Plate 23: Seedlings grown without potassium (left) are much smaller than those grown with adequate potassium.

Plate 24: A young seedling showing the beginning of 'wavy' edges (arrowed) on the younger leaves. The paler green colour of the younger leaves is not a response to low potassium as this variation in colour between older and younger leaves is typical of healthy plants.

Plate 25: Leaves separated (a) to show the development of 'wavy' edges (b) on the younger leaves of a potassium-deficient plant.

Plate 26: Brown necrotic spots and patches develop on the leaf margins (a, b) and between the veins near the leaf margin (c) of young maturing leaves on potassium-deficient plants.

Plate 27: Severe marginal and leaf tip necrosis in mature leaves of a potassium-deficient plant. Note how the marginal necrosis is more severe towards the leaf tip (a) and advances from the leaf tip towards the base of the leaf (b). Also note the abrupt colour change from apparently healthy green tissue to brown necrotic tissue with little, if any, chlorotic zone.

Plate 28: An interveinal yellow chlorosis develops in younger leaves when potassium deficiency is very severe. Note the dark green main veins and leaf margins.

Calcium (Ca) Deficiency

Symptoms

Calcium-deficient seedlings stop growing and develop short, stout stems. The roots become short and thickened, and growth of the lateral roots ceases, giving the root system an overall stumpy appearance.

The first symptoms to appear on the leaves are an interveinal pale yellow chlorosis that is similar to, but not as striking as, that produced by iron deficiency. As the deficiency becomes more severe, brown necrotic patches develop within the yellow chlorosis on the new leaves. As the deficiency progresses, a brown marginal necrosis develops on the new leaves and extends into the interveinal areas producing a colour pattern on the new leaves consisting of a dark brown necrotic margin with a pale yellow chlorotic area separating the marginal necrosis from the dark green tissue surrounding the midvein. Only the new leaves are affected; the older leaves remain a healthy dark green colour and without visible symptoms.

When the deficiency is very severe, the emerging leaves become flaccid, wilt rapidly and die, often within two days and before other symptoms can develop. Eventually, the meristem stops producing new leaves, and the youngest mature leaves, which had remained dark green, develop a marginal yellow chlorosis and brown necrosis. The oldest leaves (i.e. those that had developed before calcium became deficient) turn a deep dark green colour but otherwise show no visible symptoms.

Occurrence likely

- Acid coarse-textured soils (eg sandy soils from granites) in the humid tropics where the original calcium has been removed by heavy rainfall.
- Strongly acid peat soils where total calcium is low.
- Alkaline sodic soils where high pH and high exchangeable sodium depresses the uptake of calcium.
- Many humid tropical soils where the pH is less than 4.5 and soluble aluminium is high and exchangeable calcium is low.

Occurrence highly unlikely

- Calcareous soils (eg those derived from coral or limestone).
- Soils in arid regions.

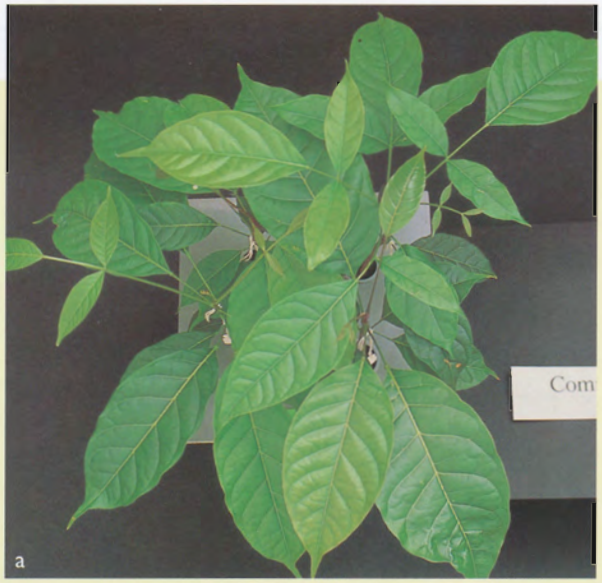

Plate 29: A young calcium-deficient seedling showing the early symptoms of an interveinal pale yellow chlorosis on the younger leaves (b) compared with a healthy seedling above left (a). Note that on some leaflets, the basal area remains relatively green and the chlorosis occurs towards the tip of the leaflet (c). (Compare this with iron deficiency where the interveinal chlorosis is more distinct and distributed evenly over the whole leaflet). Also note the darker green colour of the older leaves that is typical of healthy plants (b); but compare this colour with the deeper dark green colour that develops on the older leaves as the deficiency becomes very severe (Plate 34).

