Nutrient Management for High Yield Cotton in Brazil

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Guidelines to interpreting analysis data and recommended fertilization practices are outlined for this unique cotton production center located within the Brazilian Cerrado.

Brazil's cotton production has seen large changes over the last four decades. During the 1980s, cotton production in Brazil was severely affected by the introduction of the boll weevil pest. Strong subsidies for foreign cotton also brought down internal demand for domestic lint. Those two factors, together with low technology adoption by growers, caused a drastic decline of cultivated land within the traditional growing regions of the Northeastern and Southern states. In the second half of the 1990s, cotton production migrated to the Cerrado, a vast tropical savanna eco-region of Brazil, where soybean growers sought an alternative crop for their rotation. Climate conditions, flat lands, domestic subsidies, and high technology adoption drove cotton production forward into a period of increasing yields and good lint quality making the cropping system competitive. In 2010, Brazil was the fifth largest cotton lint producer after China, India, United States, and Pakistan followed closely by Uzbekistan (FAO, 2012). Today, the states of Mato Grosso and Bahia represent 81% of Brazil´s total lint production of 1.88 M t. Brazil´s cotton production now occurs on a fourth of the cultivated area it did in the late 1970s, but total production has more than doubled while yield is over 10 times greater (**Figure 1**).

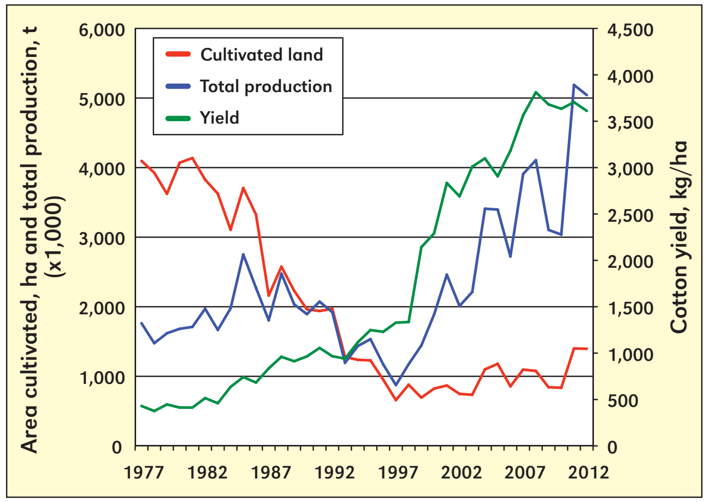

Figure 1. Cultivated land, total production and cotton yield in Brazil from 1977-2012 (Conab, 2012).

Table 1. Guidelines for interpretation of soil analysis for P and K in the Cerrado.

Interpretation class	P level: Soil clay content, g/kg <150	160-350	360-600	>600	K level: CEC <40 $mmol_c/dm^3$	CEC >40 $mmol_c/dm^3$
	mg/dm^3					
Very low	0-6	0-5	0-3	0-2	-	-
Low	6.1-12	5.1-10	3.1-5	2.1-3	<15	<25
Medium	12.1-18	10.1-15	5.1-8	3.1-4	16-30	26-50
Optimum	18.1-25	15.1-20	8.1-12	4.1-6	31-40	51-80
High	>25	>20	>12	>6	>40	>80

P and K extracted with Mehlich1.
Source: Souza and Lobato (2004).

Table 2. Guidelines for interpretation of soil analysis for other nutrients in the Cerrado.

Interpretation class	Mg $mmol_c/dm^3$	S mg/dm^3	B mg/dm^3	Cu mg/dm^3	Mn mg/dm^3	Zn mg/dm^3
Low	<5	≤4	0-0.2	0-0.4	0-1.9	0-1.0
Medium	5-10	5-9	0.3-0.5	0.5-0.8	2.0-5.0	1.1-1.6
High	>10	≥10	>0.5	>0.8	>5.0	>1.6

S level should be an average of the top 0 to 0.4 m soil layer.
Mg extracted with KCl 1 mol/L; S extracted with $Ca(H_2PO_4)$; B extracted with hot water; Cu, Mn and Zn extracted with Mehlich 1.
Source: Souza and Lobato (2004).

Cotton production systems in Brazil are very diverse. In Mato Grosso, growers are sowing cotton as a second crop after soybeans. This means the crop will grow during a period of shortened water supply (autumn) that favors fiber quality (no rain at harvesting) but it will also be more susceptible to failures in soil management practice. Cotton growers from Bahia sow their fields during the summer due to the rainfall concentration of this period which is adequate for plant growth. These situations permit the use of different nutrient rates and sources, as will be discussed later, and means that a wide range in fertilizer application rates is found in these regions.

