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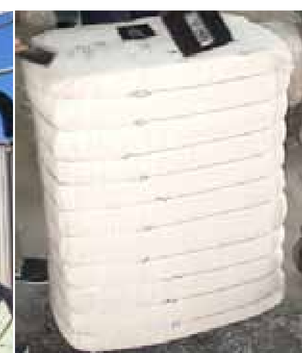

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Introduction

Biotechnology use in cotton in the form of herbicide tolerance and then insect resistance came with restrictions and apprehensions. There has also been a devoted opposition that continues and does not seem to be fading away. Researchers did their best to put forward science-based facts, and vigorous campaigns came from countries that benefited the most from biotech cotton. Often times cotton was linked to food crops which may have entirely different concerns/issues compared to a crop that is grown for fiber. Although, cotton seed oil is extensively used in human consumption. The issues about biotechnology in cotton were little related to cotton seed oil. The cotton industry has not been deterred by philosophical theories and continues to expand the use of biotech cotton. It is estimated that in 2011/12 biotech cotton was planted on over 23 million hectares. It was also estimated that 69% of global production and 64% of the cotton traded internationally that same year came from biotech varieties. Indonesia is not a big producer of cotton but commercialized biotech cotton 10 years ago and later stopped growing it. Biotech cotton area in all the other countries that adopted it has only been rising. The first article in this issue of *THE ICAC RECORDER* is an updated version of the article 'Commonly Asked Questions about Transgenic Cotton' which was published in June 2002 issue of *THE ICAC RECORDER*. Fourteen questions are explicitly discussed in the current article.

In most countries many varieties are officially recommend for commercial cultivation. New varieties are added to the list and older varieties are usually not delisted. Consequently, the list of approved varieties continues to grow, reaching hundreds of varieties particularly in India, China, USA and Pakistan. In some countries, varieties are divided into different brands and many varieties belonging to the same brand are planted on significant areas. For example, 28% of the cotton area in the USA in 2012/13 was planted to 20 varieties of the same particular brand. ICAC undertakes a survey of the varieties planted in various countries every three years. The data for 2010/11 showed that the maximum number of varieties per country was planted in India, followed by the USA. China, Myanmar, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan planted more than 10 varieties on a commercial scale in 2010/11. Farmers choose to grow more than one variety at the same time. The reasons farmers do this are discussed in the 2nd article. A multiplicity of varieties is desirable for various reasons but planting of too many varieties enhances the chances of admixtures and lower uniformity in fiber for length, strength and various other parameters. Varieties differing in fruiting periods serve as reservoirs for insects to multiply that move to vulnerable fields. Multiple varieties should only be grown if agro ecological conditions require different fits for different genotypes. Read more in the 2nd article.

The textile industries requirements have been changing, and one of the latest demands from the textile industry from the producing countries is to provide contamination-free cotton. Trash can be eliminated during pre and post cleaning operations, but contaminants once mixed with cotton are broken into smaller pieces making it hard to eliminate. Admixtures like polypropylene and plastic that can be collectively termed as packing material result in serious discounts. Some cottons may not be badly contaminated with packing materials but continuously suffer losses due to a bad reputation for contamination. The West African countries fall in this category. ICAC encouraged Mali to develop a fast track project to quantify the amount of contaminants. The project was successful and formed the basis to launch a bigger project in Burkina Faso, Cote d'Ivoire and Mali. The three-year project CFC/ICAC/38 Prevention of Seed Cotton Contamination in West Africa was launched in 2011 with the objective to minimize contamination in cotton. The project that is funded by the Common Fund for Commodities and respective countries has two major components, i.e. training and provision of cotton bags. Thus far, 166 extension agents, 30,000 producers, 240 transporters, 1,269 ginnery workers and 53 data collectors have been trained in the project. 435,000 harvesting bags, 48,830 large protection tarpaulins and 81,500 small tarps have been distributed to cotton producers. The International Fertilizer Development Center is running the project under advice from the ICAC and CFC. More details are given in the 3rd article.

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Technical Seminar 2012

The Technical Seminar at the 71st Plenary Meeting held in Interlaken, Switzerland from October 7-11, 2012 was held on the topic 'Intellectual Property Rights and the Role of Private Breeders.' Six researchers from six different countries presented papers. The publication is available for free down load at http://icac.org/publications/publication-catalog?pub=pubdetail.php?id=P0000055.

Regional Network Meeting

The 11th Meeting of the Inter-Regional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions was held in Antalya, Turkey from November 5-7, 2012. All papers presented at the meeting are available at http://icac.org/papers/papers-technical-information/communication-among-researchers/interregional-cooperative-network-on-cotton-for-the-mediterranean-and-middle-east-regions.

ICAC Books

ICAC has lowered the price of the book *Cotton: Technology for the 21st Century* from US$180 to US$100. The book has 16 chapters, each contributed by highly respected and internationally recognized authors from across the world. The book *Cotton Facts* is still sold at US$50 plus shipping. Send orders to publications@icac.org or visit the ICAC web page htpp://.icac.org.

ICAC Researcher of the Year 2013

Applications will be accepted from February 1 to March 31, 2013. For more information visit http://icac.org/technical-information/researcher-of-the-year.

Frequently Asked Questions About Biotech Cotton II

The bollworm complex caused more damage to cotton than any other group of pests during the 1980s and the first half of 1990s. Insecticide use had reached its peak in many countries and the consequences of insecticide resistance had also become evident in cotton producing countries, big and small. The only exception to the impact of bollworms was in the Americas and, more particularly, the Central American countries, where the greatest damage was not attributable to the bollworm, but to the boll weevil, *Anthonomus grandis.* The US boll weevil eradication program proved to be effective and was expanding to the west, but the Central American countries could not afford to continue increasing the use of insecticides to control that pest. Ultimately, the Central American countries succumbed to the combined impact of the high cost of insecticides and the consequences of frequent spraying. The environmental impact was, of course, a concern. However, at that time, the cotton industry was not as aware as it is today, after having witnessed the disastrous effects of insecticide use. So, the cessation of cotton production in Central American, showed how destructive resistance to insecticides could be, and the bollworm complex emerged as the major threat to cotton production. There could not have been a more suitable moment than the early 1990s for the introduction of a new technology, such as biotech cotton. The pesticide industry could not cope with demands from the field, even though target-specific pesticides employing softer chemicals were soon to be introduced, along with measures to avoid the resistance problem.

According to ICAC data, in 2011/12 biotech cotton was planted on 65% of the world cotton area. Biotech cotton accounted for 69% of global production and 64% of the cotton traded internationally that same year. Biotech cotton is still commercialized in only 12 countries, and most of them have already reached their peak in terms of area planted to such varieties. Unlike Australia, South Africa and the US, the countries in the process of adopting biotech cotton are not expected to devote 90-95% of their cotton area to biotech varieties. There are only a few countries expected to commercialize biotech cotton within the next few years. The rate of adoption, in terms of the number of countries, has certainly slowed, but this has nothing to do with the promise of the technology. This issue and other related questions are discussed herein. (This article supersedes the article 'Commonly Asked Questions about Transgenic Cotton' published in the June 2002 issue of *THE ICAC RECORDER*.)

What is the Correct Term for a Product Developed Using Biotechnology?

Biotechnology is a science and it is a very broad field that can encompass various techniques, not only for the transformation of living organisms but also for a great many other uses. The techniques used and products developed may be different, but in every case there must be a living organism involved in the improvement of another living organism. Biotechnology is also defined as the application of scientific and technical advances in life sciences to the development of new products. Biotechnology is not limited to genetic engineering, tissue culture, DNA studies, and the like; it applies to a much broader field and its possibilities are still far from being exhausted. Neither is biotechnology limited exclusively to transgenic plants, as the transfer of genes may take place within species, among species or across species. It is true that the early products developed through biotechnology, particularly in cotton, were transgenic and genetically engineered, which means that cross-species genes were used and recombinant DNA technology was employed selectively to develop insect-resistant and herbicide-tolerant cotton varieties. Cotton products developed using biotechnology have been saddled with so many incorrect names, including GMO cotton, genetically engineered cotton, transgenic cotton and Bt cotton. But none of these terms encompasses the sort of product that is not genetically modified, genetically engineered, or transgenic and does not carry a Bt gene. It is true that no such product is on the market yet, but it may very well be developed and commercialized soon. The International Cotton Advisory Committee constituted an expert panel in 2003 comprising nine members, mostly researchers. The Expert Panel published a report in November 2004 wherein they commented that the implementation of the tools of modern biotechnology is resulting in an expanding number of products best described by the term 'biotech.' The term 'biotech cotton' covers all the currently available biotech varieties and also leaves a margin for the new products hopefully to be developed through biotechnology. 'Biotech cotton' is the right term and since 2004, ICAC has encouraged its use by the cotton community.

Does Biotech Cotton Have a Higher Yield Potential?

