Plate 1: Young healthy seedling. Note the paler green younger leaves and the dark green, glossy older leaves.

Plate 2: (a) Older healthy seedling with well-developed, pale green young compound leaves and dark green older leaves.

Plate 2: (b) New growth (in foreground) is much paler in colour than older leaves even in large trees.

Plate 3: Leaves separated to show the simple older leaves that are followed by the compound younger leaves. Again, note the paler green colour of the younger leaves.

Plate 4: Extensively branched root system of a healthy seedling.

Plate 5: Pale brown to golden brown colour seen on young leaves and leaflets of the youngest leaves.

Plate 6: Glossy, dark green colour seen on the youngest mature leaves.

Plate 7: Young maturing leaves and leaflets sometimes develop a slightly mottled appearance before turning an even glossy dark green on reaching maturity.

Nitrogen (N) Deficiency

Symptoms

In seedlings, the symptoms develop rapidly when nitrogen supply becomes limiting. Growth slows down quickly and the stems become thin and spindly.

In contrast to most other species where the symptoms appear firstly on older leaves, in mahogany the symptoms always appear first and are more severe on the youngest leaves. A pale green to yellow chlorosis develops evenly over the whole leaf, producing pale green to yellow younger leaves while the older leaves remain a glossy dark green. At this early stage of development of the deficiency, it is difficult to distinguish between nitrogen deficiency and sulphur deficiency (compare also with iron deficiency).

With a mild deficiency, the older leaves remain a dark, glossy green and only the youngest leaves develop the pale green to yellow chlorosis. As the deficiency becomes more severe, even the older leaves develop the chlorosis and turn a pale green colour. When the onset of the deficiency is unusually rapid, a red colour may develop in the midvein of the older leaves and the lamina may become almost bronze in colour.

Occurrence likely

- Mineral soils low in organic matter, with a neutral to alkaline pH, and where organic matter has been depleted and is not being replaced.
- Where large amounts of organic matter with a high C:N ratio have been incorporated. This may be only a transient deficiency.
- Light-textured soils (eg sands, sandy loams) where rainfall is high and soils can be easily leached.

Occurrence highly unlikely

- Peat soils recently limed for the first time.
- Soils where large amounts of organic matter with low C:N ratio have been recently incorporated.
- Clay soils (with smectite minerals) with a recent history of ammonium fertilisation or ammonification of organic matter.

Plate 8: Nitrogen-deficient young seedlings. Note the even, pale yellow chlorosis on the youngest leaves while the older leaves remain a glossy dark green colour. (Compare with sulphur and iron deficiency).

Plate 9: Leaves separated to show the pale green to yellow younger leaves and the dark green older leaves. (Compare with newly developed leaves in healthy plants shown earlier).

Plate 10: Severe nitrogen deficiency in older seedlings has caused growth to almost cease, and the older leaves have now developed a pale green chlorosis. The younger leaves are now a pale yellow.

Plate 11: Youngest mature leaves from a nitrogen-deficient plant (top) and a healthy plant (bottom).

Plate 12: Note the decrease in severity of nitrogen deficiency symptoms from (a) to (d). While all seedlings have pale green younger leaves, those at the top have a greater proportion of yellow to pale green younger leaves and fewer dark green older leaves than those at the bottom. From (a) to (d) plants have received nil, 23, 375 and 1125 mg N/kg soil.