Soil Analysis Guidelines

Guidelines for the interpretation of soil P, K and other nutrients specific to Cerrado soils are provided in **Tables 1 and 2**. As a general recommendation, cotton growers should maintain soil levels for nutrients within the optimum ranges, thus preventing deficiencies or excesses, since both limit yield and fiber quality.

Leaf Analysis Guidelines

Guidelines used for interpretation of leaf analysis are provided in **Table 3**. Cotton fertilization programs should also be adjusted so that the leaf nutrient concentrations are maintained within the optimum range.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; C = carbon; Al = aluminum; OM = organic matter; CEC = cation exchange capacity.

Table 3. Guidelines for interpretation of cotton leaf analysis for regular and high yield production systems.

Production system	N	P	K	Ca	Mg	S
	- - - Macronutrients - - -					
	- - - g/kg - - -					
Regular	35-43	2.5-4	15-25	20-35	3-8	4-8
High yield	40-45	3-4	20-25	25-35	4-8	4-6
	- - - Micronutrients - - -					
	B	Cu	Fe	Mn	Mo	Zn
	- - - mg/kg - - -					
Regular	30-50	5-25	40-250	25-300	0.5-1	25-200
High yield	40-80	8-15	70-250	35-80	1-3	30-65

Cotton leaf diagnosis is the fifth from the top at maximum blooming.
Source: Carvalho et al. (2007).

Soil Liming

Soil acidity is the major factor causing low cotton yields due to cotton's high sensitivity to Al toxicity. Also, low levels of Ca, Mg and the short availability of other nutrients such as P can affect cotton production. The goal of liming is to raise the base saturation to 60% in the topsoil (0 to 0.2 m layer), which generally brings Al availability down to zero in most Cerrado soils. It is also recommended to manage lime application so the level of Mg in the soil is raised and maintained to a minimum of 7, or ideally 10 $mmol_c/dm^3$ (Carvalho et al., 2007).

The evaluation of soil acidity should be a routine practice within a cotton fertilization program due to the continued use of acidifying N fertilizers. **Table 4** provides a comparison between the original chemical condition of a typical Cerrado soil and two current Cerrado soils under high yield cotton.

One important detail in these examples is the level of Al in the top 0 to 0.4 m layer for both situations: zero. This is crucial for any attempt to achieve high cotton yield along with avoidance of soil compaction, which reduces root growth preventing water and nutrient uptake.

Fertilizer Application

The recommendations of N, P and K fertilizer rates for cotton are based on yield expectation and soil analysis (**Table 5**) and may vary widely depending on different conditions. Nitrogen is a nutrient taken up in large amount by cotton, which depending upon the climate, cultivar, yield, soil conditions, and fertilizer rates can use 125 to 210 kg of N per tonne of lint produced (Carvalho et al., 2007). Due to its high mobility and dynamics in soil, farmers in the Cerrado have to take texture, OM content, crop rotation, and soil management into consideration to define the right N rate to be applied. In clay soils with high OM content (25 to 35 g/kg) under crop rotation and no-tillage, cotton will not be as responsive to N rate as it is in sandy soils low in OM (15 to 25 g/kg) or under annual tillage. The type of crop preceding cotton also matters to efficiently manage N fertilization (e.g., pasture or grasses with high C:N ratio may cause N immobilization during the early stages of cotton). Zancanaro and Tessaro (2006) suggest that N rates are managed as: 10 to 25 kg N/ha at planting as starter (in-furrow), 40% of recommended N rate at first square, and 60% at first flower (broadcast).

Initial K deficiency symptoms on a high yield cotton field.

Phosphorus application is necessary to achieve high cotton yields. In soils low in P, the response of cotton to P application may exceed the effect of other nutrients. In some Cerrado soils, P fixation is extreme and creates a strong competition between the soil and the plant, therefore liming becomes a best management practice to increase P availability and promote an efficient use by plants. Despite the intense response of cotton to P application, recent research has shown that in well-managed soils high in P, yield was not increased when P rates exceeded 100 kg P_2O_5/ha (Carvalho et al., 2007). Zancanaro and Tessaro (2006) also describe research results in clay soils high in P where no response was observed with P rates higher than 80 to 100 kg P_2O_5/ha and recommend the application of 60 to 70 kg P_2O_5/ha as sufficient to maintain soil fertility and high yields. Regularly, P application is made at planting time (in-furrow).

