crop and has drawn up an ambitious plan to quadruple cotton production by 2009. A number of issues require immediate attention. If they are successfully dealt with yield, could improve significantly and bring more area into cotton production.

Land Leveling and Water Management

Land is not properly leveled, particularly in the irrigated areas, which results in uneven distribution of irrigation water and thus, great variation in yield within a given field. If the land leveling that is done were improved, it could result in significant yield increases. Enough water is available in irrigated areas, but it is not properly managed. The quantity of water applied does not comply with recommendations from researchers. Water use efficiency is low and there is a need to improve both the efficiency and effectiveness of irrigation water.

New Varieties and Planting Seed

Ethiopia must start its own cotton hybridization program. The germplasm supply from other countries is limited and growers do not have the choice of growing varieties developed for Ethiopian conditions. Imported varieties are tested over a very long period, longer, in fact, than the time during which the variety has already been grown commercially in the country of origin. It is quite possible that genetic deterioration could have occurred during that time. Ethiopia must initiate its own hybridization program to develop varieties of its own that will be suitable for local conditions and to establish a good planting seed production system.

Weed Control

Weeds start to become a problem soon after the first irrigation or after the first rains in rainfed conditions. Weed control is poor in Ethiopia because of the frequent rains, and weeds take a very heavy toll on the crop. Efforts are made to remove weeds mechanically and manually, but they are not enough to keep the fields weed-free. Commercial growers may use herbicides, but only occasionally and on a limited scale. Experimental work has already been undertaken and it is time for the government to make the decision to start importing herbicides.

Soil Fertility

Soil tests have been performed that seem to indicate that there is no need for NPK applications, although they have found a zinc deficiency in most soils. Zinc is not applied and the general recommendation for cotton, irrespective of growing conditions, is that there is no need to apply fertilizers. However, the utility of using NPK fertilizers must be reassessed. Cotton is grown in a mono-cropping system in most areas and the general recommendation must be replaced with site-specific recommendations to ensure better nourishment of the plants.

There is also the possibility that fertilizers may fail to respond adequately as a result of poor weed control. Fields must be clean to assess the real impact of fertilizers.

Integrated Pest Management

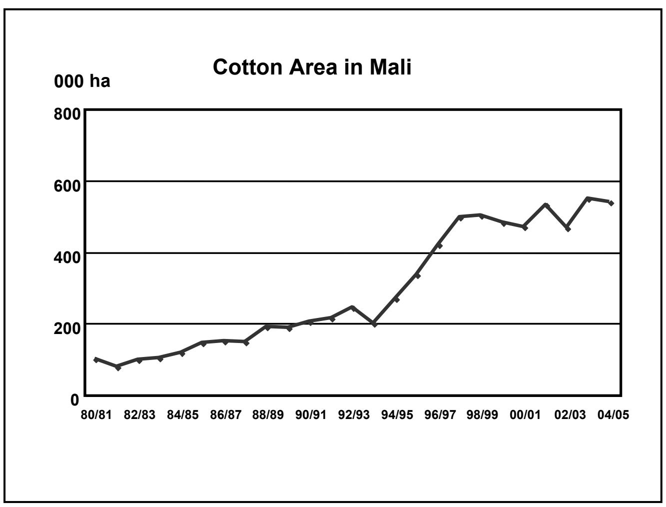
Insecticide use is high compared to the current yield level in Ethiopia. There is a need to reduce the number of insecticide applications per season and adopt less expensive control measures. Insecticide applications do have an impact, but in the case of Ethiopia, where yields have failed to increase for various reasons, higher insecticide use is a disincentive for growers to expand cotton area. Lower production costs would encourage growers to plant more cotton. Integrated pest control measures should be promoted and solutions must be found to problems like unidentified wilt diseases.

Transfer of Technology and Coordination

The current technology transfer system requires a complete overhaul. Farmers have no access to properly developed technical information or to technology packages that are specially put together for farmers to be able to achieve higher yields. Coordination within various research disciplines at the Werer Research Center is satisfactory, but there is no coordination among the various segments of the cotton industry at the national level. It is essential to improve transfer of technology and to establish a coordinating authority for cotton development and marketing at the national level.

Cotton Production in Mali

Mali devotes more area to cotton than any other country in Africa. On the average, more than half a million hectares are planted to cotton and more than three million Malians—a third of the population—depend on cotton. Mali is emerging as the largest producer of cotton in Africa. Currently, it is falling short of that mark due to low yields despite having a cotton area that is almost double that of Egypt. Cotton lands in Mali are divided into two main production regions/areas, the Southern region and the Western region. The Southern region accounts for about 90% of the total area. Cotton production dates from ancient times in this area, which is characterized by better technology and comparatively higher yields. Average annual rainfall ranges from 700 mm to 1,300 mm. Population density is high and the region employs intensive farming practices. The Western region is comparatively new for cotton Average rainfall is 800 to 1,000 mm, and production is still characterized by extensive farming practices.



Compagnie Malienne de Développement des Textiles (CMDT)

The Compagnie Malienne de Développement des Textiles – CMDT (Malian Company for the Development of Textiles) is the country's most important player in the cotton Industry; they handle input supplies, local purchases, ginning and exports of cotton. CMDT contacts growers every year prior to planting to know how much cotton they intend to plant and supplies them with the corresponding planting seed, fertilizers and insecticides.