Insect-resistant and herbicide-tolerant biotech cottons have specific objectives. The addition of a non-hirsutum gene (responsible for producing a specific toxin) from soil bacterium *Bacillus thuringiensis* in no way enhances the genetic ability of a plant to produce higher yields than its otherwise isogenic line. The inherent ability of the plant to produce buds, flowers and bolls remains the same as in the case of an isogenic line without the Bt gene. The same is true in herbicide-tolerant biotech cotton. Whether genetic potential can be improved through biotechnology is not at all certain. Yield is the most attractive character in cotton as well as in other agricultural crops, but there are no reports of successful work that might directly improve the genetic ability of the plant to give higher yields. The non-determinate nature of the cotton plant even makes it difficult to achieve yield-enhancing features devised through biotechnology.

Cotton Yields in India Increased by Over 80% in Five Years: Was it All Due to Biotech Cotton?

India commercialized biotech cotton in 2002/03, when the average yield was 302 kg/ha. The average yield in India increased to 554 kg/ha in 2007/08, an 83% increase in only five years. Of the 12 countries that have commercialized biotech cotton, none has achieved more than a 25-30% increase since adopting biotech cotton. Many reports about India, local and international, assigned all the credit to biotech cotton, but the fact is that a number of other factors also contributed to increases in yields in India. Cotton yields in India were stagnant for about 15 years, and the main reasons for low yields were poor adoption of technology and ineffective control of insects. India had reached a stage where cotton farmers were losing the economic viability of cotton production. Insecticides were used, but not as recommended by experts, and this led to mixed results. Poor insecticide use was rooted in poor extension services.

The Government of India recognized the problem and launched its Technology Mission on Cotton. There were four components, some focused on research and ginning, but the most expensive component focused on transfer of technology. The project required that grants provided by the Federal Government were to be matched by the state governments. The Federal Government provided so much money that state governments were not able to draw down the full amounts of the grants. Those cotton growers, who had already reached a level of sophistication, were assisted by the technology mission to improve future. Having been so low and stagnant for over 15 years, cotton yields in India, unlike in other countries, had a broad margin for increase. None of the other countries adopting biotech cotton at that time was in a similar situation. So increases in yields over the short span of 6 years reflected the combined effects of many factors, including the introduction of biotech cotton.

Where Does Yield Improvement, if Any, Come From in Biotech Cotton?

The genetic ability of the plant to produce higher yields does not improve with biotech cotton, and yet, the literature provides abundant references to higher yields achieved with biotech cotton varieties compared to non-biotech varieties. Cotton is vulnerable to a number of insect pests, and huge losses may occur if the plant is not sprayed with protective chemicals. The losses due to pests are directly proportional to the pest pressure in the field. Insecticide applications minimize losses due to insect pests but do not completely eliminate them. Currently, most countries follow the pest threshold method, and insecticide applications are recommended when the specific pressure threshold or level for a particular pest has been reached. Each threshold is a level or stage at which the benefits of using an insecticide are greater than the cost of the insecticide and its application. But at this stage, the plant, or its fruiting forms, have already suffered at least some damage, particularly in the case of a bollworm attack. Biotech cotton has no threshold for the target pest. The toxin is present in the plant even if there is not a single bollworm larva in the field. Thus, the use of insect-resistant biotech cotton eliminates or minimizes the pre-threshold losses that occur prior to the initiation of insecticide applications.

The situation in the case of herbicide-tolerant biotech cotton is similar, but slightly different. Pre-emergence use of herbicides kills weeds at a very early stage, thus avoiding any competition with the cotton plant for nutrients and water.

When growers employ manual or mechanical removal of weeds, they start weeding operations only when they actually see the weeds in the fields. Herbicides must not be sprayed on non-biotech herbicide-susceptible cotton and tractors cannot be taken into the fields for weeding. Neither is it feasible to remove grown weeds manually or with small implements. Consequently, when post-emergence herbicides are used, herbicide-tolerant biotech cotton (e.g. Roundup Ready Flex) has a clear advantage over non-biotech herbicide-susceptible cotton.

What Other Effects do Biotech Genes Have on Yield-Related Performance?

In the case of insect-resistant biotech cotton, the increase in yield, if any, depends on the reduction of losses due to insect damage even after the application of the usual pest control measures. The maximum increase in yield becomes apparent when a biotech variety is compared with a conventional variety grown under unsprayed conditions. When conventional fields are sprayed in a timely and effective manner against target pests, a biotech variety may produce only a minimal increase in yield, or none at all. In a non-biotech crop, the increase in yield is a direct indication of how precisely insect control practices have been followed. Insect-resistant biotech cotton usually produces early boll setting, thus changing the whole plant phenology. Yield may remain the same as in the non-biotech variety, but the location of bolls on the plant is different in biotech cotton. More bolls are formed closer to the main stem. Biotech varieties may also mature earlier than the isogenic non-biotech varieties.

Does a Biotech Variety Require Different Agronomic Treatments?

Early boll retention and more numerous bolls can change the plant's needs and drive it to reach its 'cutout' stage earlier, thus resulting in early crop maturity. Early fruit load, coupled with a heavier fruit load, might limit access to the supply of nutrients needed for normal growth, thus leading to smaller plants and lower yields, which, in turn can compromise the usefulness of a biotech event. To overcome this potential problem, when adopting biotech varieties, growers must introduce changes into their conventional agronomic practices. The critical factors that will ultimately determine farmers' decisions are: cropping systems and varietal suitability to early or delayed planting. If cotton is grown in a one-year rotation with fallow lands and there is no urgency to vacate fields by a certain date, it makes no difference whether the crop is planted early or late. But when cotton follows a different crop and there is not enough time between the harvest of the previous crop and the planting of cotton, a 2-3 week delay might provide the extra time needed to prepare the land properly for optimal germination of cotton. Similarly, the interval between the cotton harvest and planting of the following crop might affect the yield of the latter. Certain varieties may not be suitable for late planting at 2-3 weeks, so they must be planted at the right time, irrespective of whether they are biotech or conventional. Lastly, delayed planting may not affect yield, but late planting of a biotech variety can affect fiber quality. This will, in effect, preclude delayed planting by weeks.

On the other hand, the other options could be to lower or increase fertilizer dosage to affect maturity, yield and quality.

The studies conducted in Australia tested two options: delayed planting and larger plant stand. The results proved that biotech cotton (Bollgard II) had higher boll retention across all sowing dates and population stands. The Bollgard II variety produced lower yields when it was sown at a delay spread of four weeks. Total fruit retention was only affected by the number of plants per unit area with closer spacing producing fewer fruiting points. In all the trials, later sowing dates for non-Bollgard II varieties consistently produced lower yields. The decline in yield was linear (from the optimal planting date to later planting). It is not surprising that with Bollgard II as well as with the non-Bollgard variety, fiber length and micronaire were affected by the time of sowing. The data showed that with the delay in sowing dates micronaire decreased while fiber length increased. Fiber strength was not affected by variety or sowing dates in any of the experiments. The data showed that sowing of the Bollgard II variety can be delayed by a few weeks without affecting its yield or its fiber quality. Conversely, delayed sowing of a conventional variety can result in lower yields due to reduced fruit retention. There was also no evidence of yield losses with the Bollgard II varieties at any population density as compared to the non-Bollgard II variety. The experiments conducted showed that growing Bollgard II varieties also requires changes in agronomic practices in order to achieve the maximum benefits of the technology.

What is the Role of Biotechnology in Conventional Breeding?

The cornerstone of conventional breeding is to have or to create genetic variability in the population for the purposes of selection and hybridization. If there is very little or no variability in the population, opportunities for breeders to improve their population will be severely limited. This is why most breeding programs around the world are becoming increasingly concerned about having to work with a narrow genetic base. Minimal exchange of germplasm among countries, coupled with legal prohibitions against the transfer of biotech genotypes are the main factors responsible for the narrowing of the genetic base. Biotechnology has a huge potential to create non-existent traits and variations. Insertion of such special traits/events into promising genotypes for the purpose of commercial use will involve conventional breeding. Crossing and backcrossing will always require professionals to make certain that the new features have been efficiently and accurately transferred to the new genotype. When the science of genetics was born, breeders tried to understand how specific characters could be inserted in the shortest possible time and without losing any of the other benefits of the recipient parent. As the inheritance of characters became better understood, scientists found ways to speed up the breeding process and make it more precise and reliable. With the advent of biotechnology, the precision and reliability of the process has entered a new era of gene tagging and marker assisted breeding, but the objective is the same. Biotechnology will always require screening the segregating generations, in the case of a new trait, and backcrossing, in the case of transferring unique preexistent genes to another variety. Development of a pure and superior genotype utilizing the variability created by biotechnological methods is no different from the principles followed in conventional breeding. Thus conventional breeding and biotechnology are complementary.

Do Biotech Genes Have an Impact on Fiber Quality?

Just as in the case of yield, biotech genes, singly or stacked, have no impact on the genetic ability of the plant to produce better or poorer fiber quality. In the early years of the introduction of biotech cotton in the USA, there were a number of reports that showed stagnation, or even lower fiber quality in the crop. The issue was quickly analyzed and found to be related to the period during which new varieties were released. During the late 1990s, all-out efforts were focused on converting existing varieties into biotech varieties, and these effects slowed the release of new varieties. As soon as the variety release process picked up to a more normal pace, fiber quality concerns automatically disappeared. As shown above, biotech genes can change the location of bolls on the plant. Early boll setting and higher bolls formed on the first positions can have an impact on fiber quality. In the literature, both features are reported to impact quality positively in the form of mature and stronger fibers, and early maturity may certainly result in higher micronaire values. Cotton genotypes with improved fiber quality can be developed and it has long been hoped that biotech cotton with improved quality characteristics will be developed. When it will be developed and what feature will be improved remains uncertain. Quality improvement may not even involve a gene from soil bacterium.

