Plate 74: Older leaves from a zinc-deficient seedling showing pronounced chlorosis and marginal necrosis. The chlorosis and necrosis is more severe towards the margins of the leaf and may be restricted to areas between the secondary veins (a), but may sometimes occur generally around the margins of the leaf (b).

Plate 75: Close-up of the tip of the stem showing the petioles remaining after death and abscission of the leaflets on a zinc-deficient seedling. Note that the newly emerging leaf appears to be a healthy soft brown colour.

Plate 76: Tip of the stem of a zinc-deficient seedling showing (1) the yellow chlorosis developing on the youngest mature leaf and (2) the petioles remaining after the leaflets have died and fallen from the newest expanding leaves.

Plate 77: Tip of the stem of a zinc-deficient plant that is producing apparently healthy new leaves above the remnant petioles (curved) from leaves where the leaflets have died and fallen off. Note the shortened internode length in this region of the stem.

Plate 78: Young leaves from a severely zinc-deficient seedling showing the 'water-soaked' symptom that develops near the junction of the main veins and the secondary veins in the basal portion of the leaflets. The necrosis is not preceded by a chlorosis; that is, the necrotic patches did not go through an initial chlorosis, but instead had the 'wet' appearance of frozen and thawed tissue which had lost cellular integrity. This quickly dried out and turned necrotic.

Copper (Cu) Deficiency

Symptoms

The early visual symptoms on the foliage begin as a general yellowing of the young leaves. With increasing severity, the tips of the leaflets become twisted and malformed (compare with boron deficiency). As the deficiency becomes very severe, the old mature leaves become dark green whilst the younger leaves develop malformed leaflets; initially the tips of the leaflets become twisted or curled and develop a brown necrosis and die. Eventually the leaflet dies and falls off at the base of the blade, leaving the petiole attached to the stem (if a simple leaf) or rachis (if a compound leaf).

Occurrence likely

- Peat and muck soils where soluble organic ligands tie up the soluble copper in forms less available to plants.
- Soils formed from parent materials low in copper such as some metamorphic rocks (eg schists), and acid volcanic materials (eg granites, rhyolites, pumice and ash).
- Siliceous sands where total copper is low.
- Alkaline calcareous soils, such as those derived from limestone or where free lime is present and total copper is low.
- Excessively leached podsolic soils.

A temporary deficiency of copper can occur under drought conditions when uptake of copper is inhibited by the isolation of available copper in a dry soil horizon.

Occurrence highly unlikely

- Fine-textured soils (eg clays) derived from basic igneous rocks (eg basalts) unless free lime is present.
- Acid soils.
- Soils where copper fungicides have been regularly used (eg Bordeaux mixture; copper oxychloride).

Plate 79: Young seedling showing the early signs of copper deficiency. Note the slight interveinal yellow chlorosis on the younger leaves.

Plate 80: Young leaves from a copper-deficient plant showing the twisted, malformed tips of the leaflets.

Plate 81: Older seedlings showing symptoms of severe copper deficiency. Note the very dark green of the older leaves and the very malformed leaflets on the younger leaves.

Plate 82: Close-up of the shoot tip of the plant in Plate 81. Note the malformations of the leaflets: (1) the abscission of the leaflets at the base of the blade, leaving the petiole attached to the rachis; (2) death and twisting of the leaflet tips; (3) curling and malformation of the tips of many leaflets.

Manganese (Mn) Deficiency

Symptoms

Manganese deficiency manifests itself in a number of ways. In some leaves an interveinal chlorosis begins around the smallest veins. In other leaves, a marginal necrosis moves inwards between the secondary veins.

Occurrence likely

- Strongly alkaline soils, especially those with free lime, eg calcareous soils, where manganese is converted into forms less available to plants.
- Strongly acidic peat soils where total manganese is low.
- Peaty soils overlying calcareous subsoils.
- Poorly drained soils with a high content of organic matter where manganese is tied up in forms less available to plants.
- Acidic sandy mineral soils where manganese has been removed by leaching.
- Soils derived from parent material low in manganese (eg acid igneous rocks).
- Soils that fluctuate regularly between well-drained and waterlogged, where the manganese can be reduced to water-soluble forms that are then readily leached.
- Soils over-limed with lime or dolomite.
- Soils over-fertilised with copper, iron or zinc that inhibits plant uptake of manganese.

