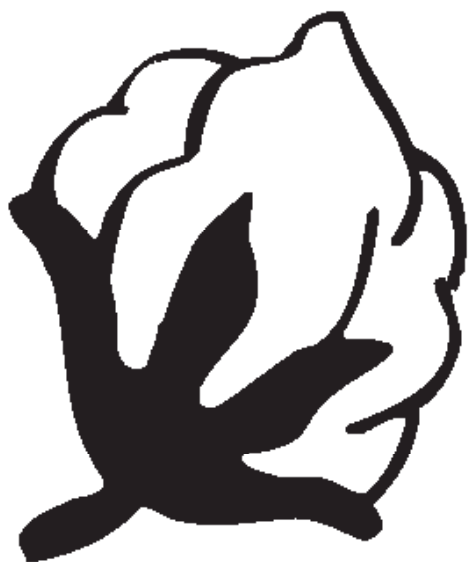




THE ICAC RECORDER

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Introduction

The cotton plant must be properly nourished so that it can produce desired results in terms of productivity and fiber quality. Nitrogen is the most important nutrient element for agricultural crops, and it is the most complicated nutrient to manage, particularly in cotton where an imbalance between vegetative and reproductive growth could have serious consequences on yield. Some imbalance may be fixable, but others lead to a certain loss. Even fixable imbalances can effect fiber quality. The quantity of fertilizer applied varies greatly among countries. Soil type and quantity of water applied are the two factors that play the largest roles in determining the quantities of fertilizers to be applied. The ICAC data show that most fertilizers are applied to cotton at two stages: before planting and at the pre-flowering stage. All the phosphorous and potassium are applied before planting, and a major portion of nitrogen is applied prior to the flowering stage or in the early boll formation stage. Both applications are through soil. Cost of production data from countries around the world show that farmers spend an average of US\$158 on fertilizers to produce a hectare of cotton. The world average net cost of production per kg of lint is US\$1.14, of which US\$0.20 are spent on fertilizers. Fertilizer costs account for 17% of the total production costs (exclusive of ginning, economic and fixed costs). Many more details on various aspects of fertilizers including bio-fertilizers and farm-yard manure are given in the first article.

A lot has been published on biotech cotton in the *ICAC RECORDER*, mostly on biotech insect resistant cotton. The second article in this issue of the *ICAC RECORDER* is devoted to herbicide resistant biotech cotton. According to the International Service for the Acquisition of Agri-Biotech Applications, biotech crops were grown on 90 million hectares in 2005/06, and 71% of this area was under herbicide-resistant biotech crops. Herbicide resistance is not a popular characteristic in cotton outside the US and Australia. Herbicide-resistant biotech varieties are available in single gene and also in stacked gene forms with the insect-resistant trait in cotton and other crops. In the USA, 98% of

the biotech cotton area in 2005/06 was planted to varieties having either the herbicide resistant genes alone or in stacked form. Many kinds of herbicide resistant biotech cottons are available. Liberty[®]Link cotton from Bayer CropScience is also a transgenic herbicide-resistant cotton similar to Roundup Ready. Roundup Ready cotton can tolerate herbicides only up to the four-leaf stage but herbicides containing glufosinate, like Ignite or Liberty, can be sprayed over-the-top of Liberty Link cotton up to the ten-leaf stage. Roundup Ready Flex varieties can tolerate herbicide almost throughout the growing season. Much more on herbicide resistant biotech cotton is in the 2nd article.

Cotton production in Brazil has gone through drastic changes. One of the most drastic has been a shift in the cotton producing area from the south and north to the mid-south of the country. The shift in area alone tripled the national yield in ten years. Cotton production moved from small-scale cotton growers to large scale mechanized farming in Mato Grosso, Goias and Bahia states. Cotton is new to this area, and now Brazil has the highest yields under rainfed conditions in the world. The rainfall pattern in Brazil is well defined, beginning in October and ending in April, so harvesting is done during the dry period ensuring good fiber quality. Domestic economic factors such as the favorable exchange rate for the Brazilian currency relative to the dollar, high production costs, excess supply worldwide, and the pressure on international prices are some of the aspects that compromise the Brazilian cotton sector and the growers' profit margin. Heavy reliance on inputs particularly insecticides and fertilizer use are reaching a critical economic level. The third article in this issue is a first hand story from a Brazilian cotton grower in his own words. Mr. Haroldo Rodrigues da Cunha talks about his way of achieving high yields, and he describes constraints in the current system.

Full Registration Opens for WCRC-4

The World Cotton Research Conference-4 will be held in Lubbock, Texas, USA from September 10-14, 2007. The US

Organizing Committee has published the final announcement, call for papers and full registration package including instruction for hotel booking. Hundreds of cotton researchers, students and industry leaders are expected to attend WCRC-4. As a realization of WCRC-4's theme "Cotton: Nature's High Tech Fiber," conference sessions will examine all disciplines of cotton production, research and utilization.

Authors and presenters interested advancing the dialogue in applications, concepts and techniques in current cotton research are encouraged to submit papers. The goal of the U.S. Organizing Committee is to set a high scientific standard in research presentations and peer-reviewed papers. The International Committee of the WCRC-4 is searching for outstanding and stimulating plenary speakers from all over the world. Particular areas of research to submit papers

include the following disciplines: abiotic stress management, agronomy and cotton farming systems, plant breeding and genetics, genomics and biotechnology, physiology, plant pathology and diseases management, arthropod management, harvesting and ginning, fiber quality, economics of production and marketing, extension and technology transfer and added value for fiber and seed.

People interested in attending the Conference can access to the full registration package and instructions to submit papers at <http://www.wcrc4.org>. Requests for specific questions may be addressed to the WCRC4 Secretariat at wcrc4secretariat@gmail.com. Researchers interested in presenting papers and posters at WCRC-4 have until April 6, 2007 to submit their papers. Even if you have already pre-registered, you must complete the formal registration process. Visa information is also available in the registration package.

Fertilizer Use in Cotton

For the cotton plant to grow and produce cotton, the soil must perform three important functions: provide the plant with mineral nutrients; meet its water needs, and provide anchorage for the plant so that it can stand and resist environmental challenges, including wind. All of these functions are mediated by the root system. The roots extend into the soil in search of water. Plants lose water into the air through transpiration, and they also absorb water from the air, albeit in much lesser quantities. The amount of water released into the air will depend on weather conditions and the stomatal conductance of the plant. Since the water in the air cannot match the plant's water needs, it has to send its roots deep into the ground to find it. As it absorbs water from the ground, the plant also takes in nutrients dissolved in the water. It is virtually impossible to find water in the root zone that is 100% nutrient free. Most of the nutrients the plant requires are supplied by soil and this function of soil may be as the most important in ensuring that the plant survives, thrives and produces cotton.

Soil Structure and Nutrient Supplies

The basic types of soils are clay, sand and silt. The percentage of clay, sand and silt in the composition of the soil determines whether the soil is classified as sandy, clay loam, silt loam, etc. The soil's structure plays a major role in its ability to hold water and, therefore, its nutrient status. The nutrient status of the soil determines its ability to meet the plant's nutritional needs. In addition to the water holding capacity, other properties are influenced by the texture of the soil, including: aeration, drainage and temperature. Sand is made up of larger particles, and sandy soils have excellent aeration, warm quickly in hot weather, cool quickly in cold weather and have a low water-holding capability. Water evaporation is high, but what is even more harmful to the plant is the leaching of nutrients that takes place in sandy soils. Leaching by water also drives nutrients

deep beyond the reach of the plant's root system. Thus, sandy soils require higher doses of nutrient fertilizers than clay and silt soils to meet plant needs.

The exact opposite is true for clay soils. Clay soils have poor aeration; they cool and warm more slowly, and have a higher water-holding capacity. The soil particles are small and they bond very closely together. Once a clay soil dries, it is difficult to break it up. Water moves more slowly through such soils and even though enough nutrients may be available in the root zone, slower nutrient mobility may affect availability to the plant.

Sandy loam soils are best as they are neither as airy as sand nor too compact to meet the plant's needs. Wastage of nutrients due to leaching is also proportionately lower in sandy loam soils.