In addition to CMDT, there is one smaller company that deals with cotton, the *Office de la Haute Vallée du Niger* – OHVN (Office of the Upper Niger Valley). The OHVN supplies inputs to farms on about 30,000 hectares, but it must purchase them from CMDT and thus operates like its agent. Furthermore, the Office of the Upper Niger Valley does not have its own ginning facilities, so farmers have to sell their cotton to CMDT. Both OHVN and CMDT deal with other crops like sorghum, maize, millet and peanuts, but cotton is the main concern for both.

CMDT has divided the cotton producing area into six regions: Fana, Koutiala and San in the north, Bougouni and Sikasso in the south and Kita in the west. Each sector is a full-fledged facility, with a ginning factory, warehouse, fiber quality lab, (except San and Bougouni), technicians and office staff that deals with all the cotton produced in about 200 villages in the area. CMDT has a technical staff for each village association to help to transmit messages and recommendations from CMDT directly to cotton growers. Village associations also employ technical staff to advise farmers in cotton production technology. Each sector has a trainer that organizes training courses for both farmers and CMDT agents to update them on recent changes in production technology and on new varieties.

Fertilizer Use

Cotton picking begins in the 3rd week of October. This is the time when CMDT starts collecting cotton from farmers and delivering fertilizers to them for the next season. Fertilizer is supplied to growers either as a complex fertilizer or as urea. Previously, the complex fertilizer used to be $14N+22P_2O_5+12K_2O+7S+1B_2O_3$ but lately it has been changed to $14N+18P_2O_5+18K_2O+6S+1B_2O_3$. On average, farmers apply 150 kg/ha of complex fertilizer, although researchers recommend using 200 kg/ha. Farmers who decide to plant cotton early, and progressive growers usually apply 200 kg of complex fertilizer. Almost all growers apply Urea at the rate of 50 kg/ha. The price of fertilizer is the same for all growers whether close or far from CMDT offices.

Cotton planting starts from the 3rd week of May in the southern regions when the rains come early, and almost no fertilizer is applied before or at the time of planting. Most farmers apply fertilizer 15-20 days after sowing, when the cotton plants reach a stage where they can withstand some drought. Whenever, farmers choose to apply complex fertilizer, it is usually applied in a single dose whether it is 150 kg or 200 kg per hectare. All urea is applied 35-40 days after sowing (and at the time of complex fertilizer application in the northern parts of the cotton area). Land holdings are small and all fertilizer is applied by hand. As all cotton is grown under rainfed conditions, fields are cultivated after fertilization, even when it is dry. Researchers recommend that fertilizer be applied on wet fields because there is no certainty of rain. Fertilizers are available to all growers and they are supposed to use them, but there are still many cotton growers who are not fully aware of the benefits or of the consequences of not using fertilizers. Organic fertilizer is not popular, but if any is used, it is applied at the time of planting. Organic fertilizer use is widespread only where there is livestock near by. Due to the amount of work involved, only a small percentage of cotton fields receive manure each year. It is applied before sowing, and usually in very high amounts (up to 50 tons/ha). In the older production areas, almost all crop residues are collected from fields to feed cattle or to make compost that is returned to the fields. Farmers are beginning to realize the need for organic manuring, and the practice is becoming increasingly popular.

Insects and Insecticides

Entomological research has three main areas of concern: verifying and monitoring the incidence of various pests every year, testing new pesticide products, and monitoring resistance. The American bollworm *Helicoverpa armigera* is the most serious pest in Mali. Other bollworms that damage cotton are *Earias insulana* and *Diparopsis watersi*. Commonly occurring leaf worms are *Sylepta derogata* and *Spodoptera littoralis*. Among sucking insects, *Aphis gossypii* and *Bemisia tabaci* may also appear close to the boll maturity stage. All cotton is sprayed with insecticides and the average number of sprays depends on the quantity of insecticides supplied by CMDT. It is estimated that 93% of the cotton area gets four sprays. Less than 5% of the area is treated with insecticides more than 6 times a season. The West African countries have been implementing a regional insecticide resistance management program for many years. The national cotton companies in various countries financed the regional program, which was very successful in implementing expert recommendations and dealing with resistance. In Mali, it is recommended that the first two sprays be made with endosulfan or profenophos and the other two with cypermethrin, especially if they are targeting cutworms or if whitefly becomes a real problem.

Researchers recommend spraying insecticides five to six times during the season. But, if crops are planted early, around mid-May, which extends the growth period, it is quite possible that seven or eight sprays may be required. Researchers monitor the pest situation every year throughout the growing season, but this information is not used to determine the number of insecticide sprays. Farmers neither evaluate nor employ economic thresholds for various pests. Scheduled spraying is officially recommended by experts. The recommended insecticide application schedule is as follows:

Spray	Application Time
First	35 days after planting
Second	50 days after planting
Third	64 days after planting
Fourth	78 days after planting
Fifth	92 days after planting

Diseases are not significant in Mali and no control measures are taken to protect cotton. The occasional diseases that may sometimes appear and cause minor losses are seedling disease, boll rot, bacteriosis, alternaria leaf spot and Rhizoctonia caused by *Rhizoctonia solani*. Excessive rains and prolonged high humidity are responsible for the occasional appearance of diseases.

