Boron Deficiency Symptoms in Palms

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1. Transverse translucent streaking symptoms of B deficiency induced in sand-cultured *Syagrus romanzoffiana*.

Boron (B) deficiency is one of the most common and widespread of all nutrient deficiencies in palms. It occurs in palms growing in high rainfall areas of the tropics, but is also found in palms growing in desert climates (Elliott et al. 2004). Foliar symptoms for most nutrient deficiencies are usually rather specific for a particular species, but those for B deficiency are extremely diverse within a single species, yet vary little among species.

Since B deficiency is a serious problem in the commercial production of coconut (*Cocos nucifera*) and African oil palms (*Elaeis guineensis*), a number of studies have attempted to document the various symptoms associated with this disorder in those species. Several symptoms believed to be caused by B deficiency have never been induced experimentally in sand or hydroponic culture. The purpose of this study was to induce experimentally in sand culture the various symptoms associated with B deficiency. These symptoms will be described and illustrated, with evidence presented linking them to B deficiency.

Materials and Methods

Medium grade silica sand was used for the potting substrate. It was rinsed thoroughly with tap water, soaked for 48 hours in 2N NH_4OH solution, rinsed thoroughly with tap water, soaked for 48 hours in 1N HCl solution, and finally leached with a minimum of 12 liters of deionized water per 4-liter batch of sand. The root balls of one-year old *Syagrus romanzoffiana* and *Phoenix roebelenii* seedlings growing in 1-liter containers were rinsed free of old potting soil prior to planting. The cleaned palm seedlings were transplanted into 4.6-liter plastic containers using the acid washed sand. Twelve replicate palms of each species received 2 liters of nutrient solution containing all essential nutrients except B every Friday, while four additional control palms of each species received 2 liters of the same solution that also contained B. The composition of the nutrient solution used is shown in Table 1. All palms received 2 liters of deionized water per container on Mondays and Wednesdays to prevent a salt buildup in the containers. All palms were grown in an open-sided greenhouse in Fort Lauderdale, FL

2. Tightly fused leaflets in second spear leaf of B-deficient *Syagrus romanzoffiana*.

Table 1. Composition of nutrient solution used to induce boron deficiency symptoms in *Syagrus romanzoffiana* and *Phoenix roebelenii* seedlings.

Element	Source	Concentration (ppm)
Nitrate-nitrogen	Calcium nitrate	150
Ammonium-nitrogen	Ammonium sulfate	150
Phosphorus	Potassium phosphate dibasic	50
Potassium	Potassium phosphate dibasic	
	Potassium chloride	200
Magnesium	Magnesium sulfate	60
Sulfur	Ammonium sulfate	
	Magnesium sulfate	428
Iron	Ferric EDDHA	3
Manganese	Manganese sulfate	2
Copper	Cupric sulfate	0.03
Zinc	Zinc sulfate	0.05
Molybdenum	Molybdic acid	0.01
Chlorine	Potassium chloride	67
Boron*	Boric acid	0.5

*Control (+B) solutions only

3. Chronic B-deficient *Phoenix roebelenii* showing multiple spear leaves with fused leaflets.

4 (far left). "Hook leaf" in *Cocos nucifera*, a symptom of mild transient B deficiency.

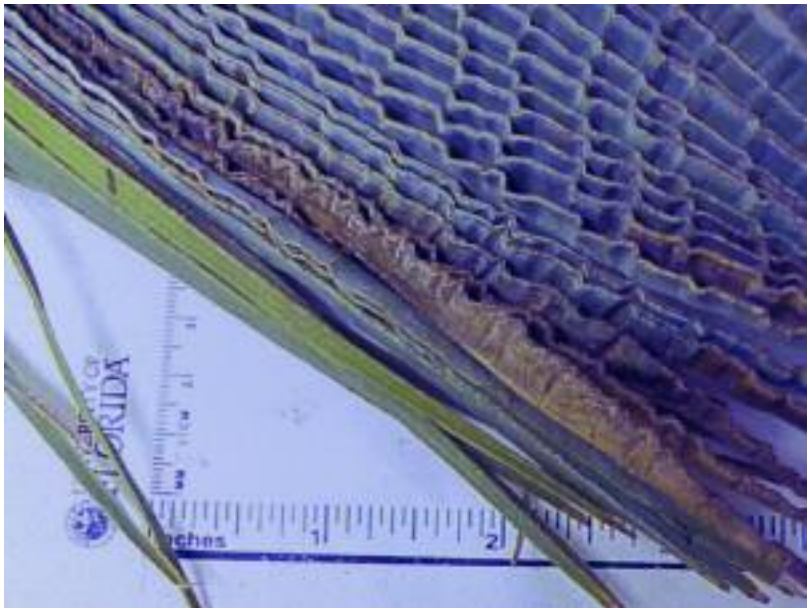
5 (left). Puckered leaflets in *Syagrus romanzoffiana* caused by mild B deficieny.