A very large amount of K is taken up by cotton. For high yields, the total uptake may reach 175 to 200 kg K_2O/ha per tonne of lint produced (Ferreira et al., 2004). Therefore, K application is the heart of the fertilizer management program

Table 4. Original and current soil chemical conditions in high yield cotton production systems in the Cerrado.

Depth	pH	OM	P†	K	Ca	Mg	Al	H	CEC	BS	Al‡
cm	$CaCl_2$	g/kg	mg/dm^3		- - - $cmol_c/dm^3$ - - -					%	
- - - Original (uncultivated) Cerrado, 17% clay - - -											
0 - 10	3.8	14	1.4	19	0.2	0.2	0.8	3.5	4.7	10	63
10 - 20	3.9	9	1.1	15	0.2	0.2	0.6	2.7	3.7	12	58
20 - 30	4.0	7	0.8	12	0.2	0.1	0.6	2.0	2.9	11	64
30 - 40	4.1	6	0.6	9	0.1	0.1	0.5	1.8	2.5	9	69
- - - Current conditions – site A, 17% clay - - -											
0 - 10	5.9	12	42	31	2.2	0.8	0.0	1.0	4.1	76	0
10 - 20	5.8	9	24	27	2.0	0.7	0.0	0.9	3.7	75	0
20 - 30	5.7	8	9	23	1.6	0.6	0.0	1.1	3.4	67	0
30 - 40	5.7	5	6	20	1.5	0.5	0.0	0.8	2.9	72	0
- - - Current conditions – site B, 42% clay - - -											
0 - 10	5.3	33	22	62	3.0	1.1	0.0	3.6	7.8	55	0
10 - 20	5.3	33	18	59	2.9	1.1	0.0	3.5	7.6	54	0
20 - 30	5.1	31	15	55	2.3	0.9	0.0	4.0	7.4	46	0
30 - 40	4.7	22	8	47	1.4	0.6	0.2	3.6	5.9	36	9

Soil conditions: (i) original Cerrado and site A: cotton field of a farm located in the state of Bahia, northeast region of Brazil; (ii) site B: cotton field of a farm located in the state of Mato Grosso, midwest region of Brazil.
† P-Mehlich 1.
‡ Al saturation.

Table 5. Fertilizer recommendations for cotton in the Cerrado, based on soil analysis and yield expectation.

Yield expectation[1]	N In-furrow	N Broadcast	Soil P Optimum	Soil P High[4]	Soil K Very low	Soil K Low	Soil K Medium	Soil K Optimum	Soil K High[4]
kg/ha	N, kg/ha		P_2O_5, kg/ha		K_2O, kg/ha				
3,000	15-20	60-80[3]	60	30	130	100	80	60	30
4,000	15-20	80-100	90	45	150-170	120-140	100-120	80	40
5,000[2]	15-20	100-120	110	55	170-190	140-160	120-140	100	50
6,000[2]	15-20	120-140	135	70	190-210	160-180	140-160	120	60

[1] Based on the highest attainable yield of the region or field with similar conditions of soil, cultivar and management practices.
[2] Less likely to obtain in areas with soil fertility under construction or precipitation under 1,200 mm on the first 160 days of the plant.
[3] Highest rates refer to areas with high potential yield response to N: low OM content; first year of no-till after grass crop. Lowest rates refer to areas with low potential yield response: crop rotation with legumes; several seasons of no-till and high OM content.
[4] On high P and K soil levels fertilization may be reduced or suppressed in years of high input:product ratio.

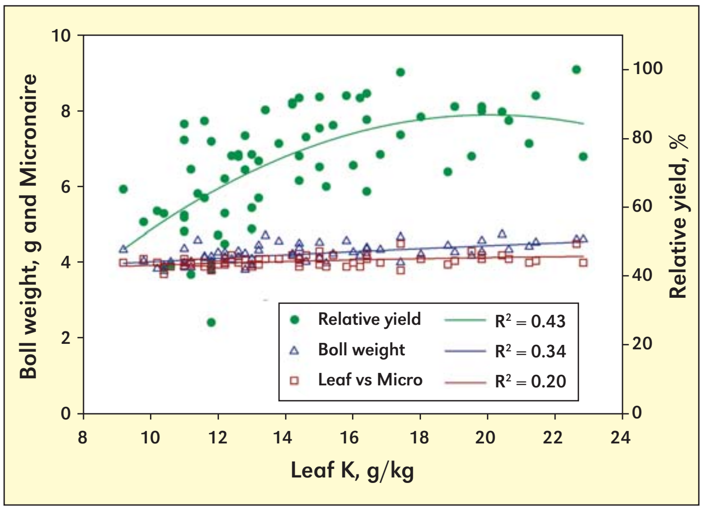

Figure 2. Response of cotton relative yield, boll weight and micronaire in relation to leaf K content (Francisco et al., 2011).