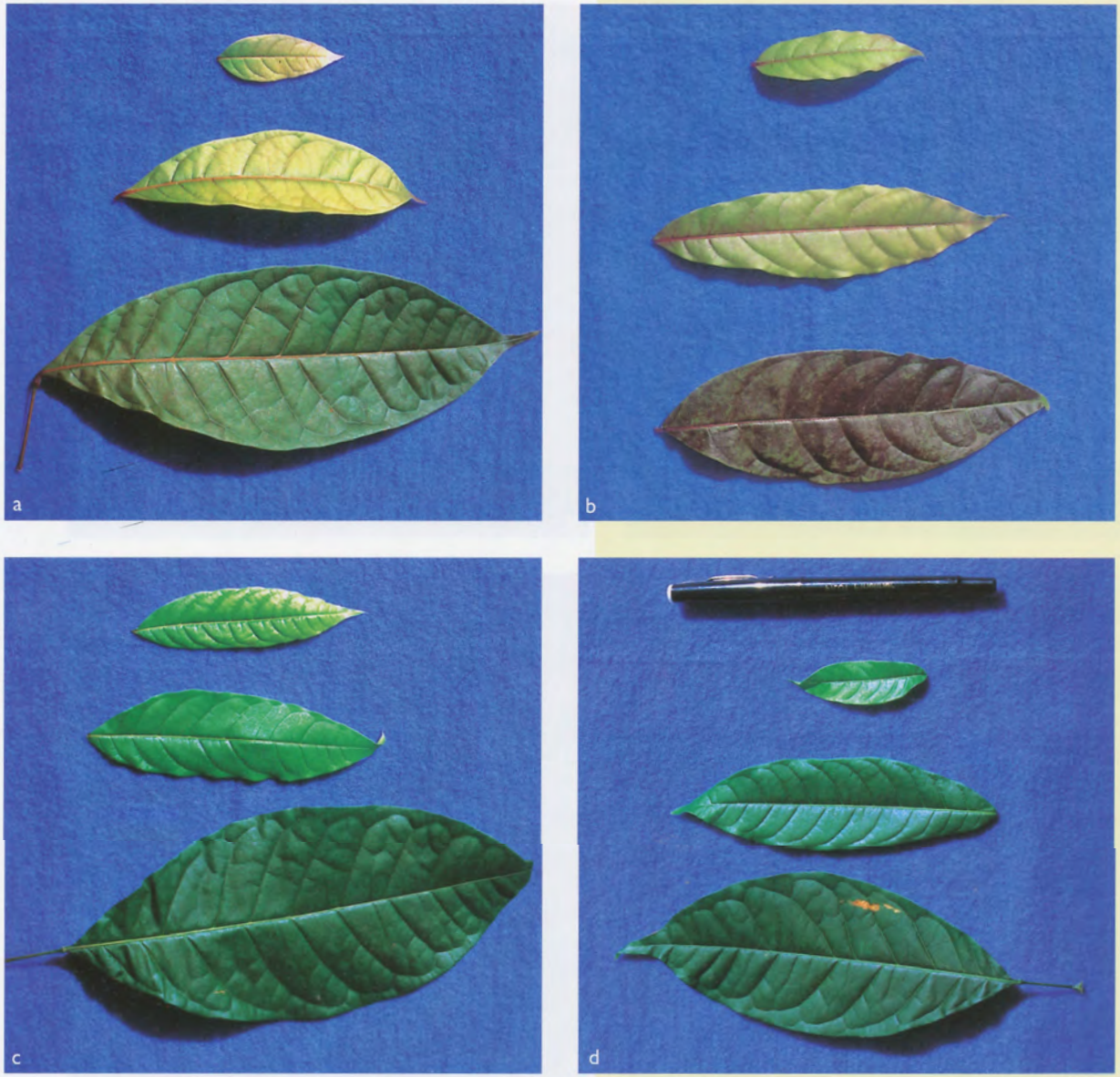

Plate 13: Appearance of leaves from plants receiving nil, 23, 375 and 1125 mg N/kg soil showing extremely deficient symptoms (a), severely deficient symptoms (b), mildly deficient symptoms (c) and no symptoms from a healthy plant (d). Within each frame, leaves are the youngest (top), youngest mature (middle), and oldest (bottom). Note the red colouring of the midrib and the bronze colouring of the lamina in the very deficient leaves in (a) and (b).

Phosphorus (P) Deficiency

Symptoms

In contrast to many other tree species, phosphorus deficiency does not produce characteristic foliar symptoms in mahogany. Seedlings lacking phosphorus grow slower than healthy seedlings, but there is generally no other difference in appearance between phosphorus-deficient and healthy seedlings. Hence, if there is *a priori* knowledge of growth rates and history of the plants, then phosphorus deficiency might be considered a possibility when there are no characteristic foliar symptoms but the plants are growing slower than expected.