Breeding

The breeding team has three lines of action: hybridization for the purpose of developing new varieties, extensive testing of new strains and seed production. In addition to seeking higher yields, breeding objectives include high ginning outturn, with a minimum of 43%, but preferably closer to 46%. Breeding lines are tested on roller gins, but as the material advances to strains, testing is done on small saw gins and most varieties yield 43-46% lint. Genotypes with less than 44% lint in the new breeding material are rejected unless they have some special characteristics. Staple length is usually achievable close to the target of over 28 mm. Micronaire is not a problem either and most breeding material falls between micronaire values of 3.8 to 4.2. However, yellowness is a big challenge for breeders. The +b value usually exceeds 10 and breeders must strive to improve cotton color in Mali.

Hybridization among adapted and high-yielding genotypes is done every year. The F_1 and F_2 populations are grown in bulk.

Single-plant selection is done on the F_2 population. Under normal conditions, out-crossing ranges from 8-12% in Mali. Thus, it is imperative that selfing is done to maintain seed purity, particularly in the segregating populations, when heterozygous plants are standing in close proximity to other heterozygous plants. Single-plant selection in the F_2 population begins soon after flowering starts and target plants are selfed regularly. Selected single plants are evaluated for fiber quality and other observable characteristics, but not for yield, which is based on the morphological performance of the plant in the field. This is done because only self-seeding is used for planting the next generation and it is not possible to self all flowers from the beginning to the end of the season. Selfing continues from F_2 to F_7 until homozygous lines are achieved. During this process single-plant selection is done within the better performing progeny rows. Some single lines are also bulked in F_7 if they seem to be performing similarly. Seeds from single progeny or bulked progeny rows in F_7 are assigned a name for yield testing in F_8. Visual observations, boll weight and boll numbers are used for assessing yield performance up to F_7.

On average 10-12 varieties are selected for yield trials from one year-hybridization. Yield trials are conducted for four years. The first year trials are done only at the research station and under the direct supervision of breeders. The number of varieties is reduced to eight in the second year. Replicated trials are conducted at the main research station in Sikasso and at four sub-stations in different ecological conditions, but still under the direct supervision of breeders. The number of varieties is reduced to only six in the third year and trials are extended to farm fields in addition to the research station and sub-stations. Six to twelve farm field locations are selected for the third year trials. The fourth year trials are conducted at more than 30 locations, but the number of varieties is reduced to only 1-2. The first year trials have four replications in a complete randomized block design. The number of replications increases as the number of varieties is reduced in the following generations. The second year trials have six replications, which increase to eight in the third year. The fourth year trials have only two replications but the length of the five rows is increased to 50 meters. Only the three central rows are considered for yield and quality evaluation.

Variety Approval and Seed Production

Breeders are responsible for developing new varieties but their acceptance as commercial varieties is at the discretion of CMDT. All cotton breeders belong to the Institut d'Economie Rurale – IER (Institute of Rural Economy) and they work with the national cotton program leader based at the Regional Agronomic Research Center, Sikasso. CMDT monitors the performance of varieties during the trials and may stop breeders from carrying out trials on any variety it would not like to commercialize. CMDT sometimes takes seed from breeders and even performs its own trials to expedite commercialization of a particular variety. Cotton breeders are responsible for producing basic seed for multiplication, and commercial scale multiplication is done directly by CMDT. The seed production process is lengthy in Mali and passes through seven different stages. These stages reflect not only the multiplication status but also the quality of the seed.

Planting seed is delinted mechanically. The recommended seeding density is 40 kg per hectare and this is the amount that is supplied by CMDT. Growers set aside some seed for replanting. In general, a grower plants three hectares to cotton, which is almost 30% of the average farm. Cotton is planted in a configuration of 80 x 30 centimeters with two plants at each spot. It is estimated that 80% of the crop is planted mechanically with planters while 20% is planted by dibbling at 5 seeds per hill. The first thinning is done at 15-20 days after emergence followed by

Planting Seed Production in Mali

G-1

This is produced at the research station and only selfing all flowers.

↓

G-2

This category is produced in isolated blocks, no selfing but produced under direct supervision of breeder.

↓

G-3

This category is produced by breeders but at farmers' field in isolated blocks. Seed thus produced is handed over to CMDT.

↓

G-4

CMDT produce this category at farmers fields in isolated blocks.

↓

R-1

CMDT extend multiplication to a village level or much bigger block compared to G-4. It is still seed production, not a commercial production.

↓

R-2

This is the seed which is planted by most growers in Mali. Seed supplied by CMDT.

↓

R-3

Some growers plant this quality.

↓

R4

This is not planted, it goes into crushing.

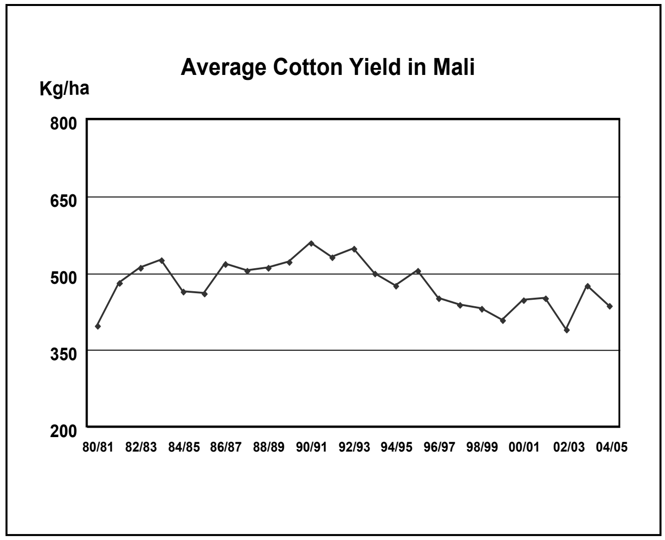
an application of NPK complex fertilizer. Second cultivation and first sprays usually go together. Earthing up is done when flowers begin to appear. 80-90% of farmers use herbicides and two cultivations. Farmers who do not use herbicides usually cultivate their fields three times. Fields are usually clear of weeds. Eighty percent of growers use pre-emergence herbicides, while 10% use post-emergence herbicides.