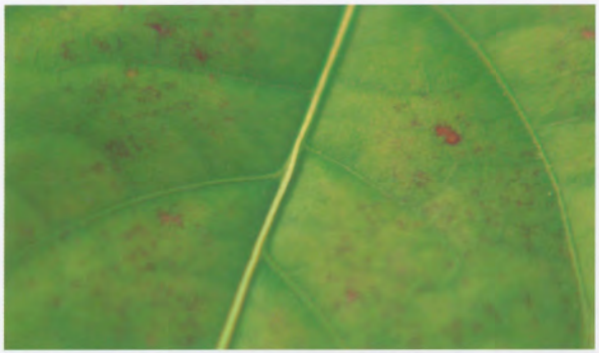

Plate 30: Brown necrotic patches develop within the yellow chlorotic areas in the young leaves of calcium-deficient seedlings.

Plate 31: Necrotic patches develop within interveinal areas on a mature leaf from a calcium-deficient seedling.

Plate 32: The leaf on the right shows further development of symptoms of calcium deficiency. The yellow chlorosis has become more extensive and some marginal brown necrosis is appearing. (Compare with boron deficiency). The leaf on the left is healthy and shows no symptoms.

Plate 33: Symptoms of severe calcium deficiency on newer, young leaves showing extensive marginal necrosis (a) that is often more severe towards the tip of the leaflet (b). Also note that the older leaves have now became a deep, dark green.

Plate 34: A young leaf from a severely calcium-deficient plant shows the 3-tone colour pattern characteristic of calcium deficiency. Note that the deeply lobed brown necrosis on the margin is separated from the green midveins by a wide zone of yellow chlorosis. A similar 3-tone pattern also develops in potassium deficiency, but there the chlorotic zone is very narrow or absent.

Plate 35: The youngest developing leaf of a calcium-deficient seedling showing interveinal yellow chlorosis and flaccid, wilting leaflets. (Compare with boron deficiency).

Plate 36: The same leaf as in Plate 35, but two days later; note that the leaflets that were flaccid and wilting in Plate 35 have died and dried out.

Plate 37: Young shoot from a seedling with severe calcium deficiency. Note the increasing severity of calcium deficiency symptoms showing up as necrosis of the leaf tips, whole leaflets, petioles, and the apical meristem. (Compare with boron deficiency).

Plate 38: A plant suffering from very severe calcium deficiency showing complete loss of young leaves, and rapid death of any newly emerging leaves.

Plate 39: The root system of plants suffering severe calcium deficiency become stunted with short, stumpy laterals caused by death of the apical growing point of the roots. (Compare with boron deficiency).

Magnesium (Mg) Deficiency

Symptoms

As mahogany seedlings became magnesium-deficient, their growth slows and their stems become spindly.

Even when plants appear healthy, symptoms appear first on the younger mature leaves where small patches of brown tissue develop generally in the interveinal areas towards the midvein. As these leaves become more mature, a yellow chlorosis develops to surround the brown spots. The yellow chlorosis spreads to become a general interveinal chlorosis evenly spread over the whole leaf while the brown spots become larger and turn necrotic. At this stage of development, the youngest leaves still appear healthy. As the deficiency becomes more severe, the youngest leaves also develop the pale yellow interveinal chlorosis, but this is much less severe than that in the young mature leaves.

When the deficiency is very severe, the oldest leaves develop symptoms similar to those shown by the young mature leaves. Brown spots appear and become surrounded by a yellow chlorosis that spreads generally over the interveinal areas of the whole leaf.