Occurrence highly unlikely

- Flooded soils where the level of total manganese is adequate.
- Acid mineral soils, especially those formed from parent materials rich in manganese (eg basic igneous rocks such as basalt).

Plate 83: Beginning in the basal part of the youngest mature leaf and extending to the tip over time, a pale yellow chlorosis develops around the smallest veins. Eventually, all tissue between the largest veins turns yellow leaving the tissue adjacent to these veins green.

Plate 84: In other leaves, just slightly older, in addition to the chlorosis described above, a reddish-brown necrosis advances from the tip to the base and inwards from the margins between the main veins.

Plate 85: In young expanding leaves, there is a pattern of chlorosis similar to that described above. However, the necrotic pattern is paler, almost pink, and the edge of the necrosis is less well defined.

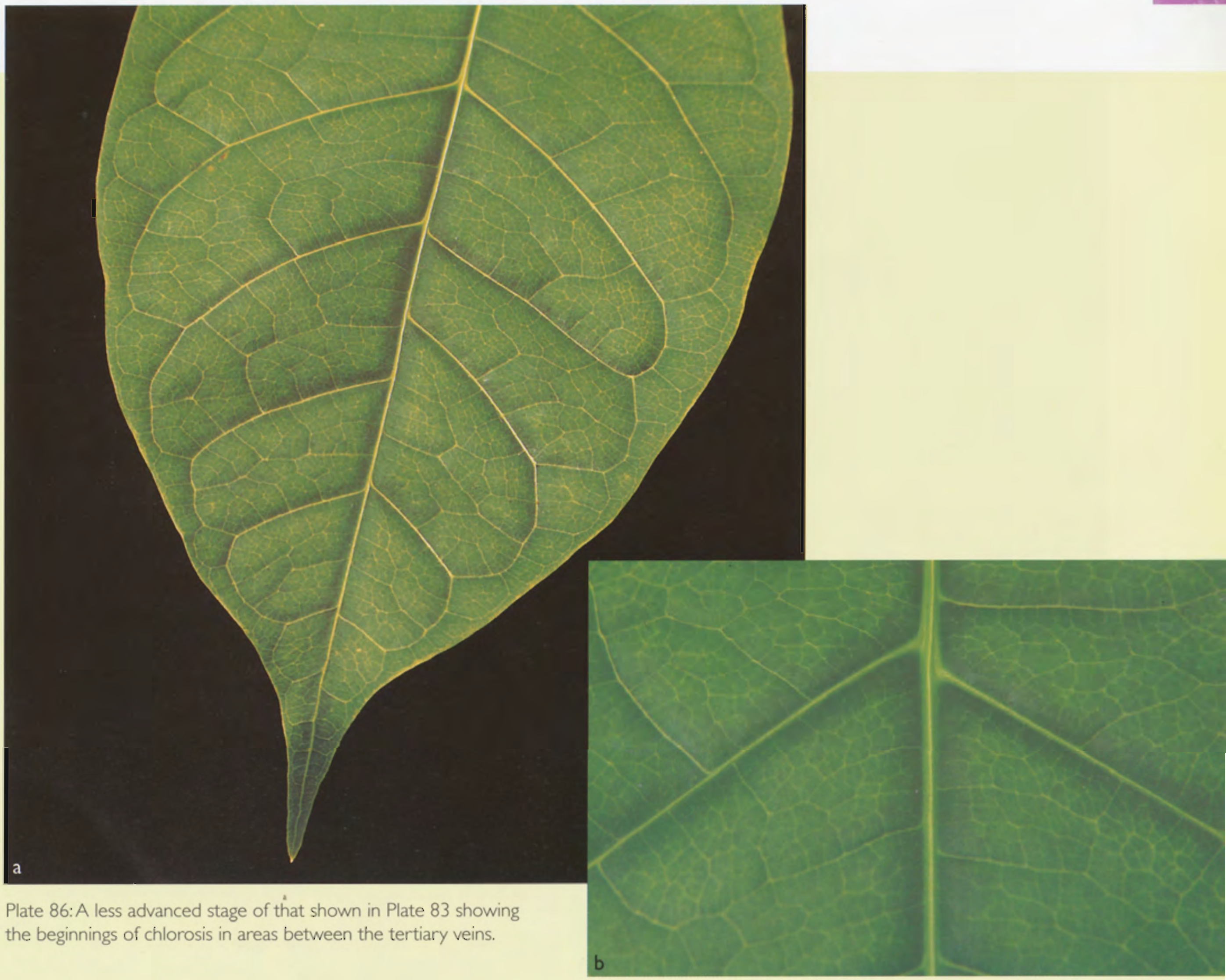

Plate 86: A less advanced stage of that shown in Plate 83 showing the beginnings of chlorosis in areas between the tertiary veins.