Major Elements and Their Use in Various Countries

Nutrient requirements are the same, regardless of whether it is Upland or *G. barbadense* when plant size and fruit load are constant. Tall and bushy plants of any species will require higher doses of fertilizer than shorter, more determinant varieties. Plants with higher boll load may require higher doses of potassium than plants with lower boll loads. This is why different varieties have their own nutrient requirements. The quantity of fertilizer applied varies greatly among countries. The two factors that play a major role in determining the quantities of fertilizers to be applied are: soil type and quantity of water applied. Some nutrients move more easily in the soil than others, and soils may also be rich in certain non-moving or minimally-moving nutrients. The role of soil structure in retaining nutrients has already been discussed above, but the quantity of water the plant receives, whether from irrigation

or rainfall, also affects how much nutrient is enough for optimal growth and boll development. Soil saturation with water makes it possible for nutrients available in the root zone to be absorbed more easily and in greater quantities, but, as the soil begins to dry, nutrient availability to the root system also decreases, reaching a minimum just before the need for irrigation. While the plant's need for nutrients is consistent and predictable (successive increases as the plant grows followed by declines as the plant matures), the actual supply/availability in the soil is highly variable. Variation is the highest with flood irrigation where the soil is saturated to the extent of leaving in the soil less than 8% of the oxygen needed by the plant for efficient growth. Nutrient losses are lower with the use of sprinkler and furrow irrigation, but the least amount of nutrients are lost with drip irrigation, where the water is released close to the root, the soil is never over-saturated and consequently, there are no losses due to leaching.

The following data were taken from a survey on production practices undertaken by the ICAC Technical Information Section every three years. Fertilizer is applied in most countries, but a significant area is not fertilized in Argentina, the northeastern region of Brazil, Ethiopia, some areas in India, Tanzania, Uganda and Zambia. Almost a quarter of the area planted to cotton in Zimbabwe does not receive any fertilizer. In Argentina, over 90% of the cotton area does not get any inorganic fertilizer at all, but that is an exception. In countries where synthetic fertilizers are not applied, it is probably due either to high cost or non-availability of fertilizers in the open market (as in West African countries). Argentina is an exception. Fertilizers are not applied in Argentina because a lot of land is available and farmers can afford to let land remain fallow to allow it to recover over a few years before planting it to cotton again. A slightly modified version of that system is followed on a smaller scale in Bangladesh where 'Jhum' cultivation may not receive any fertilizer. Jhum cultivation is a term used to designate the lands involved in shifting cultivation. In Bangladesh, the hilly terrain has a rich vegetable cover made up of a wide variety of plant types that flourish in the abundant rains. Jhum is a form of cultivation in which the land is cleared of its natural vegetation, cropped for one or two years, and then allowed to revert to its natural vegetation. After 3-5 years, the same area is cleared from weeds again and planted to cotton. In Bangladesh's Jhum cultivation system, cotton is grown as an ignored-crop and intercropped with rice, maize or chilies. However, the area in Jhum cultivation is small, whereas in Argentina cotton has been cultivated in this manner on close to a million hectares for about the last 10 years. Cotton area has recently decreased in Argentina, but cotton was still planted on 311,000 hectares in 2005/06 and most of it was grown without inorganic fertilizers. The average yield in Argentina in 2005/06 was 421 kg/ha, compared with

Fertilier Use on Cotton in Various Countries

Country	Fertilizer Applied in Kg/ha		
	Nitrogen	Phosphorous	Potassium
Argentina	60	20.00	20
Australia	200	80	75
Benin	74	46	28
Brazil (Central West)	180	120	220
Cameroon	42	27	24
Chad	19	12	19
China (Mainland)	225-300	50-150	100-220
Colombia (Sinu Valley)	100	20	
Cote d'Ivoire	53	30	30
Egypt	145	60	60
Ethiopia	46	16	
Greece	140-160	70-80	60-80
India	85-100	32-50	0-50
Iran (Khorasan & Kerman)	100	20	5
Israel	15-20	0-8	
Mali	44	33	18
Mexico	100	80	
Pakistan (Punjab)	75-150	40-50	25-50
Peru (Central Coast)	247	69	75-90
Senegal	46	39	24
South Africa	130	30	20
Sudan (Gezira Scheme)	175		
Syria	190	60	
Tanzania	38	38	38
Thailand	38	38	38
Togo	40	30	20
Turkey	140-180	60-80	80
Uganda	50	50	50
USA	99	52	83
Uzbekistan	183	45	
Vietnam	120	60	60
Zambia	43	40	40
Zimbabwe	30	30-40	20-30

the world average of 723 kg/ha and 1,247 kg/ha in Brazil. Cotton yields in Argentina are almost half of what they are in Colombia and Peru. There are other reasons for those lower yields, but it would seem that the lack of fertilizer use also has a significant impact on yields in Argentina.

Bio-fertilizers

The use of bio-fertilizers is not common in cotton. But bio-fertilizers might be helpful under organic production conditions where synthetic fertilizers are prohibited. Bio-fertilizers are not true fertilizers, as they do not add nutrients to the soil. Bio-fertilizers are cultures of microorganisms, such as bacteria and fungi that help the plant indirectly by increasing nitrogen fixation and improving nutrient availability in the soil. The mode of action of a bio-fertilizer depends on the species of the organism. Some agents, like Rhizobium cultures, enhance nitrogen fixation in legumes by imparting effective modulation, as they are symbiotic bacteria living in association with leguminous plants. There are other bacteria that enhance nitrogen availability in the soil, and there are other kinds of microorganisms that act on minerals in the soil and dissolve native nutrients, like potash, that otherwise

may not be available. The critical factors that determine the effectiveness of a particular bio-fertilizer are: suitability of the species to the target crop, suitability of the strain to the agro-ecosystem (particularly soil pH) and moisture. Other factors include the carrier material in which the culture is packed and the quality of the packing material, which determine shelf life. The conditions in which the packed materials are stored, distributed and kept by the farmers before application are important as well.

Bio-fertilizers work on existing nutrients in the soil; organic or inorganic fertilizers contribute additional nutrients to the soil. The effects of bio-fertilizers are not as apparent as the effects of synthetic organic fertilizers. However, bio-fertilizers are environment friendly and have a favorable impact on the soil as compared to synthetic fertilizers. Because it is a higher yielding crop, the cotton plant's demand for nutrients is high. Thus bio-fertilizers cannot fully replace chemical fertilizers; they can only complement or supplement the minerals in the soil to supply the plant's mineral nutrition demand.

Organic Fertilizers

The organic matter found in soils is a result of the decomposition of living things. Soils rich in organic matter remain loose and airy, hold more moisture and nutrients, foster growth of soil organisms, and promote healthier plant root development, but organic matter accounts for less than 5% of the volume of most soils. Organic fertilizers differ from synthetic chemical fertilizers in nutritional status, nutrient release time, impact on the soil, cost and in many other aspects. When only chemical fertilizers are used, the soil gradually loses its organic matter content and microbiotic activity. As organic material is depleted, the soil structure deteriorates, becoming compact, lifeless and less able to hold water and nutrients. Thus, increasing amounts of fertilizer are needed to feed the crop.

Organic matter increases the vigor of plants and the activity of various soil microorganisms, and fewer plant-deficiency symptoms are found in soils that are rich in organic matter. Every time the soil is turned or tilled, more oxygen enters the soil, thereby increasing microbial activity. Organic matter keeps soil in an uncompacted condition with lower bulk density, helps retain nutrients by providing cation-exchange and anion-exchange capacities, helps to store and transmit nutrients and water for the plant and makes soils less sticky and easier to work.

Repeated turning or tilling allows more oxygen to enter the soil, thereby accelerating the decomposition of the organic matter through increased microbial activity and changes in water, aeration, and temperature conditions. In fact, most of the organic matter in the soil will be lost in 10 years if no additional organic matter is added. The rate of decomposition is low at temperatures below 3°C, but it increases steadily as temperatures rise. Excessive use of nitrogen fertilizers enhances the decomposition process, further lowering the organic matter content of soil. Fortunately, cotton is not a

high-harvest index crop as all leaves are invariably returned to the soil and, most of the time, cotton stalks as well, but high-harvest index crops put a huge burden on organic matter.

Unlike many chemical fertilizers, organic fertilizers continually build the soil and promote better structure as well as nourish soil life in the long run. The growth or yield attained by using chemical or organic fertilizers may be similar but not the same. It may be difficult to attain the same yields using organic fertilizers in cotton because of a stricter need to keep a balance between vegetative growth and reproductive growth. Organic fertilizer is added before planting to provide a higher nutrient level in the earliest stages. However, if the nitrogen level in the soil is too high at the outset, it may enhance vegetative growth and delay initiation of the effective reproductive phase. With synthetic fertilizers, on the other hand, nutrients can be supplied to the plant in a manner more closely consistent with its actual requirements.