What Are the Expected Benefits of Biotech Cotton?

The primary objective of insect-resistant biotech cotton is guaranteed control of target insects and, in the case of herbicide-tolerant biotech cotton, protection of the plant against damage when herbicide is sprayed over the crop. Furthermore, better insect control through biotoxins has the potential to bring additional advantages in the form of lower production costs (due to reduced insecticide use), higher yields (due to better insect/weed control), better grade/quality (due to less bollworm damage resulting in less spotty cotton), better biological control and other benefits under specific growing conditions. The only common benefit, which in the long run is more significant than all the others, is the reduction of the environmental impact.

- **Cost of Production**

  Back in 1994/95, the ICAC Survey on the cost of production of cotton showed that, on the basis of world averages, of the 93 cents it cost then to produce a kilogram of lint, 21 cents (i.e., 23%) were spent on insecticides. Twenty-one cents on insecticides was almost as much as the harvesting costs and greater than the cost of any other single input or operation needed to produce a kilogram of cotton. The ICAC survey is undertaken every three years, and the latest data for 2009/10 showed that only 14 cents (12%) out of US$1.22 were spent on insecticides to produce a kilogram of lint. Insecticides are expensive and biotech cotton, along with other components of IPM, definitely contributed to lower insect control costs in the world. Herbicide-tolerant biotech cotton is grown on a much smaller area than insect-resistant biotech cotton, and the cost of weeding has increased by almost three fold during the same period mentioned above. The current cost of weed control and fertilizers stands at 23% each, thus making it imperative to find ways to lower the cost of weeding and fertilizing. Rising production costs per kg has become a major concern in the last few years because cotton yields have stopped increasing. The world average yield in 2007/08 was 793 kg/ha and since then it has fallen. ICAC estimates for the next few years also indicate that the average world yield will not be greater than 765 kg/ha. Pest pressure and the number of sprays needed per season to control target pests, plus the cost of pesticides, weighed against the cost of technology fees, will determine the extent of savings on the cost of production. However, if the target bollworms do not become a major threat in a particular country or in a given season, and a grower has already paid the technology fee, savings on the cost of production might even be negative.

- **Higher yield**

  The yield issue has been discussed in detail before. Biotech cotton should not be planted exclusively to improve yields. The overriding consideration and the primary objective must continue to be pest control.

- **Improved biological control**

  The biotech toxin in insect-resistant cotton is harmful to insects having mid-gut receptors. The toxin is not harmful to natural predators and parasites, and a reduced use of disruptive pesticides will facilitate the development of populations of beneficial insects in the fields. IPM involves a multidisciplinary approach that minimizes the use of dangerous chemicals allowing them to be applied over long periods of time. According to one of the first definitions of IPM, "The IPM program ... [gives] farmers the tools to make their own informed decisions, so they do not waste their resources, risk their health, harm their crops, or damage the environment." Biotech cotton fits in the system perfectly as a strong component of IPM.

- **Better grade**

  Color grade is determined by the degree of reflectance (Rd) and yellowness (+b). Reflectance indicates brightness and the yellowness of cotton depends on the degree of color pigmentation. Many factors can affect the color of cotton, including rainfall (particularly after boll opening), frost, fungi and contamination with trash, but the most important factor affecting yellowness is spotting due to bollworm damage. Production of spotted cotton is directly proportional to bollworm damage in the field. Biotech cotton is reported to yield a better grade due to lower bollworm damage.

- **Environmental safety**

  Global warming and environmental pollution are detrimental to the environment. The use of chemicals for plant protection, measured in terms of dollars spent, has been on the decline for many years. Cotton's share of plant protection chemicals has declined at a faster rate than that of other crops, but in absolute terms, cotton still consumes more pesticides than other field crops.

What About Targeted Insects Developing Resistance to Biotech Cotton?

Helicoverpa armigera, Pectinophora gossypiella and *Helicoverpa zea* are the three major bollworms affecting cotton and they are known by different names in different regions and circumstances. For example, *H. zea* is also common on other crops where it is known by different names: corn earworm, on corn; sorghum headworm, on sorghum; soybean podworm, on soybean; tomato fruitworm, on tomato, and others. This wide range of hosts, together with the sequence of crops on which the biotech toxins are used to target insects over a single growing season, have a meaningful influence on possible development of resistance to the biotech toxins expressed in Bollgard and Bollgard II cottons, and in other biotech crops. This polyphagy creates seasonal developmental scenarios where a limited number of generations may not be exposed to the transgenic toxins. The use of similar Bt toxins in biotech corn, soybean and cotton subjected target pest populations to multiple selection exposures within any given year. Commercialization of more biotech crops carrying the same Bt genes is only going to increase the risk of developing resistance to the toxins. In 2005, an alternate dual-gene technology known as WideStrike™ became available from Dow AgroSciences. While varieties with Bollgard II® or WideStrike™ technology provide very good control of caterpillar pests, they do not offer 100% control of bollworms. If dual gene technologies such as Bollgard II® or WideStrike™ had not been introduced, most of the targeted insects would have developed resistance to the single Cry 1Ac gene. In the beginning, refuge requirements were strictly recommended and generally followed in most countries. Since then, refuge requirements have been relaxed, in some cases, and amended in others, based exclusively on field experience. Whatever measures may be undertaken, the target bollworms still have the potential to develop resistance to the toxins in biotech insect-resistant cotton. Refuge requirements, stacked genes and various other strategies will be necessary to delay the development of resistance.

What About Weeds Developing Resistance to Herbicides?

Herbicide-tolerant biotech cotton has gone through four important developmental stages.

- The first herbicide-tolerant biotech cotton was approved for commercial production in the USA as BXN™ in May of 1995; that was even before the insect-resistant biotech cotton. The BXN™ gene that conferred resistance to the herbicide Buctril (bromoxynil) was "nitrilase" from *Klebsiella pneumoniae* subsp. *ozaenae*. Buctril™ 4EC (Bromoxynil) herbicide and the patented BXN™ cotton system allowed growers to effectively control commonly occurring broadleaf weeds in cotton from emergence until 75 days before harvest. Nitrilase gives cotton the ability to metabolize the bromoxynil herbicide while the weeds will normally be killed in 2-3 days. BXN™ could be sprayed together with Buctril compounds a maximum of three times from emergence up until 75 days before harvest.
- The second stage came with Roundup Ready® biotech cotton, approved for commercial cultivation in the USA in 1997/98. The mode of action of glyphosate lay in the inhibition of an enzyme (5-enolpyruvylshikimate-3 phosphate (EPSP) synthase), which is a key catalyst in the production of aromatic amino acids. The use of Roundup on Roundup Ready® cotton increased broad-spectrum weed control, minimized competition from hard-to-control annual and perennial weeds, and simplified weed management.
- The third stage was LibertyLink® herbicide-tolerant cotton from Bayer CropScience, approved for commercial cultivation in 2004. LibertyLink varieties were resistant to Ignite herbicide also called Liberty®, Finale® and Rely®. The chemical name for Ignite is glufosinate ammonium, so any chemicals containing glufosinate ammonium may be sprayed over the top of the cotton plant until 70 days prior to harvesting.
- Roundup Ready® Flex biotech cotton, approved in 2006/07, is the fourth and latest stage in herbicide-tolerant biotech cotton.

The first report on the development of resistance to herbicides by weeds was published over half a century ago, so the fact that a weed developed resistance to a herbicide (in biotech cotton) was no surprise to researchers. There are many reports on the inception of resistance but the development of resistance by *Palmer amaranth* to glyphosate has been confirmed. As a post emergence chemical herbicide, glyphosate controls only emerged weeds and does not stop new weeds from emerging. This means that multiple applications of chemicals are required to have season-long weed control. Initially, Roundup Ready biotech cotton limited the use of glyphosate products to only the four-leaf stage, which means that only a limited number of applications could be made in a single season. A much wider window, in the form of Roundup Ready Flex, paved the way for multiple applications of glyphosate, which meant more frequent use of the same chemicals in a single season and the ensuing likelihood of faster development of resistance. A number of other weeds have already developed resistance to glyphosate and a few more are on the verge of reaching the resistance stage. Thus the risk of resistance is very serious and must be dealt with through an alternation of chemicals with different modes of action.

How Can Resistance in Weeds Be Delayed or Avoided?