Plate 87: In the young leaf, brown patches have developed within the leaf between the main veins.

Boron (B) Deficiency

Symptoms

The first visual symptom on the foliage is the appearance of a pale brown necrosis in the interveinal areas in the basal section of the young leaves. As the deficiency becomes more severe, the edges of newly developing leaves become wavy and the leaf tips may be malformed and develop a brown necrosis. These young leaves become flaccid (or wilted), and develop a reddish tinge on the underside of the lamina.

When the deficiency is very severe, the tertiary veins of the older leaves develop a yellow chlorosis, giving these leaves a mottled appearance. The tips and margins of these leaves often become necrotic and die.

The root systems of boron-deficient plants also cease growing and the lateral roots become stunted, giving the whole root system a stumpy appearance. As the severity increases, the roots become discoloured and brown lesions develop on the older roots.

Occurrence likely

Boron deficiency is more likely to occur in highly weathered soil in high rainfall areas, with increasing distance from oceans, and in acid peat soils.

Typical sites for boron deficiency include:

- Coarse-textured soils formed from parent materials low in boron such as acid igneous rocks (eg granites), metamorphic rocks, and freshwater sandstones and shales.
- Acid sandy soils (eg podsolic soils) from which boron has been leached by rainfall.
- Alkaline, or calcareous soils, especially those with free lime.
- Soils low in organic matter.
- Acidic soils rich in aluminium oxides.
- Soils derived from pumice and volcanic ash rich in allophane.
- Peat soils, especially after liming.

A temporary deficiency of boron can occur under drought conditions when uptake of boron is inhibited by the isolation of available boron in a dry soil horizon.

Occurrence highly unlikely

- Soils formed from marine sediments.
- Soils close to oceanic coastal influences.
- Fine-textured soils with high clay content (eg from basalts or shales) unless highly weathered.
- Soils of naturally high pH that have no free lime.

