

Integrated Crop Management

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INTERNATIONAL COTTON ADVISORY COMMITTEE

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Introduction

Technical seminars have been organized by the ICAC Secretariat since the 1960s, even before the creation of the Technical Information Section. At first, the seminars comprised a few speakers, sometimes only two or three, and they were conducted irregularly. Other times papers were invited and published without presentation. Over the years the seminar has evolved and more recent changes include a regular schedule, more papers and encouragement for higher participation. Since the 59th Plenary Meeting in Cairns, Australia, the technical seminar has been conducted as an “Open Session” to encourage interaction between delegates and observers, from ICAC member and non member countries. At the 59th Plenary Meeting in 2000, 14 papers presented during the technical seminar.

The Technical Seminar at the 60th Plenary Meeting of the ICAC was held on September 20, 2001 on the topic “Integrated Crop Management.” It was conducted as an Open Session and was followed by the meeting of the Committee on Cotton Production Research. Eleven papers were presented, Mr. Neville Brown, Vice Chairman of the Commercial Cotton Growers Association of Zimbabwe, chaired the meeting. Mr. Hugo Fernandez of Argentina prepared a paper which is included in this publication, but he could not attend the meeting. The meeting reviewed progress on preparations for the World Cotton Research Conference-3 to be held in Cape Town, South Africa in March 2003 and chose the topic for the 2002 Technical Seminar.

The twelve papers published in this report cover a variety of issues within the overall framework of integrated crop management. Mr. Mike Burgess, a private consultant from South Africa, discusses four new developments in Africa which are: the establishment of independent commodity research institutions, conservation farming, improved pest management and farming in groups. Mr. Burgess proposed the idea of group farming which is already implemented in Malawi, Mozambique and Zambia where various organizations are assisting farmers to work in groups.

Mr. Isidor Gilan of AgriSwiss from the Philippines reviewed the reasons for low yields in small scale farming systems in general and further elaborated on the idea of farmers working in groups. He stated that small farming units limit the adoption of new technologies and ultimately result in inefficient farming. The solution lies in farm clustering and cooperative/group farming and the use of rational production technology accordingly, he said.

Mr. Rob Jarvis and Mr. Darlington Mutetwa of Zimbabwe presented papers on the impact of seed quality and crop management practices on fiber quality and host plant resistance, respectively. They describe in detail the process followed in Zimbabwe at various stages of variety development, seed production, pest management, picking, and seedcotton handling and

ginning so that lint quality is not scarified. In Zimbabwe, farmers are encouraged to produce contamination-free cotton through the application of premiums and discounts. Zimbabwe developed varieties having built-in resistance to jassid, bacterial blight and verticillium wilt. In the last 15 years, not only has resistance to target pests been incorporated, but yields have improved along with an improvement in length and ginning outturn from 34-36% to around 42%.

A paper from Dr. Lastus Serunjogi of Uganda elaborated on the role of breeding in integrated crop management. Breeding plays a significant role in integrated crop management by putting together desirable genes that interact with the environment—natural and farmer’s management—for the derivation of a desired crop performance. Dr. Serunjogi counted large-scale contributions of breeding work and also discussed limitations that handicap breeders.

A paper from Egypt by Dr. Hussein Yehia Awad of the Cotton Research Institute explained crop management practices followed in Egypt that produce the highest quality cotton in the world.

Bt cotton has been planted in South Africa since 1998/99 and based on three years of performance, Dr. Deon Joubert of South Africa concluded that Bt cotton gives higher yields, improved ginning outturn and lowers the cost of production, without any effects on fiber length and micronaire. Mr. Andrew Bennett of Delta and Pine Land Ltd, South Africa reported on the three fundamental requirements for utilization of transgenic cotton: formulation of biosafety legislation, testing within biosafety rules and the availability of transgenic seeds for commercial production. He also stated that intellectual property rights are crucial, without which commercial use could remain restricted. Utilization of biotech has to be a collaborative effort by developing a partnership.

Dr. Doulaye Traore of Burkina Faso and Dr. Servet Kefi of Turkey presented two more papers on transgenic cotton. Dr. Traore convincingly supported the adoption of transgenic cotton in African countries. However, there is a need to develop trained manpower in the region and the responsibility lies with educational institutions. The technology is not risk free, and an in-depth analysis was provided by Dr. Kefi. If risk analysis procedures are implemented, GE cotton could be a good component in an integrated crop management program, otherwise GE cotton may carry a serious threat for human/animal health and the environment. Proper risk assessment, risk management and risk communication programs must be managed on a case-by-case basis for successful utilization of engineered products.

The paper from Dr. Derek Russell of the Natural Resources Institute of the UK presented a look into the future of integrated pest management. Due to a shortage of labor, herbicide use is going to increase. Pest management “in the seed” will

become the overwhelmingly dominant approach in the future, thus increasing the role of breeders. Biotech applications will expand to control many more species of insects and disease-causing organisms.

The Committee on Cotton Production Research of the ICAC considered four topics proposed by the Secretariat and decided to hold the 2002 Technical Seminar on the topic "Technology, Management and Processing for Quality Fiber."

Key Success Factors in Integrated Crop Management Systems in Africa

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Introduction

While the title of this paper refers to crop management systems throughout Africa, the focus is on the management systems of small-scale cotton producers in central and Southern Africa.

Africa has the highest population growth rate in the world and this has placed tremendous pressure on the land and on traditional crop management systems. Political, social and economic upheavals have also led to a decline in the level of research and extension services provided to small-scale farmers. These obstacles have made it very difficult for individual small-scale farmers to change their management systems. However, there are four interesting developments that could make a difference. They are: 1) Establishment of independent commodity research; 2) Conservation farming; 3) Improved pest management; and 4) Working in groups.

Commodity Research Development

An independent Cotton Research Trust, directed by a Board of Trustees, has recently been established in Zambia. The Trust is now responsible for all the functions previously carried out by the government. This has only been made possible by a change in government policy and a commitment from the major stakeholders to support the Trust financially, through levies on cotton production. The government has also transferred Magoye Research Station to the trust and has seconded key staff, as an interim measure, until the Trust can recruit suitable professionals to run the research programs.

The Cotton Research Station at Magoye has now been transformed and looks neat, tidy and efficient with new trials under the breeding, entomology and agronomy sections. A detailed cotton handbook has already been completed, which will be available to all cotton producers. The Trust is also providing commercial research facilities to other organizations, as an additional source of income.

The primary objective of the trust is to provide appropriate and sustainable research for cotton producers. Once the research program is up and running the Trust will turn its attention to training and extension services to cotton producers.

The resuscitation of an effective cotton research program in

Zambia, controlled by the stakeholders, augers well for the future of the industry in Zambia. Other governments in the region should consider what this change in policy has achieved, and emulate it.

Conservation Farming

Brian Oldreive, a pioneer of conservation tillage in Zimbabwe, developed a farming system to suit smallholder farmers that was efficient, more productive and environmentally sustainable. This system, called "Conservation Farming" is now being adopted in several countries in the region, including Zambia where its development will be discussed in more detail.

The Zambia National Farmers Union, supported by several agencies, has established a Conservation Farming Unit, to research and demonstrate practical and sustainable methods of conservation farming throughout the country. Dunavant, one of the main ginners in the country, is also encouraging its growers to introduce this system into cotton production.

The technologies are simple to adopt, do not need expensive equipment and have an immediate and dramatic impact on productivity, in addition to restoring the natural fertility of the land. It is also suited to both food and cash crop farming.

The technologies involve adopting five husbandry practices, which together comprise a complete farming system, these are:

- The retention of crop residues: Soil and water loss is reduced and water infiltration improved by retaining residues on the surface. Trials in South Africa on a 4% slope showed 90% water run off and a loss of 28-tons/ha soil under conventional bare soil tillage. There was a 90% improvement under Conservation Farming methods.
- Restricting tillage of the land to the precise area where the crop is to be sown: Labor requirement per ha is then reduced and better spread throughout the year.
- The completion of land preparation before the rains: This makes it easier to plant the crops early, which results in higher yields.
- The establishment of a precise and permanent grid of plant-

ing stations: Successive crops are planted in the same holes each year. This facilitates land preparation, improves the soil structure and the residual uptake of fertilizer. In Zambia, planting holes are dug 70 cm apart in 90 cm rows across the slope. Cotton is planted at both sides of the hole, with fertilizer applied in the center. Weed populations also reduce over time, as only 15% of the ground is prepared.

- Rotations with nitrogen fixing legumes: These should occupy a minimum of 30% of the cultivated area. This reduces the requirement for artificial fertilizer. Deep-rooted crops in the rotation also improve root penetration. New research is showing a significant yield improvement from the symbiotic effects of strip planting two rows of cotton and two rows of early maturing varieties of pigeon pea. The pigeon pea roots provide nitrogen for the cotton. And, the pigeon pea benefits from the insecticides sprayed over the cotton. The pigeon pea is also harvested early, leaving room for the cotton to grow out later in the season.

The principal aim of this system is to restore and maintain the fertility of the land only in the cultivated area occupied by the planted crop. The intervening inter-row zone can remain infertile, as only competition weeds occupy this area. This system also opens doors to a number of associated technologies, which can reduce costs and labor inputs.

For example, conservation tillage enables the farmer to look after more land with the same manpower. The crop uses applied nutrients more efficiently, as they are placed only in the planting zone.

Additional technologies are also advocated for specific situations.

- *Vetiver* (*Vetiver zizanioides*) grass strips planted on the contour are the most effective way of controlling erosion. This grass forms a living barrier, which arrests soil movement. In Malawi, where farmers have begun to recognize the value of vetiver, groups of farmers, with access to water, have cultivated small nurseries to provide tillers to their neighbors.
- *Tephrosia vogellii* is a legume that can be used to effectively rehabilitate degraded soils. It is not palatable to livestock and has a lifespan of 3-4 years. In Zimbabwe 27% of communal farming land is totally degraded because of inappropriate farming methods. In Malawi the situation is even worse. Degraded soils will not respond to good management and in drought years total crop losses can occur. Planting tephrosia has helped to rehabilitate these soils after 2-3 seasons.
- *Faidherbia alba* is a deciduous tree that grows to a height of 25 meters. Unlike most trees it sheds its leaves during the rains. The leaves are nutrient rich and improve soil fertility, allowing cultivation on degraded soil beneath the branch canopy with significant benefits to crop yields.

Conservation farming is a dynamic farming system that can be adapted to the needs of the farmer and the environment. It is a sustainable and profitable system that should be actively encouraged by all extension agencies throughout the region.

Pest Management

Zimbabwe has been recognized as the leader in cotton pest management strategies in Africa that are still valid today. These are the scouting method, based on searching 24 plants per field of 20 ha and the resistant management strategy that was recommended for pyrethroid use, right from the start. There is still no instance of bollworms developing resistance to pyrethroids in Zimbabwe. These two aspects form the basic recommendations for pest management in the region.

Commercial cotton growers in Zimbabwe were instrumental in developing the Cotton Training Center in Kadoma in the early 1980s. Organizations in Zambia, Malawi and Mozambique have also sent staff and farmers to the CTC where they have gained valuable knowledge in pest and predator recognition and control management strategies.

Although these courses have helped large numbers of farmers to recognize pests and predators, only a few small-scale producers use the recommended methods of interpreting scouting results on bollworm egg numbers. Surveys have shown that over 75% of small-scale farmers find it easier to locate the larvae than the eggs and they find the recommended strategies too complicated to understand. The standard recommended system is therefore inappropriate for the majority of these farmers because of the low standard of education and farming.

A simplified system is now being developed for use in the Dunavant distributor-training program in Zambia. This system combines calendar spraying with a simplified scouting method (using a pegboard for recording the major pests and predators). The system is simple to understand and helps farmers to assess damage thresholds through scouting. It also introduces the participant to the role predator's play in integrated pest management. The calendar schedule reduces the chance of the farmer making a mistake, one of the problems found during the survey. Pyrethroids for bollworm control are only recommended after first flowers. This is in line with Zimbabwe recommendations for resistance management.

A training and check scouting system is also being developed in South Africa by Danced, a Danish aid organization concerned with producing "cleaner cotton." It is hoped that this scheme will establish a pest management system for small-scale farmers similar to the one that has been so successful in the commercial sector in Zimbabwe. The program will also include pest management strategies relevant to genetically modified (Bt) cotton.

Small-scale farmers in South Africa have grown Bt genetically modified cotton commercially for two years now and yields on some farms have improved by over 30%. The number of sprays has also been reduced significantly. This has had a ma-

for impact on profitability. It is considered that Bt cotton will prove to be of greater benefit to small-scale cotton producers than it has been to large-scale commercial operators.

Resistance management for Bt cotton is being enforced in South Africa and under these strategy farmers growing Bt cotton must also maintain a refuge consisting of non-Bt varieties of the same crop. Scouting will continue to play an essential role in resistance management strategies in Bt cotton.

Working in Groups

Over the last 20 years small scale farmers have found it increasingly difficult to successfully operate on their own. The logistical problems for suppliers and creditors and the introduction of privatized marketing services have often resulted in many potentially successful farmers unable to take advantage of services taken for granted by large-scale commercial operators.

There are however organizations in Malawi, Zambia and Mozambique that have been assisting farmers to work in groups, or associations, in order to take advantage of the economics of scale. Small-scale farmers, working as individuals, have also established a reputation of poor financial discipline and repayment of credit. The group imposes financial discipline and everyone benefits.

The National Smallholder Farmers Association of Malawi (NASFAM) was established to develop and build a commercially viable network for smallholder directed business associations to improve returns for farmers who participate.

NASFAM is now assisting 4000 clubs in 31 commodity-oriented associations. The organization also encourages improved land use management. There are now over 100 model farms established in 17 associations.

A board of directors, elected by the members, runs the associations. Farmers pay an annual fee to join the association and this covers association expenditure. NASFAM provides assistance in obtaining markets and training in business development and credit discipline. The cotton associations were only formed two years ago, but a special marketing contract has

already been negotiated and prices have risen by 15%.

In Zambia, the Dunavant distributor system is also based on a group structure with an elected representative acting as an agent for the gin company. The agent works on a commission basis that is dependent on the results of the group. Results have improved significantly since this system was introduced.

Conclusion

The basic ingredients for crop development have been identified. It is now up to the stakeholders, particularly farmers and governments, to work together and implement the appropriate key success factors throughout the region. Let us hope this becomes one of the realities of the new African renaissance.

References

- Anon. 1984. Survey of Communal Areas. Cotton Research Institute, Annual Report, Department of Research and Specialist Services, Zimbabwe.
- Anon. 1998. Conservation Farming. Handbook for Small Holders. Compiled by Conservation Farming Unit and ZNFU Zambia.
- Anon. 2000. Survey Results. Cotton South Africa.
- Brettell, J.H. 1986. Some aspects of cotton pest management in Zimbabwe. *Zimbabwe Agricultural Journal*, Volume 83(3).
- Burgess, M.W. 1983. Strategies for cotton bollworm control in Zimbabwe. *Zimbabwe Agricultural Journal*. Volume 80(3).
- Clements, D. 2000. Dunavant Cotton, Zambia. Private communication.
- Cohen M. 2001. Resistance management for Bt crops in developing countries. M.cohen@cgiar.org.
- Gibson, D. 2001. Conservation farming unit, Zambia. Private communication.
- Oldreive, B. 1989. Conservation tillage in action. *A Handbook for Commercial Farmers in Zimbabwe*. Published by Laser Print.
- Warren, D. 2001. NASFAM, Malawi. Private Communication.

The Role of Breeding in Integrated Crop Management

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Introduction

The determinants of crop performance or phenotypes are tetrapartite being:

- The genetic constitution of the crop variety (genotype).
- The natural environment, which is critical since farmers may have no control over it and in essence determines the suitability of a given location for crop production.
- The management or farmer input environment over which

farmers have most control.

- The interaction between the plant genetic component and the two types of environments.

The genetic makeup holds the potential for the crop performance while the environment determines the magnitude of the expression of this potential. The environment may positively enhance the expression of crop potential or adversely affect it. In the latter case, the environment then poses stresses on the crop. The magnitudes of the genotype by environment interactions (*gxe*) determine *inter alia* the stability of performance of the crop across varying environmental conditions, which may be due to location of the production area (sites) or to seasonal effects (Allard, 1960, Fehr 1987, Hallauer and Miranda 1988 and Epinat et al., 2001). Schulze (1993) outlined components of the natural and crop management environments. This was while he was discussing the limitations to cotton yields. In recognition of that discussion I have, in this paper, defined “Integrated Crop Management (ICM)” as “an ecological approach to crop management in which all available necessary techniques are systematically consolidated into a unified program, so that crops can be managed in a sustainable manner that offers economic productivity of quality crops with minimum adverse effects to the producer and to the environment.” This definition is derived also in appreciation of Herren and Donahue’s (1991) definition of integrated pest management (IPM).

In more precise, ICM comprises a combination of propagation of the crop genetic potential and the execution of interventions by the producer (farmer) in an attempt to increase the performance of a crop in a given natural environment. Performance refers to productivity and quality of the crop. The ICM approach aims at using an aggregate of effective and compatible options for minimizing costs to the farmer while being friendly to users and the environment.

The basic role of breeding in the ICM strategy is therefore putting in place favorable genetic combinations. These interact with the environment (s) (both natural and farmer’s management) for derivation of crop performance desired by the users (producers, processors and lint exporters in the case of cotton). In this scenario, the agronomic and pest management interventions supplement the genetic components as a means of overcoming the existing production constraints or stresses which may be biotic or abiotic in nature. This paper outlines the role of breeding in crop management. Emphasis is placed on management of the “New World” amphidiploid tetraploid cotton cultivars *Gossypium hirsutum* L. and *Gossypium barbadense* L. Limitations to the breeding efforts are discussed and recommendations are made for possible support and modifications to the breeding approach in the ICM strategy. A number of examples are cited from the experiences gained in Uganda’s and other cotton research programs.

Constraints or Stresses on Cotton Production

The stresses, which constrain cotton production, comprise both environmental and economic types. The economic stresses affect production *per se*, i.e. they form the basis for a farmers’ decision on whether to grow cotton or not. These include production costs, ease of marketing and prevailing market prices among others. The environment stresses affect the levels of productivity (yields/unit area) and quality of the crop. These include *inter alia*:

- Pests (insects, nematodes and mites) which through their feeding habits injure cotton plants by chewing plant parts or sucking plant metabolites and may in doing so introduce disease pathogens into the plants.
- Diseases (bacterial, viral and fungal) which parasite on plant parts and metabolites leading to deformation of plants, e.g. midge galls and blockage of vascular bundles in cases of fungal wilts.
- Low or excessive soil fertility leading to stunting or vegetative plant growth respectively.
- Soil salinity especially in irrigated cottons.
- Drought and flooding.
- Cold temperatures.
- Low incident light intensity.

ICM can be directed towards alleviation of both economic and environment stresses. For example, appropriate agronomic recommendations on management of soil fertility or plant populations can favorably lower production costs. Jost and Cothren (2000) found that ultra-narrow inter-row spacing of 19-38 cm reduced required production area and hence production costs. Narrow rows though gave similar cotton yields to larger spacings (76-101 cm) in wet growing conditions. Further, the narrow spacings gave higher yields than the wider ones in the dry growing season. Another example is on the effects of soil tillage systems in use, which affect cotton crop development and yields. Kennedy and Hutchinson (2001) found that a no-tillage treatment led to faster ontogenic plant development and eventually greater yields than the conventional and ridge tillage. Early season differences in soil characteristics among the tillage systems were considered a factor. The no-tillage system would also reduce production costs.

Some of the environmental stresses listed above can be automatically circumvented through natural elimination of cotton production in a given environment, for example in the case of cold stress. Cotton requires a long warm growing season. At any stage of development the cotton plant is very sensitive to frost. Germination of seeds requires a minimum temperature of 15° C. An optimum temperature for vegetative growth is between 21 and 27° C. Cotton though can tolerate tempera-

tures as high as 43°C. During the period of fruiting, night temperatures should not be below 15°C for good boll and fiber development. Based on the above temperature requirements, cotton does not grow above 1,500 m altitudes or beyond 40°C latitude North or South of the equator (Wilson, 1995 and Berger, 1969). Also persistent or prolonged cloudy weather can eliminate cotton production from a particular area. The amount of sunshine (radiation) in the season is important for proper development of the cotton plant. It is especially important during the period of early vegetative growth and full bloom. Insufficient sunshine limits ripening of the boll to full maturity and reduces fiber quality (Berger, 1969 and Pettigrew, 2001).

The rest of the listed environment stresses can be addressed by the ICM approach with much input from the breeding perspective. Breeding for appropriate agronomic and physiological traits can then be supplemented by agronomic, soil and pest management options.

Examples of Cotton Breeding Efforts as part of ICM

There are a number of examples where breeding has successfully contributed to integrated crop management:

- Breeding for resistance to diseases. The problems of bacterial blight caused by *Xanthomonas campestris* pv *malvacearum* are known in all cotton producing countries. Bacterial blight is known to cause 1% losses annually in the USA and over 50% during epidemics in Africa (Hillocks, 1992) through extensive leaf, stem and boll infection. Strong breeding efforts have led to development of cultivars with combinations of major and modifier genes conferring both vertical and horizontal resistance. (El-zik and Thaxton, 1995). In Uganda, selection of the Albar cotton stocks with B genes pyramids for resistance coupled with use of seed dressing chemicals have controlled the blight, which has been a problem since the 1920s (Snowdon, 1926 and Akello, 1999).
- Breeding for resistance to pests. One example is the breeding for plant hairiness on stems and leaves in East African cottons. The trait has successfully controlled attacks from jassid pests. The Albar upland *G. hirsutum* stocks in use are highly pubescent in comparison to the American upland, for example the *Acala* varieties (Innes and Jones, 1972). The pubescence trait being governed by single major genes is easy to transfer to new introductions if required. Other morphological traits selected for pest resistance include reduced sepals (frego bracts), nectariless on the veins of the leaf lamina's lower side and okra or cleft shaped leaves. The okra leaves were reported for offering production advantages such as earlier maturity, less boll rot and moderate resistance to pink bollworm *Pectinophora gossypiella* (Saunders) and better pesticide penetration on leaves (Heitholt and Meredith, 1998, Wilson, 1990 and Andries et al., 1969) than the normal leaves. Since the okra

leaf shape variant is governed by a single dominant allele ($L_2^0 L_2^0$) compared to a normal leaf ($l_2 l_2$) the trait is easy to introgressed into the normal leaf genotypes. Frego bracts and nectariless traits are known to offer tolerance to bollworms (*Heliothis* spp. and pink bollworm) and whiteflies.

- Breeding for physiological traits. Breeding for short days to physiological maturity falls in this category. Development of short duration cottons has been reported as a successful approach for integrated crop management. Escape of early maturing varieties from late season pests is one way of supplementing host plant resistance in management of pests in cotton (Jenkins, 1995, Russel and Hillocks, 1996). Ramalho (1994) reported the contribution of short season cultivars to the control of boll weevils (*Anthonomus grandis*) and pink bollworms (*Pectinophora gossypiella* Saunders) in Brazil where they are major cotton pests. Additionally Serunjogi (1996) discussed the contribution of short duration cottons to better crop management. Early maturity enabled concentration on cotton crop management before competition for labor sets in by food crops later in the season in subsistence farming systems.
- Breeding for particular plant habits for ease of crop management and enhancing economic returns. Selection for reduced internodal length offers "clustered" plant habits in cotton in comparison to long nodded "open" habits. Ultra-reduction in monopodial (vegetative) and sympodial (fruiting) branch lengths have led to development of "zero" or "brachless" plants. This trait is already achieved in the Uzbekistan breeding programs. These clustered and zero plant types offer ease of mechanizing crop management (weed control, pesticide application and harvesting). In Uganda, selection is aimed at plant habits where branches are subtended at 60° or less to the main stem. This "closed" habit enables crop management using ox-drawn implements (weeders). Further, it enables inter and multiple cropping of cotton with leguminous food crops, e.g. beans *Phaseolus vulgaris*, soybean *Glycine max* (L.) *merr* and groundnuts *Arachis hypogaea*. Intercropping cotton with legume crops in Uganda is recommended for ensuring food security and increased incomes for the farming community and sustenance of soil fertility through N-fixation by legumes (Elobu et al., 1994). Further intercropping leads to augmentation of populations of beneficial fauna, which predate on cotton pests. For example beans, *Phaseolus vulgaris*, increase the number of spiders, and cowpeas *Vigna unguiculata* L. increase numbers of black ants *Lepisiota* spp. in cotton. Black ants are now relied on in northern Uganda for predated on Lygus, Aphids and bollworms in "Organic" cotton production (NARO 2001). Closed plant habits would also offer high plant populations in narrow rows in cotton crops, which would reduce acreage, and costs of crop management, as discussed by Jost and Cothren (2000).
- Other contributions to crop management through breed-

ing. These include contribution on cotton and on other crops. There are many reports of successful breeding for drought tolerance, for example in maize (Edmeades et al., 1999). Problems of increased soil salinity in cotton are known in arid environments especially under irrigation. There has been some success in developing salt-tolerant crops, e.g. alfalfa (Johnson et al., 1991) and studies made for understanding the mechanisms of salt tolerance in cotton for accelerating development of salt tolerant genotypes (Lin et al., 1997).

Limitations and New Opportunities to Breeding for Contributing to ICM

Examples have been cited above on how breeding contributes to management of cotton and other crops. There are, however, problems and limitations encountered in breeding programs while developing the required genotypes. These limitations are very similar to those discussed by Serunjogi (1996) in the processes of breeding for short duration cottons. The problems were categorized under:

- Genetic and genetic x environment interaction limitations.
- Breeding tools and availability of resources.
- Environment associated problems.
- Planning, resource management, policy and dissemination of production technology.

There are however, new opportunities, which are not yet exploited by many breeding programs. A summary of the limitations and new opportunities in relationship to breeding towards ICM are discussed here.

Biological, Genetic and Genetic x Environment Interaction Limitations

Development of New Races of Pathogens and Diseases

Among the limitations to breeding for resistance to cotton diseases is the development of new virulent races of the pathogens. These overcome the resistance of the available varieties thus terminating the “durability” of the resistance. The term “durable resistance” was described by Johnson to be a “reliable, persistent and moderate degree of resistance which can remain effective for long in a wide area of crop use” (Johnson, 1983 and 1984). El-zik and Thaxton (1996) described a shift in the races of *X. campestris* of cotton bacterial blight in Texas from USA races 1, 2 and 7 to the most virulent race 18. Also new virulent races (HVS) have evolved in Africa. In Uganda, Akello (1999) while using eight host cotton differential varieties developed by Hunter et al., (1968) identified the presence of the highly virulent race 18 and other races, and even a more virulent race suspected to be race 20. The surge of new virulent races calls for constant search in breeding programs for new combinations of genes for resistance in the cotton varieties.

Another areas of concern is the unprecedented appearance of new diseases in production areas. In Uganda problems of cotton wilts caused by *Verticillium* and *Fusarium* fungi and associated root-knot *Meloidogyne* spp. nematodes encountered in the 1930-40s had been controlled by selection for resistance in the BP52 and BC177 varieties. (Jameson, 1970). Since 1995, however, extensive levels of wilts have sprung up in many of the cotton producing districts. This upsurge of wilts could be partly attributed to evolution of new strains of *Verticillium* and *Fusarium*. This will be confirmed once the fungal identification facilities are put in place in the research program. This however has led to new germplasm searches for sources of resistance to wilts and nematodes for incorporation in improved varieties through the breeding program (NARO, 2001). A search for technologies for control of wilts today form the core of the cotton research program in Uganda.