for two years. Similar numbers of another monocot, *Dracaena marginata*, a species known to be sensitive to B deficiency, were similarly treated for comparative purposes. Boron deficiency symptoms were described and documented photographically as they occurred. No control (+B) palms ever showed any abnormalities in their appearance.

Separately, the author was given 100 *Syagus romanzoffiana* seedlings growing in 2-liter containers in a potting mix that exhibited various B deficiency symptoms. Approximately 300 mL of a 125 mg B/L solution of Solubor (a mixture of sodium tetraborate and sodium pentaborate, US Borax, Valencia, CA) were drenched into each pot containing symptomatic seedlings. The seedlings were monitored for recovery from symptoms.

Symptoms of B deficiency

Transverse translucent streaking. This symptom appeared on newly-emerging leaves of all –B replicates of *S. romanzoffiana* and *D. marginata* in our experiment and was the first symptom to appear (Fig. 1). Marlatt (1978) described similar symptoms from a sand culture study using *Dypsis lutescens*. In sand-cultured *E. guineensis*, these streaks are considered to be the earliest stage of B deficiency, and may be either longitudinal or transverse in orientation within a leaflet (Bull 1961, Corrado et al. 1992, Dufour & Quencez 1979, Ollagnier & Valverde



6. Corrugated leaflets in *Butia capitata* caused by mild B deficiency.

7. Crumpled leaf ("Accordion leaf"), a symptom of severe B deficiency in *Heterospathe elata*.

1968, Rajaratnam 1972b). Anatomically, these streaked areas have been shown to be reduced in thickness and lack palisade, and often spongy mesophyll cells (Rajaratnam 1972b). Surprisingly, these fine translucent streaks are rarely, if ever, observed in older palms growing in the landscape.

Fused leaflets. One of the most common symptoms associated with B deficiency in mature landscape palms is a fusion or welding together of leaflets of newly emerging leaves. This fusion can affect leaflets along the entire length of the rachis or it may be restricted to either basal or distal portions of the leaf (Fig. 2). In a chronic state, multiple incompletely opened new leaves may be present within the palm canopy (Fig. 3). Although some *Phoenix* spp. typically display several young leaves of varying lengths, the presence of more than one full-length unopened spear leaf is abnormal and cause to suspect B deficiency.

Leaflet fusion was observed in two *S. romanzoffiana* seedlings grown without B in our sand culture experiment. It has been induced in sand culture in *E. guineensis* (Rajaratnam 1972a, Dufour & Quencez 1979) and *Caryota mitis* (Broschat 1984) and has been attributed to B deficiency in *Cocos nucifera* by

8 (top left). Little-leaf or "fish-bone" symptoms of B deficiency in *Dictyosperma album.* Note that the trunk is also bent in this palm and that it died shortly after the photo was taken. 9 (top right). *Cocos nucifera* showing the truncated leaf tip effects of three temporary B deficiency events during the development of a single leaf. 10 (bottom left). Truncated leaf tip in B-deficient *Pritchardia* sp. 11 (bottom right). Narrow terminal leaflets on B-deficient *Syagrus romanzoffiana* beginning to fall off.

12. Chronically B-deficient *Syagrus romanzoffiana* showing bare rachis tips on all but the youngest leaf. Although B deficiency symptoms affect only young leaves, the symptoms remain visible throughout the life of the leaf as shown here.

13. Chronically B-deficient *Adonidia merrillii* showing little-leaf and trunk bending symptoms.

Manciot et al. (1980), Brunin and Coomans (1973) and Kamalakshiamma and Shanavas (2002).

"Hook leaf." This symptom is best described as an acute zigzag near the tip of palm leaflets (Fig. 4). These leaflet "hooks" are quite rigid and cannot be straightened out without tearing the leaflets. They appear to be symptoms of a mild and transient B deficiency. They may be the only symptom present on a palm, or may be associated with other symptoms. Although we were not successful in inducing hook leaf symptoms in this experiment, Broeshart et al. (1957) and Rajaratnam (1972b) were able to induce this symptom in *E. guineensis* growing in sand culture.