Cotton Ginning

There are 17 ginning factories and all are operating. One more is being built and was supposed to begin operations at the end of March 2005. Three of the ginning factories are equipped with Continental Eagle machinery while the others use machinery supplied by Lummus. All ginning factories are owned by CMDT. Most factories have four gin stands but the number of saws varies (88, 130 and 158).

Farmers weigh their cotton and turn it over to the village association. CMDT works with village associations to pick cotton and take it to their sector headquarters where their ginning facilities are located. Every farmer knows how much cotton he produced and delivered to the village association. The village association collects all the cotton at one point where it is received by CMDT. CMDT pays the agreed price to the village association when it takes charge of the cotton. However, CMDT cannot take charge of all the cotton at one time because it does not have the facilities to store that much cotton, so village associations usually have to wait months before they are able to turn all the cotton over to CMDT. The village associations, in turn do not pay the farmers until CMDT has taken the cotton off their hands and paid them. CMDT pays 5,900 Francs CFA (about US$11.0) per ton of seed cotton to the village association for its services. With this money the village association is able to maintain a small staff to record all entries and handle the cotton on behalf of farmers. CMDT has its own agents (about 500) based in the villages to work with the village associations to ensure that operations flow smoothly from supply of inputs to sale of seedcotton.

Cotton is classed in ten grades: Sarama, Juli/s, Nere, Juli, Kati, Kati/c, Liba, Liba/C, Kola and Bata. Color, trash and preparation are the criteria used in grading cotton. Mali does not have an HVI system but is expected to have one before the 2005/06 harvest. Currently, an average of one sample from each 100 bales is collected and sent to an outside lab for instrument testing. From the initial 20% of total ginned production, one sample is taken for every 25 bales; from 20% to 50% of production, one sample is taken for every 50 bales; from 50 to 75% of ginned production one sample is taken for every 100 bales. When almost 75% of the cotton has been ginned, a 200 gm sample is taken for every 200 bales for HVI analysis to be done in France or elsewhere. Test data is not passed on to cotton buyers but used to verify local grades. Cotton is wrapped in plastic or cotton fabric. It is estimated that 30% of total production in 2004/05, was wrapped in cotton fabric. The cost-benefit ratio of using cotton wrapping will be analyzed at the end of 2004/05 and if it is economical, all cotton bale wrapping will be done with cotton fabric. Almost all cotton produced in Mali is exported, and CMDT, through various outlets, is the sole exporter of cotton. Domestic consumption currently ranges between 2 and 5%.



Why Are Yields Falling?

Average yields in Mali have fallen over the last 15 years. It is estimated that the average lint yield for 2004/05 will be 441 kg/ha. Yield improved slightly during the early 1990s, but due to an insecticide resistance problem, yields started to decline by 1993/94. The main reason for stagnation in yields is that the farmers' cotton growing know-how has not improved. Farmers do not have the option of choosing a particular variety and must plant whatever seed they receive from CMDT. Similarly, fertilizers and insecticides are supplied exclusively by CMDT and farmers apply them according to the schedule provided by the technical staff of CMDT. All cotton is rainfed so farmers do not have to worry about irrigation schedules. Consequently, farmers are not involved in the decision-making process and their understanding of cotton production practices is not improving. The decisions left for the farmers to make have little impact on cotton yields. Most farmers follow the same practices and use similar inputs; thus variation in yields among Malian farmers is not high, as opposed to most other countries where farmers choose varieties and decide the quantity and time of application of fertilizers and insecticides.

Yields are also falling due to poor soil fertility. Intensive farming, together with the lack of supplements from farmyard manure or green manuring, seem to be depleting organic matter in soils. Farmers commonly complain about insufficient rains and the high cost of farm machinery and equipment, but such complaints are no different from those heard in any other low-yield country.

Biotech Cotton

Biotech cotton has not been approved in Mali. Burkina Faso's decision in July 2003 to test biotech varieties is an incentive for Mali to begin thinking about biotech cotton. Since *H. armigera* is a serious pest and responsible for most insect-related losses, biotech varieties could help reduce insecticide expenditures and increase yields through better plant protection. No decision has been made, but the issue is being discussed at various forums. In the next couple of years, we'll be witnessing a number of activities in the region that may help the government to make a decision. Mali has grown varieties developed in other countries of the region, and if biotech cotton were approved, it would have to be commercialized through local varieties. A lot of information is already available on the web page of the Institut d'Economie Rurale at http://www.ier.ml/ and it seems the decision is not far away.