Availability and Acquisition of Germplasm for Genetic Diversity

The requirement for particular gene combinations to combat new diseases and pests require accessibility to germplasm pools for sources of genes. There are known pools for multipurpose utilization for examples the Multiple Adversity Resistance (MAR) program for pest resistance in cotton described by Thaxton and El-zik (1995). In maize *Zea mays* L. Crammer and Kannenberg (1992) described another example of new types of germplasm formulations extendable to cotton. This is the hierarchical open-ended (HOPE) breeding system. This non-traditional germplasm has been in operation for 15 years and now offers genetic variability not present in commercial material (Popi et al., 2000). There are however, limitations in accessing the required germplasm by breeders emanating from *inter alia* restrictive plant variety protection and patents’ acts in some countries. Formation of germplasm networks by breeders with the assistance of IPGR centers would enable more flexible accessibility. Exchanges of germplasm between regional research programs would meet this requirement to some extent. Otherwise, the use of narrow genetic bases as breeding stocks is known to offer varieties which are vulnerable to stresses (Mc Carty et al., 1998). A failure to observe this requirement would drive breeders into a panic whenever a new pathogenic race or disease appears in a region.

Presence of Genotype x Environment Interactions (GxE)

The presence of GxE is a major limitation in breeding. Large magnitudes of GxE reduce gains from selection for a trait. GxE also pose problems to breeders while ranking cultivars’ superiority and stability of performance. The biases due to GxE interactions during selection can be reduced by multi-year and multi-location testing. This can also be supplemented by environment specific variety releases. These requirements however, make breeding programs more costly and time consuming (Epinat et al., 2001).

Tools for Ease of Accessing Genes and Effecting New Genetic Combinations

Conventional breeding methods for increasing frequency of alleles for desired traits are tedious, time consuming and depend on chance for attaining new useful gene recombination. There are however, at hand new tools for easing identification of required chromosomal segments (genomic regions) associated with the expression of quantitative traits. There are also efficient tools for the transfer of specific genes to the genotypes under improvement through biotechnology (Stewart, 1991 and 1995). Molecular markers for example “isozymes” “Restricted Fragment Length Polymorphisms” (RFLP), *inter alia* are useful in identifying “Quantitative Trait Loci” (QTLs). Identification of QTLs for various traits would go a long way in reducing time for cycles of crossing and selection and in improving genetic gain and realized heritability. Yu. et al., (2001) discussed the use of isozyme markers for identifying genes for resistance to root-knot nematodes in sugar beet. Beavis et al., (1994) discussed the use of QTLs in maize breeding. Biotechnology is another tool capable of transferring genetic material from any form of life, a case which Stewart (1994) coined as “Alpha and Omega” genetic resources. Stewart (1991) discussed in detail the advances in the application of biotechnology in cotton. The ICAC’s Expert Panel on Biotechnology (ICAC, 2000) gave details on the scope of biotechnology in propagating genetically engineered cotton and the benefits of the cottons, for example, the Bt and Roundup Ready (herbicide) resistant cottons.

There are, however, setbacks in the use of biotechnology tools. Not all breeding programs have the capacity or access to such tools. The use of patented genes by successful companies requires special permission and high costs from “royalties” for accessing the technology. There are also fears in producing countries about the loss of other genetic attributes, e.g. fiber quality and resistance to other pests in the traditional varieties if countries switched to engineered varieties. This could also lead to the loss of their traditional market outlets for lint based on loss in the intrinsic quality and fears by consumers about health risks while using engineered cotton products. There are also at hand fears of the development of resistance by pests once the engineered varieties are grown widely and for long. ICAC (2001) however, discussed the merits and limitations of genetically engineered cottons. Laboratory collaboration at the international level and reduction of bureaucracy for the use of available technologies coupled with educating cotton producing countries on the merits and safety of engineered cotton would enable quicker adoption of new technologies. For a start, producing countries should be encouraged to put in place biosafety regulations or acts for testing genetically engineered cottons. This would enable the biotechnology companies to test the technologies to assess their efficacy in those countries. The countries would then have grounds to reject or adopt technologies based on the perfor-

mance and other merits or limitations. Serious consideration should be made by the biotechnology experts on the need to transfer the beneficial new genes (e.g. Bt) into the producers’ original varieties for combining with other desired traits. Further, the contributions made by conventional breeders in improvement of the “recipient” traditional varieties should be recognized while considering royalties accruing from engineered cottons. The identity of conventional breeders should not be masked by the “cosmetic” breeding of gene introgression through biotechnology into conventional varieties.

A Case Example in Uganda Where Breeding is Used as Part of ICM

The above discussions on the utilization of breeding as part of ICM and the limitations encountered in breeding programs can be capped by citing cases in Uganda. The major objective of the cotton research program is to improve varieties through germplasm collection and breeding and the development of cost effective technologies for crop and pest management (NARO, 2001). Breeder’s work is close association with entomologists, pathogenists and agronomists for deriving omni purpose varieties and technologies for dissemination to farmers (NARO 1999). The roles of breeding and other disciplines are summarized in Table 1. Utilizing ICM technologies for producers has led to increases in seed cotton yields to over 3,000 kg/ha in farmers fields on young volcanic soils. Also yields of 800 kg/ha are obtained in “organically” produced cotton, which rely on genetic resistance and biological control of pests without chemicals (NARO, 2001).

Conclusion

Breeding is part and parcel of the Integrated Crop Management (ICM). It is a corner stone in ICM endeavors. It provides the genotypes “raw materials” which the natural and “artificial” environment grind for attaining increases in crop performance and quality. Breeding will continue to play a central role in ICM as the use of chemical inputs is getting restricted due to environmental concerns. However, there are limitations in achieving objectives of the breeding programs. Some of them can be overcome by easing restrictions of the use of new breeding tools by the lesser resourced programs.

References

- Akello, B. 1999. Factors affecting incidence and severity of bacterial blight in Uganda. Ph.D. Thesis, University of Reading, 218 pp.
- Allard R.W. 1960. Principles of Plant Breeding. John Wiley & Sons Inc. London.
- Andries, J.A., Jones, J.E. Sloane, L.W and Marshall, J.G. 1969. Effects of okra leaf shape on boll rot, yield and other important characters of upland cotton, *Gossypium hirsutum* L. *Crop Sci.* 9, 705-710.
- Berger, H. 1969 (ed). The world major fibre crops, their cultivation and manuring. Centre d’étude de l’azote 6. Zurich, Swit-

Table 1. The Role of Breeding in Integrated Crop Management (ICM) in Cotton in Uganda

Activity	Responsibility*	Remarks
1. Germplasm introduction, evaluation and crossing cycles with Uganda cottons	B	For incorporating genes for resistance/tolerance to pests, diseases, drought and nematodes
2. Generation advancement and screening for resistance and plant habits	B, E, P	Intensifying genes into a new combination through selfing and artificial inoculation
3. Step-wise testing and evaluation on- station and initial seed multiplication (Breeders' plots)	B, E, P	Testing of progeny, and strains discarding genotypes due to susceptibility, plant habits, yield and quality components
4. Multi-locational testing of lines and seed multiplication (Breeders' plots)	B, A, E, P	Testing for stability of performance (gxe), for yield and fiber quality
5. Constitution of new varieties (single line or line-mixtures) and foundation seed multiplication	B, E, P	Foundation seed supplied to field inspection for roughing diseases and off-genotypes. Farmers in the seed scheme
6. Chemical testing trials	B, E, P	For insecticides and seed dressing chemicals against blight on developed varieties
7. Pest scouting trials	B, E	Development of economic threshold levels (ETLs) for bollworms, lygus and stainers. ETL for bollworms 6 larvae on 100 plants. ETL for lygus 15 lygus bugs in 50 net sweeps in developed varieties
8. Intercropping system trials	B, A, E	For identifying and augmenting beneficial fauna (predators and parasitoids) in developed varieties. Black ants <i>Lepisiota</i> spp. as biological control agents against bollworms, lygus and aphids now enables production of organic cotton without chemicals.
9. Seed bed preparation with ox-drawn implements, planting dates with ox-drawn seeders, population intercropping and soil fertility and vegetative growth control trials	B, A, S, AT	For derivation of agronomic recommendations for the developed varieties. Recommendations on spacing and sequence of planting with beans, soybean and groundnuts and for control of vegetative growth.
10. Weed control trials	B, A, AT	For management of weevils. Much done on trimming and frequency chemical herbicides of weeding regimes. There is a gap on the use of and the effect of tillage systems on crop performance.
11. On-farm adaptive testing trials	B,A,E,P,AT,S	For verification and perfection of technologies and testing adaptability to environments and farming systems.
12. Recommended production technologies	B, A, E, P, AT, S	Provision of a production package on varieties, planting seed, pest, disease and agronomic crop management including intercropping. This has resulted in reducing use of chemicals to 2-3 sprays, which protect beneficial fauna especially when systemic pesticides are used as seed dressing chemicals against early sucking pests. Vegetative growth controlled by use of pix growth regulator or detopping plants at 45 – 60 DAP**

*A = Agronomist, B = Breeder, E = Entomologist, P = Pathogenist, S = Soil Chemist, AT = Animal Traction, E = Engineer.
** DAP = Days after planting
Reference: NARO 1999

zerland.

Edmeades, G.O., Bolanos, J., Chapman, S.C., Lafitte, H.R. and Bänziger, M. 1999. Selection Improves Drought tolerance in tropical maize populations: I. Gains in Biomass, Grain Yield and Harvest Index. *Crop Sci.* 39, 1306-1315.

Elobu, P., Orwanga, J.F. Ocan, J. and Opolot, G.W. 1995. Recovery of cotton (*Gossypium hirsutum*) from intercropping suppression by beans (*Phaseolus vulgaris*). In: *Challenging the Future, proceedings of the World Cotton Research Conference—1*. Constable, G.A. and Forester, N.W. (eds). CSIRO, Australia.

El-Zik, K.M and Thaxton, P.M. 1995. Breeding for resistance to bacterial blight of cotton in relation to races of the pathogen. In: *Challenging the Future. Proceedings of the World Cotton Research Conference—1*. (Eds.) G.A. Constable and N.W. Forrester, CSIRO, Australia.

Epinat-Le Signor, C., Dousse, S., Lorgeou J., Denis, J.B., Bonhomme R., Carolo, P. and Charcosset, A. 2001. Interpretation of Genotypex Environment Interaction for Early Maize Hybrids over 12 years. *Crop Sci.*, 41, 663-669.

Fehr, W.R. 1987. Principles of Cultivar Development Volume 1. Theory and Technique. McGraw-Hill, Inc. New York St. Louis, San Francisco, Auckland, Bogota.

Hallauer, A.R. and Miranda J.B. 1988. Quantitative Genetics in Maize Breeding. 2nd Ed. Iowa State University Press Ames, USA.

Heitholt, J.J and Meredith Jr. W.R. 1998. Yield, Flowering and Leaf Area Index of Okra— Leaf and Normal — Leaf Cotton Isolines. *Crop Sci.* 38, 643-648.

Herren, R.V. and Donahue, R.L. 1991. *The Agriculture Dictionary*. Delmar Publishers Inc.

- Hillocks, R.J. 1992. Bacterial blight pp. 39-85. In Hillocks, R.J. (Ed.) *Cotton Diseases*. CAB International, Wallingford, UK.
- Hunter, R.E., Brinkerhoff, L.A., and Bird, L.S. 1968. The development of a set of upland cotton lines for differentiating races of *Xanthomonas malvacearum* phytopathol. 58, 830-832.
- ICAC. 2001. Second generation of Bt cotton is coming. *The ICAC Recorder* Volume XIX No. 1 March 2001 pp. 5-8, International Cotton Advisory Committee. Washington, DC, USA.
- ICAC. 2000. *Report of an Expert Panel on Biotechnology in Cotton*. November 2000. International Cotton Advisory Committee. Washington, DC, USA.
- Innes, W.L. and Jones G.B. 1972. Allen: a source of successful African cotton varieties. *Cott Grow. Rev.* 49, 201-213.
- Jameson, J.D. (ed.) 1970. *Agriculture in Uganda*. Oxford University Press.
- Jenkins, J.N. 1995. Host plant resistance to insects in cotton. In: *Challenges the Future. Proceedings of the World Cotton Research Conference—1*. Constable, G.A. and Forester, N.W. (ed.) CSIRO, Australia.
- Johnson, D.W., Smith, S.E., and Dobrenz, A.K. 1991. Registration of AZ-90NDC-ST alfalfa germplasm. *Crop Sci.* 31, 1098-1099.
- Johnson, R. 1983. Genetic background of durable resistance. In: *Durable Resistance in Crops* (eds). Lambert, F.M., Waller, J.M., and Van der Graaf N.A. *Life Sciences*. 55, Plenum Press, London, UK.
- Johnson, R. 1984. A critical analysis of durable resistance. *Ann Rev. Phytopathol.* 22, 309-330.
- Jost, P.H. and Cothren, J.T. 2000. Growth and yield comparison of cotton planted in conventional and ultra-narrow row spacings. *Crop Sci.* 40, 430-435.
- Lin, H., Salus, S.S., and Schumaker, K.S. 1997. Salt Sensitivity and the activities of the H⁺-ATPases in cotton seedlings. *Crop Sci.* 37, 190-197.
- Mc Carty Jr., J.C., Jenkins, J.N. and Zhu, J. 1998. Introgression of day-neutral genes in primitive cotton accessions: I genetic variances and correlations. *Crop Sci.* 38, 1425-1428.
- NARO. 1999. Increasing yields and quality of cotton. *A farmer's Guide*. National Agricultural Research Organization. A brochure with 8 illustrations and translated into six local languages.
- NARO. 2001. *Cotton: In National Agricultural Research Organization NARO (Uganda)*. Annual Report for 1999-2000 season. pp. 30-33.
- Pettigrew, W.T. 2001. Environmental effects on cotton fiber carbohydrate concentration and quality. *Crop Sci.* 41, 1108-1113.
- Popi, J., Rajnpreht, J., Kannenberg, L.W., and Pauls, K.P. 2000. Random amplified polymorphic DNA-based evaluation of diversity in the hierarchical, open-ended population enriched maize breeding system. *Crop Sci.* 40, 619-625.
- Ramalho, F.S. 1994. Perspectives on cotton insect pest management in Brazil. Luttrell, Fill, G.P. Ramalho, F.S. and Sugongaev, E.S. (eds). *Worldwide perspectives on insect pest management. Annual Review of Entomology*, Entomological Society of America.
- Russel, D.A. and Hillocks, R.J. 1966. Impact of short season cotton systems on the control of insect pests and disease. In: *Short Season Cotton: How Far Can We Go?* Papers presented at a Technical Seminar at the 55th Plenary Meeting of the ICAC, Tashkent, Uzbekistan, October 1996.
- Schulze, R. 1993. Limitations to cotton yields: genetic, environment and management. *Yield Constraints in Cotton and Producing Quality Cotton under Rainfed Conditions*. Papers presented at a Technical Seminar at the 52nd Plenary Meeting of the ICAC.
- Serunjogi, L.K. 1996. Problems in breeding for short duration cottons. In: *Short Season Cotton: How Far Can It Go?* Papers presented at a Technical Seminar at the 55th Plenary Meeting of the ICAC, Tashkent Uzbekistan, October 1996.
- Snowdon, J.D. 1926. The occurrence of angular leaf spot of cotton (*Bacterium malvacearum* E.F.S) in Uganda. Department of Agriculture, Uganda. *Cir.* 17, 1.
- Stewart, J, McD. 1995. Potential for crop improvement with exotic germplasm and genetic engineering. *Challenging the Future. Proceedings of the World Cotton Research Conference—1*. Constable, G.A. and Forester, N.W. (ed.), CSIRO Australia.
- Stewart, J. McD. 1991. *Biotechnology of cotton*. ICAC Review Articles on Cotton Production Research no. 3. CAB International, Wallingford, U.K.
- Thaxton, P.M., and El-zik, K.M. 1994. Development of MAR cotton germplasm with morphological mutant traits. *Challenging the Future: Proceedings of the World Cotton Research Conference 1*. Constable, G.A., and Forester, N.W. (ed.), CSIRO Australia.
- Wilson, F.D. 1990. Relative resistance of cotton lines to pink bollworm. *Crop Sci.* 34, 500-504.
- Wilson, M.J. 1995. *Introduction to Indian Cotton*. National Institute of Agriculture Extension Management (MANAGE), Ragendranagar, Hyderabad – 500 030 India.
- YU, M.H., Pakish, L.M. and Zhou, H. 2001. An Isozyme marker for resistance to root-knot nematode in sugarbeet. *Crop Sci.* 41, 1051-1053.

Impact of Seed Quality and Crop Management Practices on Fiber Quality

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Background

Cotton is a crop that is grown primarily for its fiber. The quality and uniformity of the fiber is vital to its marketability and destined end use. Good crops and sustained, reliable production of quality cotton can only come from an integrated technology system that is in balance with the environment and maximizes the opportunity for the crop to convert sunlight into cellulose fibers with the desired characteristics. In Africa, cotton production is largely in the hands of smallholder farmers who are resource poor and lack credit facilities, access to inputs, training and skills to produce top-quality crops. This paper explores the reasons why in Zimbabwe high quality cotton is produced by both large scale commercial farmers, who may plant 100 hectares or more of the crop, to smallholders who may only crop half a hectare or less. It examines the issue from the impact of variety and seed through production practices to the standards and strategies demanded and enforced by the growers' and marketing organizations.

Reasons for Poor Fiber Quality

Poor quality fiber has a number of causes, and the major ones are listed below. In Zimbabwe, because of the disciplined historical development of the cotton industry and the recent influence of the National Cotton Council and various strategies put in place by the ginning and marketing companies, good quality cotton continues to be produced despite the recent introduction of a liberalized marketing environment.

Each of the above potential causes of poor quality cotton is expanded upon below in explaining where Zimbabwe maximizes the opportunity to maintain quality, purity and product integrity mainly through the supply of high quality seed, control of varieties, recommended production practices and adherence to industry agreed standards.

Varietal Choice

The single largest factors that contribute to the quality of the fiber produced is undoubtedly the choice of variety and the controls or discipline practiced in the country to maintain a high standard. Zimbabwe has been fortunate to have a long standing breeding program, conducted by the Cotton Research Institute (C.R.I.) in Kadoma. CRI is a commodity-based institute in the Government's Department of Research and Specialist Services in the Ministry of Lands, Agriculture and Rural Resettlement.

This breeding program makes use of a fully equipped fiber testing laboratory which is used to distinguish superior material right from the selection of single plants through to the extensive field testing of elite varieties. Over the years, the program has received additional support to Government funding from the textile industry, growers, the Cotton Marketing Board and its successor The Cotton Company of Zimbabwe. Today the Institute has been partially commercialized and earns a royalty on seed multiplied by and sold through Quton Seed Company. Any new variety is thoroughly tested over a wide range of sites and a number of seasons prior to release. Lint output from multiplication crops is watched carefully during ginning and sent for full-scale mill tests before committing the variety to commercial production.

The breeders at CRI have always maintained close contact with the marketing organizations and even directly with end-users to make sure that any varieties grown commercially are thoroughly tested and produce the desired fiber qualities and mill performance.

In the 1960's when cotton production started to take off in the country, great efforts were made to ensure that the product was of as high a quality as possible because of the great dis-

Table 1. Causes of Poor Quality Cotton

Number	Reason for poor quality	Potential effect on quality
1	Poor choice of varieties for local environment	Low quality fiber, poor staple, strength, maturity, fineness, poor uniformity, high short fiber content, poor elongation, small bolls
2	Varietal admixture	Mixing of qualities
3	Field stress, e.g. nutrition, moisture, excessive weeds, season length, adverse weather	Weak and immature fibers, staining, grey color
4	Disease incidence	Weak, immature and/or stained cotton
5	Pest damage	Stained, damaged seed cotton, weak immature fibers
6	Honeydew	Sticky cotton, poor processing
7	Contamination	Downstream processing problems and quality claims
8	Poor harvest techniques	Mixing of good seed cotton with poorer quality cotton, contamination with extraneous matter, poor hand picking
9	Poor delivery mechanisms	Mixing of varieties, grades, qualities
10	Poor seed cotton grading	Admixture, loss of uniformity
11	Poor ginning or excessively fast ginning	Poor preparation and eroding of key quality characteristics
12	Poor classing	Failing to identify key attributes

tance from premium markets that Zimbabwe faces. There has been a steady improvement in the quality of fiber produced by the commercially released cultivars grown. These varieties today compete with the SJV and better Australian cultivars and have an advantage in most cases because the lint comes from hand-picked crops and mechanical damage in the ginneries is minimal. The National Cotton Council of Zimbabwe approves the varieties to be grown and the geographical allocation of production areas. Quton and the ginning companies then ensure that the correct seed is distributed in the agreed areas.

The mainstream variety today, Albar SZ 9314 has high yield potential, a storm-proof boll and a lint out-turn of 42% to 43%. Its fiber quality is in the good medium staple category with the bulk of the crop stapling out at 1 1/8 to 1 5/32 inches. Albar quality is generally good with strength being in the 90-95000 PSI bracket, micronaires in the premium range of 3.8 to 4.8 and the fibers being fairly fine and very mature. The hand-picked crop is not subjected to intense cleaning during ginning and the overall spinnability of the fiber is thus preserved. Dramatic improvements in lint out-turns have seen the ratio achieved in commercial ginning exceed 40% in recent years.

Zimbabwean varieties have resistance to jassids and to bacterial blight. There are some available that are more tolerant to Verticillium wilt. These inbuilt traits allow the varieties to weather severe attacks of the pest or disease. Some show improved tolerance to aphid and red spider mite attack and to susceptibility to potassium deficient soils.

Avoiding Varietal Admixture: Maintaining Seed Purity

Varietal integrity is maintained by a robust seed multiplication scheme whereby every year a few kilograms of pure breeder's seed of each variety under multiplication is released to Quton from the Cotton Research Institute. This seed is used to grow one or two breeder crops that provide the seed the next year for a wave of Foundation crops. These are grown on large scale commercial farms that have access to irrigation and the crops are closely monitored and rogued at flowering to remove off-types. Seed from Foundation crops is used to grow the Certified crop in the third season. This crop annually occupies in excess of 10 000 hectares of commercial farmland. In practice once a new variety is released it can totally replace existing varieties within three seasons from a few kilograms of seed issued by the Research Institute.

Cotton production in Zimbabwe was initially embraced by the commercial farming sector. Most of their farming operations, and particularly planting, were mechanized and this needed smooth, acid-delinted seed to allow machine planting. The Cotton Marketing Board used to produce such seed at first on a concentrated sulfuric acid system that was replaced in 1969 with a dry hydrochloric acid gas plant.

Acid delinting has several benefits that go along with the sepa-

ration of good vigorous heavy seed from less vigorous, lighter seed that is more prone to pest and disease attack and that will give rise to weak crops with poor root systems and fragile superstructure. As smallholder farmers took to the crop more and more during the 1980's and 1990's they were also supplied with processed seed and have always paid for the product on a cost plus basis. This allows the seed industry to invest in research and development and in improved processing technology. Currently Quton operates a dilute sulfuric acid processing plant that has been in operation since 1995 and has the capacity to produce 9000-10000 tons of acid-delinted, fungicide treated seed every year.

By law, cotton planting seed sold in Zimbabwe has to be certified and is grown under a strictly administered seed multiplication scheme. Seed must be 99% pure and attain a minimum germination of 70%. Quton tries to operate within a more stringent standard of a minimum germination of 85% or more.

However, in view of the ongoing land reform program in Zimbabwe a large proportion of the forthcoming crop will be switched to small-holder farmers who have already been identified to have the requisite skills and access to inputs to grow high quality cotton and seed crops. They are all established producers on The Cotton Company's Input Credit Scheme. Despite a much wider spread of cotton production into less suitable cotton areas, crop yields in the small-holder sector have been steadily climbing since the great drought of 1991/92. They are now getting close to the exceptional result achieved in 1980/81 when a far smaller crop was grown by this sector.

The seed scheme has a number of in-built standards to ensure that only seed of the highest quality is produced. These include identification of the better growers, contracting known volumes, employing a seed inspectorate to physically check each crop for off-types, isolation and field husbandry and monitoring harvesting and delivery procedures and a seed cotton grading system that identifies good seed sources through the grade achieved. The scheme operates under the overall legislative requirements of the Seeds Act (Chapter 133), Seed (Certification Scheme) Notice of 2000 and the actual rules applied by Quton to its contracted growers.

Growers are supplied with new cotton packs to deliver their seed cotton and these are labeled in such a way that the shape identifies the stage of multiplication and the color of the label identifies the variety.

Processing through the ginnery and in the acid-delinting plant is done on a variety-by-variety basis with thorough cleardowns and inspections done between each run. Ginned seed is bagged in new grain bags and labeled according to the variety, stage, seed crop origin, ginnery and year of production. This coding will follow the seed through the acid delinting plant and the seed code will also indicate a particular batch number that can identify the year of processing, plant producing it, the shift and day processed.

**Table 2. Zimbabwe Variety Pack
Identification Labels for Seed Cotton**

Variety and stage	Shape of label	Color of label
Albar SZ 9314	Foundation square, Certified triangular, Commercial rectangular	White
Albar FQ 902	Foundation square, Certified triangular, Commercial rectangular	Grey
Albar BC 853	Foundation square, Certified triangular, Commercial rectangular	Green
Albar AG 4869	Foundation square, Certified triangular, Commercial rectangular	Blue
CY 889	Foundation square, Certified triangular, Commercial rectangular	Red
LS 9219	Foundation square, Certified triangular, Commercial rectangular	Red and gray

Seed Quality: Minimizing Field Stress and Optimizing Crop Potential

Good crops can only come from good seed, and in Zimbabwe extremely high standards are applied throughout the seed conditioning process to ensure that the resultant product sold to growers is of the highest possible quality and purity. Samples of ginned seed are drawn and checked for germination and vigor before processing. During delinting, the seed is treated with measured amounts of acid and temperatures monitored throughout the process. Residual acid is neutralized with calcium carbonate and the seed screened on a series of air screen cleaners and gravity tables to eliminate dust and any light seed that is usually less vigorous than the heavier seed. The seed is treated with a suitable fungicide and in some cases with an aphicide before bagging off for sale.

A continuous trickle sampling of the seed as it is produced is drawn and submitted to the laboratory for evaluation. Quton runs a registered laboratory and this submits one in ten samples to the certifying authority, Seed Services, to check that results are within acceptable tolerances. All seed is subjected to laboratory germination tests according to ISTA rules and also to field vigor plantings at two sites before being passed for sale.

Good healthy, vigorous seedlings give the grower the best chance of achieving a high yielding, top quality crop. There are a number of factors that the grower must address to ensure that the crop has the maximum chance of achieving top yields. These include encouraging a good root system mainly through ensuring the crop is planted into a soil at or near field capacity at germination. With irrigation this is relatively easy. How-

ever, with the bulk of the small-holder crop it involves encouraging suitable crop rotations and early ploughing at the end of the preceding season thus allowing residual moisture carryover from one season to the next. Other practices to maximize potential include keeping the land weed-free, ensuring there are no undersurface impediments to root growth and that soil drainage is adequate. Early planting, to maximize season length, as much as it is practically and legally possible and employing moisture and soil conservation techniques that minimize runoff and maximize rainfall infiltration contribute significantly towards crop success. These include planting on rip-lines, permanent beds, ridge and ties, pot-holing and maintaining surface mulches from previous crops and planting directly into these.

The crops must be properly supplied with nutrients and kept weed-free especially during the first eight weeks post emergence. Growers in Zimbabwe have to pay particular attention to Potash and Phosphate requirements especially for the former on fersiallitic red clay soils and additional supplies may have to be applied in the soil prior to planting. Potassium deficient soils will succumb to *Alternaria* leaf spot and will rapidly defoliate at boll formation and result in weak immature lint from the poorly filled bolls. Deep placement of potassium will eliminate this problem. Cotton specific fertilizer formulations are normally supplied to growers and these cover the crop's basic nutrient requirements of NPK as well as its Boron and Sulfur needs. Top dressing at first flower with ammonium nitrate is a common practice to achieve high yields. Growers are aware of the dangers of over feeding with nitrogenous fertilizers and its application is usually done at the recommended times. Excessive nitrogen especially combined with adequate moisture can result in very rank unmanageable crops that result in downgrading of the seed cotton.