Occurrence likely

- Coarse-textured acid soils (eg sandy soils derived from granites) in the humid tropics where the original magnesium has been removed by leaching.
- Strongly acid peat soils where total magnesium is low.
- Soils that have been over-fertilised with calcium (eg over-limed), potassium or ammonium, thus inhibiting the uptake of magnesium.

Occurrence highly unlikely

- Soils derived from parent material high in magnesium, eg serpentine.

Plate 40: Young seedling that appears to be healthy, but has developed the very first stages of the symptoms of magnesium deficiency (see Plate 41).

Plate 41: First sign of symptoms appeared as small brown patches in interveinal areas near the main vein. This leaf is the youngest mature leaf from the plant in Plate 40.

Plate 42: A young seedling showing the pattern of development of symptoms of magnesium deficiency. Note that the youngest leaves have no symptoms and appear normal, while the middle or youngest mature leaves have symptoms of brown necrotic patches surrounded by yellow chlorosis, and the oldest mature leaves show areas of dark brown necrosis with little or no chlorosis (see Plate 43 for close-up).

Plate 43: Leaves of different age from the same seedling showing the variation in symptom development: top right is an immature leaf; top left is a young, mature leaf; bottom is an old leaf.

Mg

Plate 44: The top four leaves are young mature leaves showing different degrees of symptom development. Although the intensity differs, the symptoms are the same – a pale yellow chlorosis in the interveinal areas. The leaf at the bottom is from a healthy plant.

Plate 45: On young leaves, the symptom begins as a loss of green in the interveinal areas. The loss of colour is quite well defined with even the third order vein remaining green. Beginning at the leaf base the chlorosis becomes quite severe with patches becoming almost white.

Plate 46: A young leaf slightly older than that shown in Plate 45 where the interveinal chlorosis has became more severe. Note the development of a very pale yellow to white chlorosis in the interveinal areas at the base of the leaf.

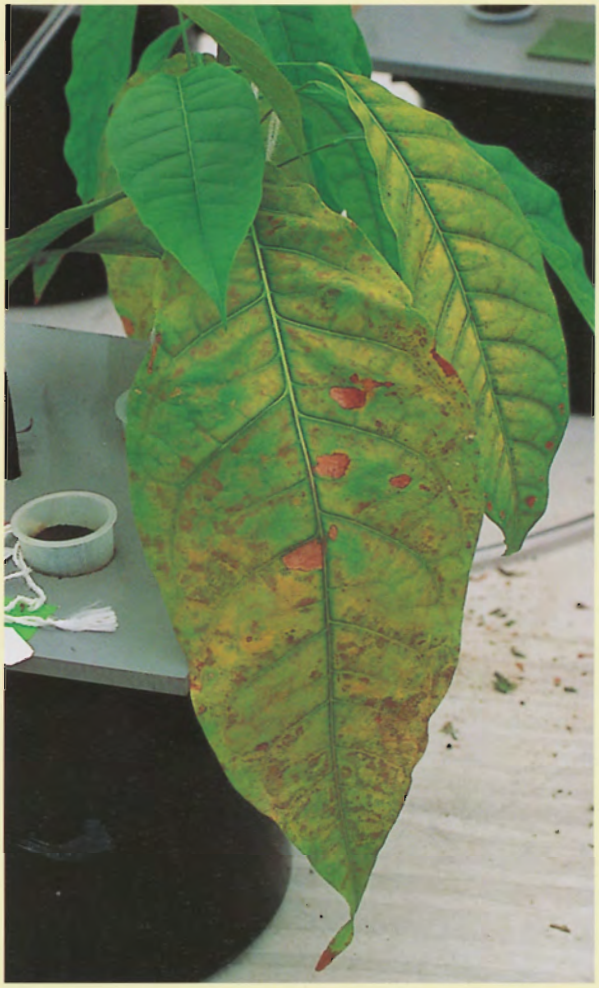

Plate 47: As the severity of the deficiency increases, the symptoms develop rapidly in the recently matured leaves with the areas of interveinal chlorosis and necrosis becoming more defined and more widespread over the whole leaf. Compare the intensity of the symptoms in this plate with those shown in Plate 42, Plate 43 and Plate 44. Note that the very new leaves (top left of this plate) are still quite green when they first emerge.