Insecticide Resistance in *Helicoverpa armigera* in Pakistan

Muhammad Islam Gill and Mushtaq Ahmed
Central Cotton Research Institute, Multan, Pakistan

Most of the work reported in this article is the result of a project entitled "Sustainable Control of the Bollworm *Helicoverpa armigera* in Small-Scale Cotton Production Systems" (CFC/ICAC 14). The project was sponsored by the International Cotton Advisory Committee, funded by the Common Fund for Commodities and executed with the collaboration of institutions in China (Mainland), India, Pakistan and the UK. Natural Resources International Ltd, UK, managed the project on behalf of ICAC.
Only the work done at the Central Cotton Research Institute, Pakistan, is reported here.

The *Helicoverpa armigera* Problem

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) occurs around the world. It is variously known as gram caterpillar or pod borer, cotton bollworm, corn earworm and tomato fruit worm. It is a very harmful pest and attacks many crops such as cotton, sunflower, tomato, peas, wheat, maize, tobacco, lucerne, potato and other crops. *H. armigera* has been a cotton pest in Pakistan for a long time and only occasionally constituted a serious problem. However, it emerged as a regular pest on cotton and other crops in 1990, almost all year round in many areas of the country. Among other factors, indiscriminate use of pesticides, especially on cotton, is thought to have prompted the outbreaks. The major occurrences of *Helicoverpa* on cotton in Pakistan were in 1977, 1983, 1990, 1994, 1997 and 1998. The *H. armigera* outbreak of 1990 came together with poor control by many recommended insecticides. The use of insecticides since 1980, particularly pyrethroids and organophosphates to control the insect pest complex in Pakistan in cotton has been phenomenal, and this may be the facilitating factor in the development of resistance in *H. armigera*. The resistance problem is alarming and poses a great challenge.

Helicoverpa armigera: Resistance to Insecticides in Pakistan

In Pakistan, *H. armigera's* resistance to cypermethrin, endosulfan and monocrotophos was first recorded in 1991 (Ahmad *et al*., 1995). Later, widespread resistance to pyrethroids (Ahmad *et al*., 1997, 1998), organophosphates (Ahmad *et al*., 1999) and carbamates (Ahmad *et al*., 2001) was reported. The development of resistance led to the severe outbreaks of *H. armigera* that drastically reduced cotton yields in Pakistan.

From 1991 to 1993, resistance was moderate to cypermethrin and cyfluthrin, low to alpha-cypermethrin, zeta-cypermethrin and deltamethrin, and very low to lambda-cyhalothrin and bifenthrin. In 1994, there was a heavy outbreak of *H. armigera* on cotton, which prompted farmers to apply pesticides frequently, especially pyrethroids. Consequently, resistance to cypermethrin, cyfluthrin, alpha-cypermethrin and deltamethrin rose to high levels in subsequent years. Resistance to zeta-cypermethrin and lambda-cyhalothrin remained low during 1994 and 1995, but it also became high during 1996 and 1997 following increased use. Bifenthrin resistance was low even up to 1996, but became moderate in 1997. Endosulfan resistance was low from 1991 to 1993 and also became high from 1994 to 1997. Resistance to profenofos and chlorpyrifos remained low up to 1995, but rose to moderate levels in 1996 and 1997. With the various management strategies implemented for cotton pests during the period, resistance to organophosphates and carbamates was reduced to the current low levels, but it still remains very high to all the pyrethroids (Ahmad *et al*., 2004). The introduction of new chemicals did help manage this pest recently, but there are now signs of the development of resistance to these novel compounds in the populations of *H. armigera* found in Pakistan. (Ahmad *et al*., 2003).

Research on Insecticide Resistance in *H. armigera* under the Common Fund for Commodities/International Cotton Advisory Committee Project:

Monitoring of Insecticide Resistance in *H. armigera*

Baseline susceptibility data of new chemicals for the susceptible German strain

A susceptible strain of *Helicoverpa armigera* known as the "German strain" received from Bayer CropScience, Germany, was used to calculate baseline LC_{50}s of new chemicals for use in insecticide resistance monitoring. The baseline LC_{50}s of indoxacarb, spinosad and abamectin for the susceptible German strain are close to those already determined for the Pakistani field populations of *H. armigera* (Ahmad *et al.*, 2003). However, the LC_{50}s of chlorfenapyr and emamectin benzoate for the German strain are much lower than on the Pakistani populations. The baseline LC_{50} values for methoxyfenozide were determined.

Insecticide resistance in field populations of *H. armigera*

Insecticide resistance in *H. armigera* was monitored from 2000 to 2004. Resistance to endosulfan declined during 2003 and 2004, but is still at moderate levels. This correlated with a drastic reduction in endosulfan use in Pakistan due to its decreased efficacy in controlling *H. armigera* and sucking pests.

Resistance of *H. armigera* to all pyrethroids remained very high. This is due to the fact that pyrethroid use did not decrease. In the last five years, the impact of spotted (*Earias vittella*) and pink (*Pectinophora gossypiella*) bollworms has increased dramatically. Pyrethroids were the best chemicals with which to control these pests and therefore continued to be used on cotton extensively. Resistance to bifenthrin was always low in *H. armigera* as compared to other pyrethroids. This may be due to its unique chemical structure, which differs from that of other pyrethroids both in the acid and alcohol part of the molecule. The bifenthrin molecule is considered to be less prone to oxidative attack.