Minimizing Disease Incidence

Inherent resistance or tolerance is the method most commonly used to minimize the effect of diseases upon crop yield and quality. In the case of bacterial blight, the disease has been kept under control by a combination of inherited resistance and the hygiene effects of supplying only acid delinted seed to grow the commercial crop and adherence to the legislated earliest planting and crop destruction dates.

Verticillium wilt is a more complex problem and although tolerant varieties such as Albar BC 853 and CY 889 allow heavily infected fields to be cropped, this strategy has to be combined with suitable crop rotations, improved nutrition, soil drainage and hygiene to keep infection levels manageable. Cotton usually needs to be grown in rotation with cereal crops to avoid a severe build-up of the disease, especially on heavy clay soils. Cool wet seasons will invariably see an increase in affected fields and farms.

Alternaria leaf spot is usually associated with crops that are grown on soils deficient in potassium, and by monitoring the

proportion of potassium to total available bases in the soil farmers need to ensure that this is sustained above 3-5%. On most soils, it is sufficient to stop the crop from becoming pre-disposed to defoliation by *Alternaria* at peak boll formation. In recent years some variability in Zimbabwean germplasm has been identified for greater ability to extract potassium from otherwise deficient soils and by extension they show tolerance to defoliation by *Alternaria*.

Boll rotting fungi are usually encountered in very wet seasons and on early planted crops that ripen during the main rains. In most years, because of the tailing off of the rains during March and April, they are not a major problem.

Minimizing Pest Damage

The practice of scouting cotton and spraying only after identifying a particular pest problem is well known and understood in Zimbabwe. The Cotton Training Centre in Kadoma has provided an invaluable service over the past twenty years in educating and training growers, farm workers, smallholder farmers and extension and agrochemical trade representatives in pest identification, scouting and integrated pest management techniques. Pest control strategies developed by the Cotton Research Institute try and take advantage of any predator populations that have built up, using inherited leaf hair to protect against jassids and choosing the least toxic spray option when pest levels have reached economic threshold levels. Spray dosage levels are based upon using a rate that is effective when the pest is at its most vulnerable and at its most vulnerable stage. In the case of the ubiquitous bollworms, scouting is centered upon the eggs laid and spraying with low dosages to control the young larvae as they hatch. The strategy also includes using the most effective pesticides, such as synthetic pyrethroids when they are most required, i.e. during the flowering and boll formation phase. This coupled with pesticide management strategies to minimize the risk of pesticide resistance developing in Zimbabwe has been singularly successful.

Quton is currently marketing some seed treated with Cruiser (a neonicotinoid systemic insecticide) the main effect of which is to provide protection from aphids and some other soil and sucking pests during the first six to eight weeks post emergence. This inclusion of pest control and management systems in the seed is being pursued as a logical way of providing a better product to growers while improving their chances of achieving higher yields and harvesting better quality crops. Precise insecticide applications to the seed during processing or through breeding and biotechnology will in time take much of the guesswork and inherent risk out of the farmers' hands. Today they have to contend with poor equipment, sometimes shocking supplies of water for the spray mix and constraints on time and supervision to make sure that the operation takes place both timorously and under optimal conditions. Even well-applied insecticides can be completely negated by sudden heavy rainfall soon after application.

Honeydew

Although honeydew is usually a symptom of poor pest management, it is treated here as a separate item because of the very serious nature of the problem in the marketplace. Usually it is a result of either a late aphid attack or of whitefly infestation when the bolls start to split and they are contaminated with sugary exudates from these sucking pests. Honeydew is not a serious problem generally in Zimbabwe and this is a result of circumspect use of pesticides during the crop's life, especially the pyrethroids that are believed to encourage the population explosions of whitefly, and of not over-doing the application of nitrogen. Control recommendations are in place for both pests and accurate and timely scouting and preventative measures will normally ensure that they are not a problem.

Avoiding Contamination

Manmade fibers are the scourge of the modern cotton industry. In Zimbabwe great efforts are taken to minimize the risk of foreign contamination of the crop. Every seed packet sold to the farmer carries a message warning growers not to use polypropylene bags to harvest their crops. The ginning companies supply fertilizer in unwoven polythene bags which can be used to harvest the cotton crop later with minimal risk. They also supply the grower with polythene picking bags to help them harvest their crops and thereby minimize contamination risk. At the delivery depots, price penalties are strictly enforced for any cotton found contaminated with manmade fibers and other contaminants. Strongly worded warnings are exhibited at every depot at the entrance and the message is conveyed at every opportunity to growers at field days and depot open days.

Cotton is delivered by the grower in jute packs and these are sewn up with cotton twine and labeled with cotton cloth to indicate variety. During seed cotton grading a careful watch is kept for contamination and during the emptying of packs on the mixing floor special teams of workers look for contaminants. As a final check the automatic lint sample taken from each bale produced is again thoroughly checked for unwanted fibers.

Maximizing Product Quality during Harvest

This is one area in Zimbabwe where the industry has taken a leading stance. Grower education is a continuous process and numerous field days and extension demonstrations are utilized by the marketing companies to achieve this. Growers are encouraged to harvest their crops by starting early, using two polythene picking bags, one for clean cotton and the second for stained trashy or weak/immature cotton. They are encouraged to further check this cotton on grading tables before packing for delivery. Cotton is only picked after any dew has dried and at weighing of each pickers out-put the cotton is checked for conformance to the grower's standards.

Zimbabwe: Delivering to Market to Maximize Lint Quality

Seed cotton is normally packed into 200-kilogramme packs when ready for market. Seed cotton is checked for moisture content on delivery and only accepted if less than 12.5% moisture.

The packs are made of jute and annually a huge exercise takes place at ginneries repairing packs to minimize contamination with dust through holes and to reduce the fraying of hole edges which can also cause unwanted contamination of the cotton.

Grading for Quality

Seed cotton is bought against nationally agreed standards that are approved each year and distributed to every buying depot. This has implications for seed quality and normally only the top three grades of seed cotton are accepted for seed crop purposes with the seed cotton grading system providing a good indicator of ginned seed suitability for processing for planting purposes.

The industry pays for a National Arbitrator whose job is to visit depots during the buying season to see that standards are being maintained. He will also arbitrate in the event of a grade dispute, and samples are kept from every pack of cotton bought for this purpose. He reports to the Arbitration Committee of the National Cotton Council and provides regular feedback on what is happening at the buying centers.

Ginning for Quality

The ginning process in Zimbabwe is almost entirely on saw gins. Several manufacturers are represented but there is an increasing trend to install higher capacity and fewer gin stands that are replacing or superseding the traditional five by 120 saw gin stand set-up. In general though ginning speeds in Zimbabwe are fairly slow and lint cleaners only used where absolutely necessary. The lint produced is relatively free of mechanical neps and ginning preparation is good. Mechanical degradation of the fiber and excessive short fiber content are

rarely excessive.

Classing for Opportunities

Great care has always been taken in classing the Zimbabwean crop. This has been done according to international (USDA) standards as well as by establishing Zimbabwean selling types. For several years, manual classing has been backed up by a 10-20% HVI testing of bales within each ginning lot. The main player in the Zimbabwean market, The Cotton Company has recently up-graded its HVI equipment installing the latest machines.

Close liaison between the marketing companies, Quton Seed and the breeders at Cotton Research ensures that the promise of elite germplasm lines is indeed translated into improved fiber qualities in the lint product available.

The Future

There is no doubt that the Zimbabwean cotton industry has been built upon a very sound foundation with the resultant products of lint, ginned seed and planting seed being of very high quality. Although at present the country has not adopted new technology such as Bt and herbicide resistant genetically modified cotton, the legislation is in place and facilities, procedures and monitoring mechanisms are ready to test this technology on the ground. This will start this coming season. It is highly likely that these advances will offer significant improvements to growers and the industry. They will free grower's time to spend more effort on keeping crops better managed and producing even higher output and qualities. The systems and controls in place in Zimbabwe lend themselves to any labeling requirements stipulated by the world markets to identify this type of cotton. Or to continue to identify non-Living Modified Organisms cotton for that matter. However it does seem that genetic modification offers an extremely efficient method of delivering technology advances precisely through the seed. And when advances in fiber quality start to become available as they inevitably will, few countries will be in a position to ignore that opportunity to rapidly improve product quality.

Fundamentals of Crop Management in High Quality Cotton

Hussein Yehia Awad, Agricultural Research Center, Cotton Research Institute, Egypt

Egypt is a leading producer of long and extra long staple cotton. Because of special climatic conditions, agronomic factors and a specific breeding program, Egyptian cotton deserves its reputation as a high quality cotton.

Climate acceptable

The Egyptian cotton cultivars of high quality are sown in the Delta region within limits of approximately 32°N latitude and 30°N latitude. These areas of production generally meet the physiological requirements of these varieties such as:

Spinning Test Report on the Egyptian Cotton Crop of 2000

Variety and Grade	Sugar Content (%)	Ring Spinning										Rotor Spinning (O.E.)		
		Lea Product			Single Yarn						Lea Product	Single Yarn		
		Carded	Combed		Carded (60s)		Combed (60s)		Combed (120s)		Carded 30s	30s Carded		
		60s	60s	120s	C.N/tex	E (%)	C.N/tex	E (%)	C.N/tex	E (%)	C.N/tex	E (%)	E (%)	
Giza 70 G/fg	0.17	2835	3055	2000	15.8	4.0	16.6	3.8	13.7	3.1				
Good	0.20	2750	2860	1965	14.9	3.1	15.9	3.8	12.8	2.8				
Giza 88 G/fg	0.14	2865	2965	1990	16.5	3.3	18.8	4.9	14.5	3.4				
Good	0.16	2755	2935	1850	15.8	3.1	16.5	4.4	14.0	3.1				
Giza 86 G/fg	0.14	2515	2795	1730	13.5	4.1	15.3	4.6	11.8	3.3	2595	13.7	4.7	
Good	0.16	2335	2680	1650	12.5	4.3	15.0	4.9	11.5	2.8	2540	12.9	4.6	

- Relatively long season of about 180 days above 15°C and not exceeding 37°C in the mid-summer.
- Continuous sunshine with long day duration especially in the mid-season, about 9, 13 and 9 hours/day, for beginning, mid and late season, respectively.
- More humid region where the mean relative humidity is about 65-70%.
- The growing degree days (DDU) ranging between 3,000-3,500 units through the whole season (Sin Curve Method California)

However, all cotton in Egypt is land irrigated because the average rainfall does not exceed 60 mms.

Cotton Soil

The basic needs of cotton from the soil are water, oxygen, nutrients and anchorage of roots.

Most of the soil in the Delta of Egypt are alluvial and may be heavy clay or clay-loams. However, the heavy soil favors growth and development of high quality varieties due to its granulation which keeps the soil loose. This allows the air to circulate more freely, prevents excess water to drain with little hindrance and makes it possible for water to respond freely to the capillary pull of the plant roots.

Sowing date

The soil temperature at 20 cm depth before knocking the ridge should be 15°C (60°F) at 8:00 am for ten successive days before planting, in order to secure the highest germination percentage (about 85%). This date permits early sowing through March, which in turn permits a long season for growth, development and maturity of the plant early in the season, where rainless and sunny days are desired.

Hoeing

Hoeing is the process of removing and destroying the weeds in cotton fields, besides filling the top of cracks in the soil loosening the soil, so that it may be properly aerated to help water penetration and keep soil in proper condition for plant nutrients.

Usually cotton fields need 3-4 hoeings through the growing season, where the cotton plants come to the middle of the row by final hoeing.

Thinning

Thinning is carried out when cotton seedlings reach the 1-2 true leaves stage by leaving two plants/hill. This stage is reached 4-5 weeks after sowing. Delaying thinning past this stage results in creation of high competition within each hill which in turn depresses plant growth and development.

Plant Density

The plant density per unit area is that which recognizes maximum photosynthetic activity accompanied by reducing plant self shedding to the minimum.

The optimum plant population ranges from 120,000 to 150,000 plants per hectare (65 cm row width x 20.25 cm between plants/hill). These numbers are reduced through the growing season by 10-20%. Remaining plants are sufficient to produce higher yields.

Fertilization

An average application of fertilizer is approximately 140 kg N, 50 kg P₂O₅; and 60 kg K₂O per hectare. Nitrogen is applied in two equal doses; after thinning and before the second irrigation. Phosphorous and potassium are added through land preparation. The addition of organic manure reduces the need

Fiber Quality Measurements on the Egyptian Cotton Crop in 2000

Variety and Grade	Visual Color	HVI measurements										Micromat measurements			Pressley
		Color		Fiber Length		Fiber Strength	Fiber Elongation	Micr. Value	Fiber Fineness & maturity			Fineness	Fiber Strength		
		Reflectance	Yellowness	2.5% SL	Uniformity	(g/tx)	(%)	(%)	Micr. Value	Maturity Ratio	Maturity	(m/tex)	o'gauge s.w.r		
		Rd %	+B	(mm)	(%)					(%)					
Giza 70 G/fg	White	72.6	9.5	35.0	50.5	33.7	7.0	4.0	4.0	1.0	90	148	11.5		
Good		71.4	9.7	34.6	49.0	33.1	6.7	3.8	3.8	1.0	85	140	11.0		
Giza 88 G/fg	Creamy	64.2	12.4	35.0	50.3	34.0	6.8	3.9	3.9	1.0	91	142	11.1		
Good		63.5	12.7	34.2	48.7	33.0	6.5	3.7	3.6	0.9	84	136	11.3		
Giza 86 G/fg	White	74.1	9.5	32.0	50.8	31.0	7.3	4.2	4.2	1.0	91	157	11.0		
Good		73.0	9.5	31.5	49.2	30.5	7.2	4.0	4.0	1.0	84	152	10.7		

for nitrogen fertilizer by 20%.

Regarding micronutrients, in case of deficiency, Fe, Zn and Mn are added to cotton by foliar nutrition technique.

Irrigation

The amount of water needed during the growing season depends upon many factors such as soil type, climatic conditions and variety.

Preplant irrigation may be made, especially when there is enough water and time to carry it. Irrigation at planting should be carried immediately after sowing. First irrigation should be carried after sowing by three weeks. This irrigation may be retarded to 4-5 weeks especially in heavy soils when rice precedes cotton. The second irrigation should be applied after three weeks from the first. Then irrigation should be followed at 12-15 day intervals. Irrigation should be carried early in the morning or at sunset. Increasing or decreasing the amount of water at each irrigation, and the number of irrigations affects cotton in many ways including maturity of fibers.

Harvesting

At picking time, rainless and sunny days are required. Rains discolor lint of open bolls. Also, rains and wind together cause locks to fall to the ground. Frequent daily rains cause seed to sprout in the boll and result in much boll rot even in open bolls.

In Egypt, picking starts when about 60% of the bolls on plants are open. The second picking is done about 3-4 weeks after the first. However, picking is carried manually and this method of harvesting produce higher cotton grades.

Reference

- Blibro, J.D. (1975). Relationship of air temperature to first blouse dates of cotton. *Texas Agric. Exp. Sta. Misc. Publ. No. 11*.
- Mc. Mahout and Low, A. (1972). Growing degree days as a measure of temperature effects on Cotton. *Cotton Growing Rev.* 49: 39-44.
- Young, E. F., Taylor Jr., A. and Petersen, H. b. (1980). Day-degree units and time in relation to vegetative development and fruiting for three cultivars of cotton. *Crop Sci.* 2: 3 70-3 7D.

Transgenic Agriculture: A Tool or a Threat for Integrated Crop Management?

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Introduction

Agricultural crops are the product of several centuries of plant breeding where desired traits have been selected to enhance yield, disease resistance, quality and agronomic performance. Plant breeding techniques have become increasingly sophisticated since 1900 and have routinely employed techniques such as cell fusion (since 1909), mutation via X rays (since 1927) and embryo rescue (since the 1960's). The latest technique to be introduced to facilitate plant breeding is genetic engineering, by which genetic material from other organisms is inserted into a plant to allow it to express novel traits. Such plants are known as Genetically Modified Plants (GMPs) or shortly transgenic plants.

The "first generation" of Genetically Modified crops (GE crops) focuses on agronomic traits to reduce crop losses due to pests and to reduce pesticide use. As expansion of transgenic crops continues, a shift will occur from the current generation of "input" agronomic traits to the next generation of "output" quality traits. Despite a number of benefits of current GE crops, there are concerns regarding their potential adverse effects on human health and the environment, and their production and consumption have been subjected to strict regulation in many countries.

Today the widespread application of conventional agricultural technologies such as herbicides, pesticides, fertilizers and tillage has resulted in severe environmental damage in many parts of the world. Integrated Crop Management (ICM) arose from the recognition of the need for sustainable and profitable agricultural production systems and concerns about environmental stewardship. ICM programs provide integrated plans for management of soil fertility, soil and water resources, pests, and crop production in a way that sustains agricultural profitability and promotes conservation of biological diversity.

The use of GE crops may have potential benefits for farmland wildlife, particularly if their use results in better targeted or lower use of agrochemicals. On the other hand, the introduction of GE crops may permit changes to land use and management, which can be detrimental to wild life. Therefore, the potential impact of a transgenic plant must be carefully analyzed and proper risk management procedures which should always be incorporated into risk assessment, must be applied during transgenic agriculture. In addition, risk communication has to play a central role in ensuring that all stakeholders, i.e. the public, the industry and scientific community, are jointly aware and convinced of the care being taken with the assessment procedure.

Present Status of Commercial Transgenic Agriculture

GE crops are currently being grown in commercial agriculture in several countries, particularly the United States, Argentina, Canada and China. At present several basic commodities dominate the market for GE crops: soybean, corn/maize, cotton, canola/rapeseed, potato, squash, and papaya. Globally in 2000, transgenic soybean occupied first place at 25.8 million hectares, with transgenic corn in second place at 10.3 million hectares, transgenic cotton in third place at 5.3 million hectares, and transgenic canola in fourth place at 2.8 million hectares. Global area of transgenic cotton increased 1.6 million hectares, from 3.7 million hectares in 1999 to 5.3 million hectares in 2000—this was equivalent to a year-over-year increase of over 40% in the global area of transgenic cotton. The most significant increase was reported for the USA where the percentage of transgenic cotton increased from 55% in 1999 to 72% in 2000. China is reported to have significantly increased its transgenic cotton area to more than 10% of its national cotton area, and most modest increases have been reported for Mexico, Australia, Argentina, and South Africa (James, 2000).

The most widely planted GE crops concern only one agronomic trait, though a few varieties incorporate two traits. During the five-year period of 1996–2000, herbicide tolerance has consistently been the dominant trait with insect resistance being second. It is noteworthy that the area of herbicide tolerant crops has increased between 1999 and 2000 (from 28.1 to 32.7 million hectares) as well as crops with stacked genes for herbicide tolerance and insect resistance (from 2.9 million hectares in 1999 to 3.2 million hectares in 2000), whereas the global area of insect resistant crops has decreased from 8.9 million hectares in 1999 to 8.2 million hectares in 2000. Globally in 2000, 16% of the 34 million hectares of cotton was transgenic, which was herbicide tolerant (2.1 million hectares), insect resistant (Bt)/herbicide tolerant (1.7 million hectares), and Bt cotton (1.5 million hectares).

Potential Benefits of GE Crops

A number of benefits are expected from the use of GE crops. These include: the decreased use of pesticides from modifying agronomic traits, and moderately higher yields from reduced crop losses. With respect to crops, due to expected lower pesticide use and constant or better yields, these GE crops should increase farmer's profits. They are also expected to decrease many of the environmental consequences of pesticide use through the use of less harmful active ingredients as well as overall reductions in active ingredients. This environmental externality of GE crops can provide important benefits to society as a whole. These benefits are given below for each type of GE crop.

Potential Benefits of Herbicide Tolerant GE Crops

Herbicide tolerance has been achieved through techniques other than genetic modification, for example mutagenesis. Modern biotechnology has been able to genetically modify a number of major agricultural crop varieties to resist/tolerate the application of wide-spectrum post-emergent herbicides, such as glyphosate based formulas. Genetic modification enables the insertion of genes which de-activate a herbicide when it is applied to the crop. Herbicide tolerance can also be achieved by inserting genes which replace an important enzyme in the crop which is susceptible to the herbicide applications.

GE cotton varieties resistant to Buctril herbicide, Glyphosate herbicide, called "Roundup Ready (RR)" and Sulfonylure herbicide became available in 1996 and 1997, respectively. It has been suggested that to obtain similar weed control results, Roundup Ready cotton requires lower herbicide use than the conventional treatments, though more than one application of Roundup herbicide is required. However, at present, it is not clear whether herbicide tolerant GE crops used in conjunction with a particular herbicide will lead to more or less herbicide use. A constancy in herbicide use rather than a reduction is possible.

The use of broad spectrum contact and systemic herbicides with herbicide tolerant GE crops may reduce the need for cultivation which encourages germination of weeds and to incorporate persistent soil acting herbicides into the soil. Mouldboard ploughing can have adverse effects on soil earthworm populations. Also reducing cultivation will help to conserve soil micro fauna and flora, and reduce soil erosion.

Broad spectrum herbicides such as glyphosate and glufosinate ammonium can be applied after weeds have emerged and remain active for relatively short periods of time. Herbicide tolerant GE crops allow the use of herbicides with a wider spectrum of activity which could be applied after the weeds emerge and which can be targeted at the correct growth stage to give the most effective control. Therefore, herbicide tolerant GE crops potentially offer greater flexibility and simpler programs of sprays.

Potential Benefits of Insect Resistant (Bt) GE Crops

Engineering plants with crystal protein genes from *Bacillus thuringiensis* (Bt), a soil bacterium, was one of the first projects in plant biotechnology (Peferoen, 1992). The use of Bt sprays had demonstrated their specificity and safety, the few Bt crystal proteins known at that time proved to be very active against certain important agronomic insect pests, the crystal proteins were encoded by single genes, and discovery programs indicated that Bt was an excellent source of proteins for new pesticidal activities (Payne and Sick, 1993; Grochulski et al., 1995).

Bt varieties of cotton were developed as alternative pest management strategies to control the principal cotton pests, cotton bollworm and the boll weevil. The transformed cotton with a Bt gene resistant to lepidopteran insects is called Bollgard™ in the USA and Ingard™ in Australia.

GE crops with insect resistance genes may reduce insecticide use by more accurately targeting the pests which attack the crop. However, the impacts on pesticide use depend on the degree of pest infestation in any given environment and year. A 1996 study of 300 growers in the Southeast United States found that pesticide applications were 70% lower, yields were 11% higher and profits attributed to Bt cotton adoption were about US\$50 higher per acre (Marra et al., 1997). An econometric study based on ARMS data for cotton for 1997 finds that the increase in adoption of Bt cotton led to a significant decrease in insecticide use and significant increases in yield and variable profits (Fernandez-Cornejo and McBride, 2000).

It has been asserted that Bt crops themselves have minimal effects on non-target insects with which they may come into contact, and they may permit the establishment of beneficial insects in the field and field margins. Bt crops may have the potential to lead to more effective control of insects pests and may reduce the current dependence on agrochemical sprays, which may favor farmland wildlife. Consequently, GE insect resistant crops may provide an additional technique which could be a useful tool in an ICM system if specific research is carried out to identify how they may be integrated safely into such programs.

Potential Adverse Effects of GE Crops

It has been suggested that a number of potential adverse effects may arise from the release of GE crops into the environment. The likelihood of these effects occurring depends on the plant which was modified, the novel characteristics introduced by the genetic modification, and the way that the GE plant is used. GE crops may have potential adverse effects on the environment, human and animal health, as well as have potential impacts on agricultural practices and socio-economic structure. These potential adverse effects could include:

Potential Impact on the Environment

Most of the environmental concerns about GE crops derive from the possibility of gene flow to close relatives of transgenic plants, the possible undesirable effects of the exotic genes or traits (e.g., insect resistance or herbicide tolerance), and the possible effect on non-target organisms.

Potential Gene Transfer from GE Crops to other Plants

Transfer of the inserted genetic material to other crops or native plants, through pollination by wind or insects, could have adverse effects. For example, transfer of genes from herbicide tolerant GE crops to other related cultivated non-GE varieties

or wild relatives via cross pollination may result in herbicide tolerant and multiple herbicide tolerant hybrids which may be difficult controlled. Insect resistance genes may also be transferred to closely related plants which could gain a selective advantage over other native plants, because insect feeding, which is an important factor in restraining plant population growth, is reduced.

The potential for genetic escape from any one plant to another (whether non-GE or other GE crop plants or related wild plant species) depends on a cycle of events coming together:

- Dispersion of pollen containing modified genetic material by wind or insect;
- Simultaneous flowering of a recipient plant leading to successful fertilization;
- Production of viable seed;
- Germination, establishment and growth of fertile hybrid plant;
- Maturation to flowering of the hybrid (or recipient crop plant) and release of its pollen containing altered genetic material.

Relevant factors which will determine the likelihood of completing this sequence of events include: (1) the distance that pollen disperses compared with the isolation distances required for a GE crop and the extent of its separation from potential recipients, and (2) the geographical occurrence, proximity and flowering synchrony of wild relatives with the potential for fertile hybridization and the subsequent hybridization rates.

Potential Gene Transfer from GE Crops to other Microorganisms

There is a potential to transfer genetic material to soil microbes which degrade modified-plant material. The extent of any such gene transfer and its significance has to be assessed taking account the considerable varieties in the background status of soil microbes. Thus antibiotic resistance transfer may occur, but this needs to be related to the extent of pre-existing antibiotic resistance within the soil's microbial system. The fitness of the transformed species needs to be considered.

There is also concern about horizontal gene transfer that the existence of a transgenic plant with resistance for a particular pest or disease might exacerbate the emergence of new resistant pests or diseases.

Potential Dispersal of the GE Crop

Potential dispersal of the GE crop in the environment through possible increased persistence, invasiveness and competitiveness with native plant species could change the population dynamics of the release site and the surrounding environment. There is a potential for "gene-stacking" or the accumulation of different traits within the same plant when genetic transfer from other simultaneously flowering adjacent crops occurs or when there are residual flowering donor plants which have remained in the field from a previous crop (volunteer plants).

A crop plant which has acquired the capacity to express genes, e.g. conferring tolerance to two different herbicides, would require different methods of control from that needed when either gene is expressed singly in a crop plant. This dual incorporation of genes may have crop protection consequences in the field but the significance of any transfer of genes to a wild related plant will depend on whether any selection pressure occurs in non-cropped habitats. This selection pressure may provide an environment that confers a competitive advantage to the novel plant. On the other hand, unless managed carefully at the farm, the volunteer plants which emerge from previous year's herbicide tolerant GE crop, will be weed for the next crop of the agricultural rotation and these may be difficult to control.

Potential Adverse Effects on Non-Target Insects

Insect resistance genes in GE crops may cause adverse effects on non-target insects, if predators or parasitoids which feed on the pest are affected indirectly when feeding on prey or hosts which contain the toxin after feeding on the GE plant. This would depend on the specificity of the toxin encoded by the genetic modification, that is the number of other wildlife species which could be effected by the toxin.

Preliminary information is available from limited laboratory studies on the effects of consuming GE crop plants or their expressed gene products on non-target insects. For example, in relation to insect resistant crop plants (expressing a Bt toxin or a lectin), there is some information available from tritrophic studies involving target insect pests and their non-target predators or parasitoids. Insects may be exposed to pollen containing the expressed products of genetic modification which may be found on both GE and non-GE crop plants or the insects may themselves be pollinators collecting and storing materials. The impact on these insects or terrestrial ecology in general of changes in GE plants cannot be fully deduced from small plot trials.

Potential Impact on Biodiversity

The presence of a herbicide tolerant trait in a GE crop may result in a change in the pattern of herbicide use from that on the non-GE crop in terms of altered amounts or use at different times. This may affect on the biodiversity or structure of non-crop weed species in the field, which in turn may have an indirect impact on invertebrates associated with such weeds present in the crop.

In most situations, it is envisaged that a switch to GE herbicide tolerant crops will not necessarily increase herbicide use. It is likely that, in practice, the pattern of use of different herbicides will change. Fewer products may be used, and in reduced quantities. However, there are concerns that if each application of a broad spectrum herbicide is highly effective, the overall impact of herbicide use on farmland wildlife may be comparatively greater.