In the final analysis, all organic fertilizers are much more productive than chemical fertilizers because they improve the structure of the soil and increase its ability to hold moisture and nutrients. Chemical fertilizers no doubt improve the dosing of nutrients but do not improve soils and can unbalance the nutrient status of the soil. Organic fertilizers, on the other hand, continually enhance soil life, improve soil structure, and foster organism growth. The nutrients in organic fertilizers may vary greatly depending upon source, age, erosion, or climate, so it is difficult to determine how much of each nutrient is being added. Chemical fertilizers are more predictable and provide a measured quantity of nutrients to the soil. Based on soil analysis, farmers may choose the synthetic fertilizer that will best suit the nutrient requirements of their soil.

Every effort should be made to preserve organic matter in soil. Planters should keep tillage at a minimum, keep the soil wet, adhere to crop rotation schemes and leave the greatest amount of crop residue in the field. But even with these measures, realizing optimum yields will always require increasing the organic matter content and keeping it above 5% of the soil composition. The current pressure to produce more food crops is increasing the need to improve cropping intensity and, consequently, the demand for organic fertilizers is increasing. But there are not many choices available for improving organic matter content.

Green manuring or cover crops, farmyard manure and crop residue are the only significant sources for improving organic matter content. Green manuring has its own limitations: lower cropping intensity, high cost and an aggravating impact on the reproduction of nematodes, especially root-knot nematodes, *Meloidogyne* spp., the most common species affecting cotton. Once the root knot nematode is established, it may be difficult to get rid of, as eggs can survive in the soil throughout the winter after cotton has been harvested. When spring arrives, the eggs hatch and nematodes penetrate plant roots near the area of cell elongation. Crops that are selected for use as green manures are usually chosen for their ability to grow rapidly

and produce a large mass. Green manuring can also lead to a white ant or termite problem if the green material is not properly decomposed prior to planting cotton.

Farmyard manure is the best way to improve organic matter and soil structure, but unfortunately, the use of farmyard manure is declining in the world, and reliance on chemical fertilizers for a quick fix is increasing. The main reason for reduced use of farmyard manure is lower availability. Farmyard manure is commonly used in China (Mainland). Data for some countries are shown below:

Organic/Farmyard Manure Use

Country	Area Treated
Bangladesh	25-30%
China (Mainland)	90%
Egypt	60%
India	50%
Mali	40%
Pakistan	10%
Tanzania	20%

In all other countries, organic fertilizer is used either on a small percentage of the cotton area or not at all.

Fertilizer Application

Of the three major nutrients, nitrogen, phosphorous and potassium, the latter two are relatively immobile in soil. Nitrogen is the most important fertilizer used on cotton, and it is also the most difficult to manage. Low nitrogen rates can reduce yield and quality while excessive nitrogen rates can cause rank growth, delayed maturity, boll rot, low yield and poor fiber quality, particularly in the form of less mature and weak fibers. Nitrogen application should be based on soil analysis, previous crop, growth history and yield target. Data from most cotton producing countries show that most fertilizers are applied to cotton at two points in time: before planting and at the pre-flowering stage. All the phosphorous and potassium are applied before planting and a portion of the nitrogen is applied prior to the flowering stage or in the early boll formation stage. Both applications are through the soil.

Foliar fertilization is one way to revive and stimulate stressed and nutrient-deficient plants immediately. Cotton has a palmate leaf and has the ability to take in nutrients more efficiently by means of foliar feeding through the stomata. However, although spraying of nitrogenous fertilizer has yielded favorable results, foliar fertilization is not common in cotton. Foliar application may be tried when soil application of nitrogen will be too late to

fix the deficiency problem. Excessive doses of foliar nitrogen can burn plants, but if the soil is really deficient in nitrogen, foliar feeding can help. Potassium does not need to be sprayed over the crop but applications can improve yields in a specific situation. The cotton plant continuously absorbs potassium from the soil but, since the demand for potassium is not high until the boll maturing stage, surplus potassium is stored in leaves. Maturing bolls require an exceptionally high potassium supply, and the leaves volunteer their spare potassium to be used by the bolls. Everything will depend on the boll load; if the number of bolls is too high, even the supply contained in the leaves may not be enough. In that situation, foliar spraying of potassium fertilizers may enhance yields and improve fiber quality.

Cost of Fertilizer

The two key factors that determine the quantity of fertilizer needed are: soil analysis and target yield. However, fertilizer costs often overrides the other two, particularly in developing countries. Cost of production data from countries around the world show that farmers spend an average of US\$158 on fertilizers to produce a hectare of cotton. The world average net cost of production per kg of lint is US\$1.14, of which US\$0.20 are spent on fertilizers. Fertilizer costs account for 17% of the total production costs (exclusive of ginning, economic and fixed costs). The amount of money spent to grow a hectare of cotton varies greatly among countries. In China (Mainland), US\$291 is spent on fertilizers to grow a

Costs of Fertilizers in Producing Cotton

Country	Cost/Ha (US\$)	Cost/Kg of Lint (US\$)	Production Costs (%)
Argentina	Not used	-	-
Australia (Irrigated)	174.2	0.12	20
Bangladesh	121.5	0.21	24
Benin	69.6	0.15	14
Brazil (Cerrado)	272.0	0.21	22
Cameroon	109.1	0.22	30
China (Mainland)	290.7	0.28	20
Colombia (Cesar)	132.7	0.16	14
Colombia (Sinu)	120.7	0.13	13
Côte d'Ivoire (Animal Powered)	97.3	0.17	27
India (North, Irrigated)	73.9	0.13	14
India (Central, Rainfed)	70.6	0.22	20
Iran	31.4	0.04	3
Israel	190.0	0.11	7
Mali	143.4	0.30	37
Mexico (Sonora)	150.4	0.13	10
Pakistan (Punjab)	195.2	0.29	21
Peru (Tanguis)	259.3	0.21	15
South Africa (Irrigated, Bt)	192.2	0.10	24
Spain	220.4	0.19	11
Sudan (Gezira)	48.8	0.12	10
Togo (North Region)	95.6	0.25	24
Turkey	153.9	0.11	10
USA	88.7	0.12	11
Vietnam	90.2	0.16	19
Average:	157.9	0.20	17

hectare of cotton, which is the highest fertilizer cost in the world. Organic fertilizer is also commonly used in China (Mainland), and it is evident that cotton is over fertilized in the Yellow and Yangtze River Valleys. Production practices show that in order to avoid the effect of over fertilization, topping of cotton has become popular in both regions. The growing tip of the main stem is pruned to avoid excessive growth, and that helps the plant to divert available energy towards fruiting. Growing conditions in the Xinjiang region are different and do not require any topping.

The cost of fertilizers per kg of lint in Israel is the lowest in the world. Fertilizer cost per hectare in Israel is US\$190/ha but comes to only US\$0.11 per kg, which is almost half of the world average cost/kg of lint. Cost per kg is low in Israel because of high yields and also because sewage is processed and used to irrigate cotton, thus minimizing the need for fertilizer applications.

Role of Soil pH in Soil Fertility

Aside from the major nutrients (nitrogen, phosphorous and potassium) and organic matter, soil pH is the key element that determines soil health. Soil pH is a measure of the relative acidity or alkalinity of the soil. The pH scale ranges from zero to 14, with 7.0 as a neutral soil. Soils having a pH value below 7.0 are acidic in nature while soils with a pH value over 7.0 are alkaline in nature. Soil pH is important because it affects the availability of nutrients to plants and the activity of microorganisms in the soil. Plant nutrients, major and minor, are most readily available within a pH range between 6 and 7. While some minor crops and vegetables do better in lower pH soils, cotton performs best in neutral or close-to-neutral soils. The parent material from which the soil was formed is the fundamental factor that determines soil pH. As far as cotton is concerned, irrigated and rainfed soils are liable to become acidic as a result of the leaching of calcium and manganese from the soil. The depleted manganese and calcium are usually replaced with greater quantities of acidic elements such as aluminum and iron. Frequent applications of fertilizers containing ammonium or urea change the nature of soils and make them acidic. Lower organic matter in the

soil also indicates soil acidity. Thus there is a need to check soil pH on a regular basis. Nutrient deficiency symptoms and slower growth are common indicators that pH values are too low or too high.