Surprisingly, *H. armigera*'s resistance to monocrotophos has increased again in spite of the fact that it is no longer being used in Pakistan. It may be a cross-resistance resulting from mechanisms developed against other insecticides. For similar reasons, phoxim resistance is also on the increase; this compound is not yet marketed in Pakistan. Resistance to thiophosphorates such as profenofos, chlorpyrifos and triazophos has dropped to very low levels. Thus, these insecticides can now be alternated for effective control of pyrethroid-resistant *H. armigera* populations. Likewise, resistance to methomyl has dropped to almost susceptible levels, and there has never been a significant problem with resistance to thiodicarb.

Tolerance to new chemicals such as spinosad, abamectin, emamectin benzoate and chlorfenapyr is still negligible, and therefore no field failures have yet been reported. However, there are now signs of a low level of resistance to indoxacarb, which is a source of concern.

The findings of the last five years indicate that the serious resistance problem in *H. armigera* in Pakistan is only in connection with pyrethroids. This resistance problem can be successfully tackled by the rotational use of still-effective organophosphates, carbamates and new chemicals, to which no cross-resistance has been developed due to their contrasting modes of action. Thanks to the effective dissemination of project results, this is actually happening under field conditions in Pakistan. For the last five years, growers have been managing *H. armigera* well with non-pyrethroid insecticides, and we have not encountered any outbreaks of *H. armigera* in cotton or in any other crop. Consequently, we were able to harvest a bumper crop of cotton in Pakistan last year with 2004 yields 50% higher than the previous year.

Cross-Resistance Patterns

Mechanisms of decreased cuticular penetration and enhanced metabolism in Asian *H. armigera*

Experiments were undertaken at Rothamsted Research, UK, to determine if Asian populations of *H. armigera* exhibited the mechanisms of reduced cuticular penetration and enhanced metabolism of insecticides. The penetration and metabolism of [^{14}C] deltamethrin was studied in both susceptible, and resistant Chinese and Pakistani strains of *H. armigera,* which were resistant to deltamethrin by 330- and 670-fold respectively. The penetration of deltamethrin into resistant larvae was significantly slower than into susceptible larvae over a 24-hour period. It took one hour for 50% of the applied deltamethrin to penetrate the susceptible strain and six hours to penetrate both the resistant strains. The larvae of resistant strains reduced internal radioactivity much more quickly than susceptible larvae. At 48 hours, 40% of the penetrated deltamethrin was still inside the larvae of the susceptible strain as opposed to 1.5-5% in the Pakistani strain and 8-14% in the Chinese strain. Both of the resistant strains produced methanol-soluble as well as water-soluble metabolites but the susceptible strain produced methanol-soluble metabolites only. Twelve, 24 and 48 hours after dosing, the amount of methanol-soluble metabolites excreted by the resistant strains was almost double that of the susceptible strain. Both of the resistant strains also excreted 5-7% of the penetrated dose as a water-soluble metabolite after 48 hours. In comparison with the Chinese strain, the Pakistani strain exhibited slower penetration, lower internal content and faster excretion of deltamethrin, which correlated with the higher resistance of the Pakistani strain. These findings show that the resistant Pakistani and Chinese strains of *H. armigera* possessed mechanisms of reduced cuticular penetration and enhanced metabolism for deltamethrin and perhaps for other pyrethroids.

The mechanism of reduced penetration in insects, on its own, usually produces only a minor shift in phenotypic response, but in the presence of other mechanisms, particularly metabolic detoxification, as was the case in the strains investigated in this study, it produces a major effect because it reinforces other resistance mechanisms by combining with them in a multiplicative manner, i.e., the reduced penetration mechanism keeps more material outside the insect's body while metabolic mechanisms degrade the amount of compound that does penetrate. Thus, even with a higher toxic threshold level of insecticide, the presence of a target-site sensitivity mechanism may prevent a lethal quantity of the toxicant from ever accumulating at the target site.

Implications of the Use of Insecticide Mixtures

Insecticide mixtures are often used to increase the spectrum of control against a pest complex. Due to their different modes of action, pyrethroids and organophosphates have usually been mixed to control sucking and bollworm pests simultaneously. In the present study, different pyrethroids were mixed with organophosphates individually in the ratio of their LD_{50}s or LC_{50}s. These values were calculated by probit analysis (Finney, 1971) and their co-toxicity coefficients (CTC) computed (Sun and Johnson, 1960).

Fenvalerate

When mixed with fenvalerate, triazophos produced a potentiation interaction in *H. armigera* but profenofos and monocrotophos produced antagonism.

Deltamethrin

A deltamethrin + phoxim mixture was synergistic in two populations but antagonistic in one and additive in a third population. A deltamethrin + methamidophos mixture was synergistic in one population but antagonistic in two populations. Monocrotophos produced an additive effect with deltamethrin.

Cypermethrin

Cypermethrin mixed with phoxim or methamidophos or monocrotophos produced either an antagonistic or an additive interaction.

Bifenthrin

All the organophosphates (phoxim, profenofos, quinalphos, triazophos, monocrotophos and methamidophos) exhibited antagonism when mixed with bifenthrin.

