Forgotten Boron: Lessons for Production Agriculture in Andic Soils of Guatemala

Mauricio Avila-Segura (NORDIC Fertilizers), Malcolm E. Sumner (University of Georgia) and Francisco Barneond (Ingenio Magdalena Guatemala)
mavila@nordic.com.gt, malcolm296@gmail.com and jbarneond@imsa.com.gt

ABSTRACT

The study of various crop problems in Guatemala yielded signs and data that point to mild to severe Boron (B) deficiencies. Crinkling of leaves, deformed adult tree crowns, short internodes, deformed and decaying roots, low sugar accumulation and susceptibility to diseases are some of the many symptoms found in crops that varied from bananas (*Musa paradisiaca*) to sugar cane (*Saccharum officinarum*) to rubber (*Havea brasiliensis*) to oil palm (Elaeis *guineensis*).

Despite the symptoms, in most cases the plant analysis showed concentrations that hovered slightly below or above the deficiency values for the crops and soils involved; therefore visual diagnostic disagrees with the currently accepted foliar and soil sufficiency ranges. Furthermore, boron is absent in most fertilization programs or used foliarly in quantities that do not match total B exports.

In Guatemala, crops such as bananas, sugar cane, and rubber often show B deficiency symptoms but few of them include B in their fertilization programs. There are about 250k has of sugarcane and about 65k has of bananas in Guatemala with average productivities of about 100TM ha^{-1} and 2500 boxes ha^{-1} respectively. If B is limiting in these crops, yield increases of 10 to 20% could be achieved with proper B fertilization. A 10% increase in yields would generate about $75M and $80M in increased gross income for sugarcane and bananas respectively.

This review of B deficiencies in soils and crops of Guatemala was performed as an initial step in redefining the diagnostic process, sufficiency ranges and B fertilization recommendations for major crops in Guatemalan agriculture. It also hints to the need to expand the diagnostic to other nutrients such as Zn, Mo and Ni.

Introduction

B functions

In plants, B performs a multitude of functions such as cell wall synthesis, cell membrane integrity and production of phenols (all essential for growth of meristematic shoot and root tissues), growth of reproductive tissues such as pollen tubes (Yamada, 2000), translocation of sugars, nucleic acid metabolism and nitrate and P absorption and assimilation (Alarcón, 2001; Camacho-Cristóbal, 2008).

Until recently, those functions were not well-known and many are not well-understood at this time. Typical visual symptoms of B deficiency are crinkling of new leaves, witches broom of new shots and roots, accumulation of sugars in leaves, and poor structural integrity of the plant as a whole with splitting, corking and hollowing of shoots (Alarcón, 2001).

B uptake and transport

Boron uptake has been shown to occur via three main pathways: a) passive diffusion through the lipid bilayer of roots cells; b) facilitated transport by protein channels; and c) active transport activated in response to low B supply (Camacho-Cristóbal *et al.*, 2008).

Once uptake takes place, the movement to the rest of the plant occurs mainly via the xylem with the transpiration stream. However, B can be moved also through the phloem in combination with various carbohydrates such as sorbitol and manitol (Camacho-Cristóbal *et al.*, 200) but the extent to which phloem transport is utilized varies with species and cultivars and overall it is seldom enough to fully supply young tissues with the B needed when low B availability occurs. Thus, crinkling and deformation of meristematic tissues are the hallmarks of B deficiencies in most crops and foliar fertilization is only a partial solution to the problem by eliminating such symptoms from the new growth.

The Signs of Boron Deficiency

Figure 1. Deformed banana roots


Figure 2. Crinkled banana leaves

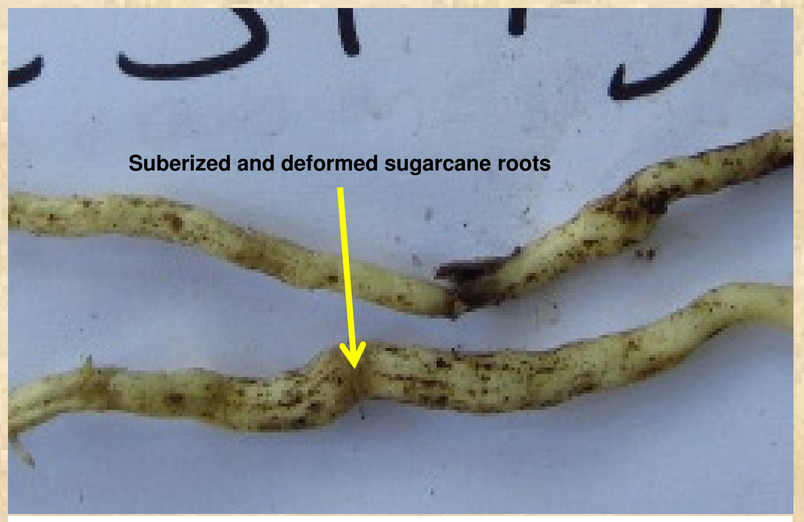

Figure 3. Suberized sugarcane roots


Figure 4. Crinkled sugarcane leaves

Figure 5. Deformed rubber tree crowns due to apical meristem death during development