Micronutrients

A number of micronutrients play an important role in obtaining high yields and optimum fiber quality. The micronutrients important for cotton are calcium, magnesium, boron, sulfur, molybdenum, zinc, copper and manganese. Most soils contain sufficient quantities of micronutrients and, if crop rotations are followed or organic fertilizers are applied, there may never be a need to apply micronutrients. However, high rainfall and frequent irrigation may reduce boron content in the soil. Boron plays an important role in the elongation of the root tip, the synthesis of DNA and RNA, and in the formation and growth of the pollen tube. The role of boron is not thoroughly understood yet, but a serious boron deficiency can affect yield. Boron is the micronutrient most commonly applied to cotton. The ICAC report on production practices presented to the 64th Plenary Meeting held in Liverpool in September 2005 showed that micronutrients are applied to cotton as follows:

Country Micronutrient and Dose/ha

Bangladesh	Boron = 1-1.5 kg, Sulfur = 15-20 kg
Benin	Sulfur = 10 kg in the South and 20 kg in the North
Brazil (Central West)	Boron = 4 kg, Sulfur = 60 kg, Copper, Manganese and Zinc = 1-2 kg
Brazil (North)	Boron = 1 kg, Sulfur = 20 kg
Cameroon	Boron = 2 kg, Sulfur 9 kg
Cote d'Ivoire	Boron 2 kg, Sulfur = 12 kg
Mali	Boron = 1.5 kg, Sulfur 10.5 kg
Pakistan (Punjab)	Boron = 2 kg
Togo	Boron 1.5 kg, Sulfur 7.5 kg
Zimbabwe	Boron + Sulfur = 5.0 kg

The list above shows the countries where micronutrients are applied, although not by all growers. The dose per hectare refers to the nutrients that are actually applied. The latest trend is the use of fertilizers designed to have low initial solubility and release nutrients to the soil and plant gradually over an extended period of time.

Herbicide Resistant Biotech Cotton

Weeds must be controlled because they harbor insect pests and compete with the cotton plant for inputs. Experiments have shown that of the three most important operations in cotton, i.e. weed control, application of fertilizers and pest control, weed control is the most important if a cotton grower has limited resources and has to make a choice. Weeds are a bigger problem in intensive farming systems. There may be fields and farms in many production systems where weeds are really not a serious threat. Such situations, however, are rare and do not persist. Weeds may be thought of as a kind of pest and, as such, require an integrated approach for sustainable control.

Weeds may be narrow leafed or broad leafed. It is always comparatively easier to control broad leaf weeds and, fortunately, they are the most prominent in most cotton fields throughout the world. To plan an integrated approach for a sustainable weed control system, it is convenient and useful to be familiar with the biology of weeds.

Weed Control in the World

Weeds in cotton may be controlled manually, mechanically or chemically by applying herbicides. Crop rotation is another means of minimizing weed intensity. In small farms where the land is worked using animal traction, the fields may be cleared manually. When cotton is not planted in rows, as was the case in many countries not very long ago, hand weeding is the only way to get rid of weeds. Planting in rows allows growers to use mechanical methods of control, but mechanical weeding damages the crop and weeding equipment may be employed in cotton fields only while the cotton plant is below a certain height. Another significant constraint affecting the mechanical elimination of weeds is the inability to remove weeds growing between the plants in a row. Earthing up rows before irrigation can partially control weeds by burying them,

but it is only a partial solution. Fields must be free of weeds until the cotton leaf canopy closes the soil to sunlight. The lack of sunlight reduces the weeds' ability to flourish normally and continue consuming inputs provided for the cotton plant. Weed intensity and type will determine the actual number of operations to be carried out. Normally, at least two manual

and mechanical passes may have to be performed. Large-scale farming and the high cost of labor dictate exploring other means to control weeds that might also help avoid the shortcomings of manual and mechanical weeding. Chemical weed control is one alternative, but it has its own consequences.

Consequences of Herbicide Use

Herbicides are not always the best way of getting rid of weeds. Herbicide applications are clearly the most effective method, but of the three possible options (manual, mechanical and chemical), it is

Area Treated With Herbicides

Country	Area (%)
Argentina	90
Australia	100
Brazil	
Central West	100
Northeast	2
Cameroon	72
China (Mainland)	18
Colombia	
Sinu Valley	100
Côte d'Ivoire	40
India	10
Iran	30-40
Israel	100
Madagascar	1
Mali	37
Pakistan	25-30
South Africa	80
Togo	5
Turkey	80
Uganda	1
USA	91
Vietnam	20
Zambia	5
Zimbabwe	10

Plant Protection Chemical Use in the World (Sale in Million US\$)

Chemical Group	2000	2001	2002	2003	2004
All Crops					
Herbicides	13,796	13,386	12,475	13,348	14,849
Insecticides	8,206	7,744	7,314	7,738	8,635
Fungicides	5,818	5,467	5,450	6,055	7,296
Others	1,364	1,347	1,322	1,374	1,569
Total:	29,184	27,944	26,561	28,515	32,349
Cotton					
Herbicides	675	740	685	673	777
Insecticides	1,548	1,467	1,351	1,423	1,618
Fungicides	57	58	57	60	70
Others	282	266	254	252	280
Total:	2,562	2,531	2,347	2,408	2,745

Source: Cropnosis, Limited, Edinburgh, UK.

also the most destructive. The consequences of herbicide use, in particular, its effects on the microbial community, are not well understood. Furthermore, the consequences of herbicide use are seldom thoroughly considered prior to the adoption of the chemical option. Unfortunately, the need for efficient weed control drives growers to rely on the use of herbicides. Soil organisms metabolize different herbicides, but it is not known what parts of the microbial community these materials eliminate. They do not seem to do much good against pathogens such as root rot, and there is a need to know what impact herbicides have on beneficial soil-born microorganisms. Herbicide chemicals are assessed by their ability to kill weeds, not by their effects on the soil microflora.

Herbicide use is on the increase in the world, and herbicides have become, or are becoming, an integral part of many weed management systems. Repeated use of the same herbicides that act in a similar manner within the target weed results in the selection of resistant weed biotypes. Herbicide resistance is defined as the inherited ability of a weed to survive and reproduce following exposure to a dose of herbicide normally lethal to the wild type. Herbicide resistance is currently on the increase along with the use of herbicides. Literature shows that over 250 weed plants have already developed resistance to herbicides. The fundamental reason for this increase in herbicide resistance is that growers continue to use a successful herbicide program until it fails, instead of proactively implementing herbicide resistance management strategies. Loss of herbicide performance brings not only economic losses to growers but also shifts in weed populations because not all the weeds controlled by the chemical will develop resistance at the same time. As natural selection acts and some weeds develop resistance, biotypes of the resistant weeds begin to overwhelm the non-resistant populations. Using mixtures of insecticides, as is done with insecticides, is a resistance management strategy but information is needed to identify which herbicides have similar mode of action.

Herbicides are frequently categorized into families according to various similarities. Examples of herbicide classification categories include: mode of action, application timing, and chemical structure. Herbicide mode of action describes the metabolic or physiological plant process impaired or inhibited by the herbicide. Essentially, mode of action refers to how the herbicide acts to inhibit plant growth. Herbicide site of action describes the specific location(s) within the plant where the herbicide binds. Site of action identifies the herbicide target site within the plant. The most common herbicide classification schemes utilize mode of action; however, in cotton, time of application (pre- or post-) is more commonly used. Herbicide resistance in plants is often due to an alteration of the binding site in the target plant. Rotating herbicides based on different binding sites may provide a more informative classification system.

Classification systems based on mode of action include anywhere from 7 to 13 categories. Some of these systems describe mode

of action categories as “cell membrane disruptors,” “seedling growth inhibitors,” and “amino acid synthesis inhibitors.” Rotating herbicides based on these categories could cause confusion among growers. For example, the mode of action category “amino acid synthesis inhibitors” would place the herbicides Pursuit (imazethapyr) and Roundup (glyphosate) in the same family, whereas classification by site of action would place these two herbicides into two distinct families, allowing growers to more accurately rotate herbicides for resistance management.

Herbicides that are applied to one crop may harm a following crop. Pursuit is registered for application on peanuts for controlling some of the most commonly occurring weeds, like yellow and purple nutsedge and morning glory. Karnei *et al.* (2002) concluded that Pursuit, if applied to a peanut crop, can significantly injure cotton in the following growing season. Karnei *et al.* (2002) correlated soil herbicide concentration of Cadre and Pursuit to cotton injury and lint yield. Both chemicals were applied in six doses, and treatments showed injury 42 days after planting. The level of injury varied according to the dose and the product, but lower stands resulted in huge yield losses.