Multiple applications of a particular chemical, whether it is an insecticide or a herbicide, will inevitably increase the chances for development of resistance. It is apparent that more serious efforts have been made to avoid the development of resistance by insects/bollworms that attack insect-resistant biotech cotton. One psychological reason behind this is the lesson learned from insecticide use on normal cotton. Certain insects were notorious; certain chemicals were more liable to develop resistance in insects, and certain practices in the use of chemicals favored the development of resistance. Insecticide use is more popular than herbicide use and, therefore, researchers and farmers had a greater amount of experience in handling resistance in insects. Now we have the herbicide resistance problem. It is here and it can be dealt with only by attacking it with the full arsenal of techniques available: alternating herbicides with different modes of action, using the minimum number of applications of any one herbicide per season, mixing herbicides with different modes of action (when possible), opting for short-residual-effect herbicides, rotating crops with different growth seasons, planting crops with different registered herbicides and, by not entirely eliminating tillage from the production system.

Are Biotech Cottons Safe in the Long Term?

By now the cotton industry has 17 years of experience with large-scale commercial production and marketing of biotech cottons. It was claimed by biotech companies that the proteins in the currently available insect-resistant biotech cotton have a history of safe use. Most of the alleged negative impacts have proved untrue, or cannot be authenticated on science-based facts. However, reports of the consequences of using cry genes still persist. The resistance problem was perceived even prior to the introduction of biotech cotton, but the fear that a bacterial gene residing within the cotton genome could have consequences has proved unsubstantiated so far. Earlier reports about excessive boll shedding in biotech cotton (in the USA) were also unrelated to transgenes. The reports have shown that biotech genes interact with different varieties differently and their effectiveness is dependent on growing conditions -- true for any biological trait -- but nevertheless an indication that consequences could be different in different production systems.

There has not been any trade impediment for countries producing biotech cotton. Australia and Burkina Faso export most of their production and have encountered no evidence of market bias against products emanating from biotechnology. But this does not mean that all biotech products are entirely safe and there is absolutely no guarantee that future biotech products will perform satisfactorily on a par with currently commercialized biotech events in cotton. Without any monitoring of instances of misuse, biotechnology can potentially lead to the development of products that may have short-term benefits, but long term negative consequences. While a new gene or event that has been thoroughly tested and approved in one country will probably have minimal implications elsewhere under similar production conditions, newer genes/events definitely require extensive testing, including testing with respect to environmental impacts.

What New Products Can Be Expected to Be Released in the Next Five Years?

ICAC estimates that 37% of the world cotton area lacks assured irrigation and that the 63% that is irrigated also suffers from irregular and/or insufficient supplies of water. It is often the case that irrigation water is not available on time for optimum water uptake and timely application of fertilizers. Assured availability of irrigation water in sufficient quantities and when it is needed can boost the world cotton yield by about 30%. It is estimated that the world average yield under irrigated conditions in 2009/10 was 881 kg lint per hectare, compared to 631 kg/ha under rainfed conditions. A lot of work has been done to identify plant parameters that impact water requirements and use, but exhaustive research efforts to develop drought tolerant varieties through conventional methods have not been successful. Reports show that Monsanto has received regulatory approval for its 'DroughtGard' corn, a variety that contains the first genetically modified trait for drought resistance. DroughtGard is expected to reduce the water requirements of the corn plant and minimize the impact of drought on yield, thus helping to avoid losses. Once the technology is commercially released for corn, it will pave the way for general adoption in cotton. The target of research efforts should be equal performance under irrigated and non-irrigated conditions.

The other new technology that is considered to be close to commercialization is nitrogen-use-efficient cotton. Nutrient-use efficiency can be defined in many ways but, in cotton, it may be defined as yield of seedcotton per unit of fertilizers/nutrients applied. Similarly, nitrogen-use efficiency in cotton might be calculated as a function of kilograms of seedcotton produced per kilogram of nitrogen applied. Nitrogen applications are always required and the most important challenge in this regard is matching the nitrogen needs of the plant as accurately as possible. The plant's need for nitrogen changes with crop growth, so both excessive and insufficient applications of nitrogen can have a negative impact on yield. Nitrogen-use efficiency will depend on the ability of the plant to efficiently take up nitrogen from the soil and effectively transport, store, mobilize and use it inside the plant. Ultimately, nitrogen-use-efficient cotton can even benefit the environment, as it would be able to make better use of naturally available nitrogen and help lower the doses of nitrogen application without affecting yields. In other words, the impact of nitrogen deficiency stress would be minimized. But increased yields and reduced nitrogen application rates are only two of the benefits. Other advantages of nitrogen-use-efficient cotton would be: reduction of the impact on climate change (reduced CO_2 emissions), less freshwater contamination, less toxification and acidification of soils, as well as reduction of the nutrient content in the soil which leads to oxygen scarcity.

It is believed that both technologies are in what Monsanto describes as phase 3 or phase 4, the advanced development and pre-launch stages, respectively.

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Cotton Varieties Planted in the World

There are very few regions or states in the world where only one variety is allowed or recommended for cultivation by all farmers. Growers always demand more varieties, and in many countries of the world, the varieties legally approved and allowed for cultivation make up a long list. It is highly unlikely that all varieties will have the same agronomic features and requirements, and these differences can have an impact on fiber quality. It is not possible to keep production segregated by variety, certainly not under small-scale production systems where each farmer cultivates one hectare of cotton or less. Mixing lint from many varieties definitely increases variability and lowers the uniformity ratio of the fiber. And yet, many varieties are recommended for commercial cultivation within a given region or area. In some countries, the number of varieties recommended for a given area may be as great as 15 to 20, and sometimes even greater.

There are countries where varieties are registered and formally approved for commercial cultivation. In some cases, approved varieties are never deregistered, thus adding to the list of approved varieties, including those that may have gone out of cultivation decades before. In these cases, termination of a variety occurs only when seed companies stop producing planting seed of that particular variety. The present article looks into all of these issues.

Cotton Varieties Grown in the United States

There are easily 10 or more brands of seed-variety suppliers in the US, and each one has many varieties that are grown in the same area and at the same time. In the US, cotton is planted in the south, from the east coast to the west coast. Some brands are more popular in one region than in others. There are brands that are not grown in some regions in certain years. Cotton areas by brand name are shown in the table below.

Brands and Varieties Planted in the USA - 2012/13

Brand	Area in Percent	No. of Varieties Planted in 2012/13
Deltapine	28,20	20
Bayer CropScience - FiberMax	24,50	24
Phytogen	18,40	10
Americot	11,20	12
Bayer CropScience - Stoneville	10,00	6
All-Tex	4,70	13
Dyna-Gro	2,40	6
Croplan Genetics	0,20	3
Bronco	0,12	1
Concho	0,05	1
Total:		96

Source: Cotton Varieties Planted 2012 CropAgricultural Marketing Service - Cotton Program, USDA

The report referred to above does not disaggregate the number of brands and varieties included under "Miscellaneous." However, USDA report *Cotton Varieties Planted 2012 Crop* showed that as many as 96 upland varieties were planted in the US in 2012/13. The number of varieties planted in 2012/13 is no different from what is usually the case in any given year. ICAC statistics show that in 2012/13, upland cotton was planted on over four million hectares in the US. This area, divided by the number of varieties, indicates that each variety would have been planted on over 44,000 hectares. In the US, all the area planted to cotton is not always harvested. The US Department of Agriculture reports planted area and harvested area. Due to extremely dry weather conditions in the cotton belt in 2011/12, the abandonment rate was very high and only an estimated 3,928,000 hectares were harvested. The fact that 34% of the planted area was abandoned suggests that some varieties may have been eliminated from the harvest altogether.

All biotech events, both insect resistance and herbicide tolerance, are approved for commercial cultivation in the US with the exception of genes locally identified in China and India. In the US, farmers prefer to grow stacked gene varieties having the Roundup Ready Flex herbicide tolerance feature, but the data by variety shows that sometimes farmers ignore the features and go for a variety that they consider capable of producing higher yields. In 2012/13, ten popular varieties belonging to five brands accounted for more that 50% of the planted area. The most popular variety, which was planted on about 10% of the US cotton area, was Phytogen variety PHY 499 WRF (WideStrike + Roundup Ready Flex). The Bayer CropScience-FiberMax variety FM 1740 B2F (Bollgard II + Roundup Ready) and the Deltapine variety DP 912 B2RF (Bollgard II + Roundup Ready Flex) were planted on just over 4% of the US cotton area. Although PHY 499 WRF is the only Wide Strike variety on the abovementioned list of the 10 most popular varieties, 422,600 hectares planted to one variety amounts to more than all the area planted to cotton in any other single country except ten countries.

It is known that the data on the percentage of area planted to varieties in 2012/13 is sourced from informal surveys undertaken by the USDA Cotton Program. The surveys include ginners, seed dealers, extension agents and other information sources. According to *Cotton Varieties Planted 2012 Crop* (Anonymous, 2012), 96% of the upland cotton area in the US in 2012/13 was planted to biotech varieties. It is quite possible (and was clearly observed in previous years) that other sources used for estimating the area under biotech varieties (like seed sales) have yielded different percentages. The differences were not too significant and it is possible that farmers may have bought planting seed for a given area but had used it on either a lesser or greater extension than that for which it was intended. The three most popular varieties -- PHY 499 WRF, FM 1740 B2F and DP 912 B2RF -- do not have a single common biotech gene. All varieties have the insect resistance and herbicide tolerance events, but when choosing varieties, farmers give serious consideration to their agronomic and quality features before deciding on the variety they are going to plant. As almost all the area is planted to biotech varieties, there is no chance that a non-biotech variety might gain any ground in the US, no matter how high yielding and agronomically superior it may be.