Hook leaf is common in *C. nucifera* and *E. guineensis* and has been attributed to B deficiency by Brunin and Coomans (1973), Manciot et al. (1980) and Ollagnier and Valverde (1968). This author has observed this symptom in *S. romanzoffiana, Washingtonia robusta, Sabal palmetto,* and *Howea forsteriana* growing in Florida landscapes.

Crumpled leaf (*"Accordion leaf"*). The mildest form of this symptom is a puckering or corrugation within leaflets of newly-emerging leaves (Figs. 5 & 6). In more severe states, new leaves emerge completely crumpled and greatly reduced in size (Fig. 7). Although we successfully induced this symptom in only one *S. romanzoffiana* seedling in sand culture without B, it a common symptom in both

14. Sharply bent petiole on *Syagrus romanzoffiana* caused by a temporary B deficiency during the development of the petiole.

seedling production and mature palms, where it is often associated with other known B deficiency symptoms. This symptom has been described for *C. nucifera* by Kamalakshiamma and Shanavas (2002) and *E. guineensis* by Broeshart et al. (1957) and Corrado et al. (1992). This author has also observed this symptom in *Butia capitata, S. romanzoffiana, Heterospathe elata,* and *Phoenix roebelenii* in container production and in Florida landscapes. Our *S. romanzoffiana* seedlings showing this symptom in container production recovered following a drench with Solubor.

It is important to note that newly-emerging lateral shoots in juvenile *Dypsis lutescens* typically show crumpled leaf symptoms. This condition is caused by the physical pressure exerted upon the new lateral spear leaf as it emerges through the side of the crownshaft. This is normal for this species and perhaps other clustering crownshaft species as well.

Little leaf. New leaves exhibiting this symptom emerge greatly reduced in size, typically with shortened, necrotic-tipped leaflets that are partially fused together (Fig. 8). This symptom is often referred to as "fish bone" in *E. guineensis* (Corrado et al. 1992, Rajaratnam 1972b). In severe cases only necrotic petiole stubs emerge and death of the meristem often follows. Although we were not successful in inducing this symptom in this study, we did observe these symptoms in an earlier sand culture study with *Chamaedorea elegans, Caryota mitis,* and *Howea forsteriana* (Broschat 1984). Marlatt (1978) reported the emergence of small, necrotic leaves followed by bud death in sand-cultured *D. lutescens*. Similarly, little leaf symptoms have been induced in sand-cultured *E. guineensis* (Bull 1961, Rajaratnam 1972b). These symptoms have been documented in B-deficient field-grown *C. nucifera* by Brunin and Coomans (1973) and Manciot et al. (1980). This author has also

observed little leaf symptoms on *Dictyosperma album, Adonidia merrillii, Roystonea regia, Dypsis* spp., and *Veitchia* spp. in Florida landscapes.

Leaf tip truncation. Young leaves showing this symptom have tips that are distinctly angular, rather than rounded as in normal leaves (Fig. 9). The identical effect has been achieved by simply cutting the tip of an unopened spear leaf with a shears. When that leaf opens up, the previously folded leaflets will all have their tips truncated, their final length being proportional to the distance of their attachment point from the tip of the rachis. This symptom, therefore, is caused by an acute, but very short duration, B deficiency. Based on growth rates of spear leaves, it appears that deficiencies lasting no more than a day or two are responsible for localized (ca. 1 cm) necroses along the spear leaf axis during its development. Although this localized necrosis and the truncated leaflets that it causes, typically occur at the tip of the leaf, as many as three such necrotic points have been observed on a single *C. nucifera* leaf (Fig. 9). Since it takes about five weeks to produce a single leaf in this species (Broschat 1997), this implies that a short duration B deficiency occurred approximately once every twelve days. Boron is highly leachable through all soil types and B deficiency is usually associated with heavy rainfall and/or irrigation events. Once leaching stops, B release from decomposing organic matter in the soil again provides adequate B for normal palm growth in most environments.

Although leaf truncation is a rather common symptom, it had not previously been induced in sand culture for *E. guineensis* and was only casually mentioned in literature pertaining to B deficiency symptoms in *C. nucifera* (Kamalakshiamma & Shanavas 2002) and *E. guineensis* (Rajaratnam 1972b). In our study we observed this symptom in two *S. romanzoffiana* and two *P. roebelenii* seedlings grown without B. In the latter, we observed that some of the leaflets tips truncated by the B deficiency-induced necrosis fell off after the emergence and opening of the spear leaf. This author has also observed this symptom on *Pritchardia* sp. and *Bismarckia nobilis*, where the entire tip of the fan leaf is truncated with a necrotic edge (Fig. 10).