Herbicide-resistant Biotech Cotton

The US Environmental Protection Agency (EPA) awarded conditional approval for the sale of the herbicide bromoxynil for use on transgenic herbicide-resistant biotech cotton in May 1995. This was the first commercialization of genetically engineered herbicide-resistant cotton. The bromoxynil-tolerant cotton was traded under the name BXN cotton, and those varieties are still commercially produced. Sold under the trade name Buctril, bromoxynil had long been registered for use on corn, wheat, oats and several other crops. However, it was not previously registered for use on cotton because it killed cotton plants. A few days after its decision on bromoxynil, the EPA also approved commercialization of a second transgenic herbicide-resistant crop. Monsanto received unconditional registration for its glyphosate herbicide (trade name Roundup) on transgenic glyphosate-resistant soybeans. Roundup Ready biotech cotton was commercialized in 1997/98.

During the first year after adoption of glyphosate-resistant Roundup Ready biotech cotton, there appeared an unexpected problem. At the peak boll formation stage, some growers found that their Roundup Ready biotech cotton showed deformed bolls and small bolls that dropped off the plant. The problem was limited to a few isolated fields scattered over thousands of hectares, particularly in the state of Mississippi. It was suggested rather quickly that the problem was associated with the Roundup Ready gene, but only 20% of the Roundup Ready cotton was affected. Researchers looked at other factors such as soil type, weather conditions and herbicide applications, which may have interacted with the engineered gene to cause the abnormalities. Extensive studies were undertaken in the following years, and it was concluded that

Biotech Cotton Area in the USA

Year	All Biotech Area (% of Total Area)	Herbicide Resistant Biotech Varieties	
		(Actual in %)	Share (%)
1996/97	13	< 1	< 1
1997/98	23	4	17
1998/99	45	26	58
1999/00	60	44	73
2000/01	72	61	85
2001/02	78	74	95
2002/03	77	72	94
2003/04	76	74	97
2004/05	80	79	99
2005/06	83	81	98

the problem was not related to the Roundup Ready gene. The problem was correlated with abnormal weather conditions and with production practices followed in the affected area. Early season cold temperatures and multiple applications of Roundup Ready Ultra in a slow growth period caused excessive shedding and changes in boll shape. Since then, no additional complaints have been reported.

Herbicide resistance is the most popular characteristic among the characteristics developed using biotechnology applications. According to the International Service for the Acquisition of Agri-Biotech Applications (James, 2005) biotech crops were grown on 90 million hectares in 2005, and 71% of this area was under herbicide-resistant biotech crops. Herbicide-resistant biotech varieties are available in single and also in stacked form with the insect-resistant trait in cotton and other crops. The herbicide-resistant biotech trait in cotton is extremely popular in the USA. The Agricultural Marketing Service of the US Department of Agriculture estimates the area planted to cotton varieties annually, and a report is published in August/September of every year. Herbicide-resistant biotech varieties were planted on about 95% of the biotech cotton area in recent years. Almost 40% of this area was under pure herbicide-resistant varieties and 60% under stacked gene varieties. Less than 1% of the biotech area was planted to pure insect-resistant varieties. The herbicide-resistant trait in cotton is gaining ground in Australia, but it is not popular in other countries.

Roundup Ready Flex Technology

Herbicide-resistant biotech cotton has become extremely popular in the USA. Since the adoption of biotech cotton in 1996/97, the area planted to herbicide-resistant biotech varieties has continuously increased, as shown in the table above. However, the herbicide-resistant biotech cotton that was resistant to Roundup had a limitation: it could be sprayed up to the four-leaf stage only; beyond that, it could damage the cotton. Consequently, beyond the four-leaf stage, farmers had to resort to other weed control measures. Roundup Ready

Flex cotton provided a solution to this problem by creating a more flexible window for over-the-top application of Roundup, one that extended until close to picking time. Roundup Ready Flex was approved for commercial production in 2006/07. According to Croon *et al.* (2005) Roundup Ready Flex is based upon a transformation event identified as MON 88913. Roundup Ready Flex cotton utilizes a *cp4 epsps* gene sequence that encodes for the CP4 EPSPS protein. The CP4 EPSPS protein expressed in Roundup Ready Flex cotton is the same protein currently used in Roundup Ready cotton that provides the tolerance to glyphosate. The increased

level of glyphosate tolerance in Roundup Ready Flex cotton has been achieved through the use of improved promoter sequences that regulate the expression of the *cp4 epsps* coding sequence.

Roundup Ready Flex technology has been extensively tested in the USA since 2001/02. Trials were conducted by Monsanto, universities and others, who studied its agronomic characteristics, including seed germination, emergence, plant growth and development, harvest quality and compositional elements of the seed. The findings indicated that multiple over-the-top applications of Roundup Ready did not have any negative effects on the agronomical and qualitative characteristics of seed and lint. According to Monsanto, owner of the technology, Roundup Ready products, like Roundup WeatherMAX® and Roundup Original MAX™, may be sprayed over-the-top from emergence through to seven days prior to harvest or 60% open bolls (Murdock and Mullins, 2006).

It is recommended that a maximum rate of up to 79 ounces/ha be applied in each pass when using ground application equipment and up to 55 ounces/ha if applied by air from emergence through 60% open bolls. If the need should arise to apply the herbicide even after 60% of the bolls have opened, the quantity should not exceed 100 ounces/ha. The benefits of extended over-the-top application and the ability to tailor herbicide applications to the weed problem itself instead of to the stage of growth are yet to be verified in the form of in-field commercial performance of the Roundup Ready Flex technology. The only disadvantage Monsanto noted was a potential for leaf injury when combinations of components of glyphosate formulations were applied to Roundup Ready Flex cotton. Therefore, Monsanto has arranged to formulate Roundup WeatherMAX® and Roundup Original MAX™ for use on Roundup Ready Flex cotton to reduce the potential for leaf injury and, consequently, only Roundup WeatherMAX® and Roundup OriginalMAX™ are recommended for over-the-top application on Roundup Ready Flex cotton.

Liberty Link Cotton

Liberty®Link cotton from Bayer CropScience is a transgenic herbicide-resistant cotton similar to Roundup Ready. However, Liberty Link is used with the herbicide glufosinate rather than glyphosate associated with Roundup Ready cotton. Roundup Ready cotton can tolerate herbicides only up to the four-leaf stage but glufosinate-containing herbicides like Ignite or Liberty (also marketed under different commercial names) can be sprayed over-the-top of Liberty Link cotton up to the ten-leaf stage. Aside from cost differences, each technology has its own advantages and disadvantages, almost always related to the weed species present in the field. The ultimate objective is to keep the fields clean at a minimum cost and with the least long-term consequences.

Studies conducted in the USA (Barker *et al.*, 2005) have shown that repeated emergence of weeds required multiple herbicide applications in order to ensure season-long weed control and achieve high yields. They compared the performance of Liberty Link, Roundup Ready and hand weeding where herbicides were applied early post-emergence, post-emergence and layby applications. Their findings indicated that a one-pass system of early post-emergence or post-emergence herbicide yielded significantly less than the two- and three-pass system (early post-emergence+post-emergence+layby). The two-pass system provided good control of some weeds, but not all weeds, thus affecting yield.

Liberty is a broad-spectrum herbicide. Its killing speed is a little slower than paraquat and a little faster than glyphosate. Liberty causes ammonia accumulation within susceptible plants and, as might be imagined, that causes a quick burn. Liberty also marketed as Basta, Ignite, Rely, Finale and Challenge, can kill a wide variety of plants.

Weed Resistance to Herbicides in Biotech Cotton

Weeds can acquire an inherited ability to survive and reproduce after a dose of herbicide that would normally kill. This means that a normal dose of a chemical that once controlled that particular weed would no longer be effective against that same weed. The development of resistance to herbicides that are used frequently on biotech cotton is an eventual certainty. The threat of weeds developing resistance is no less than the threat of insects developing resistance or morphing into new biotypes or even changing the pest complex. Unfortunately, however, herbicide resistance in biotech cotton has not received the same attention as insect or toxin resistance. Numerous reports in the USA show that weeds have already developed resistance to the most commonly used herbicide -- glyphosate.