American Pima was planted on 97,000 hectares in 2012/13, and according to Anonymous (2012), the Pima area comprised over 16 varieties or hybrids and yet, almost 3% of the area was planted to miscellaneous varieties. If the 16 varieties had been planted on equal areas, each Pima variety would have covered 16,000 hectares, as compared to 422,600 ha in the case of the upland varieties. Over 40% of the Pima area was planted to a single Phytogen variety, PHY 805RF, the only variety that had the Roundup Ready Flex gene, but it had no insect resistance gene. No other variety had either herbicide tolerance or insect resistance genes. In the case of the Pima varieties, it may be assumed that farmers preferred to grow PHY 805RF because of the Roundup Ready Flex gene. The variety that came in second after PHY 805RF was PHY 800, but it was planted on only 10% of the Pima area. All other varieties together (more than 13) were planted on 41,000 hectares or 60% of the Pima area. Pima cotton is planted mainly in California and it was there that all the Pima varieties mentioned above were planted. Arizona planted only five varieties.

Varieties Planted in Various Countries

There is no doubt that the number of varieties approved in any given country depends on the area planted to cotton: more area means more varieties. The table on page 13 shows that in 2010/11 there were only two countries in the world where only a single variety was planted. The table contains data from 47 countries and, of them, only 19 planted fewer than five varieties. The data showed that India was the country where the greatest number of varieties was planted; the US came in second. China, Myanmar, Pakistan, Tajikistan, Turkey, Turkmenistan and Uzbekistan planted more than 10 varieties on a commercial scale in 2010/11. The data clearly show that the Central Asian countries, as a region, planted more varieties per country than the other regions. It is evident from the number of varieties grown per country that breeding for the development of varieties commands a high priority in the Central Asian countries. None of the African countries planted more than six varieties on a commercial scale in 2010/11. It is conventional wisdom that whenever a country starts conducting production research on cotton, the earliest efforts focus on the development of new varieties. All the African countries on the list below are known to have breeding programs, except South Africa, where Delta and Pine Land Company Ltd. has dominated the seed market with its proprietary varieties, and the public sector has conceded to the private sector. Efforts were made a few years back to revitalize the public sector program at the ARC- Institute for Industrial Crops, in Rustenburg, but without success. Thanks to its location in the Southern hemisphere, the Delta and Pine Land research station in South Africa attracts germplasm from many northern hemisphere countries. Consequently, South Africa has the windfall advantage of getting to test, try and use germplasm from many countries.

The data in the table on the next page was taken from the ICAC report on cotton production practices, published in September 2011. The database is updated, and a report published, every three years. According to the latest data, 321 varieties/hybrids were planted in the world on a commercial scale on an area of 33.4 million hectares in 2010/11. Hybrids are planted mostly in India and China and perhaps, on a limited scale, in a few other Asian countries. Based on the area planted to cotton in 47 countries and the data reported by various countries, one variety would have been planted on about 94,000 hectares. The data by country showed that there are huge differences among countries in the area planted to a single variety (based on the calculated area, total area divided by number of varieties). The calculations show that one variety may have been planted on over 400,000 hectares in India, the greatest extension in any one country. In China, if all varieties had been planted on equal areas, each variety would have covered 258,300 hectares. Data from Benin, Côte d'Ivoire, Zimbabwe and many other countries indicate that greater areas may also be planted to a single variety in comparatively small cotton producing countries too.

Why Farmers Plant More than One Variety

It may not be true for all countries for a number of specific reasons, but the most important decision a cotton farmer makes every year is the selection of the variety or varieties he is going to plant. There is no doubt that yield potential tops the list of characteristics to which growers always assign a high priority. Just as many varieties are planted in one country, individual farmers (if they are not too small and have the option of planting more than one variety) usually go for more than one variety every year. In some countries farmers receive planting seed from a designated source and simply do not have the option of buying planting seed on the open market. Under such circumstances, farmers are obliged to plant the variety provided by the company. When it is the cotton companies that supply the planting seed, as is the case in most of West and Central African countries (with the exception of Nigeria), farmers are provided only one variety per crop. However, when farmers have a choice, they will opt for planting more than one variety for many reasons, including those listed below.

- Farmers' preference – In countries where there is no formal variety approval process, every time a new variety is officially approved or adopted for commercial cultivation), suppliers claim that it is superior in yield, quality, adaptability or a combination of multiple characters inherited or transgressed from the parental lines. Given the farmers' need to realize the different yield potentials of different varieties, they do not want to run the risk of growing only one variety. Farmers' preferences have more to do with the morphological performance of a variety. Thus they prefer to have choices and to make their own decisions as to the varieties they want to plant, based on the information they get from a range of variety developers or seed companies.
- Variety-environment interaction – It is also true that once a variety has proven the excellence of its yield potential at the research farms, it is tested in farm-field conditions before it is approved. Farmers know their production conditions better than anyone else, so they are in a better position to tell which variety is going to have the best performance with their particular production practices and conditions, including soil type. When testing a new variety, farmers are advised by the experts to limit the test area during the first season, no matter how great it looks in the data from varietal trials or in their neighbor's farm. Although the differences between most varieties are subtle, farmers may need some time to learn to manage a new variety.
- Agronomic requirements – Agronomic requirements are different for different varieties, a fact that is particularly true when it comes to planting dates. Farmers try to plant their entire cotton area within a narrow window in order to maximize the benefits of the agronomic inputs that will be applied during the season. But even so, a certain amount of cotton will inevitably be planted towards the earlier part of the cotton season and some towards the later part of the planting season, with a separation of a few weeks between them. A variety planted early in the season may not be suitable for planting later in the season.
- Avoid putting all your eggs in one basket – The population dynamics studies based on agro-ecosystems have shown that different insect pests may exert a different pressure on a given crop from year to year. The risk of being vulnerable to a particular pest or disease is always higher when the pest or disease is comparatively new to the area. Farmers want to avoid the risk of planting a single variety that may, for any number of reasons, be more vulnerable to attack by a certain pest during a particular crop year. One of the most recent examples that may be cited is resistance to the leaf curl disease in India and Pakistan. So far, chemical control of the disease is not available, and whatever it is that confers resistance to the disease is not certain either. However, inter-varietal differences became apparent in the fields and, in an effort to escape the ravages of the virus, farmers opted for growing a greater number of varieties during the early years of the prevalence of the disease.
- Price-driven demand – In countries where custom ginning is not practiced, ginners own the lint, which is sold on the basis of fiber quality. Farmers have noted that spinners

and buyers prefer one variety over another because of quality differences, and they are usually willing to pay a higher price for a particular variety. Another good example might be the difference in lint recovery from seedcotton. For example, if a variety has a higher ginning outturn, ginners are willing to pay a higher price, through their middlemen, thus inadvertently promoting specific varieties. As a region, high ginning outturn varieties have been grown and are still grown in the countries of West and Central Africa, and this is probably linked to ginners' preferences. As far as their own particular choices are concerned, farmers also take into account the price and accessibility of the planting seed.

- Special features – Preferences may have to do with a particular feature, be it a conventional agronomic feature or a biotechnological one. It is known that certain varieties owe their popularity to the biotech genes expressed in them. This was particularly true in countries that grew biotech cotton back when biotech genes were available only in specific brands and in a limited number of varieties. Farmers in many countries, including the US, preferred to grow a biotech variety to a conventional one. Farmers typically respond by increasing plantings of the most profitable variety.
- Picking advantages– According to the latest estimates from the ICAC, 65% of all cotton produced in the world is picked by hand. For various reasons, the availability of labor for picking cotton is becoming an issue in many countries, including India. The experience from handpicking countries shows that pickers tend to prefer varieties that are easy to pick so they can harvest more cotton in less time. Among the cultivated species, the easiest to pick are the *G. arboreum* varieties and the most difficult to pick are the *G. herbaceum* varieties. Among the upland varieties, the difference in picking may not be as big as between *G. arboreum* and *G. herbaceum*, but the differences are there. Farmers prefer to grow varieties that are comparatively easy to pick, which is particularly true in areas/zones with serious labor shortages.