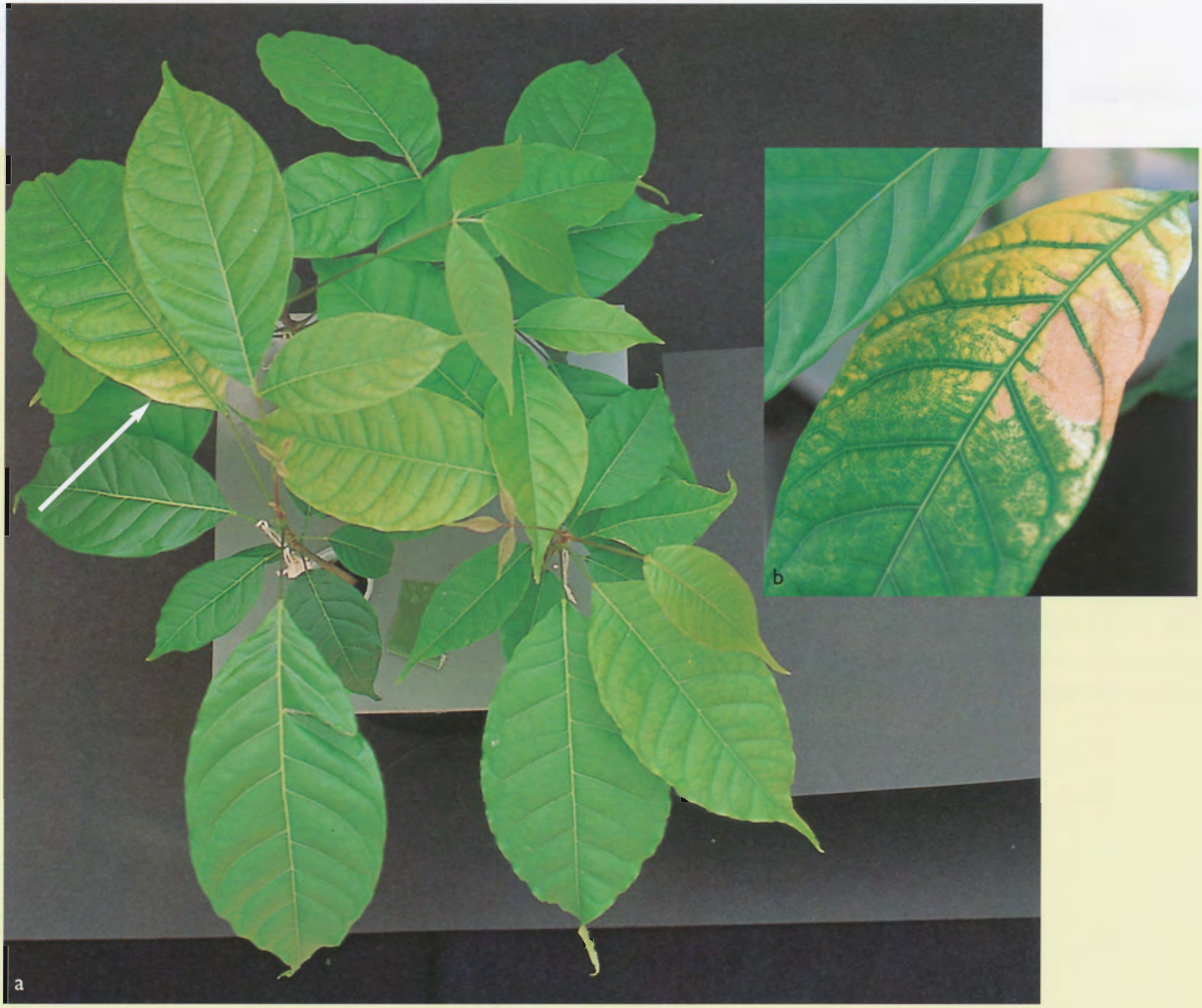

Plate 88: Young seedling showing the early stages of boron deficiency symptoms (a) on the young leaves (arrowed). Note the development of a pale brown necrosis in the interveinal areas in the basal section of the leaf (b; compare with zinc deficiency).