Figure 6. Deformed oil palm leaves with dieback

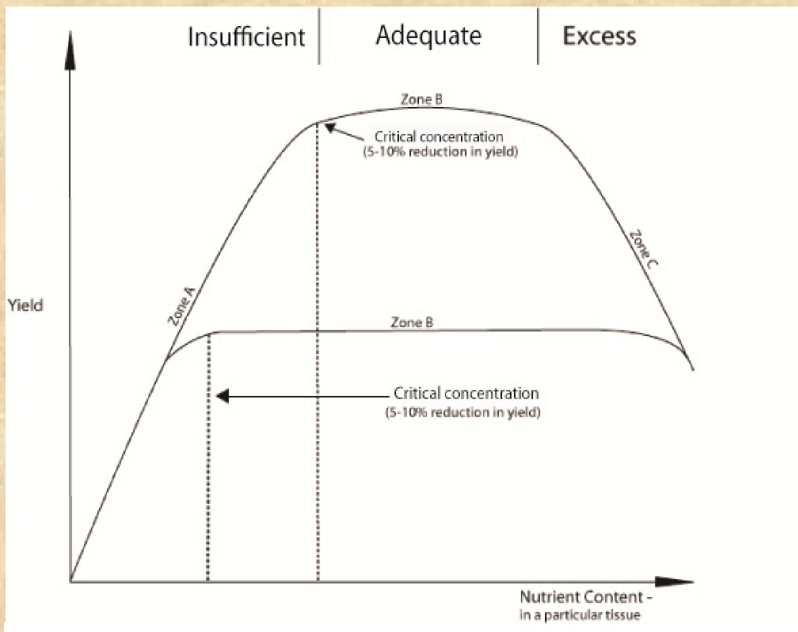

Figure 7. Relation between Yield & Nutrient Content

Soil and plant analyses data for B in sugarcane and bananas in Guatemala

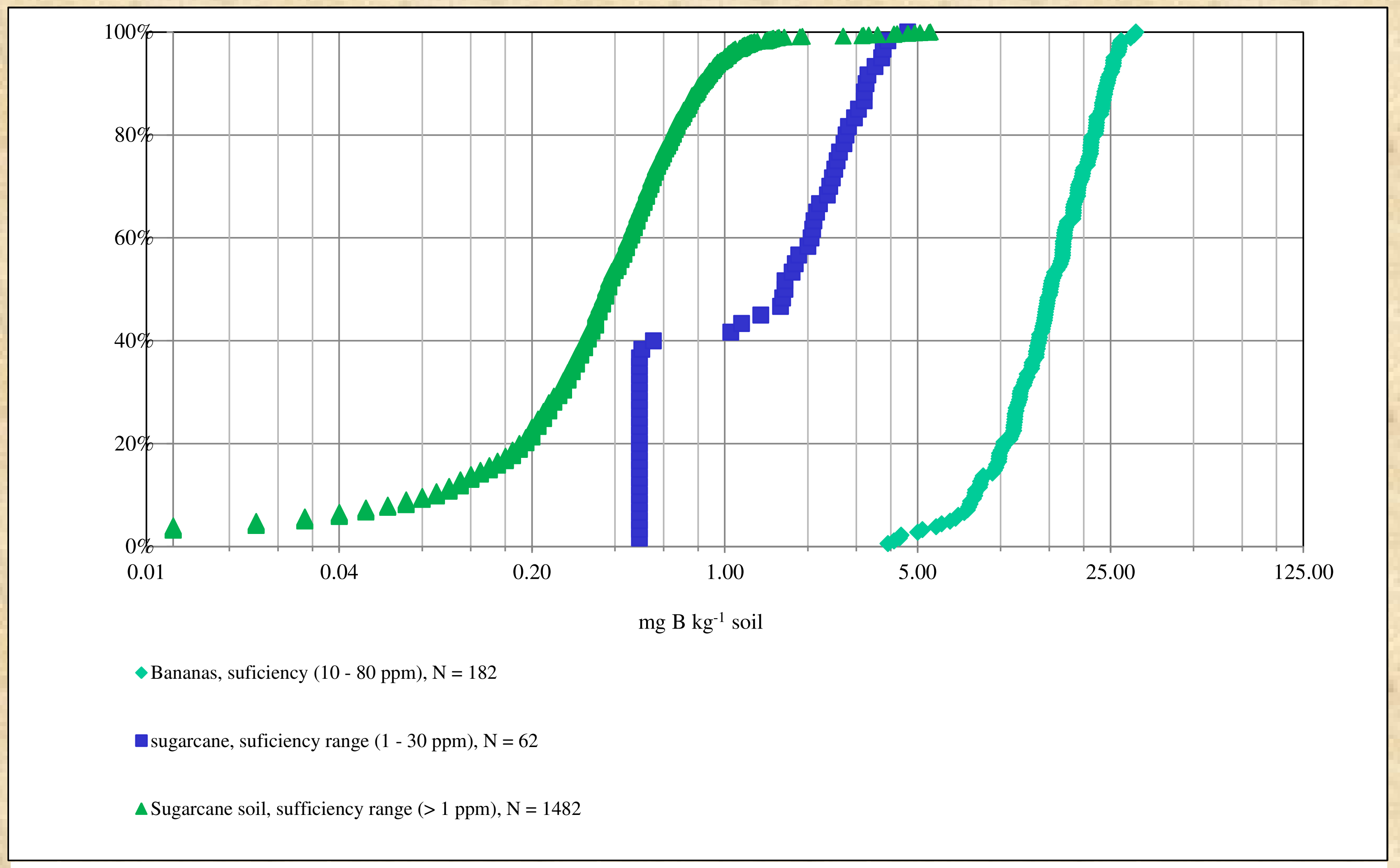

Figure 7. Cumulative distribution curves for foliar B in 14 banana farms, plus foliar and soil B in one sugarcane mill in Guatemala. The sufficiency ranges shown are those used by the labs to make fertilization recommendations to farmers.

To the untrained eye, the cumulative distributions for foliar B in bananas and sugarcane in Guatemala seem to indicate that B is adequate in nearly all plant samples. However, there are several problems with this data set:

a) in sugarcane, about 40% of the samples are at or below the limit of detection (0.5 ppm)
b) in sugarcane, although 60% of the samples appear to be above the indicated low end of the sufficiency range (1 ppm), 100% of the samples are below 5ppm even though the upper level for B sufficiency used for sugarcane is 30 ppm
c) a sugarcane sufficiency range of 1 – 30 seems too wide to provide a solid underpinning for management decisions with regards to B fertilization
d) in sugarcane, when the soil hot 0.01M $CaCl_2$ extractable B is measured, about 95% of the soils are below 1 ppm which is often cited as optimum
e) although the data for bananas does not show extreme deficiencies in most of the samples, all of them are near the lower end of the sufficiency range, which is likely a consequence of foliar B fertilization instead of soil based B fertilization and again the range used seems too wide
f) even though the banana farms have tissue analyses, neither of the 14 farms included B in their soil analyses that paired with these tissue samples and sugarcane also lacks this pairing

Table 1. Published B sufficiency ranges (in ppm) for banana and sugarcane

	Defficiency	Sufficiency Range	Toxicity	Reference
Sugar cane	< 2	2 – 15 1 – 30	ND	Alarcón, 2001 Jones *et al.*, 1991
Banana	< 10	20 – 80 10 – 80	> 300	Alarcón, 2001 Jones *et al.*, 1991

Use of foliar B in sugarcane (a partial solution)

Figure 8. Responses of sugarcane to foliar B fertilization (160 g B ha^{-1} split into two applications at 90 and 150 days)