Number of Cotton Varieties Planted in Various Countries - 2010/11

Country/Region	No. of Varieties Planted	Area Covered (%)	Calculated Area/Variety (Ha) '000' hecatres	Variety	Major Variety Area in %	Area in Hectare
Argentina	9	100	61,111	Nuopal BG/RR	60	330,000
Australia	5	95	112,100	Sicot 71BRF	65	383,500
Azerbaijan	8	100	4,000	AzNIXI-195	35	11,200
Bangladesh	10	100	3,200	GB-9	41	13,120
Benin	1	100	136,000	H 279-1	100	136,000
Brazil	8	98	171,500	Fibermax 910	24	336,000
Bulgaria	5	100	200	Chirpan-603	80	800
Burkina Faso	4	100	93,500	FK 95 BG2	50	187,000
Cameroon	4	100	35,750	IRMA L484	68	97,240
Chad	2	100	66,000	Stam F	58	76,560
China	17	85	258,300	DP 33B	11	568,260
Colombia	10	96	4,128	NuOpal RR	16	6,880
Cote d'Ivoire	2	100	108,500	R 405-96	62	134,540
Egypt	6	100	26,167	Giza 86	72	113,040
Ethiopia	4	91	19,338	Deltapine 90	72	61,200
Greece	9	77	21,389	Acala SJ2	19	47,500
India	25	98	436,768			
Iran	7	100	13,143	Varamin	71	65,320
Israel	3	100	1,333	Pima GL	70	14,000
Kazakhstan	6	81	18,100	Pa--3044	40	53,600
Kenya	4	100	4,250	HART 89M	63	10,710
Kyrgyzstan	3	100	6,667	Kyrgyz-3	60	12,000
Mali	5	100	57,200	Stam 59A	68	194,480
Mexico	5	100	23,200	Detapine 451BRR	50	58,000
Mozambique	5	100	25,600	CA - 324	80	102,400
Myanmar	11	100	31,727	Ngwe Chi 6	77	268,730
Nigeria	6	100	41,667			
Pakistan	13	85	183,077	Neelum 121	59	1,652,000
Paraguay	6	100	5,000	IAN-425	60	18,000
Peru	4	100	13,000	Taguis	65	33,800
Senegal	3	100	9,333	ISCOPG	49	13,720
South Africa (Loskpop)	4	100	4,250	NuOpal RR	93	15,810
Spain	8	100	8,000			
Sudan (Gezira)	4	77	7,900	Barakat	47	19,270
Syria	5	100	30,000	Allepo 90	32	48,000
Tajikistan	12	95	12,667	Kirgis-3	25	40,000
Tanzania	4	100	115,000	UK 91	99	455,400
Thailand	2	100	1,000	Tak-Fa 2	95	1,900
Togo	1	100	60,000	Stam 129	100	60,000
Turkey	15	98	24,827	Stoneville 468	25	95,000
Turkmenistan	11	100	50,000			
Uganda	2	100	40,000	BPA	99	79,200
USA	20	71	153,700	FM 9058 F	11	476,300
Uzbekistan	13	95	97,231	Bukhara 6	24	319,200
Vietnam	4	80	1,800	VN 20	55	4,950
Zambia	4	100	65,500	Chureza	48	125,760
Zimbabwe	2	100	195,000	SZ 9314	100	390,000

Consequences of Planting Multiple Varieties in the Same Region

It is recommended, and rightly so, that different cotton cultivars should be grown in different ecological conditions, which may vary by region or even within a region if the region is very big. Production areas may vary greatly in elevation and annual rainfall thus suggesting cultivation of different varieties in different areas. ICAC data (ICAC 2010) show that Syria is the only country where a single variety is grown per region. The Syrian cotton area is divided into six regions and only five varieties were planted on a commercial scale. Two regions planted the same variety, but each on 100% of their area. In all other countries, if the cotton area is divided into various regions, multiple varieties are planted in each of the regions. Farmers' primary interest is to improve productivity, lower the risk of crop failure and increase profitability. Thus, giving a grower the option of planting the variety of his choice is a good thing, but it is not without consequences, some of which are discussed below.

- Admixture in planting seed – Planting seed production requires the segregation of varieties, not only in the field, but also during transportation of seedcotton to the gin, and throughout the ginning process, up until the planting seed is delinted, treated and packed. Cultivation of multiple varieties within one region would also require seed production of those same varieties in the region, thereby maximizing the chances of producing admixtures.
- More varieties, more research – The development of varieties is a long process. It takes at least 10-12 years to successfully develop a new variety. And this time estimate is valid only if a breeder is lucky enough to hit on a good genotype at the earliest stages of the selection process; otherwise, it might take even longer. Allowing a region that can actually afford to grow a single variety to plant multiple varieties may give rise to an artificial need for developing more varieties. Having a greater number of varieties means more research and more resources.
- Higher variability in fiber quality – It is highly unlikely that any two varieties produced in the same region, but with different agronomic practices, will yield fiber of exactly the same quality parameters as in the case of a single variety. Agronomic practices alone are allegedly responsible for variation in fiber quality within a single variety; hence, production of multiple varieties will add to fiber quality variability.
- Technology transfer – Breeders, in collaboration with other experts, can provide a technological package designed to help growers get maximum yield from a newly released variety. When only one variety is grown per region, it is easy for extension workers to specialize in technology transfer. When the same variety is grown everywhere throughout a given area or region, extension workers can not only provide better advice during normal years, but also serve with greater expertise during times of crisis.

Conclusion

Planting multiple varieties is desirable for various reasons, but planting too many varieties increases the chances of admixtures and compromises the uniformity of fiber for length, strength and various other parameters. Varieties with differing fruiting periods serve as reservoirs for insects to multiply and move on to vulnerable fields. Multiple varieties should be grown only where the prevailing agro-ecological conditions require different fits for different genotypes. Wherever the prevailing growing conditions in any region or area allow for cultivation of the smallest number of varieties, planting a more limited number of varieties is the more recommendable option. In some countries where varieties are formally approved for commercial cultivation, once they are registered they are never deregistered or taken off the approved list. Thus, it is also necessary to legally curtail the production of obsolete varieties when they are no longer recommended for commercial cultivation. The development of varieties with a narrow genetic base as a result of working with limited access to new germplasm is a growing concern that must be addressed at the international level.

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Prevention of Cotton Contamination in West Africa

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This article is a summary presentation of the objectives and current achievements of project CFC/ICAC/38 *Prevention of Seed Cotton Contamination in West Africa* (Burkina Faso, Côte d'Ivoire and Mali). At the request of the ICAC, this project is funded by the Common Fund for Commodities, with substantive co-financing from the European Union through its All ACP Agricultural Commodities Program (AAACP). The International Fertilizer Development Center (IFDC) was contracted to implement the project, which started effectively in April 2010 with a scheduled duration of three years.

Challenges to Clean Cotton

Cotton plays a significant role in the fight against poverty and the development of national economies in many West African countries, generating foreign exchange and providing employment and income to millions of farm families. Historically, West African cotton has been highly valued for its intrinsic quality.

However, some of its value is lost during the harvesting and post-harvesting processes due to contamination by foreign matter: plant debris, insect waste and packing material residues, such as nylon and polypropylene fibers. Reports from the International Textile Manufacturers Federation (ITMF) since 2001 indicate that the level of contamination in West African cotton is among the middle-ranked sources of contaminated cotton in the world: Burkina Faso, Côte d'Ivoire and Mali rank, most of the time, between the 10th and 20th positions on the list of "most contaminated" cotton but, occasionally, also between the 10th and 20th positions on the list of "least contaminated" sources of cotton.

Contamination is a serious challenge that is hurting the cotton sector's reputation for quality and overall profitability. For instance, a small piece of polypropylene can lead to many dollars in damage. Once mixed with seedcotton during harvesting or during the ginning process, polypropylene fibers become invisible, only to show up in the finished product because they do not absorb dye. This leads to the rejection of final fabric or garments, which is extremely expensive in terms of claims and lost business. Stickiness caused by insect sugars on the lint is another problem that makes ginning difficult and entails substantial price discounts.

Lower levels of contamination mean lower costs for spinners, and should lead to better prices and higher incomes for cotton farmers. Prices paid for contaminated cotton can range between 5% and 20% less than those paid for uncontaminated cotton.

Various efforts have been initiated to reduce contamination in West African cotton[1]. However, these efforts have not led to any substantial reduction in contamination because they were not institutionalized approaches that can be applied at all stages of the cotton production and value chain.

Protecting Cotton Quality

The Project for the Prevention of Cotton Contamination in West Africa (CFC/ICAC/38) is based on the findings of a Fast Track Project (CFC/ICAC/32FT) in southern Mali that identified not only alarming levels of contamination[2] in seed cotton and lint[3] but also a potential for substantial reduction of contamination (up to 75%) through an appropriate information

1) For instance in Mali, CMDT launched a program to improve management of household waste in cotton producing villages. Cotton companies have required the coloring of polypropylene fertilizer bags, one of the main sources of polypropylene contamination, to increase the traceability of polypropylene fibers during handling.

2) Contamination includes plant debris contaminants (trash: leaves and branches of the cotton plant and others), inorganic contaminants: sand, dust, metals) and packing material contaminants (plastics, polypropylene, nylon, feathers, paper, jute, yarn, fabrics)

3) In seed cotton, there is an average of 21.5 kg/ton of total contamination: 11.8 kg plant debris and 9.7 kg inorganic matter, of which 9.5 grams per ton of packing materials. In lint, there is an average of 25.7 kg/ton of total contamination: 24.7 kg plant debris and 1 kg inorganic matter of which 4 grams per ton of packing materials.

and training program. CFC/ICAC/38 aims to implement a comprehensive quality approach to reducing contamination along the entire value chain, from production to ginning to delivery. The project supports the quality efforts of its three intervention countries – Burkina Faso, Côte d'Ivoire and Mali – and works in synergy with other ongoing cotton projects in the sub-region.

