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Nutrient Deficiency Symptoms in Five Species of Palms Grown as Foliage Plants[1]

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Proper fertilization is important for the growth of any plant, but especially in plants grown in soil-less media with little or no inherent fertility. Omission of any essential nutrient element from the fertilization regime of such plants can rapidly result in nutrient deficiency symptoms. Deficiency symptoms for most essential elements are known for most important food and fiber producing plants, but relatively little is known about specific nutritional disorders of tropical foliage plants, particularly the palms. Through the use of sand culture techniques (Hewitt 1966), it is possible to induce experimentally deficiency symptoms of most essential elements in plants, thereby relating specific symptoms to a deficiency of a single element. This has been done for palms such as coconuts (Manciot et al. 1979–1980) and oil palms (Bull 1958, Broeshart et al. 1957, Bull 1961*a*, Bull 1961*b*) which are grown as plantation crops, but limited work has been done on commercially important species grown as foliage plants (Marlatt 1978, Marlatt and McRitchie 1979). The purpose of this study was to induce experimentally and describe deficiency symptoms for all essential nutrient elements in 5 species of palms commonly used in interiorscapes.

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Materials and Methods

Seedlings of *Chamaedorea elegans* Mart., *Phoenix roebelenii* O'Brien, *Caryota mitis* Lour., *Chrysalidocarpus lutescens* H. A. Wendl., and *Howea forsterana* (C. Moore & F. J. Muell.) Becc. were grown in sand culture to induce deficiency symptoms of all essential nutrient elements. Medium grade silica sand was prepared for use as a growing substrate by the following procedure:

Particulate impurities were floated off by agitation of the sand under running tap water until the effluent was clear. Twelve-liter batches of sand were placed in 15 liter capacity polypropylene containers with small drainage holes in the bottom. Each batch of sand was rinsed with 9 liters of deionized water, soaked in 1 N HCl for 30 minutes with agitation every 10 minutes, soaked in 6 N HCl with agitation for 30 minutes, rinsed with 3 liters of deionized water, soaked in 1 N HNO_3 with agitation for 30 minutes and finally, rinsed with a minimum of 10 liters of deionized water. Sand used for induction of boron deficiency was also soaked with agitation in 2 N NH_4OH. Sand used for chlorine deficiency induction was treated with 1 N and 6 N H_2SO_4 instead of HCl, while sand used to induce nitrogen deficiency was not treated with HNO_3.

Healthy 8–12-month-old palm seedlings were washed to remove all soil from the roots and were planted in the acid-washed sand in 10-cm square polypropylene containers with polypropylene mesh placed over the drainage hole to prevent loss of sand. Five replicate plants of each species were placed in 14 separate chambers, one for each of the 13 missing elements plus a control (all essential elements provided). Plants were maintained indoors under cool white fluorescent illumination (88 $\mu E/m^2/sec$) (16 h photoperiod) at 23 ± 2° C. They were irrigated once per week with one–half strength Hoagland's solution (Hoagland and Arnon 1950) for the control plants or half strength Hoagland's solution minus each of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, or Cl. Plants were also irrigated twice per week with deionized water only. Nutrient solutions were prepared using reagent grade chemicals and deionized water.

Deficiency symptoms were described as they occurred on each plant. An attempt was made to restore normal growth to the deficient palms by supplying Hoagland's solution including the deficient element. This was generally successful for N, P, Mg, and S, but with severe Ca, B, Mn, Zn, and Mo deficiencies, death of the meristem prevented recovery by the palms.

Results and Discussion

Nitrogen deficiency symptoms appeared in all five species of palms as a gradual loss of green color, first on oldest leaves, but eventually throughout the foliage. Nitrogen-deficient palms grew much more slowly, and had fewer and smaller leaves than control palms. Symptoms first appeared after about four months for *Chamaedorea*, but all species showed severe symptoms after seven months without nitrogen. After returning the deficient plants to a complete fertilizer solution, recovery was complete within four months for all species.

Growth of all 5 species of palms ceased almost immediately after they were placed in a phosphorus-free environment. Leaf color remained normal for about 7 months, but gradually faded to a light olive green color (Fig. 1). The leaves of phosphorus-deficient *Caryota* turned completely yellow after 11 months, however. Since no new leaves were produced in the absence of P, the plants eventually lost all but one or two of the newest leaves. Plants began to recover about four months after restoration of P to the fertilizer solution.

Potassium deficiency symptoms first appeared as necrotic spots or blotches on lower leaves of *Chamaedorea*, *Caryota*, and *Howea* about 9 months after starting the experiment (Fig. 2). Similar symptoms appeared on *Chrysalidocarpus* after two years. The necrosis was confined to the margins of older leaflets of potassium-deficient *Chamaedorea*, but in other species appeared within the older leaflets as streaks (*Howea* and *Caryota*) or spots (*Chrysalidocarpus*). Obvious potassium deficiency symptoms were not apparent in *Phoenix* within two years. Recovery of *Howea*, *Caryota*, and *Chrysalidocarpus* for potassium deficiency occurred within four months, but due to the severity of the symptoms the *Chamaedorea* did not recover.