Horseweed is a particularly dangerous weed that, if allowed to receive fertilizer and other inputs along with the normal crop, can grow taller than the cotton plant. Horseweed may have different names in different countries, and it is botanically

known as *Conyza Canadensis*. It grows straight upright on a central stem surrounded by long, thin leaves. Horseweed was an occasional weed in California, USA, but now it is a common weed in irrigation canal banks, vacant lots, orchard and vineyard floors, roadsides and gardens. According to the University of California, biotypes of horseweed have evolved that are unaffected by the most commonly used herbicides containing glyphosate, which is the active ingredient in over 55 brand-name products approved in California. (http://www.chemicalhouse.com:8080/nl_new/jsp/viewnewsletter.jsp?id=361). The main problem with certain weeds such as horseweed is that they can produce as many as two hundred thousand seeds per plant and any breeze can spread them over hundreds of meters. This is why every effort must be made to ensure that such weeds do not reach the seed formation stage.

Glyphosate-resistant weeds can become a problem when farmers grow Roundup Ready resistant biotech crops in the same field year after year. Rotation of non-biotech crops in a cotton farming system is a valuable tool for avoiding greater problems. Production systems that do not allow for growing other crops in rotation with cotton must consider the weed resistance issue more seriously than systems that allow planting non-biotech crops other than cotton in their cotton fields. Cotton-wheat-cotton is a popular rotation, particularly in many Asian countries, and it is perfectly suitable for avoiding weed resistance problems in biotech herbicide-resistant cotton.

Reports from Australia show that ryegrass has developed resistance to glyphosate. Spurred by the need to minimize the development of resistance to glyphosate herbicides, the Grains Research and Development Corporation (GRDC) launched the Glyphosate Sustainability Working Group initiative. The Glyphosate Sustainability Working Group reported that, although still proportionally low, the incidence of glyphosate resistance in annual ryegrass had doubled in a single year. The practices recommended to grain growers to reduce the risk of resistance development include: use of the double-knock strategy, effective in-crop weed control, alternative herbicides, crop topping and non-herbicide weed control techniques, such as hay and weed seed collection.

Managing Herbicide Resistance in Biotech Cotton

Sustained exposure of weed plants to the same herbicide chemical, as a result of repeated use during a single season against the same weed species, increases the probability that the weed plant will develop resistance to that particular chemical.

Herbicides may be classified in several different ways: site of uptake into the plant (root vs. shoot), means of translocation within the plant (systemic vs. contact), time of application (pre-planting incorporated, pre-emergence, post-emergence), chemical structure similarity (phenoxy vs. triazine) and mode

of action. There are many modes of action by which herbicides get dissolved into the weed tissues, above and below ground, and ultimately kill the weed. One such mode of action is through acetolactate synthase (ALS) inhibitors. According to York (2006) there are many herbicides within the four chemical classes (Imidazolinone, Sulfonylurea, Pyrimidinyl benzoate and Triazolopyrimidine) that kill weeds by inhibiting ALS. The herbicides known as Staple and Envoke, which are frequently used on cotton, are ALS inhibitors, and resistance to this group can develop in as few as 3 to 4 years. The other mode of action where resistance is of great concern is the 5-Enol-pyruvylshikimate-3-phosphate synthase (EPSPS) inhibitors. Glyphosate belongs to this group and in the USA a number of weeds affecting cotton have already developed resistance to these groups.

Like insects, weeds of any species may take many years to develop resistance to a particular herbicide, or just a few years. The time it will take a particular species to develop resistance depends on a number of factors. There is no doubt that the frequency with which the same chemical is used to get rid of the same weed species is very important. In the long run, it is much easier and always more economical to avoid development of resistance instead of having to deal with it once resistant weed plants start appearing in the crop. Any economically viable practice that will help minimize the use of herbicides may be recommended to help delay the development of resistance. Many agronomic practices including pre-planting cultivation, early and healthy establishment of the crop, control of seedling diseases, avoidance of abiotic stress, and physiological stress can help the crop compete better against weeds on its

own. Rotating crops that do not share the same weeds can also have a long-term impact. In-crop cultivation should be utilized as much as possible to minimize reliance on herbicide control. Early detection is also an important component in any herbicide resistance management strategy.

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Cotton Production in the Brazilian Savanna: The Challenge of Achieving High Productivity and Sustainability

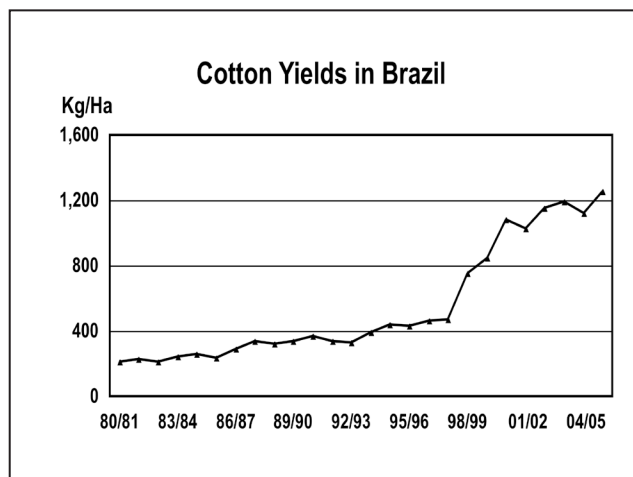
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Introduction

Cotton production in Brazil went through significant changes during the second half of the 1990s as the center of production shifted to the central-western region of the country. A major reason for this change, the one that really supported the move, was the fact that cotton is particularly suitable for cultivation in the Brazilian savanna. As cotton production expanded and started to occupy larger areas in this region, new business management models replaced the old family management model. Technology became an intrinsic part of cotton production practices, resulting in gains both in terms of productivity and quality. These advances opened the door to the international market, and in 2002 Brazil started to export cotton.

The Brazilian savanna region currently accounts for more than 90% of Brazilian cotton production. This region is characterized by flat plains and low-fertility soils that need to be corrected. The rain pattern is well defined: it begins in October and ends in April, so harvesting is done during the dry period, thus ensuring good fiber quality.

In spite of the state-of-the-art technology that has been adopted and good increases in productivity, cotton growing hasn't always been a profitable activity, especially during the last few years. Domestic economic factors, such as the favorable exchange rate of the Brazilian currency against the US dollar, high production costs, excess supply worldwide, and the pressure on international prices are some of the aspects that compromise the Brazilian cotton sector and the growers' profit margin.



This paper deals primarily with a number of technical aspects that are incorporated into the cotton production model used in the savanna, geared toward ensuring high productivity levels. The paper takes an example from the management practices adopted in the southwest part of the State of Goiás, which has been growing cotton since 1991. This fertile land is about 500 meters above sea level. The lands are located in a region where cotton is a traditional crop. It has some advantages, such as soil fertility, and a number of disadvantages, i.e. a higher incidence of pests such as caterpillars and the cotton boll weevil, *Anthonomus grandis*. Farmers specializing in cotton have invested a great deal in machinery and equipment.

Mean Monthly Rainfall (mm) from 2001 to 2005, Turvelândia-Goiás

Month	Rainfall (mm)
January	360.0
February	192.0
March	221.0
April	45.0
May	35.0
June	0.1
July	3.2
August	2.5
September	54.0
October	100.0
November	195.0
December	292.0

Soil Management

Soil management at the sample farm has evolved significantly. During the 90s, 100% of the land was prepared for planting according to conventional practices. Nowadays, however, each year only 25% of the land is tilled, either because the soil needs to be decompacted or because it needs some kind of correction. Currently, zero-tillage cultivation is used on approximately 35% of the area, following a rotation of soybean, millet or grass. The remaining 40% is managed according to a minimum-tillage model, which is an intermediate process between the two systems described above. In this case, millet is planted on the cultivated land. The millet crop is killed by spraying glyphosate just before cotton planting begins.

It used to be that crop rotation associated with zero-tillage planting and an intermediate model—a common practice on many cotton farms—was an indicator that the grower was

really concerned about his final product, but since then it has become a standard necessity. For any crop to be considered successful, a number of considerations have to come into play, such as environmental conservation, cost-reduction policies, higher productivity rates and, as a consequence, a higher profit margin.

It has become clear, not only for the Brazilian savanna, but for the country's whole agricultural sector, that reliance on monoculture systems or alternating exclusively between two crops (e.g. soybean/cotton) will undermine the sustainability of the system. An increase in the population of phytopathogenic fungi, nematodes or herbicide residue, among other problems, will lead to a decrease in productivity and an increase in costs, a situation that does not translate into profit.