A preparatory mission of the project stressed the critical importance of getting access to premium prices for 'clean' cotton and the development of a mechanism to share these premiums among farmers and ginneries.

The general objective of the CFC/ICAC/38 project is to increase the income of smallholder cotton farmers by improving their crop cultivation practices and reducing lint contamination. To attain this objective, the focus is on: 1) sensitizing and training; 2) developing a program to promote the adoption of less contaminating harvest and post-harvest techniques with appropriate preventive measures; and 3) developing an efficient marketing strategy to facilitate market penetration and ensure that price premiums are achieved for cleaner cotton on the international market.

Cotton production areas within countries were selected in consultation with cotton companies, trade associations, cooperatives and producer associations. Selections were based on defined criteria including a high concentration of cotton growers, road accessibility and proximity to a ginning plant. The project started on April 1st, 2010 and will end on March 31st, 2013

A Comprehensive Quality Plan

Sensitization and Training

Obtaining cotton with consistent quality parameters requires a set of good practices for each step of the value chain. Sensitization and training programs are essential to enable the stakeholders involved at different stages to satisfy the demands and quality requirements of markets and consumers. In each of the project countries, extension agents receive training in: 1) cotton cultivation techniques; 2) pest and disease control, and 3) harvest and storage of seedcotton. Each extension agent trains farmers who, in turn, share their knowledge on their own farms and with other families.

A training program was also designed for ginners because their work is critical to lint quality and significantly impacts producer prices. Ginning is more than just separating seed from lint; it involves cleaning, conditioning and controlling moisture content. The CFC/ICAC/38 project promotes ginners' adherence to the overall quality approach to ensure efficient handling and processing of cotton from the moment it is unloaded into the factory until delivery.

Throughout the logistical supply chain, significant losses in quality and value can occur. The project seeks to reduce quality losses during handling, storage and transportation of seedcotton from the farm to the gin and of cotton lint from the gin to the export sites. In each project area, drivers from

Table 1: Number of People Trained

Country	Extension Agents	Producers	Transporters	Ginnery Workers	Data Collectors
Year 1: 2010/11					
Burkina Faso	37	3,000	40	150	4
Côte d'Ivoire	26	3,000	40	61	0
Mali	25	3,000	40	150	4
Total	**88**	**9,000**	**120**	**361**	**8**
Year 2: 2011/12					
Burkina Faso	45	8,500	40	669	7
Côte d'Ivoire	31	1,000	40	89	31
Mali	72	8,500	40	150	7
Total	**148**	**18,000**	**120**	**908**	**45**
Year 3: 2012/13					
Burkina Faso	-	-	20	-	-
Côte d'Ivoire	18	3,000	20	-	-
Mali	-	-	20	-	-
Total	**18**	**3,000**	**60**	**0**	**0**
Grand Total	**166**	**30,000**	**240**	**1,269**	**53**

N.B: The training program in 2012 is mainly oriented toward improving skills of formerly trained staff and producers. Only Côte d'Ivoire will have an extension of the training program into new areas.

The different training programs include:

- For producers: importance of clean cotton, cleanliness of the village environment, field preparation and maintenance, pest and disease management, harvest practices, use of cotton-made harvesting kits, temporary storage in the field, construction of field racks, transportation to the village, temporary storage at village level, management of village cotton markets
- For transporters: importance of clean cotton, information about producers' efforts to reduce contamination, preparation and maintenance of trucks used for cotton transportation, appropriate use of tarpaulins.
- For staff and workers in the ginneries: importance of clean cotton, cleaning and maintenance of the gins.
- For extension workers: all of the above in addition to training competencies

the cotton companies and private transportation systems are trained in good transportation practices to ensure that vehicles used are equipped with protective covers and clean, leak-resistant containers.

Promoting Contamination Reduction Harvesting Kits

Informing smallholder cotton farmers about contamination is one thing; getting them to implement the recommended practices is another, as the lack of money and equipment is always a constraint. The CFC/ICAC/38 project supports production and, temporarily, free distribution of picking kits made of cotton material to prevent cotton contamination during harvest, storage and transportation. Each kit contains ten picking bags, three buying tarps, and at least one protective storage tarpaulin. Once the technology has had sufficient impact and farmers begin to receive better prices, commercial production and distribution of kits will be encouraged.

The kits were produced by textile industries in West Africa. After initial problems of robustness and durability, the kits to be distributed by the end of 2012 measure up to the users' needs. Costs per kit depend on their composition. A typical kit of 10 sacks, 3 small tarps and 1 large tarpaulin, which will last for at least 3 years, costs about US$70 (or about 140 to 175 kg of seed cotton at the farm-gate price)[4]. Large-scale production of the kits could diminish the unit cost. While some individual farmers are interested in buying the kits cash in hand, costs are generally too high for the average smallholder. Farmer organizations and cotton companies are currently considering a 50:50 cost share arrangement for the kits once their introduction proves to be successful. It is clear that the additional income received by farmers and cotton companies through premiums for quality must be substantially greater than the cost of the investment to the grower before large-scale introduction can take off.

Table 2: Distribution of Harvesting Kits

Country	Harvesting Sacks	Large Protection Tarpaulins	Small Tarps
Year 1: 2010/2011			
Burkina Faso.	21,000	3,000	6,000
Côte d'Ivoire	21,000	3,000	6,000
Mali	21,000	3,000	6,000
Total	63,000	9,000	18,000
Year2: 2011/2012			
Burkina Faso	94,000	16,000	28,500
Côte d'Ivoire	19,000	2,200	6,000
Mali	94,000	12,630	28,500
Total	207,000	30,830	63,000
Year 3: 2012/13			
Burkina Faso	57,500	0	0
Côte d'Ivoire	50,000	9,000	500
Mali	57,500	0	0
Total	**165,000**	**9,000**	**500**
Grand Total	**435,000**	**48,830**	**81,500**

Measurement of Contamination Levels

To prove that contamination levels decrease through project interventions, two different methods are explored. Both methods have their strong points but, unfortunately, they also have their weak points.

One method is a systematic sampling of the seedcotton when it arrives at the gins and, later, of the lint at the end of the ginning process. Comparison of cotton from the project areas to cotton from non-project areas indicated improvements stemming from the project. However, the question about which are the best and most cost-effective sampling and analysis methods was not really answered. In collaboration with cotton researchers and the cotton companies involved, the project opted for sampling seedcotton from incoming truckloads (every tenth truck coming from the project areas and every tenth truck coming from non-project areas) and sampling the lint after ginning of the same truckloads[5]. Analysis of the samples was done by the Centre de Recherche et de Formation pour l'Industrie Textile-CERFITEX[6] (Research and Training Centre for the Textile Industry) under controlled laboratory conditions. The main issue with this method is the number and volume of samples that have to be taken to arrive at conclusions with acceptable confidence intervals.

Another method that may be used to get an impression of contamination levels would be to have systematic feedback of information from traders and spinners about the cotton lint they purchased. Here we enter into a whole different set of constraints: traceability, willingness to ask and to respond, knowledge of what exactly happens to the cotton after delivery to traders, role of intermediaries, lack of transparency, etc. The project was designed to motivate different actors to stay in contact with each other and to make the trade and information stream more transparent. A general

4) In 2012, unit costs were as follows: harvesting sack US$3.5, small tarps (1.6m by 1.6 m) US$6.0, large tarpaulins (2.5m by 3 m) US$15.0.
5) The sampling and analysis protocol was developed in collaboration with the Institut d'Economie Rurale-IER cotton research program. The sampling itself was done by specifically trained gin workers. Analysis of samples was done by specifically trained teams of students of CERFITEX supervised by CERFITEX researchers who were also in charge of reporting.
6) CERFITEX: Centre de Recherche et de Formation pour l'Industrie Textile

observation made by the cotton companies is that they hardly receive any negative feedback about quality or polypropylene contamination. When they do receive a complaint, however, most of the time it turns out that there were mistakes in tracing the origin.[7]

Marketing Cleaner Cotton

The marketing of cleaner cotton is first of all the responsibility of the cotton companies and their professional organization, the African Cotton Association (ACA), has an important role to play in improving the overall image of African cotton. Improving the competitiveness of West African cotton starts with an understanding of market and buyer requirements in order to address identified bottlenecks along the entire value chain. The CFC/ICAC/38 project promotes the idea of efficient marketing of cleaner cotton to interest potential buyers in purchasing cleaner cotton at a premium price.

Outputs

About 30,000 producers, 170 extension agents, 1,250 workers in the gins and 300 transporters have received training on quality and contamination issues.

Exchange visits by about 200 producers and 100 extension workers of the three countries were organized to discuss their experiences in the fight against cotton contamination.

So far, 143,223 tons of seedcotton (equivalent to 59,502 tons of lint) have been produced by growers participating in the project.

Regional organizations such as ACA and AProCa (Association of African Cotton Producers) signed a 'Quality Charter', a commitment to fight together against contamination, to increase quality and improve the image of African cotton on the international markets.

Training materials produced within the framework of the project have been integrated into the documents that accompany the Quality Charter.

Intermediate results of the project have been presented at different international forums and received a positive feedback.