Cyhalothrin

A cyhalothrin + phoxim mixture produced synergism in two populations whereas it was additive on one population and antagonistic on another population. A cyhalothrin + profenophos mixture had an additive impact on two populations but was highly antagonistic on two other populations. Quinalphos mixed with cyhalothrin produced an additive effect on one population, an antagonistic effect on two populations and a slightly synergistic effect on one population. The cyhalothrin + triazophos mixture had a potentiation effect on one population but an antagonistic effect on three populations. Monocrotophos also produced very high antagonism with cyhalothrin. Cyhalothrin + methamidophos was additive on two populations but antagonistic on a third population.

Betacyfluthrin

Phoxim and profenophos were both antagonistic in conjunction with betacyfluthrin. Quinalphos had an additive interaction with betacyfluthrin, but methamidophos was synergistic.

The above findings revealed inconsistent trends. The same mixtures behaved differently in different populations. It seems that the potentiation or antagonism interaction of a given mixture was dependent upon the underlying resistance mechanisms present in the treated populations. Thus pyrethroid + OP mixtures are not a good option, at least not for resistance management. They are hardly able to suppress one metabolic mechanism i.e. detoxification by esterases. When that mechanism is suppressed, other mechanisms are selected, which are then insensitive to both compounds in the mixture. So, mixtures give rise to multiple resistances that may extend across other chemical classes and that are difficult to manage.

Laboratory Measured Resistance versus Field Control

Methodology

Three insecticides, endosulfan, cypermethrin and spinosad, were evaluated for their efficacy against *H. armigera* both in the field and in the laboratory. In the field, 1/10, 1/3, 3 and 10 times the field doses of these insecticides were applied along with their standard doses.

First instar larvae of *H. armigera* were collected in large numbers from the same locality. These larvae were fed singly on an artificial diet for about 5 days. Of these, 2400 larvae weighing 10-20 mg (3rd instar) were selected and released @ 100 larvae per treatment plot of cotton (25' x 30') at the Central Cotton Research Institute (CCRI), Multan. In all, 24 plots were used for six treatments, including the unsprayed control, in four replicates and larvae were released on 100 central plants in each plot. These plants were isolated by pushing the surrounding plants away slightly before releasing the larvae to minimize their escape onto the adjacent plants. The experiment was laid out in a randomized complete block design. The plots were sprayed after 24 hours with selected doses of each insecticide. Mortality was recorded by counting live larvae 48 hours after spraying.

One hundred field-collected larvae weighing 30-40 mg (4th instar) were treated topically with a discriminating dose of a particular insecticide. These larvae were kept singly on an artificial diet in the laboratory and their mortality was recorded after 48 hours. Larvae were considered dead if they failed to make a coordinated movement in response to touching. Surviving larvae found in plots sprayed with standard field doses of insecticides were collected and given topical application with the discriminating doses in the laboratory. Mortality was recorded after 48 hours to determine post-treatment resistance levels.

Results

Cypermethrin

Under field conditions, the field dose rate of cypermethrin provided 54% control of *H. armigera*. In treatments at 1/3 and 1/10 of field doses, it decreased to 46% and 35%, respectively. The level of control increased to 62% and 70% at three- and ten-times the field dose rate, respectively. Topical application in the laboratory at the discriminating dose showed a mortality of 16% with the field-collected larvae and 5% with the larvae that survived spray application.

Endosulfan

Endosulfan at field dose rate produced 66% mortality in *H. armigera*. At 1/3 and 1/10 of the field dose, the mortality was 55% and 47%, respectively. At 3 and 10 times the field dose, larval mortality increased to 72% and 81% respectively. At a discriminating dose of 10 µl/larva applied topically to the third instar larvae, the mortality rate was 58% for the field-collected larvae and 29% for the larvae that survived the application of the standard field dose rate.

Spinosad

Spinosad at the recommended field dose produced 75% mortality in *H. armigera.* At 1/3 and 1/10 of the field dose, the kill rate of Spinosad was found to be 66% and 57%, respectively. At 3 and 10 times the field dose, mortality was 84% and 91%, respectively. A discriminating dose of 10 µl per 30-40 mg larva produced 89% mortality in the field-collected larvae compared with 67% mortality in the larvae that had survived application of the recommended field rate of spinosad.

None of the insecticides tested produced close to 100 % control of *H. armigera,* even at 10-times the field dose rate, indicating the existence of some highly resistant individuals in the field. All the chemicals killed part of the population even at the lowest test dose rate of 1/10 of the field dose, which showed the presence of some susceptible individuals in the field. It may be concluded from these results that the laboratory-measured resistance correlates with the field efficacy of insecticides tested on a particular population of *H. armigera*. The monitoring of insecticide resistance in the laboratory can therefore predict insecticide failures in the field due to the development of resistance.

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Short Notes

- ## Microbial Activity of Stored Cotton Bales with Ambient and Moderate Moisture Levels

Some earlier work shows that the addition of water to lint before packing could reduce fiber quality and enhance microbial activity during storage. Mr. David Chun and his colleagues, David McAlister and Dean Cobb of USDA-ARS, Cotton Quality Research Station, Clemson, SC, USA, while working with moderately moistened cotton did not observe any significant damage to cotton quality or increased microbial activities. The addition of moisture to lint before packing has two benefits for the ginner and farmer. The addition of moisture requires less force to pack bales, and farmers get higher weight. But, excessive water could lower quality. While excess moisture in cotton could spoil cotton during ginning, ginning generally results in excessively dry cotton and some moisture is needed to make up the lost moisture during drying. Mr. Chun and his colleagues added only a moderate quantity of moisture and checked for its effect on fiber quality. Bales of cotton of the same variety and from the same field were ginned under normal conditions following a sequence of module feeder, feed controller, two split-fed tower dryers, two incline cleaners, dryer behind gin stand, incline cleaner, impact cleaner, distributor, gin stand feeder, gin stand, two lint cleaners, battery condenser, Cotton Moist System and bale press. The gin drying temperature was set at 176˚C.