Building the fertility of soils to a depth of 60 cm, in addition to crop rotation practices and planting systems employing cover crops, are the factors that have determined the success of cotton agriculture in the Brazilian savanna. The formation of this so-called 60 cm soil layer needed for successful cultivation of cotton was the result of intensive use of lime (at a rate of 10-12 tons/ha) during the first years that these soils were used for planting. This was followed by maintenance liming with smaller doses in subsequent years, plus applications of calcium sulfate and the use of soybean as a leguminous crop. The best results are obtained when the productive layer is corrected, preferably with soil having a clay content of more

than 35% and an organic matter content of more than 2.5%. Calcium levels should also be above 45 millimoles (mmol) per liter, magnesium between 15 and 20 mmol, potassium should be in the range of 3-5 mmol, and sulfur above 12 ppm, as determined by soil analysis tests.

The low natural availability of nutrients in the Brazilian savanna led to the need for new fertilization rates for cotton in these areas, both in terms of macro- and micronutrients. The use of 90-150 kg/ha of P_2O_5 , 100-160 kg/ha of K_2O and 100-150 kg/ha of N, in addition to B, Zn, Cu, Mn, Mo in NPK formulations and in foliar application systems has now become a standard management practice for successful commercial crops. Sulfur has also been widely used, and in most cases it is provided in the form of calcium sulfate.

Fertilizers account for 20 to 30% of production costs. A more rational use of fertilizers was therefore needed to achieve sustainability. This need to optimize costs, coupled with the technical expertise gained by professionals working in the region, as well as research generated in different production regions, resulted in new adjusted fertilization protocols tailored to individual needs. Factors such as rainfall pattern, previous crop, variety, planting system, cropped years, pest situation, detection of nematodes, brown stink bugs (*Scaptocoris castanea*), and beetles (*Phyllophaga*), among others, are important aspects of soil analyses, and the results must be assessed before making any recommendations. The following is an example of soil analysis and fertilization.

Soil Analysis

Physical Analysis			Chemical Analysis														
%			mmol			ppm		%	mmol	%	ppm						
Sand	Silt	Clay	Ca	Mg	K	S	P	V	CTC	M.O.	B	Zn	Cu	Mn	Fe	Mo	
21	15	64	63	20	5	5.8	7	68	130	4.1	0.23	2.6	3.1	40	29	-	

Fertilization Use on Cotton

Product	Time	Modality	Amount per Kg/ha									
			S	P	K	N	B	Zn	Cu	Mn	Mo*	
Soil correction	Before Planting	Casting	120									
Macronutrient	Planting time	Furrow		130			0.8	0.8	0.6			
Macronutrient	Up to 30 DAE	Cover			50	80						
Macronutrient	Up to 60 DAE	Cover			50	50						
Micronutrients**	From 45 to 110 DAE	Spray					2.5	1.5		0.4	0.025	
Total Kg/ha			120	130	100	130	3.3	2.3	0.6	0.4	0.025	

DAE – Days after emergence

* Molybdenum was added to the spray to improve nitrogen uptake.

** Spray applications are repeated every 7 to 10 days, as needed, according to weather conditions and the nutrient used.

Note 1 – Urea is used as a source of nitrogen.

Note 2 – Calcium sulfate is used as a source of sulfur, and contains 13% sulfur and 16% calcium.

Plant Management and Protection

Seed treatment

Seed treatment is extremely important for the health of the crop and, as such, it is an essential aspect of plant protection. Guaranteeing that the stand will remain within planned parameters will have an important impact on cotton management. Uniform emergence of the crop is especially useful in the management of herbicides, growth regulators as well as defoliant and boll openers.

Seed choice is also extremely important in guaranteeing the desired stand and using top quality seeds can ensure a good stand with less than 10 kg/ha of planting seed. Reduced seed rates also translate into savings in seed treatment and represent a reduction of at least one application of insecticides for the control of aphids. Plant population will depend on the variety chosen, but in the area of southwest Goiás the best results have been obtained with a population of 80-90 thousand plants per hectare. This prevents plant competition and possible boll rot, a very common occurrence in the region resulting from the abundant rains of March and April.

There is a high incidence of nematodes and soil fungi, such as *Fusarium*, *Colletotrichum* and *Phytium*, among others, in corrected soils ready for cotton. There are also several pests that can damage this crop, right from the planting stage: brown stink bug, the granulate cutworm moth, cornstalk borer, spodoptera, the Egyptian cotton leafworm and other defoliating caterpillars common at the time of plant emergence. These problems are currently being solved with products registered and sold in the country, which are used to treat the seeds as well as in direct sprays on the furrows. The most common are neonicotinoid-based insecticides (i.e. thiamethoxan) in a mix with two or more systemic or foliar fungicides.

Weed Management

In zero-tillage or minimum-tillage systems, weed control begins with soil preparation. Systemic herbicides are used over the cover crop at least 15 days before planting in both systems. Contact or even systemic products are applied, and the plants that have germinated are eliminated a day before the cotton is planted. The Brazilian savanna has more than 35 species of broadleaf and grassy weeds that are a threat to cotton. The most important of them are *Ipomoea* spp., *Bidens pilosa*, *Euphorbia heterophylla*, *Digitaria ciliaris*, and *Commelina* spp.

Control of broadleaf weeds (dicotyledones) is more difficult because there are not many cotton-specific herbicides to choose from. Most herbicides are selective in terms of position and dosage, which means the risk of phytotoxicity is high. Thanks to certain endemic characteristics in the soil of the savanna, growers can obtain the desired results with smaller dosages applied in different ways.

Our weed control program includes products for pre-emergence of cotton, pre-emergence of weeds, post-emergence of cotton, total post-emergence and direct spray. The most common strategy is to apply desiccants such as Diuron in association with an active pre-emergence product, followed by one or two applications in direct sprays. In this operation, farmers combine foliar and systemic products that have a residual action. Depending on the level of infestation and the type of weed, farmers may use one or two over-the-top applications. (It should be noted that only two types of products are available in Brazil.) The table below is an example of a weed control program where decisions on herbicides and application modalities were based on a plant survey made at the end of the previous harvest. The program below is for no-tillage planting on a residue of soybean and millet planted in August/September.

Weeds and Infestation Levels

Weeds		Level of infestation		
Common Name	Scientific Name	Low	Medium	High
Alternanthera	<i>Alternanthera tenella</i>		x	
Caruru (Redroot pigweed)	<i>Amaranthus</i> spp.	x		
Trapoeraba (Comelina)	<i>Commelina benghalensis</i>			x
Corda de Viola (Morning glory)	<i>Ipomoea grandifolia</i>	x		
Erva de Santa Luzia (Pillpod sandmat)	<i>Chamaesyce hirta</i>		x	
Capim pé de galinha (Goosegrass or wiregrass)	<i>Eleusine indica</i>		x	
Capim Colchão (Southern crabgrass)	<i>Digitaria ciliaris</i>			x
Capim brachiaria (Grass silage)	<i>Brachiaria plantaginea</i>	x		

Weed Control Program

Objective	Time	Modality	Target	Product	Dose SC/ha
Zero-tillage planting	30 days before planting	Total area	Broadleaves	24 D Amina	0.5 L
Zero-tillage Planting	15 days before planting	Total area	All weeds	Glyphosate	3.0 L
First flow	1 day before planting	Total area	All weeds	Paraquat	1.0 L
Flow	After planting	Total area Apply and plant	All weeds	Trifluraline Gold	1.5 L
				S-metolachlor	0.6 L
				Diuron	1.8 L
Flow	7-10 Days after planting	Total area	All weeds	S-metolachlor	0.8 L
Flow	As needed	Total area	Grass	Fluazifop-p	0.6 L
Flow and escape of pre- and post-	45-60 days after germination	Direct spray	All weeds	Diuron	2.0 L
				MSMA	1.5 L
Management and initial escape	15-30 days after germination	Manual	All weeds	Mandays	0.5 mandays/ha

Insects and Diseases Management

Having a team of qualified crop monitors is essential to the achievement of good pest and weed management. Crop managers are responsible for following the cotton from the pre-planting stage, they do surveys of existing weeds, count bolls and estimate yield right up to harvest time. The team receives on-going training from a specialist in each area and is managed by an agronomist who receives the data, analyzes the information and makes decisions about actions to be implemented.