The insect pattern is also going to change due to cultivation of Bt crops. If one species of insects is suppressed strongly and continuously by Bt crops, some major insects will become minor pests, while some minor insects may become major ones. Also new insects may adopt to Bt crop more quickly due to less use of insecticides. Although effective control may be observed by Bt crops on one or more primary pests, all pests will not necessarily be controlled and chemical pesticides may still need to be applied. The need for two types of pest control methods may therefore increase the impact on non-target species and any perceived environmental benefits from the use of the GE crop may be lost.

Potential Impacts on Animal and Human Health

There are numerous potential concerns about consumption of GE crops, such concerns have focused on the potential for allergic reactions to food products, the possible introduction or increase in production of toxic compounds as a result of the GE technology, and the use of antibiotic resistance as markers in the transformation process (FAO and WHO, 1996).

Allergenicity

A food allergy is an adverse reaction to an otherwise harmless food or food component that involves the body's immune system in the production of antigen-specific Immunoglobulin E (IgE) to specific substances in foods. Almost all food allergens are proteins, although the possibility exists that other food components may also act as haptens (FAO, 1995).

Assessment of allergenicity for GE products includes comparing the similarity of the transgenic protein with known allergens (i.e. whether the sequence homology is or is not the same as any known allergens). "Allergens homology" is clearly not a sufficient criterion to assess the allergic potential of a new protein and even less of a whole novel food derived from GE plants (Metcalf et al., 1998).

Many of the genes now being considered for introduction to provide insect resistance depend for their action on disrupting the digestive function of the pest. It is therefore important to exclude the possibility that some of the enzyme inhibitors and lectins being considered may produce similar effects in mammals. In addition, if absorbed, these components could have effects on many aspects of metabolism, including the immune and hormonal systems (OECD, 2000 b).

Toxicity

Many crop plants contain natural toxins and allergens. The potential for human toxicity or allergenicity should be kept under scrutiny for any novel proteins produced in plants with the potential to become part of food or feed. Toxicants may be accumulated if the processes of introducing the transgenic material alter an existing metabolic pathway or introduce a new one both by gene technology and by modern conventional plant breeding (WHO, 1991).

Antibiotic Marker Genes

Marker genes are inserted into GE plants to facilitate identification of genetically modified cells or tissue during development. There are several categories of marker genes, including herbicide resistance genes and antibiotic resistance genes. Antibiotic resistance markers have been utilized during the transformation/selection process in the development of the vast majority of GE plants.

The concern has been raised that the wide spread use of such genes in plants could increase the antibiotic resistance of human pathogens (WHO, 1993). Kanamycin, one of the most commonly used resistance markers for plant transformation, is still used for the treatment of the following human infections; bone, respiratory tract, skin, soft-tissue, abdominal infections, complicated urinary tract infections, endocarditis, septicemia, and enterococcal infections.

Scientists now have the means to remove these marker genes before a GE crop plant is developed for commercial use. Developers should continue to move rapidly to remove all such markers from transgenic plants and to utilize alternative safe markers for the selection of new varieties. No definitive evidence exists that these antibiotic resistance genes cause harm to humans, but because of public concerns, all those involved in the development of transgenic plants should move quickly to eliminate these markers (OECD, 2000 a).

Substantial Equivalence

The concept of substantial equivalence is a useful framework to identify significant similarities and differences between GE foods and a suitable comparator that has a history of safe use (WHO, 1995). However, substantial equivalence does not give a clear idea about food or feed safety of GE products.

Long-term Nutritional Impact

The ability to modify substantially the composition of plants means that there are potential benefits as well as risks to the nutritional well-being of the population. When evaluating transgenic plants to be used for animal and/or human consumption to ensure that the nutritional quality of the crop is maintained or even enhanced rather than reduced during the practical procedures involving the selection of the most suitable transgene. If transgenic crops become an appreciable part of the diet then the long-term impact of nutritional changes in the amount, bio-availability or precise structure of any macro- or micro-nutrient could have a substantial impact on the health of the population. However, an evaluation of the long-term impact of these unpredictable changes on health and environment is poorly documented (European Commission, 2000).

Potential Impacts on Agricultural Practices and Socio-economic Structure

The constant exposure of insect pests to the expressed gene products when feeding on insect-resistant GE plants, may re-

sult in the more rapid development of resistance in target insect species compared with the use of discrete topical pesticide applications at infrequent intervals. Thus, with GE insect resistant crops, an earlier onset of failure to control the targeted insect pest may result. Target insects will develop resistance in five to seven years. Development of resistance could happen earlier, even in three years, if appropriate steps are not taken (Gould, 1995).

Resistance management options designed to delay or prevent the development of resistance include the siting of non-GE plants or “refuges” at sites adjacent to the Bt crops. This approach aims to provide nearby sources of susceptible insects to mate with so that the speed of developing resistance is decreased through genetic dilution. The refuges also provide local sources of natural parasites and predators (Andow, 1999).

The recommended levels of refuge use may be different for each species of GE insect resistant crop and its cultivating environment. For example, the following two types of refuges are recommended for cultivation of Bt cotton in the USA and Bt cotton growers must choose one of these options:

- For every 100 hectares of Bollgard cotton planted on the farm, 25 hectares of non-GE cotton varieties must be planted and treated with insecticide (except foliar Bt products).
- For every 100 hectares of Bollgard cotton planted on the farm, 4 hectares of non-GE cotton varieties must be planted and treated with any insecticide except those used for worm control.

In Australia, the following refuge options are recommended for Bt cotton cultivation:

- For every 100 hectares of Ingard cotton, a grower has to plant 10 hectares of irrigated non-Bt cotton which will not be treated with insecticides used to control *H. armigera*, or, for every 100 hectares Ingard cotton, plant 50 hectares of irrigated conventional cotton, which can be treated with insecticides to control *H. armigera* and *H. punctigera*.
- The refuge crop must be planted by November 15 close to Bt cotton. The refuge crop will be grown like a normal crop and will not be treated with Bt insecticides.
- Twenty hectares of irrigated sorghum or corn will be grown in every season and managed to flower between January 15 to February 28. Sorghum or corn will not be treated with products normally used to control worms (Fitt, 1996).

Genetically modified varieties are more costly than conventional varieties, due to a technology fee applied to the seed cost. These fees are based on the need for firms to recoup R&D investments in the development of the patented variety. Purchase of these varieties also carry specific requirements, fixed under contract, such as, no use or sale of own-grown seeds (for up to three years in certain cases) and a application of one of the refuge recommendations.

Economic models suggest that, under normal growing conditions and with a 10-15 year planning horizon, farmers capture

most, if not all, of the benefits from Bt technology by planting a 20-30% refuge. At lower levels of refuge, the economic models are more sensitive to underlying biological and genetic uncertainties. Risk analysis shows that the cost to farmers of planting too much refuge is less than the cost of planting too little refuge (Sears and Schaafsma, 1999). Increasing a refuge from 10% to 20% is expected to decrease the value of Bt technology by less than 1%, while reducing the probability of resistance developing from 37% to less than 1%. On the other hand, reducing the refuge from 10 to 5% is expected to increase the probability of resistance development from 37 to 74%.

Large scale utilization of Bt genes is going to affect the economics of cotton production due to not only the cost of seeds (including technology fee) but also the cost of refuges. Adoption of Bt cotton seed purchased at a higher price will ensure the supply of pure seed and careful planting for better establishment. However, the cotton growers in developing countries will depend on importing of Bt, or in general GE, cotton seeds every year.

Risk Analysis: Risk Assessment, Risk Management and Risk Communication

The focus of debate on GE crops has been their safety in respect to food use and the consequences for the environment. Relatively little attention has been paid to broader questions of risk analysis. Risk analysis is recognized internationally as a process that facilitates fair and safe use and trade of GE crops and their products. It has been defined as a three-stage process, including risk assessment, risk management, and risk communication (Beringer, 2000).

Risk assessment is the procedure used to determine how safe a GE crop or food might be. Risk assessment demands that the people producing a Genetically Modified Organism (GEO), and those regulating the safety of its use, are aware of the possible harm that might arise from its use and how likely it is that the harm will arise. Risk assessment procedures should be carried out by independent scientists on case-by-case basis. Once the risks are understood, there is a need for individual countries to decide on the desirability of using the GEOs concerned.

In conducting risk assessment it is essential to remember that human safety is not the sole criterion. Often genes are cloned into organisms whose release might cause environmental harm. The potential harm is relatively simple to determine, but it is often less straightforward to assess the likelihood of the organisms accidentally entering the environment and infecting susceptible hosts. Even less straightforward, and sometimes neglected, is an assessment of the possibility that an accidentally-released GEO might cause environmental harm by displacing native organisms.

Risk management is the use of procedures for the identifica-

tion, documentation, and implementation of the measures that can be applied to reduce the risks and their consequences. Risk management allows the handling of transgenes safely, even though their potential for harm might be very great. Risk management should always be incorporated into risk assessment, so that the GEO user is fully aware of the constraints.

Risk communication is the process for communication of the risk assessment results to the regulators of the import programs, and to other interested parties such as industry and public. Risk communication has to play a central role in ensuring that all stakeholders, i.e. the public, the industry and scientific community, are jointly aware and convinced of the care being taken with the assessment procedure.

Different approaches to risk analysis followed by countries have led to marked differences in market access, timing, and market share. Other countries of the world tend to be a part of either the U.S. or EU camp regarding current acceptance of modern biotechnology, although some have carved out intermediate positions. The U.S. and EU approaches show a different propensity to include what have come to be referred to as "other legitimate factors" in the risk analysis process. There is no definitive list of other factors but they may include economic interests, food security, animal welfare, environmental impacts, consumer acceptance, and other ethical concerns (Caswell, 2000).

Integrated Crop Management (ICM)

Enormous improvements in crop varieties, crop protection products, fertilizers and irrigation systems helped more than double world grain harvests in the last 40 years, but all agricultural activities had some level of environmental impacts. However, agriculture must be productive and sustainable, able to meet the needs of society and the consumer, without hindering the ability of future generations to produce enough food. Society requires not only sufficient, safe, and affordable food produced in an environmentally-friendly way, but agriculture must respect the natural resources of soil, water, energy and wildlife.

Integrated Crop Management (ICM) arose from the recognition of the need for sustainable and profitable agricultural production systems and concerns about environmental stewardship. ICM is a strategy which best meets the requirements of sustainable agriculture and sustainable development by managing crops profitably without damaging the environment or depleting natural resources for future generations. It is a dynamic system which uses the latest research, technology and experience in ways that suit local conditions to optimize food production, enhance energy conservation and minimize pollution world-wide.

Conclusion

Appropriate steps must be taken to meet the urgent need for sustainable practices in world agriculture if the demands of an

expanding world population are to be met without destroying the environment or natural resource base. In particular, GE technology coupled with important developments in other areas should be used by carrying out all necessary risk analysis procedures to increase the production of main food staples, improve the efficiency of production, reduce the environmental impact of agriculture, and provide access to food for small-scale farmers. Consequently, if transgenic agriculture is applied taking into account all risk analysis procedures, it may be a new tool for Integrated Crop Management, otherwise it may be a serious threat for human/animal health and the environment.

References

- Andow, D.A. 1999. Management of transgenic pesticidal crops. Paper presented at the Conference on Biological Resource Management: Connecting Science and Policy, OECD Paris, 29-31 March, 1999.
- Astwood, J.D. and R.L. Fuchs. 1996. Food biotechnology and genetic engineering. In: *Food Allergy: Adverse Reactions to Foods and Food Additives*, 2nd Edition, Ed: Metcalf, D.D., H.A. Sampson and R.A. Simon. Blackwell Scientific Publications, Boston, MA, 65-92.
- Beringer, J.E. 2000. Risk assessment and risk management. School of Biological Sciences, University of Bristol, Woodland Road, Bristol, BS8 1UG, UK.
- Caswell, M.F., Fuglie, K.O. and Klotz, C.A. 1996. Agricultural biotechnology: An economic perspective. *Economic Research Service Report*, No.687, USDA. Washington D.C., USA.
- Caswell, J.A. 2000. An evaluation of risk analysis as applied to agricultural biotechnology (with a case study of GMO labeling). In: *Transitions in Agbiotech: Economics of Strategy and Policy*. Ed. William H. Lesser. Proceedings of NE-165, Conference June 24-25, 1999. Washington, D.C., USA.
- European Commission. 2000. Risk Assessment in a Rapidly Evolving Field: The Case of Genetically Modified Plants (GMP). Scientific Opinion of the Scientific Steering Committee. Expressed on 26/27 October 2000.
- Evenson, R.E. 1999. Global and local implications of biotechnology and climate change for future food supplies. Proceedings of the National Academy of Sciences, USA. Vol. 96:5921-5928.
- Fernandez-Cornejo, J. and W. McBride. 2000. Genetically engineered crops for pest management in U.S. Agriculture: Farm-level effects. *Agricultural Economic Report*, Number:786.
- Fitt, G. 1996. Transgenic cotton resistance strategy. *The Australian Cottongrower*, Volume 17, No.3, May-June 1996.
- FAO. 1995. Report of the FAO Technical Consultation on Food Allergies. Food and Agriculture Organization, Rome.
- FAO and WHO. 1996. Biotechnology and food safety. Report of a Joint FAO/WHO Consultation. Rome, Italy. 30 Sept.-4 Oct. 1996. FAO Food and Nutrition. Paper 61.
- Gaskell, G., Bauer, M., Durant, J. and Allum, N. 1999. Worlds apart? The reception of genetically modified foods in Europe and the U.S. *Science*. July 16, vol. 285:384-387.
- Gianessi, L. and J. Carpenter. 1999. Agricultural Biotechnology: Insect Control Benefits. National Centre for Food and Agricultural Policy.
- Gould, F. 1995. The empirical and theoretical basis for Bt resistance management. ISB News Report, December 1995, Information Systems for Biotechnology, 120 Engel Hall, Virginia Tech., Blacksburg, VA24061, USA.
- Gould, F., Anderson, A.A. Reynolds, A., Bumgarner, A. and Moar, W. 1995. Selection and genetic analysis of a *Heliothis virescens* (Lepidoptera: Noctuidae) strain with high levels of resistance to *Bacillus thuringiensis* toxins. *J. Econ. Entomol.* 88:1545-1559.
- Grochulski, P., Masson, L., Borosova, S., Pustzai-Carey, M., Schwartz, J.L., Brousseau, R. and Cygler, M. 1995. *Bacillus thuringiensis* CryIA(a) insecticidal toxin: crystal structure and channel formation. *J. Mol. Biol.* 254:447-464.
- Holman, D. and Richard, C.L.. 2000. EPA advisors assess risks, benefits of Bt crops. CAST, *The Science Source for Food, Agricultural and Environmental Issues* (www.cast-science.org). Rev. October 17, 2000.
- James, C. 2000. Global status of commercialized transgenic crops: 2000. ISAAA Briefs No. 21:Preview. ISAAA: Ithaca, NY.
- Kinsey, J. 1999. Genetically modified food and fiber: A speedy penetration or a false start? *Cereal Foods World*. 44:7 487-489.
- Klotz-Ingram, C., Jans, S., Fernandez-Cornejo, J. and McBride, W. 1999. Farm-level production effects related to the adoption of genetically modified cotton for pest management. <http://www.agbioforum.missouri.edu>.
- Marra, M., Carlson, G. and Hubbel, B. 1997. Economic Impacts of the First Crop Biotechnologies. Electronic publication of the North Carolina Agricultural Research Service. University of Georgia Agricultural Experiment Station and USDA Southern Region Pesticide Impact Assessment Program.
- McGaughey, W.H. 1985. Insect resistance to the biological insecticide *Bacillus thuringiensis*. *Science*. 229:193-195.
- Metcalf, D.D., Astwood, J.D., Townsend, R., Sampson, H.A., Taylor, S.L. and Fuchs, R.L. 1998. Assessment of the allergenic potential of foods derived from genetically engineered crop plants. *Crit. Rev. In: Food and Nutrition*.
- OECD. 2000 a. Modern biotechnology and agricultural markets: a discussion of selected issues. AGR/CA/APM (2000)5/REV 1.
- OECD. 2000 b. Genetically modified foods: widening the debate on health and safety. Paris, France.

Payne, J.M. and Sick, A.J. 1993. *Bacillus thuringiensis* isolate active against lepidopteran pests, and genes encoding novel lepidopteran-activa toxins. US Patent 5 246 852.

Peferoen M. 1992. Engineering of insect-resistant plants with *Bacillus thuringiensis* crystal protein genes. In: *Plant Genetic Manipulation for Crop Production*. Ed. AMR. Gatehouse, VA Hilder, D. Boulter. 6:135-153. Wallingford, UK: CAB International.

Sears, M. and Schaafsma, A. 1999. Responsible deployment of Bt corn technology in Ontario. Plant Biotechnology Office, Canadian Food Inspection Agency, Variety Section, Plant Health and Production Division. At: <http://www.cfia-acia.agr.ca/english/plaveg/pbo/btcormai2e/shtml>.

Serageldin, I. 1999. Biotechnology and Food Security in the 21st Century. *Science*. 285:387.

WHO. 1991. Strategies for assessing the safety of foods produced by biotechnology. Report of a Joint FAO/WHO Consultation. World Health Organization, Geneva.

WHO. 1993. Health Aspects of Marker Genes in Genetically Modified Plants. Report of a WHO Workshop. World Health Organization, Geneva. WHO/FNU/FOS/93.6

WHO.1995. Application of the Principles of Substantial Equivalence to the Safety Evaluation of Foods or Food Components from Plants Derived by Modern Biotechnology. Report of a WHO Workshop. World Health Organization, Geneva.

Monitoring Cotton Growth

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Introduction

The present situation shows that the average international lint price indices for the last three seasons was bellow 60 US cents/pound. Approximately 55% of cotton production worldwide benefits from direct economic support programs or price subsidies.

Thus, it is important to weigh critically all the factors that affect final yield and crop profitability, with the goal of sustainable and more efficient production, particularly, in countries without protective subsidy policies.

It is important within this task to try to reduce all random factors in the production system. Cotton is an extensive crop, which, for its own nature and costs, must be managed intensively.

In Argentina, there is a generalized idea about cotton management focused on weed and insect control, but this is not the same with phenology monitoring. Growth monitoring is not yet seen as a useful tool relative to other tools in the growers' mind.

For the last few years, growers could make use of new technologies, such as genetically modified varieties (Bt, RR, BR or BXN) and new products like broad leaves selective over-the-top herbicides or biological pesticides of high specificity and efficacy and low environmental impact. These technologies spread rapidly due to market globalization and solved many problems improving yield expectations.

Nevertheless, consequent benefits, in the case of Argentina, could not be reached and therefore these advances were not sufficient to change the critical trend in which the industry is immersed; crop acreage fell dramatically in the last three years, directly related to low lint prices in the world.

Monitoring Growth

“Cotton plant is an excellent teacher, if you can translate its language”. When agronomists and farmers can learn this “language”, they get the most valuable tool, a very useful input, to obtain sustainable and more efficient production, and more predictable production.

The cotton management concept involves different aspects such as weed and insect control, plant growth monitoring, the use of PGR's and harvest aids. In this circumstance, the focus will be directed to the measuring techniques required for the success of the crop according to growth stages.

More recently, knowledge about cotton plant growing and development, and its physiology and phenology, has advanced to a fine-tuning stage, and so field situations can be finely interpreted and this can lead to successful final results. However, this knowledge and its field practices, are not generally applied and in most cases they are not part of common production practices. If we are able to insert them in the actual input menu in Argentina, for sure a synergism of all factors and improvement of global results could be obtained, integrating them in a better final result, higher yields and better quality. In this paper, the most relevant or easiest indices are mentioned, excluding some others that are also important.

Days - Degree

An easy way to estimate the crop progress during the growing season is through the use of “day-degrees”. Due to the relationship between cotton growing and heat accumulation, “day-degrees” are an expression of available energy for growth, and they permit an estimation of length and earliness of each crop stage, and therefore enable growers to make better decisions. Day degrees can be calculated as followed:

(Max temperature – 15.5° C) + (Min temperature – 15.5°C)/2
 # Base temperature considered is 15.5°C

In the vegetative stage, plant age can be estimated through the number of nodes, considering that node development is a function of heat accumulation (day-degrees accumulation).

Each node develops at an almost constant accumulation of between 40 to 50 day degrees.

Stage	Days - degree	
	Maximum	Minimum
Sowing to Emergence	60	50
Emergence to First Square	475	425
Emergence to First Flower	875	825
Emergence to First Open Boll	1,750	1,700
Emergence to 60% Open Bolls	2,230	2,180

These are the basics required for understanding and adjustment of local production windows and varietal performance, according to particular season length.

Height-to-Node Ratio

Growth curves allow a precise estimation of crop evolution comparing field situations to the standards. These curves are applicable, in most cases, always taking into account specific variations. It is advisable to check four different places within the field and no less than five plants in each place, considering height and number of nodes. The recommended frequency for registration of data is at least once a week.

The cotyledonar node is defined as the 0 node and subsequent nodes along the stem are counted from 0 to the top; height, which is a good expression of growth vigor, is measured also from the 0 node to the top.

From the field data thus collected, a field curve can be made and compared to the optimal situation (standard curve).

Early in the season, the number of nodes is a function of day degrees, until approximately the fifteenth node. To evaluate if height is correct according to the plant age, height can be ex-

pressed as a function of the age; that is the height-to-node ratio (or the internode length average). This is the relationship between average height and the number of nodes, as taken in the field. This figure is usually less than 2.5 cm until approximately the eighth node.

The height-to-node ratio is very sensitive to temperature. If the temperature is below average before the seventh node, the potential crop yield is not likely to be affected, because the leaves associated with boll loading have not yet developed. In the next stages, the crop production structure is defined and here the height-to-node ratio values is critical. This “sensitive” zone is situated within the seventh to eighteenth nodes (or first to twelfth fruiting branches) which are a source of carbohydrates.

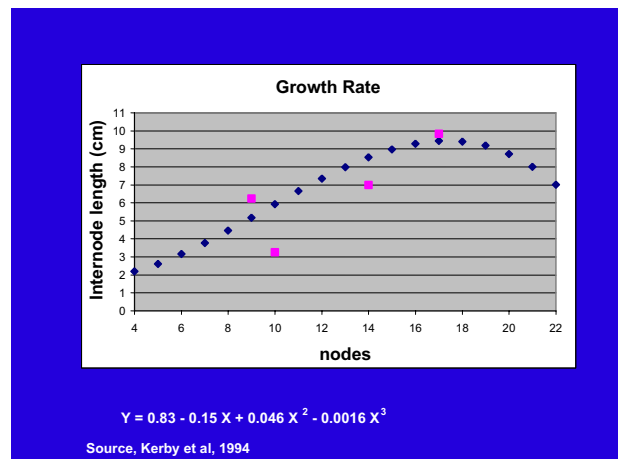
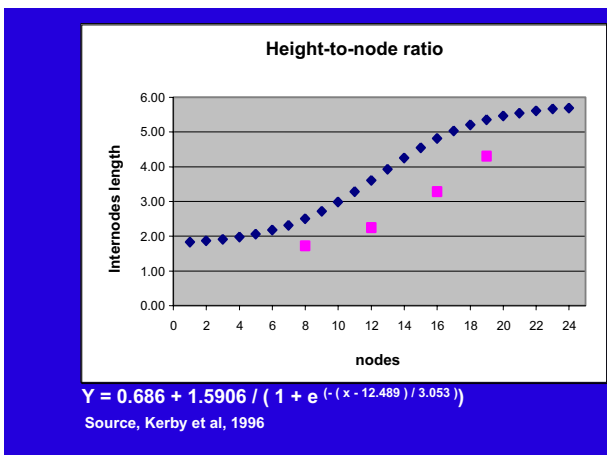
The changes in the rate of growth can be seen by comparing field values with the standard, which reflects optimum growing conditions without stress.

Growth Rate

Another useful index to evaluate crop development is the growth rate. When field data for height and node number, are recorded at regular intervals (7 to 10 day intervals), the change in the data between subsequent readings gives valuable information about the growth rhythm.

The differences between present and previous values of height and node number are used to calculate the rate of growth in height and node number. The result is a figure that represents the average number of newly formed nodes. This value should be graphed on the Y-axis of the reference curve and compared to the exact middle point between both nodes monitored (present and previous) on the X-axis. It is desirable that the real value obtained is equal or very close to an optimal situation.

The growth rate declines after flowering due to various factors, like boll setting and loading, diseases, fertility, irrigation, management and pests. At this moment, the height-to-node ratio and GR cease to be sensitive indices to monitor crop progress.



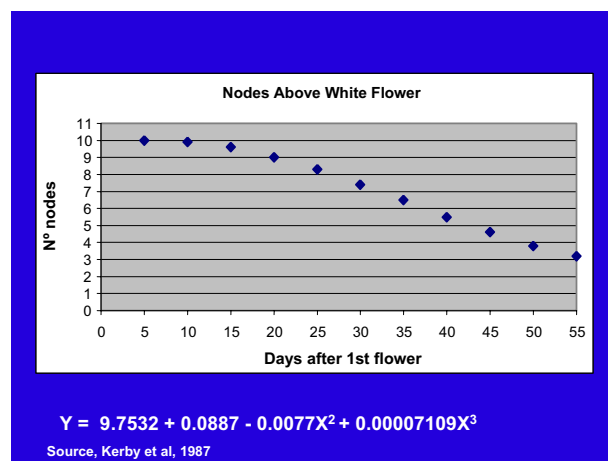
Nodes Above White Flower (NAWF)

During vegetative growth, cotton plant can develop a new node each 40-50 day degrees. However, the node production rate decreases when fruiting positions start to compete with stems for carbohydrates. This begins at about the fifteenth node. At this stage squares turn into flowers at a regular rate generally, a 3 day interval between first position flowers of successive branches can be expected.

To determine NAWF, the node associated with first position open flower in the first fruiting branch is counted as node 0 and count successive nodes to the top, considering the last to be counted the one associated with a leaf of at least 2.5 cm in diameter.

At this stage the fruiting development increases the carbohydrate demand over the vegetative growth; the NAWF gives the difference between each new node rate and an idea of the movement of the first position flower through the main stem. The NAWF values, obtained when the first blooms appear or even when first position flower gets close to the top, are still good indices to estimate the balance between vegetative growth and development.

The first flower in a non-stressed crop is commonly associated with 8 to 9 NAWF. A value of less than 8 is evidence of limiting circumstances often related to water status, soil compaction, salt, diseases or nematodes. Under optimum conditions, the NAWF initial value decreases normally at a rate of one node each 8.3 days. The crop cut-out occurs at about 5 nodes above the white flower. This suggests that insect protection must extend at least until two weeks after crop reaches 4 nodes above white flower. With 5 nodes above the white flower, 95% of all harvestable first position bolls at the flowering stage. Common practices that can affect this index include early boll setting, irrigation schedule (or water availability), nitrogen



rates, and PGR use.

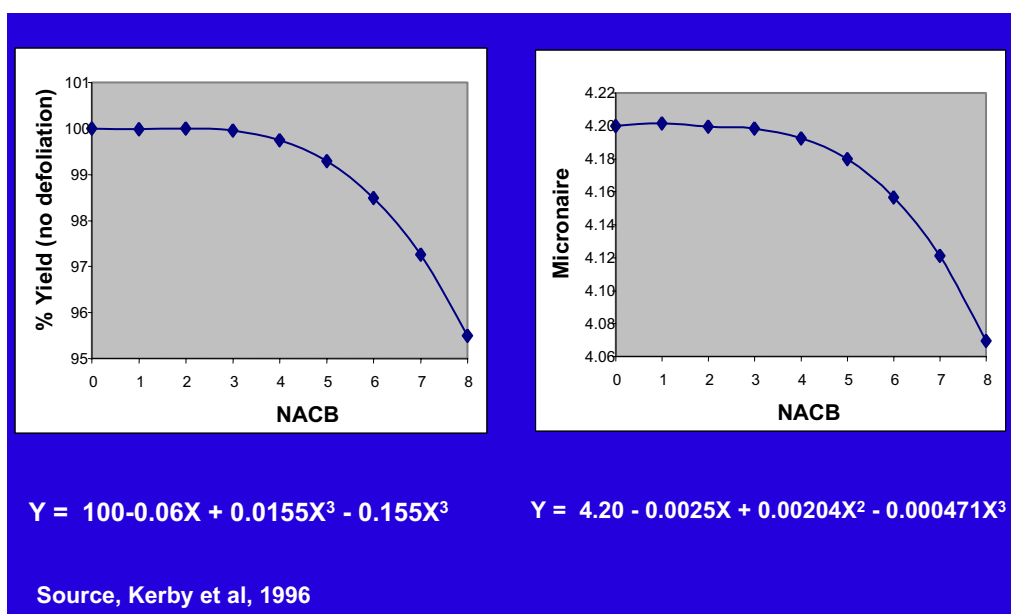
Nodes Above Cracking Boll (NACB)

Boll maturity can be evaluated according to node position on the main stem and position on the branch.