Regular water was sprayed before baling at the lint slide using computer control. The five nozzles could be activated or deactivated individually based on the cotton feed rate of each gin feeder and the moisture level in the lint. Moisture was monitored with infrared and radio frequency technology. Four moisture treatments were evaluated in the experiment: a control with no moisture added, and 6%, 8% and 10% moisture levels. The moisture content of the control cotton was 5%. The bales were wrapped in a single layer of polypropylene sheet and bound by six plastic straps. Bales were stored for approximately one year; six months under warehouse conditions and six months under processing conditions (23.9±1.1˚C and 55±2% RH) before they were opened for sampling. Bales measured 53.3 x 139.7 x 78.7 cm and had a universal density of 448.5 kg/m^3. A 20-gram sample was used to measure dust, and a one-gram sample was analyzed for microbial populations of total bacteria, Gram-negative bacteria and total fungi. Initial, target and actual moisture content was recorded as follows:

Treatment Target Moisture (%)	Actual Moisture After Treatment (%)	Moisture at Bale Opening (%)
Control	5.0	5.7
6.0	5.4	6.0
8.0	8.0	6.8
10.0	9.5	7.2

As seen from the table above, the control and 6% treatment bales gained 0.7% and 0.6% moisture respectively in one year. The two treatments with comparatively high moisture levels i.e. 8% and 10% at the time of packing bales lost moisture by 1.2% and 2.3% respectively in one year. The data show that the weight of a bale may decrease or increase during storage depending upon the moisture level of cotton in the bale and storage conditions. In one year, the 10% moisture cotton lowered its reflectance and increased yellowness resulting in a change in color from white to light spotted and lower grade. The other two treatments and the control did not show such effects. Micronaire, short fiber index and strength did not improve in the treated bales. The added moisture did not enhance microbial activity, which was supported by the failure to observe significant fiber quality deterioration, or increased dust potential. The study, based on the color change in the 10% moisture treatment, suggests that moisture contents must not exceed 8% at the time of packing. Increasing the moisture level may bring the additional benefit of weight to farmers in some countries and ginners in others but there is a narrow limit particularly beyond 8% moisture, otherwise microbial activity and color deterioration could affect prices negatively.

For more details consult the full article 'Microbial activity of stored cotton bales with ambient and moderate moisture levels' by David T.W. Chun, David D. McAlister and Dean R. Cobb published in the Journal of Cotton Science, Volume 9, Issue 1, 2005 available at <http://www.cotton.org/journal/2005-09/1/upload/jcs09-024.pdf>.

• More Bt Hybrids Approved in India

The Government of India allowed commercial production of Bt cotton hybrids in March 2002. Commercial cotton hybrids are planted on almost half of the cotton area in India, and initially only three Bt hybrids were approved for commercial production. Those three hybrids were developed by a single company, Maharashtra Hybrid Seed Company (Mahyco), under license from Monsanto, the owner of Bt technology. The performance of Bt gene was successful under Indian conditions and lately three more seed companies have been permitted to commercialize their Bt hybrids. Now, the number of Bt hybrids approved for commercial production stands at 21, seven from Mahyco, eight from Rasi Seeds, three from Ankur Seeds and three from Nuziveedu Seeds. Monsanto has sub-licensed agreements to more than 20 seed companies in India for producing Bt hybrids patented as Bollgard for Bt gene. More companies are working on other technologies. Ajeet Seeds has received approval for large scale testing of a Bt hybrid ACH-155-1 in the South. So far all hybrids have a single Bt gene. The Genetic Engineering Approval Committee, which is the final authority for approval field trials and commercial production, has allowed Mahyco to test three Bollgard II gene hybrids in the Central and South zones. However, the trial area will not exceed 0.41 hectare (one acre). Lately, the Genetic Engineering Approval Committee has started tightening conditions for large-scale trials and seed production. The two changes that have already been approved and notified are

1. First-year seed production is limited to only 0.41 hectare, compared to an earlier limit of 100 hectares. In the second year, the Committee may allow an increase to eight hectares.

2. Large-scale trials will be conducted for two years instead of one year as in the past, before any hybrid is approved for commercial production.

Effect of Moisture Content on Fiber Quality and Dust in Baled Cotton

September 2001 (At the Time of Packing Bales)				A Year Later (September 2002)						
Treatment (% Moisture)	Color Grade	Reflectance (%)	Yellowness (+)	Color Grade	Reflectance (%)	Yellowness (+)	Micronaire	Strength (cN/tex)	Short Fiber Index	Average Dust (mg/20 g lint)
Control	31	76	9.1	31	76.0	9.0	5.28	27.66	10.15	2.82
6.0	31	76	9.0	31	76.0	9.3	5.30	27.42	10.20	2.73
8.0	31	76	9.0	31	75.8	9.2	5.30	27.66	10.33	2.75
10.0	31	77	9.2	32	74.8	9.6	5.33	27.66	10.48	2.70