When a very severe phosphorus deficiency is prolonged (eg 4 to 5 months duration), the seedlings are very stunted and all leaves may develop a slight chlorosis.

Occurrence likely

Phosphorus is one of the most widespread deficiencies in tropical soils. Deficiency of phosphorus is more likely to occur in:

- Mineral soils low in organic matter.
- Highly weathered, aluminium- and iron-rich acid soils (eg old soils from basalt) where phosphate is fixed in less available forms.
- Acidic soils that contain allophane (eg volcanic ash soils) or kaolinite clays.
- Alkaline soils high in calcium and magnesium where the phosphate may be tied up in insoluble phosphates.
- Leached quartz sand, and peat soils.
- Soils where the topsoil has been lost through erosion.

Occurrence highly unlikely

- Soils recently converted from agricultural use (where P fertilisers were used).

Plate 14: Seedlings which have had phosphorus withheld for one month have a healthy appearance with no characteristic foliar symptoms. Compare this with the rapid onset of symptoms in this species when other nutrients are withheld.

Plate 16: Seedlings which have had phosphorus withheld for five months are very stunted and all leaves develop a pale green chlorosis, the only foliar symptoms to appear. The marginal necrosis near the tips is atypical.

Plate 15: Seedlings which have had phosphorus withheld for three months still have a healthy appearance with no characteristic foliar symptoms. However, there has been a slight reduction in growth rate.

Plate 17: The foliage of seedlings grown without phosphorus (left) and with phosphorus (right) is very similar in appearance even though there is a substantial effect of phosphorus deficiency on growth.

Plate 18: Close-up of phosphorus-deficient plants in Plate 17 showing little in the way of diagnostic symptoms.

Plate 19: Adding phosphorus substantially increases growth of seedlings. However, it has little effect on the appearance of leaves. From left to right, rates of application are 0, 25, 50, 100, 150, 200, 250, 500 and 1000 mg P/kg soil.

Plate 20: Young leaves from plants shown in Plate 19. Note that increasing the addition of phosphorus from 0 mg P/kg soil (top left) to 1000 mg P/kg soil (bottom right) has no effect on the appearance of these young leaves even though it has a substantial effect on seedling growth.

Plate 21: Youngest mature leaves from plants shown in Plate 19. Note that increasing the addition of phosphorus from 0 mg P/kg soil (top left) to 1000 mg P/kg soil (bottom right) has no effect on the appearance of these young mature leaves even though it has a substantial effect on seedling growth.

Plate 22: Mature leaves from plants shown in Plate 19. Note the mottled yellow interveinal chlorosis that has developed on the most severely deficient plant receiving 0 mg P/kg soil, the first and only appearance of foliar symptoms (top left). Also note that increasing the addition of phosphorus from 25 mg P/kg soil (top, second from left) to 1000 mg P/kg soil (bottom right) has no effect on the appearance of these mature leaves even though it has a substantial effect on seedling growth.

Potassium (K) Deficiency

Symptoms

As potassium becomes deficient, the young seedlings grow more slowly and stems become thin and spindly.

The development of wavy edges on the younger maturing leaves is the first foliar symptom to appear. As the deficiency increases in severity, brown necrotic spots develop in the lamina between the main veins and near the margins of the young maturing leaves. As these leaves become mature, the necrosis spreads towards the leaf margin to form a continuous necrotic margin. Initially, the marginal necrosis is more pronounced towards the leaf tip than the leaf base, but spreads from the tip towards the base of the leaf as the severity of the deficiency increases in the maturing leaves. When the deficiency is very severe, the young leaves also develop a strong yellow interveinal chlorosis between the main vein and the leaf margin which remain dark green.

Occurrence likely

- Highly weathered mineral soils low in organic matter.
- Light-textured soils (eg sands and sandy loams) formed from parent material low in potassium (eg sandstone, limestone and some granites).
- Mineral soils where the original potassium has been leached by heavy rainfall.

Occurrence highly unlikely

- Potassium deficiency is unlikely in **young** soils formed from parent material that is rich in potassium, eg soils from igneous rocks.