Newly formed bolls are located in the upper portion of the plant 90% of the time. Taking into account this condition, a technique called Nodes Above Cracked Boll was developed, and its main practical use is to estimate the correct time to defoliate.

To get NACB value in the field one has to locate plants with a cracking boll in the first position (cracking boll is one that splits open when pressed in the hand) and count from the associates node, considered as node 0, to the top until the one that has the last boll with a harvestable size. It is recommended to monitor 10 plants in at least 4 different locations in the field.

At 4 NACB in a field, the crop can be safely defoliated, without risk of losses in yield or micronaire. This threshold is safe enough, though defoliation can also be decided at 5 NACB;



$$Y = 100 - 0.06X + 0.0155X^3 - 0.155X^3$$

$$Y = 4.20 - 0.0025X + 0.00204X^2 - 0.000471X^3$$

Source, Kerby et al, 1996

having a loss of 1% or less.

However, it is not advisable to use this method in fields where the main stem was lost due to pests or herbicide damage, and most of the plants are in the state of “crazy top”. Here one should determine defoliation time following conventional methods.

Conclusions

Crop growth monitoring and its indices in cotton production makes it possible to:

- Interpret each one of the phenological crop phases and their corresponding needs.
- Project crop growth trends and be able to predict them.
- Fine-tune field operations management and timing.
- Minimize random factors in production (more predictability).
- Increase sustainability of the whole production system.

Final Words

Agriculture is a highly risky activity, whose unpredictability has an important impact on final results.

Environmental conditions influence and modify the crop. Weather, which the grower cannot control, also conditions the result.

To learn through experience is invariably very expensive. Everything that can be done to measure and diminish risk and to enable the farmer to understand the situation and how to change it or take advantage of it provides a useful tool and insurance against uncertainty.

Growth monitoring techniques, used regularly and consistently, allow increased production efficacy and to predict sustainability.

Unfortunately, knowledge and agriculture extensionism do not have the same marketing effort as other agriculture inputs. When we talk, (and make use of) the so called Genetically Engineered Organisms, we should probably think of Engineered Management of Production and how to communicate it, especially in those countries where prices place farmers in a difficult position.

References

- Anonymous, (1998). Deltapine Seed, *Cotton Management Guide*. 64 pages.
- Constable, G. A. (1992). Managing cotton growth. 1992. *Proceedings of the Australian Cotton Conference*. August 12 – 14, 1992.
- Hake S. Johnson, Kerby T. A. and Hake K. D. (1993). *Cotton Production Manual*. University of California. Division of Agriculture and Natural Resources. Publication 3352, 417 pages.
- Mauney, J. R. (1986). Vegetative growth and development of fruiting sites. In J.R. Mauney and J. Mc D. Stewart. *Cotton Physiology*. The Cotton Foundation, Memphis, Tennessee.

South African Experience with Bt Cotton

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(Presented by G. D. Joubert)

Introduction

The bollworm is a major pest in South Africa. The last three seasons Bt cotton cultivars were registered in South Africa and were tested extensively in different cotton-production areas. During the 1998 planting season, the first cotton seed with the Bollgard™ gene, produced by Monsanto, was commercially released by Delta & Pine Land Inc. South Africa. The cultivars were NuCotn 35B and NuCotn 37B.

Adaptability

South Africa is divided into eight (Fig 1) cotton-production areas. This division is based on climatic differences. The evaluation program showed that the Bt cultivars were well adapted to all the production areas. At present, Bt cotton is planted

successfully in all the production areas under widely different climatic conditions.

Among commercial cotton farmers, 195 bought licenses. However, the level of acceptance was lower among those commercial producers who planted cotton under rainfed conditions. By contrast, the number of small-scale farmers who planted Bt cotton increased phenomenally from 76 in the first season to 411 the following year. During the 2000/2001 season, 1,184 small-scale farmers bought licenses. In this sector, the yield increased from 40-300%. The lower the management skills, the higher the percentage yield obtained.

These farmers saw the following advantages:

- Safety: Families were no longer exposed to highly toxic

chemicals throughout the season.

- Convenience: Since water was not readily available for mixing chemicals, Bt cotton was more convenient to handle.
- Profitability: higher yields and reduced costs meant more money.

Yield

Bt and non-Bt cotton cultivars were used in trials conducted under widely different climatic conditions. These trials were done over three seasons under irrigated and rainfed conditions.

Figure 2 represents the seed cotton yield of Bt and non-Bt cultivars under irrigation. The results indicate that, over the three seasons, the Bt cultivars produced significantly higher seed cotton yields than the non-Bt cultivars.

The seed cotton yield under rainfed conditions over three seasons was 2,308 kg/ha for Bt cultivars and 1,949 kg/ha for non-Bt cultivars. The data in Figure 3 also demonstrate that the yield of Bt cotton was higher, but not significantly higher, than that of non-Bt cotton.

Fiber Properties

Many samples of Bt cotton were analyzed and, in general, the fiber properties of Bt cotton were more acceptable than those of non-Bt cotton. Figure 4 represents the ginning outturn (GOT) data of Bt cotton planted under irrigation over three seasons. The GOT of Bt cotton was higher than that of non-Bt cotton and the difference was significant for the 1999/2000 and 2000/2001 seasons. Under rainfed conditions, the Bt cotton produced a significantly higher GOT during the 1999/2000 season (Fig 5).

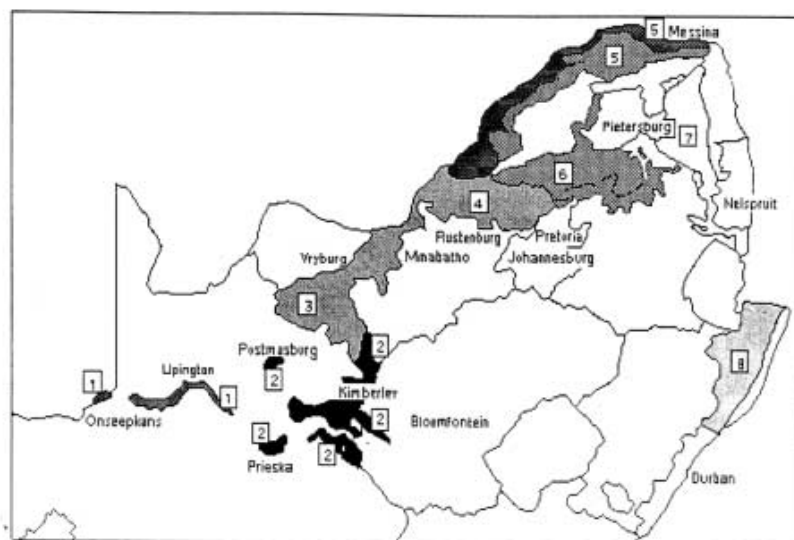


FIG. 1. Cotton Areas in the RSA (areas 1 to 8)

1. Lower Orange River (Irrigation)
2. Griqualand-West (Irrigation)
3. North-West - Vryburg
4. North-West - Rustenburg
5. Limpopo Valley
6. Loskop - Springbok Flats
7. Lowveld (Irrigation)
8. KwaZulu-Natal

No significant differences in length and strength were found between Bt and non-Bt cotton under irrigated and rainfed conditions. There were also no significant differences in micronaire between Bt and non-Bt cotton under irrigated and rainfed conditions, but there were some indications that the micronaire values of both Bt and non-Bt cotton were lower under rainfed conditions (Fig 6).

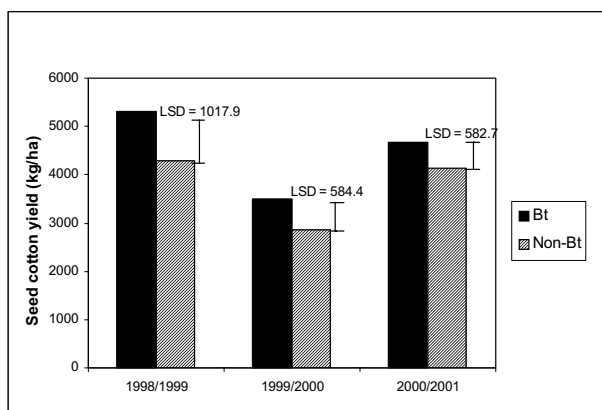


Fig. 2. A comparison of the seed cotton yield of Bt and non-Bt cotton under irrigation over three years

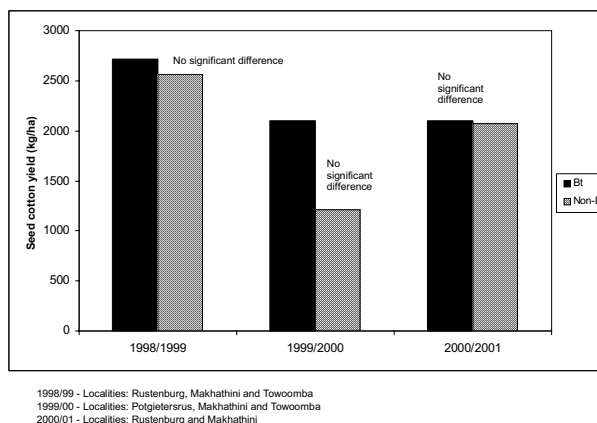


Fig. 3. A comparison of the seed cotton yield (kg/ha) of Bt and non-Bt cotton under rainfed conditions for different season

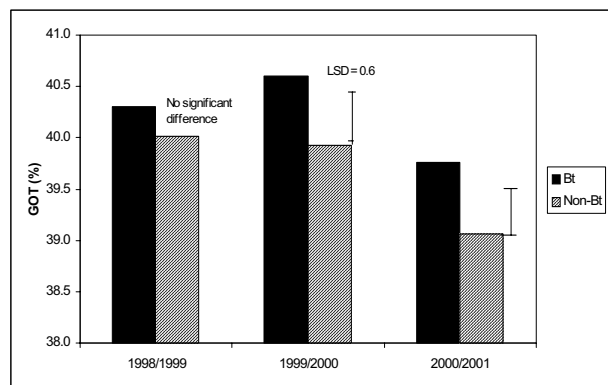


Fig. 4. A comparison of the GOT (%) of Bt and non-Bt cotton under irrigation over three years

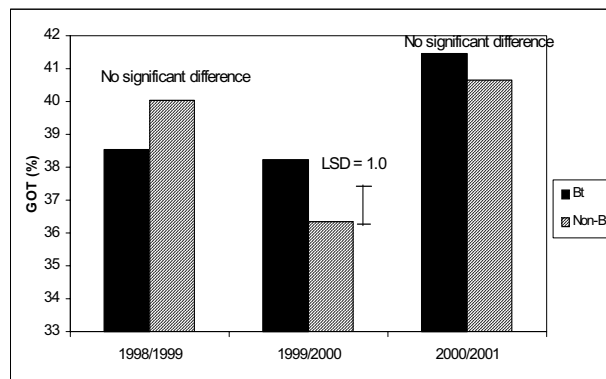


Fig. 5. A comparison of the GOT (%) of Bt and non-Bt cotton under rainfed conditions over different seasons

Plant Diseases

Since their introduction into South Africa, Bt cotton cultivars have been included for evaluation in our annual national cotton cultivar trials. This has enabled us to evaluate these cultivars extensively for their reaction to the various cotton diseases that occur in different cotton-growing areas. A wide range of fungal and bacterial diseases occur in all the cotton-growing areas of South Africa. However, not all these diseases are of economic importance. The following diseases are found:

- Verticillium wilt (*Verticillium dahliae* – two pathotypes of the defoliating strain)
- Seedling diseases (*Rhizoctonia solani*, *Fusarium* spp., *Pythium* spp., *Thielaviopsis basicola*)
- Alternaria leaf spot (*Alternaria* spp.)
- Bacterial blight (*Xanthomonas campestris* pv. *malvacearum* – races 2, 4, 5, 8, 9, 11, 12, 15, 18, 18, 19, hyper-virulent)
- False mildew (*Ramularia gossypii*)
- Various primary boll rots (*Alternaria* spp., *Xanthomonas campestris* pv. *malvacearum*, *Fusarium* spp., *Glomerella* spp.).

The occurrence of these diseases on cotton is highly dependent on environmental and seasonal conditions as well as on the inoculum potential of the pathogen. Fortunately, at this stage, Fusarium wilt (*Fusarium oxysporum* fsp. *vasinfectum*) and viral diseases do not occur in South Africa.

Except for bacterial blight and false mildew, all of the cotton diseases mentioned above have been isolated from Bt cotton cultivars and non-Bt cultivars currently grown in South Africa. The Verticillium wilt tolerance of these Bt cultivars compares well with the level of tolerance expressed by the Verticillium wilt-tolerant non-Bt cultivars grown in South Africa.

The results indicate that the Bt cotton cultivars currently released in South Africa react almost in the same way as non-Bt cotton cultivars to the cotton diseases that occur in various cotton-growing areas.

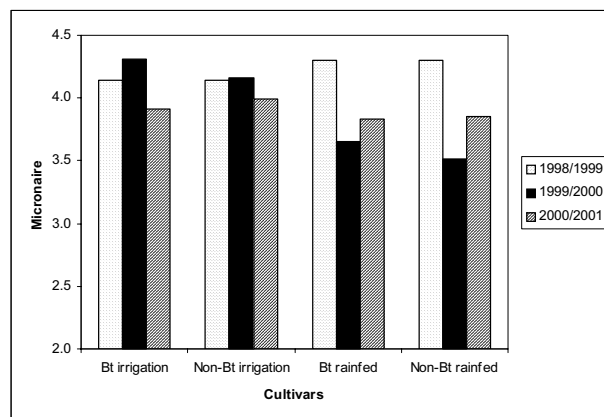


Fig. 6. Micronaire of Bt and non-Bt cotton under irrigated and rainfed conditions for three seasons

Pests

The Bt gene is used specifically for the control of the three bollworm species. This fact was explained to growers repeatedly and at length. Despite this effort, individuals had the mistaken perception that all spraying was now something of the past. Experience has taught us to be on the alert for jassids, stink bugs and stainers. These pests should still be sprayed when thresholds are exceeded. Aphids and mites are normally controlled biologically on Bt cotton, but that does not mean they cannot get out of hand. The message remains clear: scouting is still vitally important in cotton production, only the emphasis has shifted.

As is to be expected, the number of bollworms found in Bt cotton is low. In controlled experiments, an average of 0.075 to 3.9 bollworm larvae per 24 plants were found on Bt cotton during weekly scouting, compared with up to 18 larvae per 24 plants on normal cultivars. The number of larvae still found on Bt cotton should not cause too much concern because the integrated pest management system recommended to farmers is based on a spraying threshold of 5 larvae per 24 plants.

In addition, it is mandatory that growers plant a refugia of either 5% unsprayed or 20% sprayed non-Bt cotton. However, the implementation of refugia in small-scale farmer situations may be difficult.

Of great concern is the possibility that previously minor pests, or other little-known pests, may increase and attain major-pest status in the absence of adequate chemical control. In this regard, jassids pose a serious threat, while the green vegetable stink bug, which had gone unnoticed for nearly 50 years, reappeared during the last two seasons. The

appearance of the green vegetable stink bug was, however, not confined only to Bt cotton.

The variation in the pest spectrum brought about by the planting of Bt cotton differed in different production areas, but the pest pressure also varied over different seasons.

Efforts to Expand Genetically Improved Cotton in Africa

Andrew Bennett, Monsanto SA (Pty) Ltd, South Africa

Abstract

The procedure required to move forward with regard to getting genetically improved cotton accepted and commercially available is discussed. Three steps generally need to be taken, namely getting biosafety guidelines or regulations in place, secondly testing the technology for efficacy and suitability, and then thirdly, moving forward with commercialization thereby making the technology available to cotton growers. This paper also looks at some of the benefits of Bt technology under small scale production, in order to encourage efforts to expand the availability of these technologies in Africa. The adoption of this technology amongst smallholder growers in South Africa has been characterized by a high rate of acceptance, increased yield, reduced spraying and easier crop management.

Introduction

Bt cotton in the form of Bollgard™ received regulatory approval in South Africa in 1997. The technology provides superior control of the species comprising the bollworm complex, namely *Helicoverpa armigera*, *Diparopsis castanaea* and *Earias* spp. The gene components comprising the Bt technology which are introduced into the cotton genome do not alter any of the fibre properties of the variety, and fibre produced from a transgenic variety is indistinguishable from fibre produced under similar conditions in the isoline variety (Kerby et al, 2001). Furthermore, the “behavior” of fibre produced from transgenic varieties is identical to that produced from fibre produced by the isoline variety with respect to dye uptakes, spinning and fabric properties (Ethridge & Hequet, 2000). These properties ensure that lint produced from transgenic varieties is not subject to the controversies surrounding other genetically improved agricultural products, and the lint is marketed without restriction.

The Way Forward for Biotechnology in Africa

Africa needs to be proactive in developing a biotechnology policy. It is very important that Africans decide for themselves

whether they wish to adopt these technologies or not, since Africa is faced with its own unique set of circumstances. It is not helpful for Africa to have western organizations making policy for Africa. In developing such an indigenous policy, it is very important too that biosafety guidelines and legislation be developed and put in place. Capacity in the form of institutions and technical personnel need to be developed, so that procedures for testing and assessing these technologies can be done in Africa. Testing of technologies needs to be done on an individual basis – some technologies will be suitable and others not, and Africans must be in a position to make these judgements.

Collaborative research programs must be initiated and supported, with the focus of this research being aimed at crops and technologies that satisfy African requirements. It is also critically important that public awareness of the benefits and disadvantages of these technologies is developed. It is equally important that the debate around biotechnologies is conducted on the basis of factual, scientifically based information, and not on the emotions of different groups that have varying interests in the success or failure of biotechnologies. If a “European” type debate is conducted in Africa, Africa will surely lose out on the benefits that these technologies can offer.

In order to reap sustainable and long term benefits from biotechnology, further scientific capacities need to be developed. This is not to say that these capacities do not already exist in Africa, for they most definitely do. However to be able to test, adapt and implement new technologies rapidly and responsibly, greater capacities will be needed in the future. The rapid and responsible implementation of technologies that are appropriate to African needs will maximize the potential benefits of biotechnology.

Lastly, some form of intellectual property protection needs to be developed, implemented and applied. Initially, investor companies will be more comfortable in investing new technologies in Africa, but more importantly, as indigenous African biotechnologies, which have global value, are developed, they too will require protection.

Protection of Intellectual Property Rights

Currently, plant variety protection and patent protection is only available in South Africa, Zimbabwe and Kenya. Acceptance and implementation of International Union for the Protection of New Varieties of Plants and other international conventions by African countries will contribute greatly to the adoption and expansion of biotechnologies.

Biosafety Guidelines/ Legislation

Although many African countries are working hard to get legislation in place, at present only Egypt, Uganda, Kenya, Zimbabwe and South Africa have acts or regulations in place, which govern the responsible use of biotechnologies.

In Zimbabwe, approval has been granted for the testing of Bt cotton. In Kenya and Uganda, applications for trials to take place have been submitted and are currently under review. Burkino Faso is in the process of developing biosafety legislation. Swaziland and Malawi are showing a strong interest in developing guidelines and legislation, while in Tanzania, strong media support is developing.

Partnerships for Progress

Current agricultural biotechnologies (so called first generation) are aimed at benefiting agricultural producers. It follows that the farmer should be the centre of efforts to make these technologies available and sustainable. In Africa it is estimated that about 70% of the population is closely connected with an agrarian way of life, thus these first generation technologies seem to be very suitable for Africa. However, all role players need to be involved in developing “partnerships for progress”. Governments need to lead in guiding policies in the fields of commerce, agriculture and the environment. They can also develop extension services aimed at increasing farmer success and sustainability. NGO’s and other international organisations can assist by providing training and expertise. Multinationals also have a role to play initially, by providing technologies, expertise and know how. The role of multinationals may be expected to diminish in time as local capacities, infrastructures and technologies are developed. Distribution and financing are also opportunities which present themselves through the adoption of these technologies (Figure 1).

What Africans Say

“Africa is already in the biotechnology revolution. We should not be debating whether or not the continent should go for the technology but what specific policies and institutions are required to enable Africa to maximize benefits and minimize

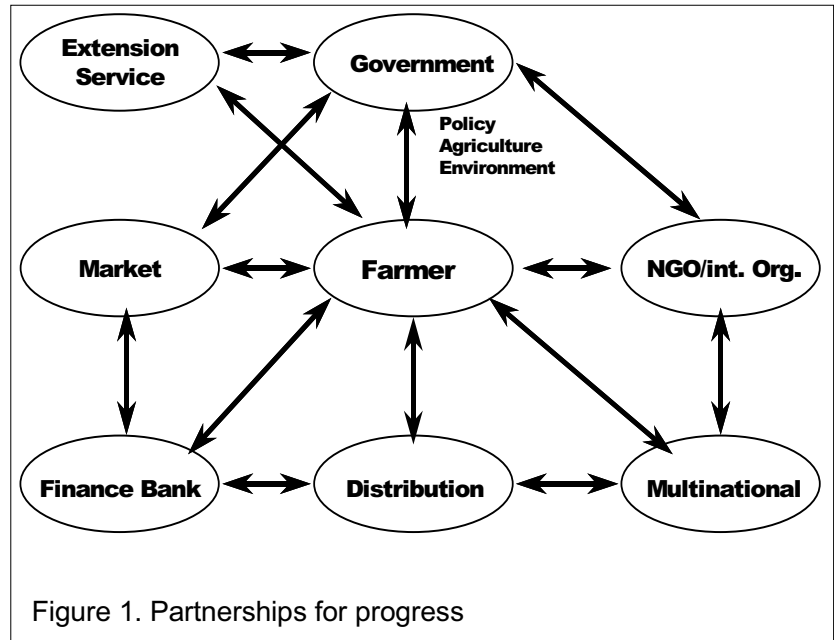


Figure 1. Partnerships for progress

risks associated with genetic engineering.”

Dr. John Mugabe

Director African Centre for Technology Studies

“Africa missed the Green revolution which helped Asia & Latin America achieve self sufficiency in food production. Africa cannot afford to be excluded from the Biotechnology Revolution”.

Dr Florence Wambugu

Bt cotton Benefits to Small Holder Cotton Farmers in the Makhathini Flats, South Africa

Smallholder growers in the Makhathini Flats are organized into some 42 independent farmers associations comprising approximately 4500 growers. Typically, these farmers grow between 1 and 3 ha of rainfed cotton annually, with the total crop covering anything between 2,500 and 10,000 ha. The number of hectares grown each year depends largely on the availability of financing as well as the cotton price. Currently, a single ginnery serves the entire area, with cotton being collected from various depots in the region. Farmers are served to a lesser or greater extent by the ginnery extension personnel, government extension officers and technical advisors from commercial companies. This paper synthesizes the results of several studies conducted in the Makhathini Flats, and presents data on adoption rates, yield, spraying, and some socioeconomic parameters. It is concluded by noting the contribution that these types of technologies can make to the quality of life and the alleviation of poverty across Africa.

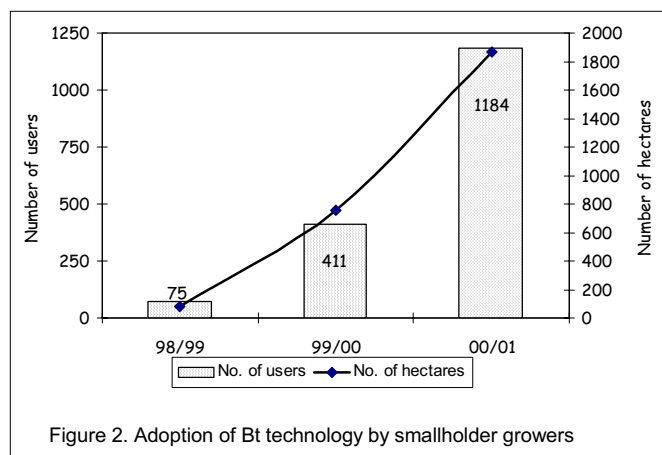


Figure 2. Adoption of Bt technology by smallholder growers

Adoption Rate of Bt Technology

In the three seasons that Bt cotton has been available, the growth in the number of smallholder users has doubled 4 times i.e. a 16-fold increase (Figure 2) (Unpublished Monsanto records). The fact that this response has been observed coupled with the fact that the transgenic seed is more expensive, clearly indicates that real advantages accrue to adopters of the technology.

When questioned on why they adopted Bt technology, 24% cited expected increases in yields as the main reason. 44% of the respondents cited saving on chemicals and pesticides and 10% believed that the labor saving properties of Bt cotton were critical in the adoption decision. Adopters of Bt cotton (35%) felt strongly that pests were their major problem and this prompted them to adopt the bollworm resistant variety. (Ismael et al 2001).

Agronomic Benefits of Bt cotton

Yield Improvements and Spray Reductions

In a set of four strip trials, yields were compared between the Bt variety and its non-transgenic isolate. A mean yield increase of 27.3 % (388 kg seed cotton/ha) was observed (Table 1) (Bennett, 2001). In the same set of strip trials, the numbers of sprays between the two treatments was also observed. On average, 5.8 fewer sprays were required by the Bt cotton compared with the non-transgenic isolate (Table 1). Taking the variable costs involved, including the additional technology cost,

it was calculated that the Bt cotton delivered a direct incremental benefit of R 943.00/ha (\$112/ha) over the non-transgenic cotton.

In a recently conducted independent study (Ismael et al 2001), in which 100 Makhathini farmers were investigated, it was found that:

- The farmers who adopted the Bt cotton variety in the 1998 and 1999 seasons benefited from the new technology, according to all the measures used.
- Using a stochastic frontier model, Bt adopters were 81% efficient on average over two seasons, compared with 57% efficiency of non-adopters
- Similarly, deterministic frontier results for both years show that the adopters were over 62% efficient, while the non-adopters averaged only 46%.
- Finally, there was no evidence that wealthier farmers gained more than the less affluent: indeed, income inequality was slightly reduced.

Savings

Non-transgenic cotton requires up to 8 or more sprays for bollworm. Bt cotton can eliminate this requirement almost completely and provide savings in the following:

- Time and labor: To properly spray one hectare of cotton with a knapsack takes the best part of a day and entails walking at least 20 km.
- Water: The provision of good quality water for the spraying of insecticides is difficult, and Bt cotton largely obviates this.
- Insecticide and equipment costs: Less insecticide is required for Bt cotton, with concomitant savings in inputs.

Improved Safety

- Bt cotton reduces the need to handle hazardous chemical insecticides.
- Insecticide containers are often used to transport drinking water - Bt cotton reduces the numbers of containers available for this dangerous practice.
- Reduction in insecticide usage reduces the risk of contamination of domestic water sources in rural areas, e.g. streams and dams.