Results so Far

Increased awareness about cotton contamination, cotton quality and increased commitment to tackle the quality issue are some of the results of the project to date. Thanks to project interventions, producers and other actors involved in the cotton chain are more aware of the contamination problems and the possibilities of reducing them. At the field and village levels, cotton is treated more adequately and protected against contamination. Only suitable trucks are accepted for transport. With the support of the EU sponsored World Bank program, African cotton companies and producers have committed themselves to work on the quality issue through the signing of the Quality Charter by their representative bodies ACA and AProCa.

Level of Contamination

Based on analyses by the CERFITEX laboratories in Ségou, the provisional results of the first two production and harvesting seasons (about 60,000 tons of cotton lint) have not shown any substantial reduction of contamination in cotton lint. The average overall contamination level in lint was about 5 kg per ton in the project areas while average lint contamination with polypropylene still remained at 2 grams per ton in those same areas. Results also showed considerable variation among country averages and among villages.

Table 3: Level of Contamination in the Sikasso Area of Mali

Description	Pre-project 2006/2007		Year 1: 2010/11		Year 2: 2011/12	
	CMDT Mali	CMDT Sikasso study area	Project Area	Outside Project area	Project Area	Outside project Area
Average level of total contaminants in seedcotton (Kg/MT)	22	12	7	9	6	10
Average level of trash in seedcotton (Kg/MT)	12	7	2	4	3	5
Average level of inorganic matter in seedcotton (Kg/MT)	10	5	4	6	4	5
Average level of packing material contaminants in seedcotton (**g**/MT)	10	5	44	44	1	1
Average level of polypropylene in seedcotton (**g**/MT)	n.a	n.a	2	0	1	1
Average level of total contaminants in cotton fiber (Kg/MT)	26	22	6	6	4	7
Average level of trash in fiber (Kg/MT)	25	21	5	5	3	5
Average level of inorganic matter in fiber (Kg/MT)	1	1	0	1	1	2
Average level of packing material contaminants in cotton fiber (**g**/MT)	4	0	0	54	1	6
Average level of polypropylene in cotton fiber (**g**/MT)	n.a	n.a	4	11	0	1

Source : Yattara *et al*, 2008; CERFITEX, 2011 ; CERFITEX, 2012
(CMDT : Compagnie Malienne pour le Developpement des Textiles)

7) One spinning company in Mali (which generally works with the poorest quality, non- exportable cotton from CMDT) considers contamination with PP to be a non-issue. They receive feedback from textile industries in Morocco about their yarn quality, but complaints about PP are extremely rare.

The most complete data set on contamination levels is the one for the Sikasso area, in Mali.

Marketing of 'Clean' Cotton

Due to the relatively small quantities of less contaminated cotton lint (only 10,000 tons) delivered in the very first year of the project, cotton companies have not yet been able to negotiate premium prices. It was anticipated that the expected 50,000 tons of the second year would improve opportunities for premiums, but most of the cotton produced in the project areas was needed to fulfill earlier commitments. CMDT in Mali and Sofitex in Burkina have tried to negotiate premium prices for some small quantities (CMDT: 200 tons) but have not yet reported back to the project. Ivoire Coton used to have premium arrangements in the past, but no recent contracts have been reported**.**

Increase in Top Grade Lint

Cotton companies reported an increase of about 5-7% in 'top grade' lint in the project areas. This increase in top grade lint has led to increased income (still to be quantified) for the involved cotton companies, but no specific mechanisms have been established to share this additional income with participating farmers (other than the traditional additional payment to farmers at the end of the season, if financial results allow).

Share of Additional Costs and Revenues

While the objective of project efforts is to increase benefits at the farm level thanks to better selling prices for 'clean' cotton, the current situation does not yet allow that objective to be reached. As mentioned above, for the time being, the involved cotton companies have not yet been able to negotiate better prices for considerable amounts of 'clean' cotton lint from project areas. No additional revenues have been reported.

But even if there should be additional revenues, the question of how to share them is still a matter of debate. One of the issues still on the table is how to make sure that there will not be an influx of cotton from non-project areas to project areas once the cotton company starts to pay premium prices to participating farmers.

Another question is the matter of the cost of harvesting kits made of cotton. As already mentioned, the 50:50 split is on the table, but no decision can be expected as long as the effectiveness of the introduction of such kits has not been confirmed by higher prices.

Discussion of Results

Project efforts have led to at least two measurable results in the area of awareness raising and training, but still not in the area of polypropylene reduction.

- First of all, there has been a general decrease of about 5 kg/ton in overall contamination in seedcotton. This means a direct reduction of the cost of purchasing and transporting 500 tons of contaminants per 100,000 tons of seedcotton production. That is, a per annum cost reduction of about US$300,000 to US$1,500,000 for each of the involved cotton companies. This calculation does not yet include the additional gain resulting from the reduction of quantities of sand and stones that arrive with seedcotton at the gin gates.[8]
- Secondly, the involved cotton companies reported a 5-7% increase in the volume of their top grade cotton, leading to a better negotiating position and potentially higher revenues.

The measurement of PP contamination levels is problematic. So far, reduction in PP contamination has been achieved, but it is difficult to demonstrate. Furthermore, there is no generally accepted standard for measuring contamination levels. Only zero contamination by PP seems to be acceptable, but zero PP contamination cannot be guaranteed, and no one would dare to give such a guarantee.

One general remark that project staff often hear at our meetings with decision makers is: "Probably the name of West African Cotton is more contaminated than the cotton itself". This is also an indication of the emphasis that cotton companies have to put on their marketing efforts.

Table 4: Percentage of Top Grade Cotton Within and Outside Project Area

Country	Year 1: 2010/11			
	Production in Project Area		% Top Grade	
	Seed cotton (ton)	Cotton lint (ton)	Outside project area	Project area
Burkina Faso	4,071	1,710	73	77
Côte d'Ivoire	11,140	4,330	66	71
Mali	9,742	4,181	81	88
Total	**24,953**	**10,221**		
	Year 2: 2011/12			
	Production in Project Area		% Top Grade	
Country	Seedcotton (ton)	Cotton lint (ton)	Outside project area	Project area
Burkina Faso	54,850	23,419	83	91
Côte d'Ivoire	17,768	7,689	55	61
Mali	45,652	18,173	83	92
Total	**118,270**	**49,281**		

8) The West African Cotton Improvement Project-WACIP (a project implemented by IFDC in the C4 countries and financed by USAID) measured the loads of sand and stones and estimated that there might be another 0.5 kg/ton weight reduction as a result of an intensive information and training campaign emphasizing quality.

Prospects

The project helped raise awareness and increase training on the importance of good agricultural practices and quality control. Results show that further dissemination of programs such as this one would be important for immediate cost reductions and possible additional revenues for the cotton companies through reduction of the most visible contaminants and increase of intrinsic lint quality.

While weight reductions in contaminants at the farm level lead to cost reduction and additional revenue for the cotton companies, it is important to ensure that farmers are compensated for their efforts. When they reduce the level of contamination without any compensation they, in fact, reduce their own income.

Given that it will be difficult to guarantee zero polypropylene contamination, it is extremely important that cotton companies continue to increase their marketing capacities and to improve the image of (West) African cotton.

Issues such as traceability, direct contacts between cotton companies and spinners, and transparency in the role played by traders and in cost calculations must be tackled to get a better understanding of the real potential of a policy to further reduce contamination with a view to commanding premium prices.

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Basic Project Information

Funding: The CFC/ICAC/38 project is funded by the European Union (through its All ACP Agricultural Commodities Program (AAACP) and the Common Fund for Commodities.

Duration: Three years (2010 – 2012)

Target Groups: Smallholder cotton farmers, ginners and transporters in the three cotton-producing countries of Burkina Faso, Côte d'Ivoire and Mali.

Expected Impact: The project is expected to sensitize farmers, transporters and ginners who will collectively produce higher quality cotton for export that will sell at higher prices in international markets. This will result in higher farm-gate prices and help repair the image of African cotton, which is now perceived to be of poor quality.

Intervention Areas: The cotton areas of Bobo Dioulasso in Burkina Faso, Korogho in Côte d'Ivoire and Sikasso in Mali.

Project Partners

The CFC/ICAC/38 project is managed by IFDC and implemented by a regional coordination unit based in Bamako, Mali, with the support of the National Consultative Committee established in each country. Project partners include the following cotton companies: SOFITEX in Burkina Faso, Ivoire Coton in Côte d'Ivoire and the Compagnie Malienne de Développement des Textiles (CMDT) Filiale Sud SA in Mali.

CFC/ICAC/38 works in collaboration with research institutes, farmer/producer organizations, agricultural councils, national Ministries of Agriculture and national, regional and international organizations.

The project has established working relations with other initiatives in the cotton sector, such as the two EU/AAACP funded activities of the World Bank (focusing on institutionalization aspects) and of the regional economic organization UEMOA (cotton strategy). The World Bank project supports, among other involved stakeholder organizations, the African Cotton Association (ACA) and the Association of African Cotton Producers (AProCa) to develop a Quality Charter. The international Trade Center has organized visits of Asian spinners to the project areas.