Symptoms of calcium deficiency first appeared in *Chamaedorea* and *Howea* after about six months as stunted, deformed new leaves (Fig. 3). Newly emerging leaves failed to expand normally with leaflets becoming necrotic, leaving only the petiole base alive. Only necrotic petiole stubs emerged in succeeding leaves, the leaflets and most of the rachis having died before completely developing. These necrotic petiole stubs were usually water-soaked in appearance. Calcium deficiency eventually killed the meristem in these palms so that recovery was not possible. Calcium deficiency symptoms were not induced in *Caryota*, *Chrysalidocarpus*, or *Phoenix*.

Magnesium deficiency symptoms appeared first in *Chrysalidocarpus* as

1. Phosphorus-deficient *Chamaedorea elegans* (left) showing stunted growth compared to control plant (right).

interveinal chlorosis of the oldest leaves. After nine months the oldest leaves of *Chamaedorea*, *Phoenix*, *Caryota*, and *Howea* began to yellow, progressing from the lateral margins of each leaf inward as symptoms progressed (Fig. 4). The rachis and veins of these leaves initially remained green, but under severe magnesium deficiency, the oldest leaves became completely yellow with progressively more

2. Lower leaf of *Chamaedorea elegans* showing marginal necrosis typical of K deficiency.

3. Calcium-deficient *Howea forsterana* showing necrotic new leaf.

green on the veins and rachis of younger leaves. Recovery from magnesium deficiency required 6–9 months after restoration of magnesium to the fertilizer solution during which time the chlorotic lower leaves were replaced by healthy leaves.

Sulfur deficiency symptoms appeared in *Chamaedorea*, *Howea*, and *Caryota*

4. Magnesium-deficient *Chamaedorea elegans* with severe chlorosis on oldest leaves.

5. Sulfur-deficient *Chrysalidocarpus lutescens* (left) with uniformly yellow new foliage. Control plant on right is normal green color for this species.

palms after about one year and in *Chrysalidocarpus* after nearly two years. Symptoms were similar in these four species and appeared as uniform yellowing of the new leaves (Fig. 5). As the deficiency progressed, new leaflets often showed necrotic tips. Older leaves remained green in all but the most severely deficient plants, however. Sulfur deficiency was not induced in *Phoenix* and recovery of the other four species required about seven months.

Caryota, Phoenix, and *Chrysalidocarpus* showed iron deficiency symptoms after about one year. Symptoms were identical for these species and consisted of interveinal to general chlorosis of the newest leaves, the older leaves remaining green (Fig. 6). After two years *Chamaedorea* palms showed indistinct interveinal chlorosis of the newest leaves with some necrosis on leaflet tips. Also, newly emerging spear leaves did not open normally in this species, leaving two or three unopened leaves at the top of each plant. Recovery of iron deficient *Phoenix* and *Chrysalidocarpus* was complete in about five months, but *Chamaedorea* and *Caryota* never recovered. *Howea* palms showed no symptoms of iron deficiency after two and one-half years in a virtually iron-free environment.

Mild manganese deficiency symptoms appeared on all but *Howea* palms after about six months without manganese. The earliest symptom was an indistinct interveinal chlorosis of the new foliage (Figs. 7,8). As the deficiency progressed, necrotic spots appeared in new foliage of *Chamaedorea, Chrysalidocarpus,* and *Caryota.* New leaves of *Chamaedorea* emerged with necrotic margins, the necrosis becoming more severe on succeeding leaves so that eventually only necrotic stubs of petioles emerged. Death of the meristem followed. In *Phoenix*, new leaves emerged chlorotic with necrotic edges, reduced in size, and did not expand normally, resulting in several partially opened leaves being present in the bud region. Manganese deficiency

6. Chlorotic new (left) and green old (right) leaves from a single Fe deficient *Phoenix roebelenii* palm.

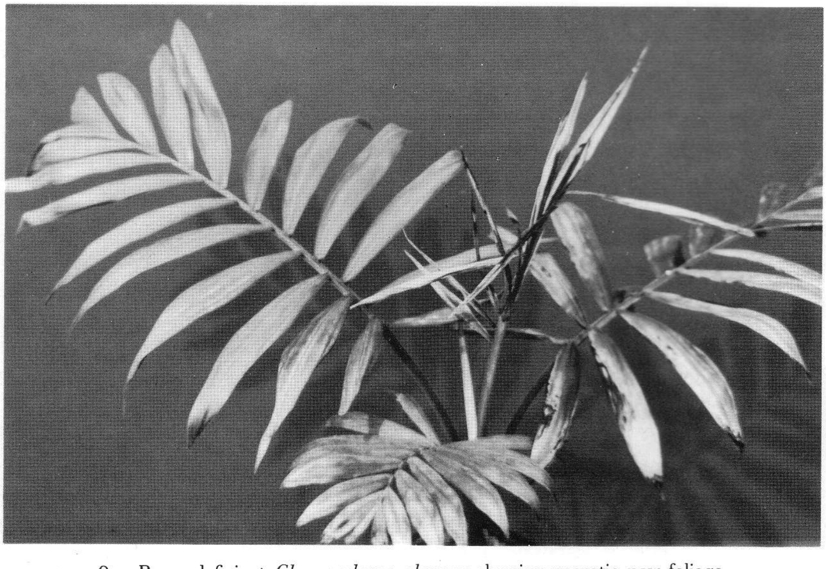
was not induced in *Howea* after two and one-half years. Recovery of palms deficient in manganese, as well as boron, zinc, copper, and molybdenum was not possible because such plants were severely weakened or killed by the deficiencies.