Table 1: Comparison of Bt and non-Bt yields in the Makhathini*

Trial no.	Yield (kg/ha)		Yield increase		Value of increase @ R2.50 / kg	Spray Cost R/ha			Total benefit inclusive of tech cost (R/ha)	Number of sprays saved
	Bollgard	non-Bt	kg/ha	%		Bt	non-Bt	difference		
1	2,349.40	2,005.30	344.1	17.2	860.25	0	172.2	172.2	807.45	7
2	1,507.80	1,205.50	302.3	25.1	755.75	0	147.6	147.6	678.35	6
3	1,475.00	1,149.30	325.7	28.3	814.25	29	189.8	160.8	750.05	6
4	2,090.40	1,509.40	581	38.5	1,452.50	34.8	147.14	112.34	1,339.84	4
Mean	1,855.70	1,467.40	388.3	27.3	970.69	22.61	220.48	197.87	943.56	5.8

*Bennett et al, in press
1 US\$ = App.8.4 Rands (R)

Improved Bollworm Control Efficiency

- The effect of weather on bollworm control is reduced. Wind during spraying affects insecticide coverage negatively, and rain after spraying can necessitate a re-spray, with additional costs.
- Even under optimum spraying conditions, bollworm control is not as efficient as with Bt cotton.

Socioeconomic and Environmental Benefits of Bt Cotton

Economic Upliftment

In the Makhathini, average yields have increased since the introduction of Bt cotton. Prior to the past season, the highest average yield for the region was 620 kg/ha. The 2000/01 season realized an average yield of 980 kg/ha with the improvement being ascribed to Bt technology, since the variety composition has not changed (Grey, pers.comm). Yield increases of these magnitudes result in greater inflows of cash into the region, and increased economic activities.

Bt Technology Provides for more Efficient Land Utilization Through Superior Yields

- Varieties containing Bt technology provide higher yields than the same varieties without Bt technology.
- Improved yields ensure more efficient land utilization, and land is fast becoming a limited resource.

Bt Technology Reduces the Use of and Reliance on Broad-spectrum Insecticides

- Reduced broad-spectrum insecticide usage lessens environmental pollution.
- In rural areas, pesticide runoff often enters bodies of water and rivers, which are used as a source of drinking water for the rural population.
- Reduced broad-spectrum insecticide usage promotes the

biological control of secondary pests. (aphids and spider mites), which further reduces the number of sprays on cotton.

Conclusions

Effective Bt technology in cotton represents an effective and safe means of controlling major pests. This results in increased yields, more efficient land usage and reduced environmental impacts from pest control in cotton production. The successful and rapid adoption of this more expensive technology in the Makhathini Flats provides an initial model for smallholder cotton farmers in Africa, and testifies to the incredible benefits that can be achieved through the responsible implementation of agricultural biotechnologies.

These benefits can be realized across Africa when biosafety legislation, intellectual property protection, additional capacity building, public awareness based on facts and partnerships for progress are implemented.

References

- Bennett, A. L. , Bennett A., Green, W., Du Toit, C. L. N., Van Staden, L., Joffe, T., Richter, E., Brits, D., Friis, F. and Van Jaarsveld, J. In press . Bollworm control with transgenic (Bt) cotton. First results from Africa. *African Entomology*.
- Ethridge, M. D. and Hequet E. F. 2001. Fiber properties and textile performance of transgenic cotton versus parent varieties. *Proceedings of the Beltwide Cotton Conference 2000*.
- Ismaël, Y., Beyers, L., Thirtle, C. and Piesse, J. 2001. Efficiency effects of Bt cotton adoption by smallholders in Makhathini Flats, KwaZulu-Natal, South Africa. Paper for the 5th International Conference on Biotechnology, Science and Modern Agriculture. A New Industry at the Dawn of the Century. Ravello, Italy.
- Kerby, T., Hugie, B., Howard, K., Bates, M., Burgess, J. and Mahaffey, J. 2001. Fiber quality comparisons among varieties for conventional, Bollgard and Roundup Ready versions. *Proceedings of the Beltwide Cotton Conference 2000*.

Limits on The Use of Genetically Modified Cotton In Africa: the Case of Burkina Faso

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(Presented by Doulaye Traoré)

Introduction

Development policies in Africa place a heavy emphasis on efforts to alleviate hunger, malnutrition and poverty. This approach is predicated on a substantial increase in agricultural output with methods that are environmentally sound. To achieve food self-sufficiency and eliminate hunger, existing methods generally involve increasing the amount of cultivated land. In many cases the plants are not very productive and the use of

organic and inorganic fertilizers is very low. This results in greater pressure on the land, ongoing deforestation, depletion of the mineral content of soils and, ultimately, lower yields.

To stave off poverty, farmers grow cash crops such as cotton in the case of Burkina Faso. Here again, an increase in output means increasing the area under cultivation. Apart from the low use of fertilizers, the main obstacles to increased output

are insect pests and weeds. To address these constraints, the methods that have been developed involve the use of chemical pesticides. But it must be acknowledged that such methods, even though they may be effective, are likely to pollute the environment and disrupt the equilibrium of the ecosystem. Furthermore, the repeated and ongoing use of such pesticides may eventually produce insects that are resistant to these toxins.

Current cropping techniques have reached their limit, in terms of alleviating hunger and poverty, and could even aggravate these problems. It therefore makes more sense to find an alternative that could increase agricultural output, generate savings and also protect the environment in order to feed the ever increasing African population. The use of biotechnologies could be such an alternative.

Alternative Methods: Biotechnologies

It is hard to find a single definition for biotechnology in the literature. The term “biotechnology” first appeared in the French literature in 1979, in a report published by Professor François Gros et al. entitled *La révolution biologique des technologies utilisant les propriétés du vivant à des fins pratiques et industrielles* (The Biological Revolution of Technologies Using the Properties of Living Organisms for Practical and Industrial Purposes). As such, “biotechnology” may be defined as a set of techniques that use living organisms or parts of living organisms to develop -or modify products, improve plants or animals, or develop microorganisms for the specific needs of humans. It is not a discipline in and of itself but rather an area of inquiry that calls upon numerous disciplines such as genetics, molecular biology, biochemistry, embryology, cellular biology, chemistry, information technologies, robotics, etc.

Modern biotechnology, as defined in the Cartagena Protocol, encompasses:

- a) the use of *in vitro* techniques with nucleic acids, including recombination of deoxyribonucleic acid (DNA) and direct introduction of nucleic acids into cells or organelles;
- b) cellular fusion of organisms that do not belong to the same taxonomic family, overcoming natural barriers of the physiology of reproduction and recombination, separate from conventional techniques of reproduction and breeding.

Biotechnology also involves the ongoing development of new techniques and the availability of an ever greater variety of technologies. It encompasses traditional techniques (known to man since ancient times), widely used techniques developed over long periods of time (lactic and alcoholic fermentation, plant and animal domestication and breeding, cereal and leguminous crop rotations, etc.) and newer, so-called “modern” techniques – not yet proven in certain cases – including recombinant DNA, monoclonal antibodies and new methods for growing cells and tissues.

The techniques of recombinant DNA, generally referred to as “genetic engineering,” emerged in the 1970s and are the subject of considerable attention. They involve transferring genetic material from one living organism to another in order to alter the second organism’s genetic structure in profound ways and either cause the organism to produce new substances or provide the organism with new, more effective functions. Our *in vitro* capabilities now allow us to implant a whole range of genes in plants, animals and microorganisms. Such genetic manipulations can overcome the natural barriers of the physiology of reproduction and give life to transgenic organisms or, as they are commonly called, modified organisms.

With respect to agriculture, modern biotechnologies raise new hopes for developing countries faced with problems of food supply. Food production must not only keep pace with population growth but actually exceed it if citizens are to have access to food products of sufficient quality and quantity. To meet the challenge of survival, modern biotechnologies appear to hold tremendous potential.

In Burkina Faso, modern biotechnologies offer a clear advantage for developing the country’s agricultural sector by achieving greater yields (through improved pest management, resistance to disease, better weed control). Farmers can increase their yields and still protect the environment by growing genetically modified plants. Crops that offer the potential to obtain high yields will have a direct impact on efforts to improve food security and eradicate poverty.

In terms of cash crops, cotton provides a useful example: this crop requires the extensive use of pesticides to control insects and weeds. But such practices, as noted above, may harm the environment.

Genetically modified cotton, if it proves effective under the growing conditions of Burkina Faso, would be a good alternative for increasing farmers’ income while safeguarding the environment.

The Stakes of Biotechnologies for Africa and the Significance of Transgenic Cotton for Burkina Faso

Since the 1970s, biotechnologies have produced a true scientific, industrial and socio-economic revolution around the world. In the history of mankind, no scientific field of endeavor has ever before allowed the human race to approach so much real and potential progress, nor presented so many risks for people, for society and for the environment, even to the point of calling into question basic moral principles.

At the economic level, the biotechnologies of today are the technologies that provide the highest growth rates. The world market, with more than 2,500 biotechnology companies, largely dominated by the Americans, achieved annual growth rates of 20% to 25% and expanded from US \$8 billion in 1992 to more

than US \$83 billion (excluding agroprocessing) at the start of the 21st century.

During the year 2000, some 44 million hectares were planted with genetically engineered organisms around the world, including 5 million hectares of transgenic cotton. The countries most heavily involved in growing transgenic plants are the United States, Canada, Argentina, Australia, New Zealand, China and India. A number of African countries have already taken steps to benefit from the recent technological advances, upon which the economic stakes of the future depend. Egypt, Zambia, Kenya and Uganda are now at the stage of conducting advanced trials. South Africa started marketing GE organisms in 1997. In the space of three years, 40% of the land planted to cotton in South Africa has been switched to transgenic cotton. The technology has been very rapidly adopted because of easily quantifiable economic and ecological benefits (yields 30% higher than conventional cotton and just one or two insecticide treatments per crop year instead of eight).

Thus, GE organisms are acquiring greater and greater strategic importance in international trade and relations. Estimates of growth in the world trade of transgenic plants are highly indicative of the “fever” surrounding this technology, and the figures speak for themselves.

In Africa, agriculture is the most important economic activity, occupying 60% to 80% of the population and accounting for 30% to 50% of GNP, with 80% of all food products grown on small farms. For ten years, agricultural output has declined for various reasons, leaving many countries of Sub-Saharan Africa increasingly dependent on food imports or food assistance. African crop yields are the lowest in the world. This situation is only exacerbated by post-harvest losses, sometimes as high as 40%, due to inadequate storage and preserving techniques.

Meanwhile, the continent’s population is rapidly expanding and the phenomena of poverty, unemployment and malnutrition are becoming endemic. Over the last 60 years, the world population has tripled from 2 to 6 billion; in less than 12 years, it rose from 5 to 6 billion, i.e. an increase of 250,000 people per day. Statistics indicate that the world population will double over the next 20 years. Of the projected 8 billion people, 6.7 billion will live in the developing countries. The population of Africa will double, reaching 1.5 billion. With such a high population growth rate, agricultural output will also need to double by 2020 if there is to be enough for all.

In addition, environmental deterioration is becoming more and more pronounced in Africa, due to a variety of factors: erosion, overgrazing, depletion of the organic and mineral content of soils, proliferation of harmful insects, diseases, weeds, soil acidity, deforestation and overfishing.

An appropriate response to this state of affairs would be to increase the yields of arable soils in order to protect the environment. The challenge for agriculture in Africa could come down to a radical transformation permitting increased produc-

tivity by integrating improved cropping practices and new technologies, including modern biotechnologies, which would be key factors in increasing productivity on a sustainable basis.

The benefits of transgenic crops could include, among other effects, reduced costs, increased productivity due to improved yields, and environmental protection as a result of fewer chemical applications on crops and therefore less pollution of ground water. The quality of food products would also be improved (more vitamins and mineral salts, better taste). In brief, three types of products can be identified, each of them adaptable to different environments:

- Biotechnological products that offer agronomic advantages for farmers and the environment (development of plants resistant to harsh climates, drought, impoverished soils and insects);
- Biotechnological products that provide qualitative advantages to consumers and industry (rich in vitamins and trace elements):

Scientists in Switzerland have discovered how to use biotechnology to increase the vitamin A and iron content of rice, the staple food of more than half the world’s population. At the same time, Monsanto has developed a colza and mustard oil rich in vitamin A. This is significant progress in view of the fact that 230 million children around the world suffer from vitamin A deficiency;

- Industry or factory plants that naturally synthesize products beneficial to industry, consumers and the environment (vaccines, protein).

In the particular case of transgenic cotton, three groups are now available on the market:

- cotton plants with a gene that tolerates herbicides;
- cotton plants with the *Bacillus thuringiensis* (*Bt*) gene, capable of effectively controlling lepidopterous caterpillars;
- cotton plants containing a combination of genes to tolerate herbicides and control caterpillars.

Bt cotton has been produced in the United States since 1996, as well as Mexico (1996), Argentina (1998), China (Mainland) (1996), Indonesia (1999), Australia (1996) and South Africa (1997). The 44 million hectares planted in transgenic cotton in 2000-2001 include 72% of the land on which cotton is grown in the United States, 40% in South Africa, 30% in Australia, 25% in Mexico, 15% in China (Mainland) and 5% in Argentina.

In all these countries, biosafety regulations are already in place. On the African continent, some of the countries mentioned above have instituted regulations, while others have apparently organized large-scale transgenic cotton trials with no such regulations. Nigeria has reportedly released US \$26

million to stimulate technological advances in this area. Ghana has just finished developing its own regulations.

In closing this discussion, it should be noted that products of GE organisms are apparently already present in our countries, whether knowingly or not. Apart from pharmaceuticals derived from GE organisms, it is entirely possible that food products containing GE organisms find their way into our regular diet. For this reason, every effort should be made to encourage African countries to utilize the strengths and expertise of all parties to study and develop biosafety regulations that will enable them either to import or to reject GE organisms from a position of full knowledge.

Nevertheless, it must also be recognized that objective limits hinder the implementation of biotechnologies.

Limits on the Use of Methods and Products Derived from Modern Biotechnologies in Burkina Faso

Burkina Faso signed the Cartagena Protocol on May 24, 2000. In the area of agricultural research, the need for Burkina Faso to focus increasingly on the new techniques of biotechnology was clearly expressed. However, nothing has yet been done in this regard, since the country has no relevant legislation. For this reason, a workshop was held in Ouagadougou on March 20-22, 2001 in order to develop draft regulations on the use of GE organisms in Burkina Faso. A commission was formed to draw up guidelines, and its work is now nearly complete. A workshop will be organized in the very near future to adopt regulations that will then be submitted to legislators.

An informational meeting on biotechnologies had already taken place in Ouagadougou on May 10, 2000. Monsanto/Africa organized this informational session in order to explain the biotechnologies and the stakes at hand. The participants, mainly representatives of the National Union of Cotton Growers of Burkina Faso (*Union Nationale des Producteurs de Coton du Burkina Faso*: UNPCB), displayed keen interest in evaluating the viability of these technologies under African conditions.

The concerns about using and handling GE organisms in Burkina Faso, which are altogether legitimate, are focused on the biotechnological risks (risks to biological diversity and human and animal health). This matter has been widely debated, and the consensus is that, although the risks are real, they can be minimized and managed.

The most important barrier to be overcome for using GE organisms in Africa in general, and in Burkina Faso in particular, is still the lack of legislation, i.e. the development of a biosafety protocol for the country. In addition, there is no operational framework in Africa for real dialogue on these issues. The African Biotechnology Agency could readily fill this gap if its resources matched its mission statement. Lastly, there are problems of access to the technology, closely linked to the training of specialists, as well as general problems affecting

all users of new biotechnologies and problems specific to African countries.

Biosafety

It is widely recognized that modern biotechnologies represent the best hope for a world experiencing exponential growth but that possesses very limited natural resources. All indications suggest that the benefits derived from applications of this science will lead to significant advances in agriculture, health, the environment and industry. But it also turns out that using the results of these biotechnologies, especially GE organisms, carries potential threats to biological diversity and human health. It is therefore of critical importance to institute biosafety measures.

At the present time, the largest categories of GE organisms are new seeds and pharmaceuticals. There are transgenic varieties of many species, from microorganisms to plants and animals: fish, poultry, swine, sheep, tomatoes, melons, wheat, rice, soy, colza, potatoes, cassava, tobacco, spruce, cotton, maize, etc. Transgenic fish with human genes already exist, and there is more and more talk about putting scorpion genes in maize, human genes in swine and bacteria, a gene from bacteria in plants, etc.

In view of the high stakes and potential risks of modern biotechnologies for both the environment and human health, the Cartagena Protocol on Biosafety, an outgrowth of the Convention on Biological Diversity, was developed.

Burkina Faso is a party to the Convention and has already signed the Protocol.

Burkina Faso therefore needs to develop an outline of national biosafety guidelines that can lead to regulations on the use of transgenic plants and the establishment of a national biosafety framework, in accordance with the Cartagena Protocol.

To explain the real limits on using transgenic products in Africa, a brief description of the Cartagena Protocol is necessary.

Brief Description of the Cartagena Protocol On Biosafety

It is important to provide information on the potential risks associated with modern biotechnologies and on the contents of the Cartagena Protocol in order to better understand the urgent need to develop national biosafety guidelines on the use of biotechnologies in Africa.

Biotechnological Risks

The use of biotechnologies entails certain risks. These risks include the possibility of seeing:

- microorganisms in the soil destroyed and plant survival compromised;
- more competitive transgenic bacteria and viruses;
- the emergence of new, resistant varieties that could over-

run non-targeted species, creating an imbalance within the ecosystem;

- spontaneous hybridization (gene transfers) with related species (either domesticated or wild), resulting in unanticipated changes in competitiveness, virulence or other characteristics of the non-targeted species;
- slightly modified DNA fragments escaping from laboratories;
- the appearance of DNA fragments in the blood from ingested food or other transgenic products.

These are the reasons why precautions must be taken to avoid or at least to minimize risks. The Cartagena Protocol was developed to help ensure an adequate degree of protection for the safe transfer, handling and use or to minimize the adverse effects of GE organisms.

Cartagena Protocol

The Convention on Biological Diversity called for the development of an international protocol on biosafety. This instrument, called the Cartagena (Colombia) Protocol on Biosafety, was negotiated and adopted on January 29, 2000 in Montreal (Canada).

Burkina Faso participated in the protocol negotiations from start to finish, signed the protocol on May 24, 2000 and would not hesitate to ratify it.

The protocol contains 40 articles and 3 annexes, organized as follows:

Articles

The first six articles deal with general issues, particularly:

- ◆ The objective, which is based on the principle of a precautionary approach;
- ◆ General provisions specifying the obligations of each party, namely to take necessary and appropriate legal, administrative and other measures to implement the protocol, and also to ensure that the development, handling, transport, use, transfer and release of any modified organisms are undertaken in a manner that prevents or reduces the risks. These provisions also emphasize the sovereign rights and independence of States. States are in no way restricted from taking action, based on their specific context, that is more protective of the conservation and sustainable use of biological diversity than called for in the protocol.

The protocol applies to all modified organisms except those contained in pharmaceuticals addressed by other relevant international agreements or organizations.

Articles 7-14 deal with different procedures for importing modified organisms and how these procedures are to be applied. Two main procedures are advocated:

- ◆ Procedures for modified organisms intended for intentional introduction into the environment of the Import Party:

1) Advanced informed agreement

This procedure applies prior to the first intentional transboundary movement of modified organisms for intentional introduction into the environment of the Import Party. Article 11 covers modified organisms intended for direct use as food or feed, or for processing. The advanced informed agreement also does not apply to modified organisms recognized by the Conference of the parties to the Protocol as having little effect on the environment and human health.

2) Notification

The responsibility for notification of import falls to the Export Party. Annex I of the protocol specifies the minimum information on modified organisms that the Export Party must provide in the notification, but the Import Party may also require other relevant information, depending on its particular concerns. The Export Party has the legal responsibility to ensure the accuracy of the information provided.

3) Acknowledgment of receipt of notification

The responsibility for providing acknowledgment of receipt of notification falls to the Import Party, which must provide the required information concerning the procedure to be followed within 90 days of receiving the notification.

4) Decision procedure

Taking into account the time needed to assess the risks, the Import Party has nine months after receiving the notification to communicate in writing its informed decision.

In all cases, the Conference of the parties must decide upon appropriate procedures and mechanisms to facilitate decision-making by the Import Parties.

- ◆ Procedures for modified organisms intended for direct use as food or feed, or for processing:

A Party that makes a final decision regarding domestic use, including placing on the market, of a modified organism intended for direct use as food or feed, or for processing, must, within fifteen days of making that decision, inform the other parties through the Biosafety Clearinghouse. Annex II specifies the minimum amount of information to be provided. Particular attention is given to developing countries and countries where the economy is in transition, if they encounter difficulties, in order to help them better manage the domestic introduction of modified organisms through the Clearinghouse.

- ◆ Other procedures are also described in the protocol: review of decisions; simplified procedure; bilateral, regional and multilateral agreements and arrangements.

Articles 15 and 16 deal with risk assessment and risk management. Risk assessments are to be based on proven scientific methods, in accordance with Annex III of the protocol. The Import Party must ensure that the assessment is carried out

before the decision to import is made. The Import Party may require that the Export Party carry out the assessment or bear the cost of the assessment.

With respect to risk management, all parties must cooperate in identifying modified organisms or specific traits of modified organisms that may have adverse effects. In addition, each Party must take appropriate measures to prevent unintentional transboundary movements of modified organisms, including a risk assessment prior to the first release of a modified organism into the environment.

Article 17 addresses unintentional transboundary movements of modified organisms and emergency measures to be taken. Any Party initiating an unintentional transboundary movement must notify the affected or potentially affected states, the Biosafety Clearinghouse and, where appropriate, relevant international organizations.

Article 18 addresses the handling, transport, packaging and identification of modified organisms. This article concerns all modified organisms covered by the protocol. The measures to be taken by each Party should include requirements concerning safety conditions that the Export Party must fulfill for modified organisms covered by the protocol, specifically in relation to handling, transport, packaging and identification.

At the international level, the Conference of the parties should develop standards for the identification, handling, packaging and transport of modified organisms.

Article 19 deals with the institutional framework governing the protocol. This framework includes competent national authorities and national focal points. Each Party designates a national focal point to be responsible on its behalf for liaison with the Secretariat. Each Party also designates one or two competent national authorities to be responsible for performing the administrative functions required by the protocol.

Articles 20 and 21 deal with information-sharing. The parties must share any and all information that is useful in preventing biotechnological risks. Article 21 discusses confidential information.

To coordinate information concerning biotechnologies and modified organisms, a Biosafety Clearinghouse is established under Paragraph 3, Article 18 of the Convention on Biological Diversity.

Article 22 addresses capacity-building in the areas of biotechnology and biosafety, particularly in developing countries, the least developed countries, small island countries and countries with economies in transition. To be able to implement the protocol, such countries need scientific and technical training, as well as technical and institutional capacity-building. All parties and all national, regional and international organizations and institutions should cooperate in building these capacities.

Articles 23, 24 and 25 deal respectively with public awareness of, and participation in, biosafety; non-parties to the pro-

col; and illegal transboundary movements.

Articles 26 and 27 address socio-economic considerations, liability and redress. These articles encourage the parties to cooperate on research and information exchange.

Article 28 addresses financial mechanisms and resources for implementing the protocol.

Articles 29, 30, 31 and 32 describe the bodies related to the protocol: the Conference of the parties, serving as the meeting of the parties to the protocol; subsidiary bodies; the Secretariat; and the relationship with the Convention on Biological Diversity. Article 32 specifies that the provisions of the Convention apply to the protocol.

Articles 33, 34 and 35 deal with monitoring and evaluation mechanisms for implementation of the protocol.

The final articles (36-40) address the issue of how the protocol goes into effect.

Annexes

Annex I describes the information required in notifications to be provided by the Export Party under Articles 8, 10 and 13.

Annex II describes the information to be provided for any modified organism intended for direct use as food or feed, or for processing.

Annex III describes the points to be taken into account in risk assessments.

Eighty countries have signed the protocol (including Burkina Faso on May 24, 2000), but only two countries have ratified it so far. The United States signed the Convention on Biological Diversity but has not yet ratified this Convention. As a result, although the United States participated in negotiating the Cartagena Protocol on Biosafety, it has not yet signed it, because no country that is not a member of the Convention may join the Protocol.

A number of African countries have developed a biosafety framework. This work remains to be done in Burkina Faso, and is one of the main objectives of current activities.

Purpose of Biotechnological Risk Assessment

The purpose of a biotechnological risk assessment is to identify and assess the potential adverse effects of modified organisms on the conservation and sustainable use of biological diversity within the potential or probable target environment, including risks to human health. Risks, however small, do indeed exist, and a threshold of acceptability must always be established. It is also necessary to establish accountability and seek redress for any damage resulting from modified organisms.

The risk assessment is used by the competent authorities to make informed decisions about modified organisms. Risks associated with modified organisms or products derived from

them should be examined in terms of the risks posed by the receiving organisms or by related, unmodified organisms within the potential or probable target environment.

A risk assessment should be performed on a case-by-case basis. The nature and degree of accuracy of the information that is needed may vary, depending on the particular modified organism, its intended use and the potential or probable target environment.

Method of Biotechnological Risk Assessment

The method of risk assessment consists of two main steps:

- identification of the risk
- quantification of the risk

Risk assessment goes hand in hand with risk management. The risk must first be assessed in order to take measures to minimize it.

The following elements are indispensable parts of a risk assessment:

- characteristics of the donor: vector and insert (transferred DNA)
- characteristics of the recipient (prior to modification of its genome)
- characteristics of the modified organism
- characteristics of the target environment
- information on the intended use of the modified organism

African Biotechnology Agency

By creating the African Biotechnology Agency (ABA) in 1992, the member countries (Algeria, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Morocco, Nigeria, Senegal, Tunisia and Zimbabwe) sought to establish a community-wide mechanism in order to prepare present and future generations of Africans for this new human adventure. Africa is organizing itself to participate on an equal footing with other regions of the world over the coming decades in this adventure of emerging technologies.

The meeting of African ministers held in Algiers on February 3-5, 1992 was the founding conference of the African Biotechnology Agency. The agency is headquartered in Algiers, Algeria. Agenda 21 of the United Nations Conference on the Environment and Development called for the creation of the ABA, with the long-term objective of promoting a strategy to develop new and traditional biotechnologies in order to effectively address issues of development, environmental protection and the quality of life in Africa.

ABA Agenda

The ABA agenda focuses on the following priorities:

- Plant biotechnologies (micro-propagation of food-producing plants and tree species; genetic improvement)
- Human and animal health (production of vaccines and diagnostic products)
- Animal production (production of semen and embryos; development of agricultural by-products)
- Protection and conservation of nature (industrial and urban waste treatment; micro-propagation of forest species)
- Industrial production (production of proteins of unicellular organisms and metabolites; food technology)
- Biodiversity, biosafety and bioethics

ABA Mission

- Build the national capacities of member countries in the area of biotechnology, specifically by carrying out training and research and setting up infrastructure and equipment
- Coordinate and promote cooperative research programs in key biotechnological fields to further the development of member countries
- Facilitate the dissemination of scientific and technical information at the regional and subregional level, as well as experience-sharing
- Encourage the production, distribution and marketing of biotechnological products consistent with the objectives of sustainable development and the need to protect the environment
- Develop and standardize legislation on biosafety, intellectual property, patents and inventions and develop entrepreneurship

Organizational Structure and Management of the ABA

The ABA has a Board of Governors, a Scientific and Technical Council and a Secretariat.

Board of Governors

This body is composed of representatives of member countries. In addition, the Board may grant associate membership status to any organization or institution considered to play a useful role in achieving the ABA's objectives. The Board steers the activities and approves the budget.

Scientific and Technical Council

The Council is composed of experts from the member countries and associate experts. This body provides advice to the Board on scientific and technical issues related to the program of activities.

Secretariat

The Secretariat is composed of the managing director, two deputy directors, experts (program facilitators) and officials in charge of administration, finances and communications.

The headquarters agreement was concluded with the Govern-

ment of Algeria on October 14, 1997. Collaborative relations have already been established with most of the member countries, which have appointed their respective members of the Scientific and Technical Council and designated their national focal institutions responsible for coordinating joint projects with the ABA.