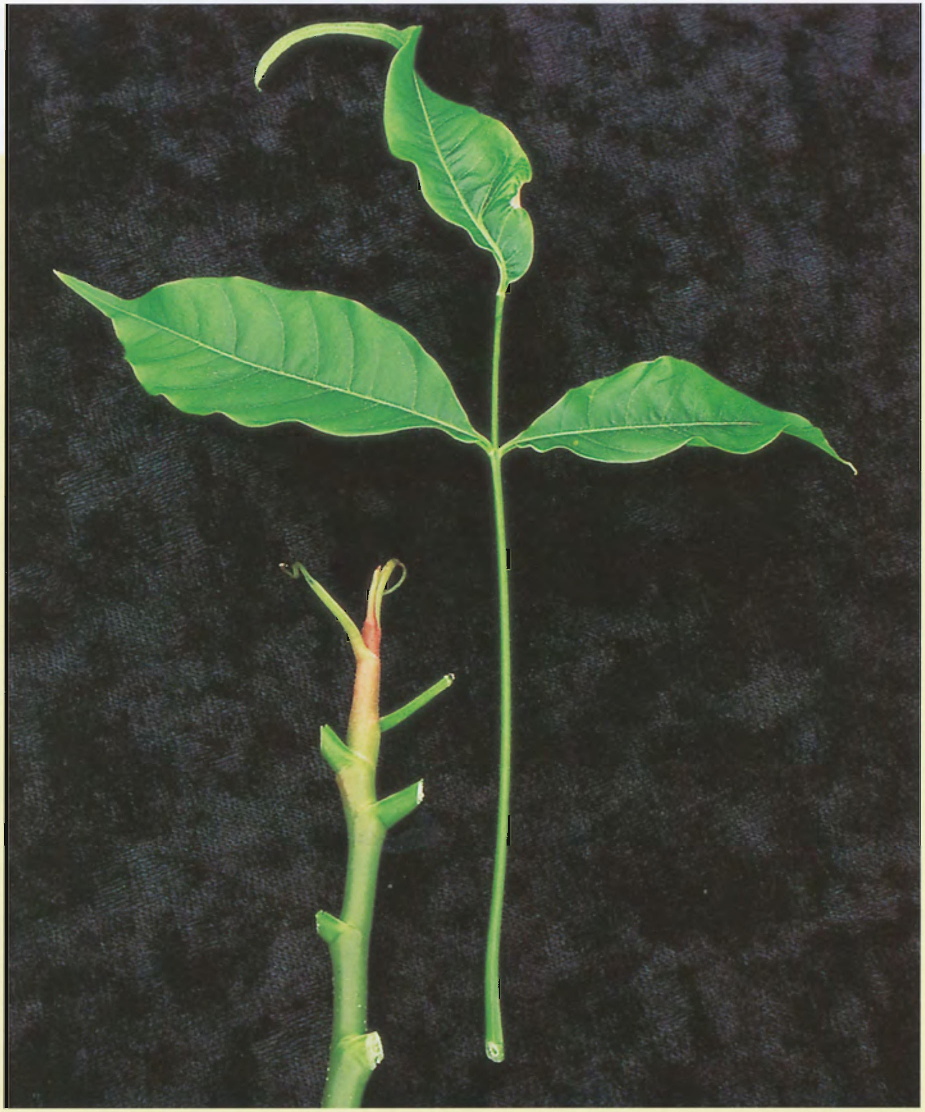

Plate 89: Malformed new expanding young leaves from a boron-deficient seedling. Note the wavy edges, and malformed and necrotic tips of the leaflets. (Compare with calcium deficiency).

Plate 90: Young leaves from a severely boron-deficient seedling. The young developing leaves have became flaccid and wilted (a; compare with calcium deficiency) with a wrinkled appearance and reddish tinge on the underside of the leaf blade (b).

Plate 91: Seedling showing symptoms of severe boron deficiency (a). Note the development of necrosis of the tips and margins (b; compare with calcium deficiency) and the appearance of mottling in the older leaves caused by chlorosis of the tertiary veins (c).

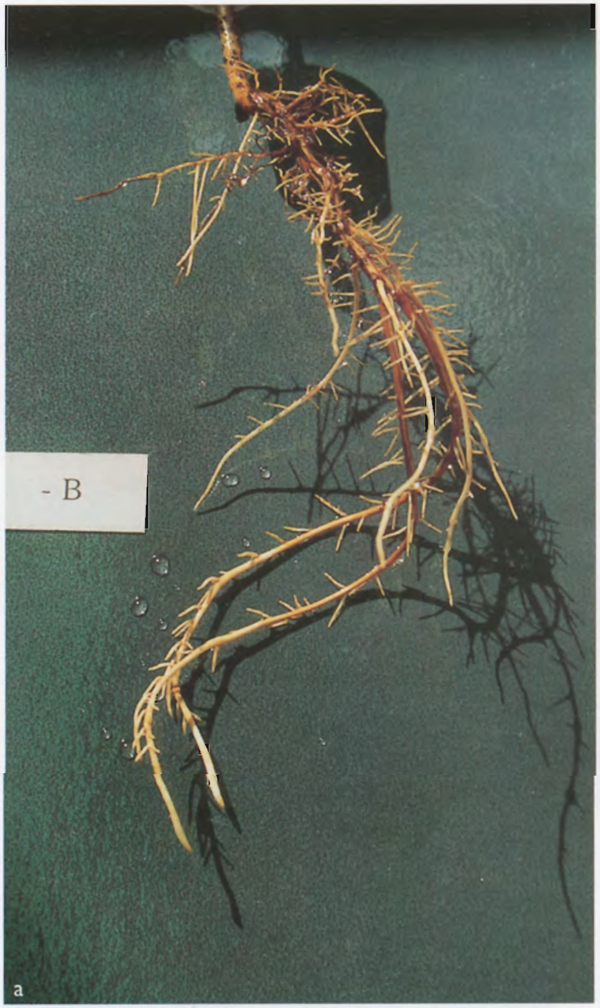

Plate 92: Root system from a seedling suffering from boron deficiency (compare with calcium deficiency). The poor development and growth of the lateral roots give a stumpy appearance (a) and the brown lesions developed on the main roots (b) when the severity of the deficiency increases.