Bare rachis tip. This symptom had been observed only in mature *S. romanzoffiana*

15. Twisted (epinastic) leaves of *Hyophorbe lagenicaulis* with chronic mild B deficiency.

16. Lateral growth axis of B-deficient *Veitchia joannis* that has forced itself through the lateral wall of the crownshaft's older leaves. This gives the appearance of having a branched stem. 17. Premature fruit drop in *Cocos nucifera* caused by B deficiency.

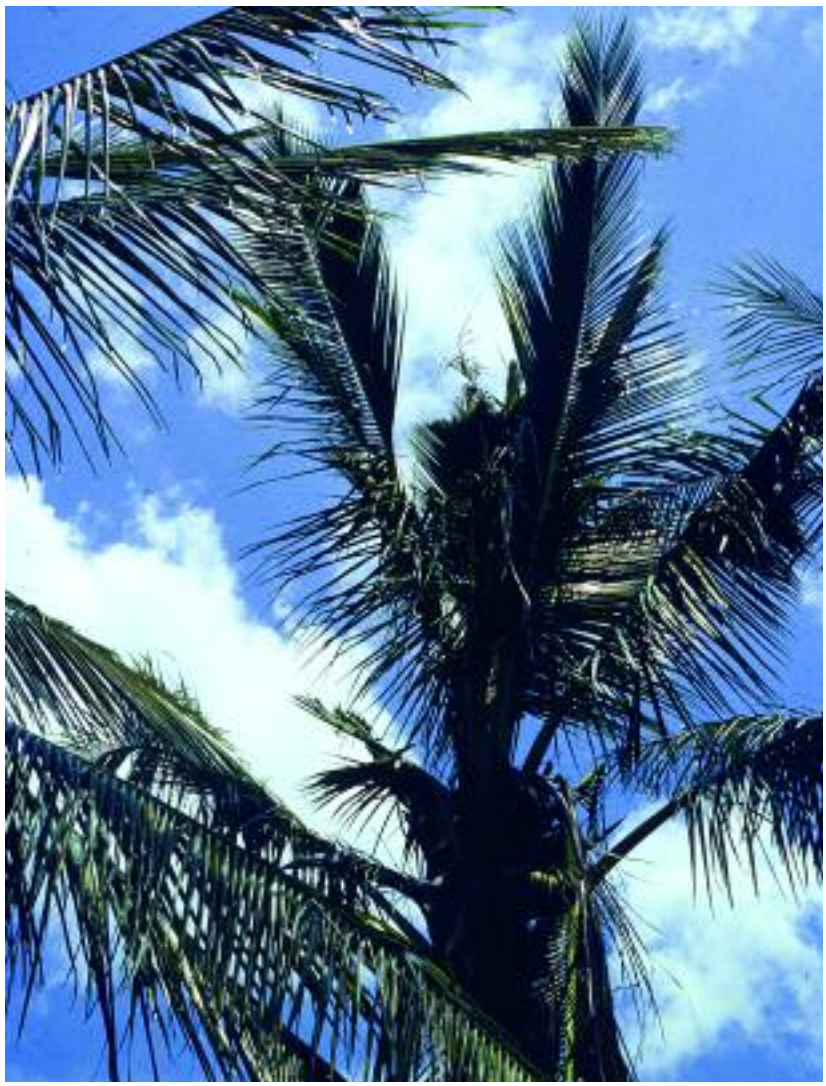
growing in Florida landscapes. New leaves appear normal when they emerge and open, except that the distal leaflets appear narrower than usual (Fig. 11). Within a month or so these distal leaflets begin to fall off, leaving the distal 20 cm or more of the rachis devoid of leaflets (Fig. 12). We observed this symptom in three *S. romanzoffiana* seedlings in our sand culture experiment grown without B.

Epinasty and trunk bending. Palms in the landscape occasionally are seen to be growing laterally and perpendicularly to the vertical trunk axis (Fig. 13). This symptom has never been mentioned in other studies on B deficiency in *Cocos* or *Elaeis*. We were able to easily induce this symptom in *D. marginata* in sand culture without B in this experiment and in a similar one done about twenty years earlier (Broschat, unpubl. data). This was the first clue that this loss of geotropism in palms was caused by B deficiency. The presence of more typical B deficiency symptoms on most palms showing this bent trunk provided additional evidence linking this symptom to chronic B deficiency. Although we did not induce this symptom in our sand cultured palms, it was observed in about ten *S. romanzoffiana* seedlings in production containers. Treatment of these seedlings with Solubor corrected their growth orientation.