Problems Associated with the Development of Biotechnologies

Biotechnologies carry great hope, especially for the least developed countries. However, it must be recognized that they also create difficulties and risks. Some general problems affect all countries:

- *Ethical and regulatory problems:* The perception of these problems may vary, depending on the society to which one belongs and one's location.
- *Biosafety problems:* Doesn't the use of GE organisms (transgenic bacteria, viruses, plants and animals) pose a threat to humans, biodiversity and the environment?
- *Problems in protecting intellectual property:* Doesn't the principle of intellectual property sometimes extend beyond the goal of rewarding innovation and creativity and deprive some populations of the advantages of a modified organism that is part of the world heritage, or even related scientific knowledge, under the pretext of confidentiality?

Other problems specific to developing countries are exacerbated by the phenomenon of globalization:

- *Disruption of the world's agroprocessing equilibrium,* further widening the gap between developing and industrialized countries: In this context, Africa is in the process of forfeiting all its advantages, particularly in agriculture. Sugar provides a striking example, as enzymatic extraction of fructose from starch has drastically disrupted the world market. Similarly, synthetic fibers have cut into the production of jute and sisal.

Africa continues to face serious problems of food shortages. Will the continent be able to purchase transgenic seeds when the rest of the world is able to do so?

- *Inequality of the rules that govern the globalized marketplace:* Regulations favor those who make the rules and who dominate the market. The recent banana "war" between the European Union and the United States is one example.

Conclusions and Prospects

Negotiations on biological diversity, particularly within the context of the Convention on Biological Diversity, have uncovered major conflicts of interest regarding resources and have sparked a fundamental debate on risks associated with technological change and on fair and ethical behavior.

How should we respond to concerns about the potential risks and benefits of genetically GE organisms? How should we

address the ethical and commercial issues raised? The recently developed protocol on biosafety provides a way to take into account consumers' concerns about GE organisms.

On January 29, 2000, after five years of negotiations, representatives of more than 130 countries finally concluded an agreement in Montreal concerning the Protocol on Biosafety. This legally binding document aims to protect the environment from the risks associated with transboundary movements of GE organisms produced by modern biotechnologies. The challenge was to determine whether a country could restrict imports of GE organisms (including crops, seeds, viruses and viroids) based on the risks to the environment, biological diversity and human health.

This protocol is also the first agreement to regulate trade in GE organisms. It requires that exporters provide the competent national authorities of the importing country with information on the origin and destination of the GE organisms prior to import. The protocol permits countries to block imports of GE organisms as a precautionary measure when there is insufficient scientific proof of their harmlessness. It is thus incumbent upon producers to provide such proof that their GE organisms are harmless, in contrast to WTO provisions, which require that governments seeking to prevent imports must provide evidence to support their position.

However, the protocol does not address the safety of fields producing transgenic plants at the dissemination/extension stage.

Genetically modified plants have shown that they can help farmers to significantly improve their productivity when they are accompanied by appropriate economic and social reforms. Biotechnologies in Africa should be considered a key element for increasing agricultural output, eliminating poverty and protecting the environment.

Farmers benefit from the use of biotechnologies, regardless of the size of their farms. Most farmers in Africa have small-scale operations, under five hectares. By growing transgenic crops, they can increase their yields, control insects more effectively and protect the environment.

On the Makhathini plateaus of northern Kwazulu Natal in South Africa, small farmers have begun to grow transgenic cotton, increasing their yield by 33% and eliminating six insecticide treatments. Their net income has increased by 27%. In Hebei, a province of China (Mainland), the average yield has increased by 39%, generating a 57% increase in income, where 13 insecticide treatments were previously required. Better yields combined with fewer insecticide treatments translate into more money.

Farmers are good observers. They purchase what works best, and this technology has rapidly advanced because it is considered effective. In view of steadily increasing food requirements in Africa and the desire to achieve self-sufficiency, African agriculture should take advantage of the capacity of biotechnologies to raise productivity. Africa sidestepped the Green

Revolution, but it would be a mistake for this to happen again with the Biotechnological Revolution. Accordingly, it is proposed that policies for developing and implementing these emerging technologies take the following path:

A national biotechnology committee should be established in every African country after broad consultation among potential actors, in order to define short, medium and long-term objectives in the area of emerging technologies.

Given the competition between conventional products and those derived from biotechnologies, African countries should diversify their output and promote biotechnologies to achieve food self-sufficiency, reduce poverty and meet the challenge of globalization.

In terms of scientific development, the manner in which concepts are used is in flux. Biology, to develop as a science, needed chemistry, physics, mathematics, etc. As a result of biotechnologies, we are witnessing a reversal of this trend, as biology becomes a source of models for other sciences: robots patterned on insects, microchips patterned on neurons, etc. A high priority should be placed on a total reform of schools and universities in order to produce qualified individuals who can properly utilize biotechnologies.

African countries should hasten to implement regulations guaranteeing intellectual property in order to protect their plants and animals from international piracy and to give researchers the right and the duty to protect farmers from being forced to accept only seeds produced outside the continent;

National guidelines should be established to protect local biodiversity from anarchic management. Given the fear of losing rare species forever, each country should establish a gene bank for future generations;

Efforts should be made to draft national biosafety guidelines that can lead to regulations on the use of transgenic plants and the development of a national biosafety framework;

Every African country should attach great importance to ethi-

cal considerations, and the welfare of the underprivileged should be the first priority;

African governments should encourage and promote subregional and regional cooperation in the development and use of biotechnologies through seminars, conferences, collaborative research, networking, etc.

Every new scientific discovery or development can have positive or negative impacts on society. It is incumbent upon the users of the technology to make rational choices, based on what is best for mankind. Biotechnologies are part of the picture. This is why precautions need to be taken in order to avoid a disaster. We have already embarked on this human adventure, and each of us must contribute as best we can to ensure that the adventure is successful and that we arrive at our intended destination.

Bibliography

African Biotechnology Agency, 1999. *Bulletin trimestriel d'information pour le développement des biotechnologies en Afrique, N° 00.*

African Biotechnology Agency, 1999. *Bulletin trimestriel d'information pour le développement des biotechnologies en Afrique, N° 01.*

African Biotechnology Agency, 2000. *Bulletin trimestriel d'information pour le développement des biotechnologies en Afrique, N° 02.*

Anonymous, 2000. Report of the informational symposium on biotechnologies and the stakes of such technologies, held on May 10, 2000 at the Silmandé Hotel in Ouagadougou.

Anonymous, 2001. Report of the national workshop on biosafety, held on March 20-22, 2001 at the Silmandé Hotel in Ouagadougou.

Monsanto, 2000. *Biotechnologies pour l'Afrique, Burkina Faso.* Presentation at the informational symposium on biotechnologies and the stakes of such technologies, held on May 10, 2000 at the Silmandé Hotel in Ouagadougou.

Cotton Pest Management – The Future

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This paper explores the likely long-term future trends in cotton pest management worldwide. Predicting the future is a notoriously risky thing to attempt. Doubtless the detailed expectations described here will prove to be wrong, as technologies and experience leads us down different routes. Nonetheless, the sorts of pressures and opportunities currently being experienced must take us at least a certain way down the paths explored here. Much of what is said is in very general terms. Clearly not everything applies to all growing countries and

systems and not all systems will move in the same direction or at the same rate.

Drivers for Change

As the fiber market becomes ever more global, and competition with artificial fibers intensifies, grower margins become ever tighter. Pest management accounts for some 25 to 45% of the variable costs of growing cotton in most countries (ICAC,

1998). The pressure is on everywhere for reliable pest management at lower costs. Historically, the less developed countries have had the advantage of relatively cheap and plentiful labor. Global social developments are such that this is changing rapidly. Legitimate aspirations for improved living standards are pushing the labor costs of weed and insect control upward. For most parts of the world it is also true that the ready availability of cotton pest management advice, and often materials, from state extension systems, is in decline. The political paradigm is away from direct support and supervision of growers, which are seen as ‘distorting the market’ and providing an ‘undesirable subsidy’. Whatever one thinks of the wisdom of this from a seed quality and pest management point of view, the trend appears to be clear. As margins get tighter, cotton is less successfully competing for prime land. With agricultural soil and water quality declining globally (some 25% of world’s agricultural land is significantly degraded and the proportion is probably higher on cotton lands), many areas producing cotton face drought and salinity challenges. With the increasingly free movement of people and crops across the world and a relative decline in the effectiveness of quarantine systems, the increasing spread of pests, and more especially of diseases, becomes a certainty. Added to this is the rapid and sustained increase in the level of environmental concern expressed by cotton consumers and society at large. Cotton is a major consumer of pest management chemicals (probably some 10% of the global market and in many producing countries consuming as much as 50% of pest management products). Not unnaturally, therefore, a great deal of public pressure is being brought to bear on cotton producers and the agrochemical industry to minimize the human, environmental and soil impacts of cotton pest management. This trend seems set to continue and intensify.

Set against these pressures to decrease the labor input; the pest management costs; the volume of pest control products and the environmental impact of pest management, we have the growing availability of ‘in the seed’ solutions. Many of these are the result of careful conventional breeding, including the development of multiple adversity resistance (MAR) material. The increasing importance of biotechnological manipulation of the germplasm, from marker assisted breeding, through enhanced expression of natural cotton gene products, to the incorporation of a range of genes from other organisms, seems certain to continue. Clearly the improved germplasm will need to be integrated with appropriate soil management, agronomy and IPM practices. Equally clearly the resistances currently being bred or inserted into varieties will sooner or later be overcome by the selection pressure they impose on the disease, weed and pest complex. In other words, the pressure to develop improved genetic material will continue and we will no doubt have our short-lived successes and even failures. However, it is my opinion that the delivery of key components of pest management solutions ‘in the seed’ is the overwhelming trend in cotton pest management for the foreseeable future.

Table 1. Existing Biotech. Herbicide Tolerance

Target	Method
Bromoxynil detoxification	Production of nitrilase
Glyphosate resistance	Strong constitutive promotor for mutated EPSP
2,4-D detoxification	Monoxygenase gene from
Sulphonyl urea and	Alcaligenes eutrophus
Imidazolinone tolerance	Acetolactate synthetase gene

Modified from Kranthi et al., 2000

Reduced Labor Availability

Increasing urbanization and improved standards of living and in some countries, the declining availability of labor, are driving cotton production towards increased mechanization, reduced tillage and the increasing use of herbicides. Although reduced tillage assists in minimizing the spread and impact of some soil borne diseases, it carries with it implications for reduced efficacy of control of some current key pests which spent considerable portion of their lives in the soil e.g. pink bollworm (*Pectinophora gossypiella*). Equally importantly we can confidently expect increasing problems with a range of currently minor pests eg. white-grubs, termites, mealybugs, scale insects etc. This trend will exacerbate nematode control problems unless rotational practices, which are falling into disuse globally, are reinstated vigorously. Worsening disease control will expand the use of fungicide seed treatments and the need for acceptable soil fertility will see the growth in the use of artificial fertilizer (especially Ammonium nitrate), farm yard manure being difficult to use in reduced tillage situations and not generally sufficient to support acceptable yields.

Weed control

In the light of reduced labor availability/ affordability and reductions in tillage, herbicide use will rise dramatically, initially particularly in Asia. The experience in the USA and elsewhere is that the ability to use herbicides on a need-only basis, post emergence of the crop, will strongly promote the adoption of herbicide tolerant varieties. Current transgenic varieties are tied to the herbicide product of the patent holder’s company. Multiple herbicide tolerance will provide better grower options for the prevention of the development of weed resistance to herbicides (Table 1).

Diseases (Table 2)

Except in high input (often subsidized) growing systems, appreciation of the need for disease control and availability of finance for chemical control is limited. Although chemical control of bacterial blight (*Xanthomonas*) and *Fusarium* and *Verticillium* wilts is sometimes recommended, costs are high and plant coverage is rarely adequate. In consequence host plant resistance remains the major current control option. The majority of chemical interventions are fungicide applications for seedling diseases. The, usually inadequate, use of rotations and

Table 2. Current Disease Control Options

Disease	Measures
<i>Fusarium</i> and <i>Verticillium</i> wilt and bacterial blight	Host plant resistance
Root-knot nematode	Rotations, fallow. Chemicals in high yield situations.
Seedling diseases – <i>Anthraco</i> se, <i>Pythium</i> and <i>Rhizoctonia</i>	High quality, acid-delinted, fungicide treated
<i>Alternaria</i> and <i>Ramularia</i> leaf spot	Seeds, sustainable soil management Residue destruction/incorporation. Chemical fungicides and bactericides where affordable

After Hillocks 2000

fallows is relied on for other disease control (Hillocks, 1998). The seed-based tolerance/resistance to diseases continues to be an active area of research, with varieties under development which show a number of promising biochemical and morphological traits. The use of genetic markers for these traits and the consequent ability to detect the trait directly in seedling tissue, is greatly speeding this process.

Disease resistance is a cornerstone of Multiple Adversity Resistance (MARs) breeding. Success is being achieved simultaneously with the wilts, *Phymatotrichum* root rot, leaf spots, and root-knot and reniform nematodes in the best current material, without compromising the original bacterial blight tolerance (Thaxton and El-Zik, 1998, El-Zik and Thaxton, 1989). It can be expected that these multiple simultaneous selection systems for disease, insect and abiotic stress resistance will become more widely used over time. Given the genetic complexity of the combined resistances, direct introgression into

unrelated germplasm is likely to be very difficult. Support is needed for the development of MAR varieties in cottons other than USA *G. hirsutum*.

Disease biocontrol through microbial pathogens (sometimes engineered for increased efficacy) is becoming a reality. This area may expand rapidly as it has the potential for low cost solutions to intractable problems with sessile, protected disease organisms.

Further down the line, a range of directly engineered solutions is under development. Doubtless in time, the ability to directly manipulate and insert the relevant defences will make these as important as the Bt transgenics are for insect control today.

Insects

It is now generally accepted that heavy reliance on the use of broad-spectrum chemistries is not going to provide sustainable pest control. These materials significantly disrupt such natural pest control as may be available, forcing the increased use of chemistry to control secondary pests. In all countries where chemical use has been heavy, key pests have consequently evolved resistance, further exacerbating the situation and promoting further uneconomic pesticide applications. However, there is little evidence that even diverse cropping systems harbor sufficiently high populations of natural enemies to routinely suppress populations of all the pest species below the level at which economic damage is caused. This, of course, is the situation which led to the embracing of integrated pest management (IPM) as allowing a diversity of measures to cumulatively prevent unacceptable crop damage.

Leguminous intercrops and field margin crops are frequently used and recommended as trap crops and to increase the density of beneficial insects (e.g. cowpea in India and lucerne in Australia and central Asia). This can clearly add pest management value. However, increasing habitat diversity for its own sake is frequently difficult in commercial cotton cultivation and its biological and economic benefits have not been convincingly demonstrated. My own feeling is that the agronomic difficulties of operating such systems on any significant

Table 3. Conventional/Marker Assisted Breeding for Resistance

Disease	Traits
<i>Fusarium</i> wilt	Red pigmentation and unidentified traits in <i>G. arboreum</i>
<i>Verticillium</i> wilt	High tannins
<i>Rhizoctinia</i> root rot	High terpenoids
<i>Xanthomonas</i> bacterial blight	Unidentified material in <i>Gossypium</i> 'A' genotypes
Various	Few, small, sunken and hairy stomata

Modified from Kranthi et al., 2000

Table 4. Conventional/Marker Assisted Breeding for Insect Resistance

Target	Traits
Jassid	Morphological: Leaf hairiness; tough leaf veins, thick lamina, long hair Biochemical: high non-reducing sugars; tannins; free gossypol, silica, total phenol and epicuticular wax
Heliethines	Morphological: Nectariless, thick boll rind, red leaf, glabrousness, okra leaf, frego bract Biochemical: gossypol; heliocides H1,H2, hemigossypolone, catechin, quercetin, isoquercetin
Pink bollworm	Morphological: Glabrous, nectariless, okra leaf Biochemical: Gossypol, flavanol
Whiteflies	Morphological: Red leaf, glabrous, okra leaf, frego bract, deep vascular tissue Biochemical: Total sugar, tannins, flavenols, phenols and gossypol

Source: various

scale makes it unlikely that they will become major contributors to cotton pest management, in what will be an increasingly competitive industry.

The early promise of pheromones as tools in pest management has not been fully realized.

Although widely useful for monitoring purposes (especially in boll weevil programs), their use in area wide control has been limited. Considerable success was achieved with pink bollworm control in Egypt in the 1990s and in parts of the USA and control of *Earias* bollworms has been technically demonstrated in Pakistan. Recent area-wide trials in Asia with the more polyphagous Heliothines has shown their unsuitability for this type of control. Red bollworm (*Diparopsis*) in southern Africa is a potential target for this method.

Entomopathogenic viruses have a useful future as quality control and registration system are put in place. NPV for *Spodoptera* species could be usefully managed in cotton. *Helicoverpa* NPV is showing promise in Australia. In other countries inactivating interactions with cotton leaf chemistry need to be tackled in addition to quality control questions before it can become a reliable control tool. The use of entomopathogenic fungi is in its infancy in cotton but may be particularly useful for the control of hemipterous sucking pests.

A clearly desirable route to successful insect control has been through the introduction or augmentation of natural enemies (predators and parasitoids). Historically such endeavors have been generally disappointing. Critical studies of even the widely released egg parasitoids (Trichogrammatidae.), while showing success in, for example, stem borer control in other crops, has been unable to demonstrate significant benefits. This may be partly explained through the quality of the reared and released material, but is also a reflection of the extremely high level of egg mortality required to produce unsubstituted mortality in key pests. Some success has been achieved with released insects acting on later life stages, for example with larval parasitoids (e.g. *Bracon* spp.) and with Chrysopid predators. On the other hand, the protection and enhancement of naturally occurring enemies is clearly beneficial. Predators such as *Orius*, *Geocoris* and especially *Chrysopa* spp. are important, particularly early in the cotton season and in more seasonal, temperate, areas. Parasitoids especially *Encarsia* and *Eretmocerus* are useful for whitefly control. Ants (eg *Pheidole* in Africa and *Solenopsis* in the Americas) are an under-utilized resource whose active management merits further study.

Most cotton systems have a suite of useful arthropods early in the season. These naturally decline later in the season, even in the absence of pesticide applications. If insecticide spraying

Table 5. Existing Biotech. Insect Pest Control Tools

Method	Target	Status
Bt endotoxins	Disrupts potassium pump in insect mid-gut cells	Commercialised
Protease inhibitors	Inhibits mid-gut proteinases in lepidoptera (e.g. cowpea trypsin for <i>H. armigera</i>)	Experimental
Cholesterol oxidase	Digestive inhibitor active against boll weevil	Experimental

can be avoided during the first 60 to 70 days after crop emergence, these beneficials have a very useful role to play. This, however, necessitates the control of early pests (esp. aphid and jassid species) by cultural, varietal or systemic insecticidal means. To this end, the use of seed-applied systemic neonicotinyls will be increasingly important. This need to avoid early season spraying is a key message to both farmers and breeders and one that is increasingly being heeded, to great effect, in countries such as India.

As with diseases then, the role of the breeder will be increasingly important in providing insect resistant germplasm. The range of morphological and biochemical characters which contribute to tolerance/ resistance is large.

Certain of these characteristics, while effective in discouraging one pest, are positively attractive to others. Particular suites of resistance are required for particular pest complexes, necessitating sustained breeding efforts in many regional centres. This is currently lacking. A start has been made on the insertion of alien genes into cotton for insect pest control. The only currently commercialized products contain Bt endotoxins effective against a limited range of lepidoptera. The ability to impact on even this very limited target range (essentially certain of the noctuidae and gelechiidae and some other lepidopteran families), has resulted in one of the most successful agri-product launches of all time covering some 5.3 million hectares only five years from its commercial debut in 1996-7 (Anon 2001). These products show the enormous potential for seed-borne solutions to otherwise intractable problems and undoubtedly pave the way for more sophisticated products to

Table 6. Promising Biotech. Insect Control Tools

Target	Method
<i>Anthonomus grandis</i> and <i>Helicoverpa virescens</i>	Cholesterol oxidase from Streptomyces fungus
<i>Manduca sexta</i> and <i>Myzus persicae</i>	Over-expression of IPT hinders synthesis of cytokinin
Lepidoptera/homoptera control	Lectin genes – digestive system/blood cell agglutination
Lepidoptera control	Insecticidal peptides from spider and scorpion venom
Bruchid beetles/lepidoptera	Digestive enzyme inhibiting alpha-amylases
Development and moulting	Active element of spinosad into plant
Various	Insect neuropeptide hormones, straw itch mite genes, genes ex. <i>Photorhabdus luminiscens</i>

Modified from Kranthi et al. 2000

come.

These products are susceptible to resistance development although no field problems have been reported to date. Already, stacked gene products have been developed which incorporated two Bt toxins which are not cross resisted (Anon, 2001) in USA, China (Mainland) and Australia. This is intended to delay the onset of resistance and to widen the spectrum of activity to include the armyworm and looper, leaf feeding, caterpillars as well as bollworms. Advances have also been made on the insertion into the plant genome of small proteins engineered to cut the enzymes responsible for resistance. Plant feeding by the insect inactivates the ability to resist.

As lepidoptera come under control, the next generation of insecticidal transgenics needs to address the sucking and leaf-feeding pests, especially nezara, aphids, jassids, weevils and mites, which are increasing in transgenic areas in the absence of pesticide applications.

Shortly these genes will be incorporated in germplasm along with other genes affecting other pest species in the complex. Bt insecticide and herbicide tolerant stacked genes are already a commercial reality. This sort of direct genetic manipulation for multiple pest control will form a major part of the pest manager's armory in a further ten years.

Spray Application Technology

Spray application efficacy is poor. An examination of the droplet distribution on the plant from conventional spraying with any equipment shows how remarkable it is that we get even the level of control we do. Much of the poor efficacy that is usually ascribed to plant protection products, would, in fact, be better laid at the door of the application technology used. It is therefore extremely disappointing that so very little funds go into research into spray application methods.

With a growing appreciation of the problems of large-scale use of broad-spectrum insecticides, the risks of resistance development and the increasing costs of newer plant-protection chemicals, the use of aerial spraying is declining sharply in all except the highest input systems. Some advances have been made in tractor-mounted spraying. Air-assisted spraying through sleeved booms, improves plant coverage and consequent control, although under-leaf coverage, for disease and sucking pest control in particular, remains difficult. It has been known since the 60's that the use of drop-legs which pass between the plant rows, with or without upwardly directed nozzles, improves plant coverage greatly (Tunstall et al., 1961). It is to be hoped that both tractor mounted and knapsack sprayers developed under a recent ICAC/CFC project (Gan-Mor et al., 2000) will be successfully commercialized in the near future.

The choice of knapsack sprayers in low-input, small-scale systems, usually comes down to price, and the quality of machines is not improving globally. Indeed it is probably getting worse in LDCs. For most purposes on cotton beyond the seedling stage, hand-pumped sprayers have a very poor efficacy. Al-

though ultra low volume (ULV), oil-based applications, provide good plant coverage and have been extensively used to great effect in West Africa, the limited insecticide product and manufacturer range has meant that the technique does not appear to be on the increase. However, the labor, canopy penetration and cost advantages of low volume application (e.g. electrostatic/ spinning disk) are increasingly appreciated. It is expected that very low volume (VLV) use at c. 10 liters/ha and droplet sizes around 100-120 μ m, will increase, as water and labor shortages increase. The use of precision spraying techniques will increase in high-input systems, both as a means of reducing application costs and in order to slow resistance development.

Extension Delivery

The World Bank (1992) and many individual countries have adopted IPM as their preferred pest management system. Despite the widespread currency of definitions of IPM which restrict the role of pesticides to exceptional situations, for the foreseeable future, the role of biocides (sprayed or within the plant) seems likely to dominate cotton pest management worldwide where farmers can afford pest-management inputs. This is certainly the case in China (Mainland), India, Pakistan, USA and parts of South America and is increasingly the case in southern Africa (Fitt, 2000). This does not represent only the success of the marketing forces of the crop-protection industry, but a recognition that, in most parts of the world, in most seasons, there are major pests, such as the Heliothine bollworms, for which reliable nontoxic solutions are not readily available. IPM programs are strongly supported on a national scale in many countries, with important success in e.g. China (Mainland). These have, however, a strong reliance on purchased pesticidal inputs.

Historically such IPM programs have been run by state extension systems. Over most of the cotton world, the trend is away from top-down state employee delivery of pest management advice. This has to do with prevailing economic philosophies of the free-market, rather than with the needs of the crop, although it must be accepted that most state extension systems have been cumbersome, expensive and frequently ineffective. In the most developed countries, the extension officer's role is increasingly taken by the commercial crop-consultant, most often paid on the basis of area managed, rather than of pests controlled or yield protected. This is partly a result of the need to minimize labor inputs in high labor-cost economies and partly a response to the decline in use of broad-spectrum, persistent, products which makes management more complex. It is expected that this model will become the norm in the USA, Australia, Europe, Israel and other high-input systems. Farmers in low input systems are being left more to themselves, on the pretext of the need for individual decision making, frequently at a level too complex for the individual farmer to be expected to succeed. In many areas, then, the quality of farmer decision making is actually declining. IPM training programs are having some impact, although often they amount to little

more than a brief talk and the distribution of literature. Farmer Field Schools are a way in which the knowledge for, and confidence in, decision making, can be developed in farmers. The success in rice in S.E. Asia has raised hopes for cotton. Delivery costs are, however, high and the number of directly trained farmers going through season-long Farmer Field School training is small. Zimbabwe is a leader in this area under World Bank funding and is probably able to demonstrate more benefit from the system than any other country to date. Following a pilot program funded by the Asian Development Bank, the EC is supporting a seven country Asian initiative (2000-2004) implemented by FAO. It would be true to say that FFS are yet to prove their economic worth in cotton on any significant scale in the absence of considerable external donor funding. The pest management problems on cotton are more complex than those on rice. It remains to be seen whether this will represent a major way forward.

Organic Cotton

Production of organic cotton has increased again in recent years, with the USA, Turkey and India servicing the bulk of the market (ICAC 2000). Despite promising research results in a number of countries, output remains low because of difficulties in maintaining yields, the very considerable costs of certification and the uncertain market. A number of countries in which the restricted availability of inputs makes farmers *de facto* organic, have capitalised on this situation by seeking certification. Uganda is a good example. Keeping small quantities of organic cotton separate through the post-harvest chain adds very considerably to the expense of final products at present. To cover these costs and to compensate the farmer, expansion of production will depend on significant price premiums, particularly as yields cannot generally be maintained at the level of those in non-organic systems at present. It is unclear what the prospects for market expansion are. It would seem that insecticides can frequently be removed in appropriate situations but the maintenance of soil fertility remains a problem. Much more work needs to be carried out on non-chemical pest and disease IPM for organic cotton if production is to expand to a significant proportion of total cotton output. There is little sign of this at present. In my opinion, the certifying bodies' current refusal to accept biotech cotton is probably fatal to expansion in the medium to long term.

Conclusion

- Labor costs and technology development will put the future focus of pest management on the cultivar.
- Inputs will be increasingly problem-specific (narrow spectrum).
- The knowledge component of IPM will continue to increase; the cost and quantity of applied materials will decrease.
- IPM techniques will become more, not less, high tech. although potentially simpler for the farmer to apply.

- The technology availability gap between high and low income countries will not narrow unless central governments or international institutes ensure it. (Note that there is no international research center for cotton).