The fields are divided into plots with homogenous characteristics and measuring no more than 100 hectares. Every three days, a monitor goes through the whole area and assesses the presence of pests, plant growth and weed emergence. The team's data and observation notes are then used to define the control measures to be adopted, the products to be used, dosages, flow rates of the spray equipment, along with other variables.

Insects Management

The main insects affecting cotton productivity are caterpillars and the cotton boll weevil. The latter was responsible for driving cotton agriculture out of the south and up into the central-western region of Brazil. The cotton boll weevil started to affect the State of Goiás in the 90s and has become a significant threat. In some regions, up to 16 direct spray applications per harvest had to be made, specifically targeting the cotton boll weevil, and even so, productivity rates fell. Consequently, cotton institutions in the state, such as the Association of Cotton Producers of Goiás (AGOPA), Fundo Incentivo a Cultura do Algodão em Goiás (FIALGO) and FUNDAÇÃO-GO (Goiás Foundation, a private research

institute) got together to develop a control program that would make it possible to decrease pest infestations to controllable levels, and keep cotton feasible.

The program, first implemented four years ago, has proven itself success. Cotton growers are joining the program and, in addition to the institutions mentioned above, state agencies, research institutions and specialist consultants have decided to take part in this initiative. The results have already become visible and the program is now a model for other Brazilian states. It is the foundation for the implementation of a pest control program that is currently being studied with a view to generalized implementation throughout Brazil and in other MERCOSUR countries.

The program consists, basically, in setting up traps in the planted areas to measure the level of boll weevil infestation and, on the basis of that information, determine the measures to be adopted. The main control actions are: application of insecticide on border plants; 2 to 3 applications after the appearance of the first flower bud; use of insecticides every time 5% of the flower buds are attacked; another series of 2 to 3 applications approximately 90-100 days after emergence.

The delay in the approval and release of biotech cotton has cost cotton growers a lot of money. Transgenic technology could be lowering the cost of production by 20% or more because of its added resistance to caterpillars and herbicides. Caterpillars represent a significant problem, most especially the *Heliothis virescens*, *Spodoptera* spp., and the *Pectinophora gossypiella*. Several insecticides from different chemical groups are being used to control caterpillars, and the best results have been obtained when organophosphate insecticides are rotated with others from the carbamate group.

Other pests that command special attention are aphids, mites and stink bugs. Some of the most common cotton varieties are particularly sensitive to a viral disease called Blue disease, transmitted by aphids. Regions that are vulnerable to Blue disease must be managed aggressively to keep the infestation level below 5%. The products used to control this pest are very specific and that is why costs are high as compared to the cost of products designed for varieties that are more resistant to Blue disease. Strategies to achieve pest management include the adoption of different forms of control. This implies strict observance of the levels of economic damage that have been previously defined by research, rational use of agrichemicals to prevent environmental pollution and safe practices to ensure that farm labor is protected.

Diseases Management

Demands from industry for better quality and productivity forced Brazil to import varieties that were not very well suited to our soil and weather conditions. These varieties are more sensitive to diseases such as areolate mildew, ramulosis, ramularia, bacterial blight, stemphylium and other important diseases that may yet become bigger problems. To control these diseases, farmers have developed strategic programs that rely on safe products, such as benzimidazole, triazol and strobryl to mention just the most commonly used.

Management begins from the moment the first flower opens and continues through the terminal growth stage, normally at 50 to 60 days, and up to until 120 days. During this time, treatment is needed every 15 days (50, 65, 80 and 95) or as symptoms become visible and are detected in field inspections. Weather conditions play a significant role in disease infestation, and every year presents a different challenge.

Plant Growth Management

The correct use of growth regulators is another fundamental aspect that must be taken into account to achieve high productivity rates. Growth monitoring begins on the 20th day after emergence (DAE), and the first application is done approximately on the 28th-30th DAE. Making the first application at precisely the right time and in the exact dosages is of utmost importance to the process. Every possible precaution must be taken to ensure that it is done correctly so as to keep the amount of regulator to be used throughout the cycle at a minimum and to yield the best possible results. Our goal is to keep plant height at 1.1 to 1.2 m and internodes always smaller than 5 cm.

The main benefits to be gained from good management of growth regulators are better aeration of the crop (thus decreasing the incidence of ball rot); more efficient use of agrochemicals (better target coverage); greater retention of flower buds (since the plant will naturally direct photo-assimilators to its reproductive parts), and as a result, an increase in harvest yields.

Mechanized harvesting requires plants of short stature. Taller

plants result in greater contamination with leaves and stem particles. A great deal of attention has been paid to this aspect of cotton growing in an effort to improve the quality of the cotton for both domestic and foreign markets.

Harvesting and Processing

Growers have begun to pay more attention to these stages of the productive process because they are of crucial importance in ensuring cotton quality. If this process is not done correctly, the result will be low-quality cotton and the entire investment in the crop may be compromised. Therefore, crop management, as described above, must necessarily consider the harvest as an additional factor to be taken into account.

A uniform crop with plants of the same stature becomes ready for defoliation at the same time. Contemporary planning and programming of the cotton harvest requires the use of defoliant and/or boll openers in precisely the right amounts to achieve the desired lint quality. Boll openers (normally, ethephon-based products) are used on approximately 20% of the area. The aim is to begin harvesting and continue to the end without any interruptions, since planting is done intensively. The remaining area is defoliated approximately 10 days before picking.

Several measures are taken to preserve quality. For example, all paths and roads bordering cotton fields are always kept wet to reduce the level of dust in the planted area. Even so, harvesting is done separately on the edge of the plot, where the cotton may be stained by the red dust typical of the savanna soils.

Cotton ginning is currently one of our greatest concerns. Since the vast majority of the gins in Brazil are old and designed for manual operation, several adjustments have been made to preserve the quality of the lint and ensure that the cotton will be cleaner. New studies are currently under way to improve ginning so that the process will preserve the intrinsic characteristics of the fiber. Researchers are also trying to achieve the same goal by identifying better varieties with less foliage.

Final Considerations

Cotton growing in Brazil has surprised the world. It has managed to transform itself and recover its market position, turning the country from net importer into one of the world's largest cotton exporters in a relatively short period of time. The achievements of Brazilian agribusiness in this segment are due mostly to the efforts, dedication and organization of the growers and of the public and private institutions that are connected to cotton. However, for Brazil to become a more competitive player in the international market, there are still a great many challenges that need to be overcome.

In the area of modern technology, the country urgently needs to pass legislation to approve genetically engineered cotton if it is to increase its productivity and decrease current production

costs. Brazil needs to have improved, disease-resistant, better yielding varieties that are easily adaptable to the different growing regions in the country.

While Brazil already has the technological advances that play a considerable role in determining the ultimate outcome, the country must continue to improve in terms of farm management by focusing on efficiency, profitability, net yield, capitalization and long-term planning. At this point in time, the most important obstacles to the development of Brazilian cotton agriculture are beyond the reach of individual growers

and the economic viability of cotton as a crop still faces some major challenges that fall within the purview of the federal government: lack of investment in infrastructure; a monetary policy favoring high interest rates; lack of a long-term agricultural policy; unfavorable exchange rate policies for the industrial sector, and an unfavorable tax policy. Thus cotton growers are left with no other option than to go on working and fighting for survival while, at the same time, continuing to pursue new ideas incisively, in an organized manner and with great determination.

INTERNATIONAL COTTON ADVISORY COMMITTEE

The International Cotton Advisory Committee is an association of governments having an interest in the production, export, import and consumption of cotton. It is an organization designed to promote cooperation in the solution of cotton problems, particularly those of international scope and significance.

The functions of the International Cotton Advisory Committee, as defined in the Rules and Regulations are

- To observe and keep in close touch with developments affecting the world cotton situation
- To collect and disseminate complete, authentic and timely statistics on world cotton production, trade, consumption, stocks and prices
- To suggest, as and when advisable, to the governments represented, any measures the Advisory Committee considers suitable and practicable for the furtherance of international collaboration directed towards developing and maintaining a sound world cotton economy
- To be the forum for international discussions on matters related to cotton prices

Membership of the Committee, which represents the bulk of the world's production, trade and consumption of cotton, comprises the following governments:

Argentina
Australia
Belgium
Brazil
Burkina Faso
Cameroon
Chad
China (Taiwan)
Colombia
Côte d'Ivoire
Egypt

Finland
France
Germany
Greece
India
Iran
Israel
Italy
Korea, Rep. of
Mali

Netherlands, The
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