Several foliar B fertilization trials are under way at Magdalena Sugar Mill (Figure 8) and the main responses observed are the elimination of the leaf crinkling and better root formation. However, due to low B mobility in the plant, foliar B fertilization a flash of nutrient that supports the next flash of growth but does not have enough to supply the entire plant (particularly the roots) with all the necessary boron for good growth and plant function.

Furthermore, adding B to the soil fertilization programs is not necessarily a solution because many soils in Guatemala present high pH and Andic properties which induce B fixation and low availability for plant uptake thus requiring the development of new fertilization formulations and application equipment and techniques in order to be successful.

Issues to be resolved regarding B nutrition and fertilization in Guatemala

The process by which B fertilization issues must be resolved implies redefining how the B deficiencies are identified, measured and managed and will require the following steps:

a) Agribusinesses must pair soil, tissue and yield data with regards to B nutrition and fertilization and determine the extent to which B deficiency limits productivity
b) Foliar and soil B fertilization trials must be conducted in every crop with risk of B deficiency in order to quantify the economic return of investing in B fertilization
c) Sufficiency ranges for B in soils and plants should be recalibrated in the next 10 years
d) The B fixing capacity of the major soil groups of the country must be determined
e) Devise strategies for effective B fertilization in high B fixing and high pH soils
f) The interactions between B and other nutrients (particularly Zn, Ca, P and N) need further study and experimentation in order to optimize their combined fertilization
g) Methods for soil and plant analysis must be revised and updated if necessary

References

Camacho-Cristóbal, JJ, J. Rexach, A. González-Fontes. 2008. Boron in plants: deficiency and toxicity. J. Integr. Plant Biol. 50(10):1247-55.

Alarcón, A.L. 2001. El boro como nutriente esencial. Horticultura. 155:1-11.

Yamada, T. 2000. Boro: será que estamos aplicando a dose suficiente para o adequado desenvolvimento das plantas? Informacoes Agronómicas 90: 1-5.

Jones JB, Wolf B, Mills HA. 1991. Plant Analysis Handbook. Micro-Macro Publishing inc. Athens, Gergia.

Molina, E. 2000. Nutrición y fertilización de la naranja. Informaciones Agronómicas. 40:5-13.