Boron-deficient *E. guineensis* are known to have superoptimal concentrations (about 500 ppm) of indole-acetic acid (IAA), the plant hormone associated with geotropic responses (Rajaratnam 1972b). He found that spray applications of IAA at concentrations of 300 ppm induced little leaf symptoms identical to those of B deficiency. Although most palms showing stem bending grow more or less horizontally, some obviously B-deficient palms actually grow downward, with a twisting of the stem axis as well. Other palms may show sharp bending of the petioles (Fig. 14) due to a temporary B deficiency during petiole development. Some palms may exhibit leaves twisted along the entire length of the petiole and rachis (Fig. 15). These epinastic symptoms appear to be variations on the trunk bending theme and are likely also mediated by excessive auxin (IAA) concentrations.

Some B-deficient palms with crownshafts may appear to have developed a branched crown, but closer examination of such palms has

18. Inflorescence necrosis in *Syagrus romanzoffiana* caused by B deficiency.



19. Boron-deficient *Cocos nucifera* showing multiple and intermediate foliar symptoms.

revealed that the new growth axis has bent sharply and is simply pushing through the base of the crownshaft of older leaf bases (Fig. 16). However, true branching has been observed in two B-deficient *S. romanzoffiana* where other symptoms such as little leaf and epinasty were present on both shoots. Boron deficiency resulted in death of the apical meristem, followed by proliferation of subapical shoots in all B-deficient sand-cultured *D. marginata*. The author has observed these trunk bending and/or epinasty symptoms on *S. romanzoffiana, Roystonea regia, Howea forsteriana, Hyophorbe lagenicaulis,* and *Adonidia merrillii* growing in Florida and California landscapes.

Brittle leaf. Although this symptom is not visible, leaves showing little leaf, crumpled leaf or other symptoms are noticeably brittle. This symptom was apparent on all sand-cultured *S. romanzoffiana* having malformed leaves.

Inflorescence necrosis and premature fruit drop. Necrosis of palm inflorescences has been induced in sand-cultured *Chamaedorea elegans* (Broschat 1984). Floral necrosis and premature nut drop are associated with B deficiency in *C. nucifera* (Kamalakshiamma & Shanavas 2002) (Fig. 17). They also noted that fruits of B-deficient *C. nucifera* were often cracked, had blackened husks, or lacked a shell. They found a strong correlation between copra production and B fertilization rates.

It is important to note that lethal yellowing disease (LY) of *C. nucifera* is also characterized by inflorescence necrosis and premature fruit drop (Elliott et al. 2004). The fruits of LY-affected palms will usually show blackening of the calyx end, whereas B-deficient fruits will exhibit only random browning, if any, of immature fruits. Look for other foliar symptoms of either LY or B deficiency to distinguish between these two disorders. This author has also observed floral necrosis on B-deficient *S. romanzoffiana* growing in Florida landscapes (Fig. 18).

Other symptoms. The symptoms described above are by no means the only ones associated with B deficiency in palms. Leaves having abnormally thin leaflets sparsely spaced along the rachis were produced in two of the sand cultured *S. romanzoffiana* without B in this study. On the other hand, Kamalakshiamma and Shanavas (2002) reported that abnormally compact leaves with essentially no distances between leaflets were associated with B deficiency in *C. nucifera*. The symptoms described above are typical, yet symptoms intermediate between two or more of the above symptoms are also commonly observed (Fig. 19). One of the few symptoms associated with deficiencies of other nutrient elements that is not typical of B deficiency is chlorosis. It is also important to keep in mind that while all B deficiency symptoms develop on newly emerging leaves, they will remain on these leaves as they age and are naturally forced down into lower positions within the palm canopy (Fig. 12). Thus, in the case of a transient B deficiency first observed many months following its actual occurrence, the only symptomatic leaf may well be located in the middle or even lower parts of the canopy. Fortunately, none of the nutrient deficiencies that affect older leaves (N, P, K or Mg) show symptoms other than chlorosis, discoloration, or leaflet tip necrosis (Elliott et al. 2004), and thus should not be confused with old B deficiency symptoms.

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