References

- Anon 2001 Second generation of Bt cotton is coming. *ICAC Recorder*. Washington DC, USA. 19(1): 3-8.
- El-Zik, K.M. and Thaxton, P.M. 1989. Genetic improvement for resistance to pests and stresses in cotton. Chapt. 8 In: Frisbie, R., El-Zik, K.M. and Wilson, T. *Integrated Pest Management Systems and Cotton Production*. Wiley-Interscience.
- Fitt, G.P. 2000. A future for IPM in cotton: The challenge of integrating new tools to minimise pesticide dependence. *Proc. World Cotton Research Conference-2*, Athens, Greece, September 6-12, 1998. Pp. 75-84.
- Gan-Mor, S., Grinstein, A., Riven, Y., Beres, ., Kletter, E., Spenser, J., Forer, G., Tzviele, E. and Zur, I. 2000. A new technology for improved pesticide coverage on cotton canopy: Part I. Sprayer development. *Proc. World Cotton Research Conference-2*, Athens, Greece, September 6-12, 1998. Pp. 900-903.
- Hillocks, R.J. 2000. Cotton disease control: Contrasting *Proc. World Cotton Research Conference-2*, Athens, Greece, September 6-12, 1998. Pp 69-74.
- ICAC. 1998. *Survey of the Cost of Production of Raw Cotton*. International Cotton Advisory Committee, Washington DC, USA. pp109
- ICAC. 2000. *Growing Organic Cotton*. International Cotton Advisory Committee, Washington DC, USA. pp109
- Kranthi, K.R., Kranthi, S. and Dongre, A.B. 2000. Cotton Biotechnology. *CIRC bulletin* 10. Central Institute for Cotton Research, Nagpur, India. pp46.
- Matthews, G.A. 2000. Application techniques to meet the requirements of IPM, IRM and the transgenics. *Proc. World Cotton Research Conference-2*, Athens, Greece, September 6-12, 1998. Pp 789-792.
- Thaxton, P.M. and El-Zik 2000 Host plant resistance to pathogens in MAR cotton germplasm. *Proc. World Cotton Research Conference-2*, Athens, Greece, September 6-12, 1998. Pp113-119.
- World Bank 1992. *World Bank Operational Directive on Agricultural Pest Management*, July 1992.

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Improving Host Plant Resistance without Sacrificing Yield and Quality in Zimbabwe

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Introduction

The Cotton Research Institute (CRI) which falls under the agricultural ministry carries out cotton variety improvement in Zimbabwe. The Institute started as a Cotton Breeding Station in 1925 and the present program of cotton production research includes cotton breeding and pathology, cotton agronomy and cotton pest research. The breeding program includes the development of medium staple and long staple varieties adapted to different climatic conditions and production requirements, and the incorporation of disease and pest-resistant characteristics into these varieties.

Cotton is grown by large scale commercial growers where the levels of inputs and management are high and where the crop may be grown under irrigated or rainfed conditions. However, it is mainly grown by small-scale commercial and communal growers, primarily under rainfed conditions and usually at lower input and management levels. The altitude where cotton is grown varies from 300 meters above sea level to 1200 meters above sea level. While the bulk of the cotton produced in Zimbabwe is medium staple, some long staple cotton is also produced. Over 98% of Zimbabwean cotton is hand picked.

Host plant resistance refers to any inherited characteristics of a host plant which lessens the effect of parasitism. That is to say, resistant plants are less damaged by parasites than are susceptible plants. In Zimbabwe, host plant resistance has been improved over the years successfully for the control of jassid, and the diseases bacterial blight and verticillium wilt to some extent. Currently all varieties grown in Zimbabwe have good tolerance to bacterial blight and have good jassid resistance.

The Improvement of host plant resistance to jassid, bacterial blight and verticillium wilt takes place alongside other characters that are evaluated during the overall variety improvement/breeding program.

The Breeding Program

The aim of the breeding program is to develop, evaluate and maintain cotton varieties that satisfy the needs of farmers, ginners and marketers in Zimbabwe. The needs of these stakeholders can be summarized under field and fiber characteristics (Table 1).

The priority of individual characters vary as circumstances change but will largely be determined by the needs of the grower, ginners, marketer and spinner. As such all sections of the cotton industry are consulted at regular intervals to ensure that breeding objectives are up to date and that they reflect the industry's requirements. Since it takes up to 12 years or more

from the time of single plant selection to commercial variety release, it is essential that the program is able to anticipate future requirements by carrying a sufficiently broad genetic base to enable it to react quickly to changing needs.

In order for a breeding program to respond to industry needs the breeding program is divided into six parts:

The Medium Staple Middleveld Programme aims at developing medium staple Albar cotton varieties for the traditional cotton growing areas that lie between 600 meters and 1,200 meters about sea level (a.s.l.). The emphasis is to produce good quality varieties capable of giving a satisfactory return over a wide range of growing conditions.

- The Medium Staple Lowveld Programme is designed to develop Albar varieties for the southeast lowveld areas that lie between 300 and 600 meters a.s.l. where cotton is grown by both low input and high input farmers.
- The Long Staple Programme caters for high quality, long staple varieties that can be grown under a range of input levels to meet local and overseas requirements. Despite their lower yield potential, long staple varieties can be favored by the premium paid for their high quality.
- The Highveld Programme whose main emphasis is the development of Albar varieties which are sufficiently adapted to cooler growing environments and which complete their growing cycle before the risk of frost becomes high.
- The Mechanical Harvesting Programme which aims at developing varieties that are machine harvestable with minimum input use. The programme was started in response to a shortage of labor for hand picking of cotton on large commercial farms.
- The Verticillium Wilt Programme whose aim is to improve host plant resistance to verticillium wilt.

It is important to note that improvement of jassid and blight

Table 1.

Field characters	Adaptability, seed cotton yield lint yield (high ginning %), boll mass, plant habit, stress tolerance, growth pattern spray penetration, pickability
Quality characters	Color, fiber length, uniformity strength, elongation, maturity fineness, seedcoat attachment
Disease resistance	Bacterial blight, <i>verticillium</i> wilt, <i>Alternaria</i> leaf spot
Insect resistance	Jassid, aphid, bollworms

resistance is paramount in all of the breeding programs above except the Mechanical Harvesting Programme. This is because leaf hairiness, which imparts jassid resistance, constitutes trash for machine picked cotton, and in order to reduce trash glabrous varieties are preferred. Blight resistance is however important even for machine picked cotton.

Variety Improvement Trials are conducted in all major and potential cotton producing areas of Zimbabwe. On average 200 breeding trials are conducted annually on about 80 sites of which at least 50% are in the communal dryland areas. Over 80% of the trials are on-farm and are managed by cotton farmers (both communal and large scale) under the guidance of research personnel.

Jassid Problem in Zimbabwe

Jassids have been a serious threat to cotton production in Zimbabwe since as far back as 1925 where the commercial variety then, improved Bancroft, was described as “generally susceptible” to jassid attack. Leaf hairiness - a combination of hair density and hair length, particularly on the underside of leaves imparts resistance to jassid attack. The mechanism of resistance is that the leaf hairs interfere physically with the feeding, movement and oviposition of the jassids. Unlike many other characters which confer resistance to cotton pests, the breeding of a jassid - resistant varieties does not conflict unduly with the need to maintain yields and quality.

Jassid is very important for the communal farmer who often does not have money to buy chemicals to spray. Only those varieties assessed for at least three seasons and found to have enough jassid tolerance to avoid economic yield loss are recommended for dryland production in the communal areas

In the breeding programme a number of hairy exotic varieties mostly West Africa have been used in the crossing programme with the locally adapted varieties. Single plants are selected for, among other characteristics, hairiness. Screening of varieties for resistance to jassid starts from the second season of testing onwards. All varieties in the programs mentioned before are assessed for jassid resistance. Varieties found to be too susceptible to jassid are discarded if they are not suitable for machine picking.

Jassid Screening:

During the jassid screening programme varieties from the second stage of testing onwards from all the breeding programs are grown under the unsprayed conditions. No chemicals are sprayed for the control of any pest except aphids in which case a selective aphicide is used. The aphids are only sprayed when their counts are so high that they make the cotton leaves unattractive to jassids and this is usually early in the season before the jassid counts are high.

To encourage jassid built up the cotton selections are planted with cow peas at regular intervals. The cow peas are more attractive to jassids and so attract the jassids early on in the

season. When the jassid have built up in the cow peas, the cow peas are then uprooted to dry and as the cow peas dry the jassids migrate to the cotton plants. In resistant varieties the leaves are not visibly affected or in very severe attacks the leaf margins turn pale yellow while in susceptible varieties, leaves become badly curled and reddened and plant growth is severely stunted.

In Zimbabwe over 80% of the crop is produced by communal farmers. Jassid is a particular problem in these areas where pesticide use is often limited by availability or cost. Therefore, all dryland varieties are selected for good jassid resistance which drastically reduces yield loss from this particular pest. Large scale commercial farmers on the other hand have the capacity to spray for pests when and as the need arises and as such some high yielding varieties which are not necessarily resistant to jassid can be recommended. This is because the regular pesticides applied to control other pests inadvertently control jassid in most cases.

However, it is important to note that several adverse factors are associated with hairy or pubescent varieties. White flies can be more abundant and heliothis moths prefer to lay eggs on pubescent varieties compared with glabrous ones. So, there is a conflict and a decision has to be made about which pests can be controlled with resistant cotton varieties and which have to be controlled by other methods, usually insecticides. In Zimbabwe, while white fly is a problem in some seasons under high input conditions it is not serious under dryland growing conditions where the bulk of the crop comes from.

Bacterial Blight in Zimbabwe

Bacterial blight is a very important cotton foliar disease in Zimbabwe. The disease is caused by *Xanthomonas campestris* and yield losses can range from 10 - 70% depending on severity of the epidemic and well as variety susceptibility to the disease.

All Albar varieties grown commercially in Zimbabwe have good levels of resistance to bacterial blight, and as a result the disease is rarely seen.

Bacterial Blight Screening Program

The bacterial blight programme is concerned with screening for host plant resistance within the main pedigree breeding programme. Routine screening is carried out annually on introductions, crosses, hybrid pools, population development programs, non-replicated progeny rows and in the preliminary and advanced variety trials.

Bacterial blight resistance is one of the characteristics on which single plant selection (SPS) is based at the very beginning of the pedigree breeding programme. Breeding material is inoculated each season from the SPS stage onwards, with susceptible material being rogued. Once the material reaches the strain stage of selection, evaluation for blight resistance is conducted in replicated trials where roguing is not practiced.

Table 2.

Category of Disease Reaction	Description	Stem Lesion (Score 1 - 6)	Boll Lesions (diameter mm)
RR	Highly resistant	1 (no reaction)	1 (no reaction)
R	Resistant	2	2
I	Intermediate	3	5-Mar
S	Susceptible	4	9-Jun
SS	Highly susceptible	6-May	10 or above

Screening is based on stem and boll inoculation. Stem inoculation is made by a puncture at the top most internode of the young plant with a machine needle dipped into the inoculum. This is usually done at 6 weeks post-germination and plants are assessed about 3 and 6 weeks later. Assessment is made by direct measurement of lesion size on the stem. The more variable the material under test, or the more advanced its stage of testing, the larger the amount of plants are inoculated and assessed for reaction to black-arm infection. Natural infection may also be used in seasons favorable to the disease.

The severity of disease reaction in response to inoculation which separates resistance from susceptibility is decided upon in any one season with reference to the controls but generally for SPS a score of 3 or lesion diameter of 3 mm or more is considered susceptible for stem inoculation and boll inoculation respectively. In replicated trials the material are categorized as in Table 2.

Selection of Isolates

Each season isolates of *Xanthomonas malvacearum* are collected on infected leaves, stems and bolls from as many different localities as possible. The isolates are tested in a glass-house before the start of new season by inoculating them into the 8 host differentials. An isolate is then selected on the basis of virulence and apparent "race". An isolate corresponding to race 10 is preferred as this race is virulent to a wider range of material than race 6.

Because bacterial blight is very important in Zimbabwe all single plants and varieties under test from all the breeding programs are assessed for resistance to blight and only the resistant single plants and varieties are selected for further testing.

The *Verticillium* wilt Problem in Zimbabwe

Verticillium wilt became an important disease of cotton in Zimbabwe, due mainly to the development of commercial varieties which had much improved yield and fiber qualities but which were susceptible to *verticillium*. Indications are that *verticillium* is becoming distributed over a wider area each season. The development of new commercial varieties which were less resistant to the disease than previous varieties derived from strictly Albar populations, allowed *verticillium* wilt incidence to increase in areas where it was absent, or present at a very low level in the past.

Wilt incidence in Zimbabwe increased dramatically in 1983 when the variety then called Albar 72B was replaced by Albar K602 whose genetic background involved some non-Albar material.

Sources of Resistance

Both Albar G501 and Albar 72B have some resistance to wilt and have been used in the wilt crossing program. Acala varieties from USA and particularly the MAR germplasm have also been crossed with locally adapted varieties together with Australian varieties. However, the use of the old varieties like Albar G501 and Albar 72B compromises fiber quality and yield to some extent. The old varieties have coarse, weaker, shorter and less uniform fiber and do not yield as well as the newer varieties. Wilt resistant varieties with acceptable fiber quality have been used a lot in the breeding programme.

Breeding for Resistance

From the strain stage (F_5) of the pedigree line breeding programme onwards, when sufficient seed is available for replicated screening trials, material is evaluated for wilt resistance on land heavily infected with the pathogen and where the disease is sufficiently evenly distributed to rely on natural infection. However, because of the risk of disease escape, natural infection is unreliable for single plant selection and artificial inoculation is required. Stem inoculation is used for selection in unreplicated material and in addition, all replicated trials which are screened by natural infection planted in duplicate for stem inoculation. Stem inoculation is successful in the field provided the trials are sown late so that inoculation is carried out in cooler weather.

There appears to be some site-to-site variation in the expression of resistance to wilt and the aim has therefore been to screen material in the geo-climatic zone for which it is intended. Also, at each site there should be two screening areas which are used for trials in alternate years. In the intervening years a susceptible variety is grown to even out the distribution of the pathogen.

Currently two varieties Albar BC 853, a medium staple variety and CY 889, a long staple variety can be grown under wilt conditions in Zimbabwe.

Achievements of the Past 15 Years

Seed Cotton Yield

Over the past 15 years all new varieties have demonstrated some seed cotton yield improvements over their predecessors with the average level of improvement ranging from about 3% to 20%, depending on the season. A striking feature of the yield performances of more recent varieties is their ability to perform much better than older varieties under stress conditions.

Fiber Quality

A major push towards developing higher quality medium staple Albar cottons occurred during the past 10-15 years and this has resulted in the present varieties having superior fiber quality (particularly length, strength and fineness) to that obtained before. The improved quality in the new varieties has been recognized by the various marketing groups who now give growers a 7-20% seed cotton price premium for a range of these "improved Albar" varieties (Table 3).

Ginning % and Lint Yield

The percentage of lint removed from seed cotton during ginning (referred to as ginning percent or gin outturn) was between 34% and 36% in the older varieties. However, following a shift in selection priorities and the use of high ginning % foreign varieties in crosses with local material, major advances have been made such that our most recent cultivars now have values of around 42% (using a 40-saw gin). Under commercial ginning the newer varieties produce at least 10% more lint than the old varieties.

Diseases

The two most important cotton diseases in Zimbabwe are bacterial blight and verticillium wilt. The former is widespread in all cotton growing areas and can cause yield losses of around 20% in susceptible varieties. Combined efforts from the pathologists and breeders have ensured that all our current cultivars have sufficient bacterial blight resistance to prevent yield loss from this disease.

Verticillium wilt is largely restricted to heavier soils such as those found in the large scale sector where it can cause substantial yield loss when infection levels are high. Two varieties, medium staple Albar BC 853 and long staple CY 889 were developed and released specifically for farms where the disease is endemic. They combine good wilt tolerance with good fiber quality.

Pests

Insect pests are a major cause of yield loss in cotton if preventative measures are not taken. In most cases this requires the use of pesticides, but one of our major pests, jassid, can be controlled by variety resistance. Jassid is a particular problem in the communal areas where pesticide use is often limited by availability or cost. Therefore, all our dryland varieties have been selected for good jassid resistance which drastically reduces yield loss from this particular pest.

The drier-than-normal seasons during the first half of the 1990s encouraged widespread aphid buildup and this allowed the breeders to identify material with increased aphid tolerance.

Table 3. Fiber Characteristics of Zimbabwe Varieties

Variety	Staple (inches)	Strength 1/8 gauge g/tex	Maturity	Fineness	Micronaire Range
Albar SZ 93 14	1 3/32 to 1 5/32	27-30	82-99	130-175	4.0-4.9
Albar FQ 902	1 3/32 to 1 5/32	27-30	82-99	160-180	3.8-4.8
Albar BC 853	1 3/32 to 1 1/8	27-30	> 80	130-170	3.8-4.6
LS 9219	1 7/32 to 1 5/16	29-33	> 80	160-190	3.8-4.6
CY 889	1 3/16 to 1 1/4	29-33	> 80	160-190	3.8-4.6

The breeding programme has also improved the chances of better pest control by producing some varieties with an open plant structure which allows better spray penetration into the crop and an increased chance of hitting the target area.

Long Staple Cotton

Long staple cotton is a high value crop which was principally grown under high input conditions and which usually produces between 12,000 and 15,000 tons of seed cotton per season. The first of Zimbabwe's long staple varieties, called Delmac, was developed in the early 1970's but it had an erratic yield performance and it was very susceptible to bacterial blight. Currently a new long staple variety called CY 889, which was released in 1994 has since built a good reputation among growers for its reliable yield performance and good disease resistance. Another long staple variety called LS 9219 was released in 2001 and can be grown under both low input and high input management systems.

High Altitude Cotton

In 1996-97, Zimbabwe released its first high altitude cotton cultivar. Traditionally, cotton has been grown in Zimbabwe at altitudes between 300 meters and 1,200 meters, although efforts to raise the ceiling by producing cool tolerant cultivars have been ongoing since 1976. The release of the new variety, called HAP 1, has enabled the extension of areas suitable for cotton production to 1,350 meters and will allow growers at these altitudes to consider cotton as a new option in their farming systems.

Conclusion

The present breeding programme contains an extremely broad genetic base that presents every opportunity to introduce improvements over existing and imminent varieties. The short to medium term objectives of the breeding programme are to continue improving the yield, drought, pest and disease tolerance as well as the general fiber quality of Zimbabwean varieties with special emphasis on fiber uniformity, strength and elongation. The long term objective is to reduce the number of varieties grown in the country by introducing broad adaptability genes in our germplasm. Some genes will be introduced that confer resistance to a number of bollworm species and specific herbicides into our varieties. The Bt and Roundup Ready genes are top on our priority list.

Non-Traditional Approach to Small Scale Farmers Management Practices

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Abstract

The farm management practices of small cotton farm holders in the Philippines and their low productivity are discussed, and a production model to overcome the limitations of these traditional practices and farm management is proposed.

Introduction

A reservoir of cotton technologies and practices are available to suit the varying growing conditions and needs of growers, from low input manually-operated farm practices common in Africa and South East Asia to intensive highly mechanized farm practices found in the United States, Australia, Mexico and the Middle East.

This variation in production practices reflects growers' efforts to fit crops to the climate and soil conditions in each locality, and the available labor and farm resources.

This paper attempts to describe the farm management practices typical of small cotton farm holders, and propose a production scheme that would address its limitations and raise cotton productivity, make it sustainable, efficient and competitive.

Small Farm Holder Cotton Production System

In the Philippines cotton is grown by resource-poor farmers in small farm lots, following low farm management and limited use of farm inputs.

Several programs were designed by the government to develop the local cotton industry. But, despite the three decades of commercial cotton plantings, the cotton industry remains marginalized with farmers' participation unsteady, and productivity low and erratic.

The soil and climatic parameters are not constraints to high productivity as shown by the high seedcotton yield potential of up to 6.5 tons/hectare when cotton is grown under high input, intensive management and close farm supervision (Cosico et al, 1997, 1998). This is vouched by the 2–3 tons/ha seedcotton yields obtained in commercial fields by progressive farmers who comply with technical recommendations.

The cotton production landscape in the Philippines is characterized by small fragmented farm lots, sparsely dispersed, tilled by numerous farmers of varied cultures, training and farm ex-

perience. Wide farm-to-farm variation exists due to diverse growing conditions and practices.

Cotton is grown in mixed culture with other crops in staggered planting giving rise to a highly diversified ecosystem. The mix cropping is practiced to minimize the risk caused by abnormal weather conditions and fluctuating farm prices, and to optimize labor productivity on the farm.

On the other front, cotton growing technology is tailored for small farmers with low input and manual farm operations. The technology is well-tried and considered appropriate given the existing resources and growing environment of resource-poor farmers (Agridev, 1999). Productivity, however, is low averaging about 1 ton of seedcotton per hectare. The low level of farm inputs and management could not support higher yields, and the small farm size prevents the adoption of technological advances and efficient mechanized farm operations (Agriswiss, 1999).

Extension services are provided by local government agricultural technicians who supervise multiple crops grown by farmers. Cotton is relegated to the back seat, giving food crops like rice and corn top priority. Quality extension services suffer due to unfocused and loose technology transfer prone to short cuts/deviations by farmers.

The access of farmers to credit from government financing institutions and a private development company is limited. With low farm inputs and often times untimely availability and/or application, productivity is affected.

Lastly, farm management through individual small farmers is loose, highly variable, costly and inefficient.

These inherent limitations of the small land holding production system results to low, erratic yields and high production costs which are not sustainable (Agriswiss, 2000).

Towards Developing a Non Traditional Approach to Small Scale Farm Management

The high productivity of cotton in growing regions with large farm size and where agriculture is intensive and mechanized, is related to efficient farm management and the application of modern technological advances.

It is difficult to succeed in agriculture managed by a large number of small farmers with limited resources. Technological

knowhow can not efficiently and economically be transferred to farmers, or farmer have no resources to adopt these technologies and farm practices. (Agridev, 1999)

A requisite to farm mechanization and the application of modern technologies in the traditional small land holding agriculture is the consolidation of small farm lots, the organization of farmer groups, rationalization of cotton growing technologies and professional and centralized farm management mediated by a private development company.

Farm Clustering

In the context of the Philippine setting, corporate farm management is not feasible due to agrarian laws that limit large land ownership and other restrictions. The compromise alternative is to consolidate small farm lots of farmers to form clusters of economic size in order to achieve economies of scale in farm operations, thus effecting efficient farm management and mechanization of farm operations. A definite cropping pattern where cotton fits in should be institutionalized to optimize the use of farm labor, machineries and equipment.

Formation of Farmer Cooperatives/Groups

Coupled with farm clustering is the formation/organization of farmer cooperatives and groups. Centralized and efficient implementation of farm activities is made possible with organized farmer groups. Arrangements for volume purchases of seeds and farm inputs give advantages compared to individual farmer's purchases. Groups will also allow affordability in owning costly implements for mechanized farming and farm infrastructure.

Cotton Growing Technologies and Practices Rationalization

Cotton growing technologies and practices should be modified to suit a large farm setting that will allow application of modern farm practices and efficient farm management. Specifically the following practices merit consideration:

- Weed control

The traditional approach of weeding performed by hand pulling and manual cultivation should be modified to accommodate the integration of herbicide. Manual weeding is not only arduous but labor intensive requiring numerous man-days. It takes time to complete the operation and can not be performed efficiently during inclement weather. Usually performed late, significant crop-weed competition has already occurred, reducing yields (CRDI, 1980).

Pre-emergence application of diuron followed by early-post emergence application of fluzifop butyl against grass weeds and/or directed spray of glyphosate proved effective and economical in controlling weeds (CRDI, 1980).

- Mono Cropping

To simplify field operation mono cropping should be adopted following a defined crop rotation, normally rice-

cotton in lowland paddy areas and corn-cotton in upland areas. Mechanized planting, cultivation, spraying, and fertilization could be carried out efficiently in a mono-crop field.

Rice and corn crops are shallow-rooted. Followed them with cotton with a tap root system will result in an efficient nutrient foraging ability of the cotton roots for the inherent and residual nutrients applied to rice and corn. Of course the issue of diverse habitat in mix cropping in relation to enhancing biological control is there (Fitt, 1989), but in large farms especially for a generalist pest like *Helicoverpa* spp. there is little evidence that reduced diversity per se leads to pest outbreaks (Hearn and Fit, 1992). In fact a monoculture may dislocate pests' life cycle by removing alternate host and diluting the attack over an abundant crop (Fitt, 2000)

- Higher Rates of Fertilization

Low rates of fertilization are unable to support higher yields but are justified under the traditional system because yield can not be maximized due to generally low inputs and management. However, with improved insect control, irrigation and weed control, higher fertilization is needed to support high productivity.

- Coordinated and Centralize Irrigation

A centralize irrigation source will supply water requirements to a group of farmers or a production cluster efficiently in a coordinated manner instead of each small farm having its own source.

- Insect Control — Integrated pest management undoubtedly is effective and cost efficient. This includes identification and constant monitoring of pest infestation through scouting, use of threshold level, proper timing and dose of application, combined with cultural and biological control measures. The IPM system should be built on cotton with inherent resistance to common pests as in hairy varieties against leafhoppers and transgenic Bt cotton against *Helicoverpa* and other lepidopterans.

Farm Mechanization

With economic farm size achieved through area consolidation, farm operations could now be mechanized such as in plowing, harrowing, furrowing, planting, and fertilizer application which bring advantages in terms of fast and precise input application. Precise row and hill spacing and seed placement will ensure the desired plant density, uniform seedling emergence and plant stand. Moreover, the utilization by the plant of applied inputs such as fertilizers and pesticides will be more efficient when mechanically applied.

Anchor Firm—Based Farm Management

Cotton cultivation is exacting and demands constant vigilance against a variety of pests and diseases. The complementary partnership of the farmer cooperatives and a development com-

pany is necessary in addressing and providing professional farm management, timely provision of inputs, technical advise, supervision and an assured market.

The Pilot Farm

The above production technology package and farm management is currently pilot-tested to validate its technical, economic and operational feasibility. A contiguous area of 20 hectares owned by individual small farmers was consolidated. The enhanced package of cotton growing technology makes use of mechanized land preparation, planting using delinted seeds, moderate to high level of fertilization, herbicide-based weed control, centralized irrigation, and integrated pest management anchored on a jassid resistant cotton variety, use of threshold levels, screened and tested pesticides and coordinated pesticide sprays. The farm owners supply labor and implement the prescribed practices in a coordinated manner. An Agriswiss technician provides the overall farm management and supervision.

Conclusion

A prerequisite to farm mechanization and the application of advanced technology in small farm size production systems is the consolidation of small farm holdings into an economic size and the organization of farmers into functional groups.

The decline in land area devoted to agriculture due to massive conversion into industrial and commercial uses, crop competition and increasing cotton demand call for maximizing to the fullest productivity per unit area coupled with cost-efficient cotton production. This could be achieved through the application of modern technology and farm mechanization.

The approach being proposed will address the low productivity of small farm holding agriculture and will make cotton growing more productive and competitive. The problem, however of area consolidation and farm infrastructure needs to be over-

come. The task is formidable owing to social, cultural and economic differences and needs of farmers.

References

- AgriDev, 1999. Cotton development project in the Philippines. A business plan prepared for Agriswiss Corporation and the Philippine Government. Israel, P.O.B. 213, Rehovot, 6101, Israel.
- Agriswiss, 1999. Pre feasibility study on large scale cotton production in the Philippines. Prepared for the Department of Agriculture. Makati City, Philippines.
- Agriswiss, 2000. Philippine Cotton Development Program; Marketing, Technical and Socio-Economic Feasibilities. Makati City, Philippines.
- Agriswiss, 2000. Philippine Cotton Development Program. A Vision and Model Plan. Makati City, Philippines.
- CRDI Annual Report, 1980. Determination of minimum weed-free and weedy periods permissible to obtain optimum seedcotton yield under different weed situation Cotton Research and Development Institute. Batac, Ilocos Norte, Philippines. pp 152-206.
- Anonymus, 1980. Evaluation of different weed control methods in cotton. Cotton Research and Development Institute, Batac, Ilocos Norte, Philippines, pp 138-151.
- Cotton – Miles To Go. 1998. The East India Cotton Association Ltd. Mumbai, India.
- Fitt, G. P. 1989. The ecology of *Heliothis* species in relation to agroecosystems. *Annual Review of Entomology*. 34: 17-52.
- Fitt, G.P. A Future of IPM in cotton: The challenge of integrating new tolls to minimize pesticide dependence. 59th Plenary meeting, ICAC.
- Hearn, A.B. and Fitt, G.P. 1992. Cotton cropping systems, in field crop ecosystems of the world, Ed C. Pearson, Elsevier Press, Amsterdam, pp. 85-142.