of any cotton production system in Brazil. Visual symptoms of K deficiency in cotton are: initial yellowing in between the veins of old leaves that will later develop brown spots, with the tips and margins showing a scorched appearance, and eventually turning reddish-brow and eventually falling off the plant. However, in modern cultivars with high yield potential and a short period of boll filling the intensity of K translocation in the plant is such that regular symptoms begin to show up on new mature leaves at the top of the plant.

Potassium recommendation may vary from 30 to 210 kg K_2O/ha depending on soil level and yield expectation (**Table 5**). Research has shown yield response with the application of 180 kg K_2O/ha in a soil low in K (30 mg/dm^3) and no response to the application of 60 kg K_2O/ha in a soil high in K (90 mg/dm^3). But caution is required regarding K leaching—especially in sandy soils. Carvalho et al. (2007) report results of a soil with 83% sand and CEC of 34 mmol$_c$/kg where only 66 mg/dm^3 of K was measured after an application of 320 kg K_2O/ha. They also report an increase in K levels at depth. Zancanaro and Tessaro (2006) recommend that K application must be split in sandy soils: 50 kg/ha of K at planting as starter (in-furrow) and the rest in two applications until first flower (broadcast).

In Mato Grosso state, where cotton is being grown as a second crop after soybeans in 60% of the cropped land farmers must keep watch on K status of plants due to the interaction with climate. Typically there is low rainfall during early reproductive stages followed by a total absence at harvesting time. Reeves and Mullins (2002) point out that K plays an important role for micronaire quality and is present at the highest proportion among cations in fiber composition. Therefore, low K status of the plants may severely affect fiber quality and yield. This is shown through the results of Francisco et al. (2011) with a study of K rates for cotton grown in a clay soil low in K and under the same condition described above (low rainfall during reproductive stages). **Figure 2** presents the relationship between leaf K content and relative yield, boll weight and micronaire. In all cases, a positive effect of better plant K status is observed.

Sulfur application generally occurs along with N or P fertilizers such as ammonium sulfate (22 to 24% S) and single superphosphate (10 to 12% S), or by the annual use of phosphogypsum at 400 to 600 kg/ha. But this management has become a challenge for growers since prices of ammonium sulfate and phosphogypsum have increased and the use of higher content P fertilizers, such as triple supherphosphate or monoammonium phosphate, has been preferred to reduce the time required to seed fields. The use of new phosphate fertilizers with high P and some S content is currently being evaluated and is being promoted for its convenience.

Boron is the only micronutrient applied regularly in cotton at rates ranging from 1.5 to 3.0 kg B/ha, generally as a soil application at planting. BC

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References

Carvalho, M.C.S., G.B. Ferreira, and L.A. Staut. 2007. *In* Nutrição, calagem e adubação do algodoeiro, E.C. Freire, (ed). pp. 581-648. Brasília, DF: Abrapa.

Conab. 2012. Acompanhamento da safra brasileira: grãos. Accessed on-line on February 2012.

FAO. 2012. Food and Agricultural Commodities Production. Accessed on-line on February 2012.

Ferreira, G.B., L.S. Severino, J.L. Silva Filho, and M.B. Pedrosa. 2004. *In* Resultados de pesquisa com a cultura do algodão no Oeste e Sudoeste da Bahia, safra 2003/2004, Embrapa (ed). pp. 80-106. Campina Grande: Embrapa Algodão.

Francisco, E.A.B., L. Zancanaro, and C. Kappes. 2011. *In* Adubação nitrogenada, fosfatada e potássica na cultura do algodoeiro em sistema de cultivo adensado. Research Foundation MT, 2011. Internal Report.

Reeves, G. and G.L. Mullins. 2002. *In* Beltwide Cotton Conference. Atlanta-GA, 2002.

Sousa, D.M.G. and E. Lobato. 2004. Cerrado: correção do solo e adubação. Brasília, DF: Embrapa.

Zancanaro, L. and L.C. Tessaro. 2006. *In* Calagem e adubação, Facual (ed). pp. 57-81. Cuiabá, MT: Facual.