Boron deficiency symptoms appeared first on *Chamaedorea* after about seven

7. *Chamaedorea elegans* showing symptoms typical for Zn, Mo, Mn, and Cu deficiencies in this species.

8. *Phoenix roebelenii* showing symptoms typical for Cu, Zn, Mo, and Mn deficiencies in this species.

months. Early symptoms for *Chamaedorea*, as well as *Caryota* and *Phoenix* included chlorotic new leaves which were usually malformed and failed to expand normally (Fig. 9). Leaf margins were often necrotic and in severe cases, only necrotic stubs of petioles emerged with death of the meristem following. Flowers in boron-



9. Boron-deficient *Chamaedorea elegans* showing necrotic new foliage.

deficient *Chamaedorea* aborted and blackened. Symptoms were similar for *Howea*, except that no chlorosis was present and the symptoms were not expressed for two and one-half years. Boron deficiency was not induced in *Chrysalidocarpus*, but Marlatt (1978) reported transverse chlorotic streaks on new leaves which, as the deficiency progressed, coalesced and became necrotic. Death of the meristem also occurred in this species.

Zinc deficiency symptoms were induced in all but *Caryota* palms. Symptoms for *Chamaedorea* and *Phoenix* were indistinguishable from Mn deficiency, but in *Chrysalidocarpus* and *Howea* no chlorosis was present (Figs. 7,8). New leaves were reduced in size in all species and often had necrotic tips on leaflets. Zinc deficiency symptoms appeared first in *Chamaedorea* and *Chrysalidocarpus* after about nine months but *Phoenix* required about 14 months and *Howea* two and one-half years for symptoms to appear. Marlatt and McRitchie (1979) reported zinc deficiency symptoms in *Chrysalidocarpus* similar to those described here except that interveinal chlorosis was also present on the new leaves of their plants.

Copper deficiency symptoms were induced in *Chamaedorea*, *Phoenix*, and *Howea* and were similar to the zinc and manganese deficiency symptoms of those species except that chlorosis usually was not present on the new foliage (Figs. 7,8). New leaves were reduced in size, had necrotic margins, and eventually consisted solely of necrotic tipped petiole stubs. Death of the meristem occurred in *Chamaedorea* and *Howea*.

Molybdenum deficiency symptoms were induced only in *Phoenix* and *Chamaedorea* palms, requiring nine months for *Chamaedorea* and 14 months for *Phoenix* to show symptoms. In both species new growth was chlorotic, the leaves usually having large necrotic areas near the tips and margins and were deformed and reduced in size (Figs. 7,8). In *Chamaedorea*, Mo deficiency eventually resulted in only necrotic petiole stubs emerging, followed by death of the meristem as with manganese, boron, zinc, and copper deficiencies.

Chlorine deficiency was induced only in *Phoenix* and *Caryota*, the symptoms appearing after about eight months for both species. The only visible symptom in *Caryota* was a mild chlorosis of the new leaves, but in *Phoenix* chlorosis was more severe and was accompanied by incomplete separation of leaflets of new leaves such that five or six incompletely opened leaves were present on each plant (Fig. 10). These leaves had a ladder-like appearance, with leaflets being attached at the margins so securely that they could not be separated without tearing the leaflets.

In conclusion, nutrient deficiency symptoms in these five species of indoor palms are similar to those reported for larger species such as coconuts and oil palms (Bull 1958, Broeshart et al. 1957, Bull 1961*a*,*b*, Manciot et al. 1979–1980). Macronutrient deficiency symptoms were easily induced in these species of palms and were easily distinguished by their symptoms. Deficiency symptoms for these elements are similar to those described for other plant families, but this is not the case with micronutrient deficiency symptoms. Iron and chlorine deficiencies had rather distinctive symptoms, but other micronutrient deficiency symptoms were virtually indistinguishable from one another and correct diagnosis could be accomplished only by leaf elemental analysis once these symptoms were observed.

Deficiency symptoms for most elements required from 6 to 15 months or longer to be expressed in these palms. This was largely due to the slow growth rate of these palms under low light intensities, and stored nutrient reserves in the seed could also have supplied the limited amount of micronutrients required for several

10. Chlorine-deficient *Phoenix roebelenii* with typical chlorotic, ladder-like new foliage.

months' growth. Palms recover slowly or not at all from nutrient deficiencies, particularly deficiencies of calcium and those micronutrients which cause necrosis of the new foliage. Once severe symptoms are present and the palm's only bud is damaged or killed, recovery is impossible. In this way palms differ from most other plants which have lateral meristems capable of growth following death of terminal meristems.

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