Mg

Plate 48: In contrast to the recently matured leaves (Plate 47), the symptoms in the older mature leaves do not change as rapidly. For some time the symptoms in the older mature leaves remain as brown spots with little or no encircling chlorosis.

Plate 49: When the deficiency is very severe for an extended period, the symptoms on the older mature leaves progress to resemble those on the younger mature leaves, i.e. green veins with strongly patterned brown necrosis surrounded by a yellow chlorosis in the interveinal areas.

Sulphur (S) Deficiency

Symptoms

Symptoms develop rapidly when sulphur is omitted from the nutrient supply; within two weeks seedlings stop growing, become very spindly, and develop an overall pale green to pale yellow appearance.

Early stages of symptom development are characterised by the youngest leaves turning pale yellow while the older leaves remain green. At this stage it is difficult to discriminate between sulphur and nitrogen deficiency, although the veins stay slightly greener than the surrounding tissue in sulphur deficiency (compare also with iron deficiency).

As the deficiency becomes more severe, small necrotic spots appear on the older leaves, especially near the veins. Eventually, the older leaves develop chlorotic patches between the main veins. After some time, the chlorotic patches spread across most of the old leaves, leaving them slightly mottled compared to the younger leaves.

Occurrence likely

- Acid sandy soils in the humid tropics where the original sulphur has been leached by heavy rainfall.
- Coarse-textured soils (eg sandy soils) low in organic matter.
- Soils formed from parent material low in sulphur (eg from volcanic rocks and ash).

Occurrence highly unlikely

- Soils high in decomposing organic matter.
- Soils where atmospheric inputs could be high (such as soils adjacent to coal-burning industries, major cities, oceans, or marshes), especially calcareous soils or soils high in aluminium and iron hydrous oxides (eg highly weathered basalts).

Plate 50: Young seedling showing early stages of sulphur deficiency. Note the pale green to yellow young leaves with darker green older leaves.

Plate 51: Leaves separated from sulphur-deficient seedlings (a and b) to show the rapid change in colour from pale green to yellow younger leaves and the dark green older leaves.

Plate 52: Close-up of a young leaf from a sulphur-deficient seedling showing the even, pale yellow chlorosis and pale green veins characteristic of sulphur deficiency. (Compare with iron and nitrogen deficiency).

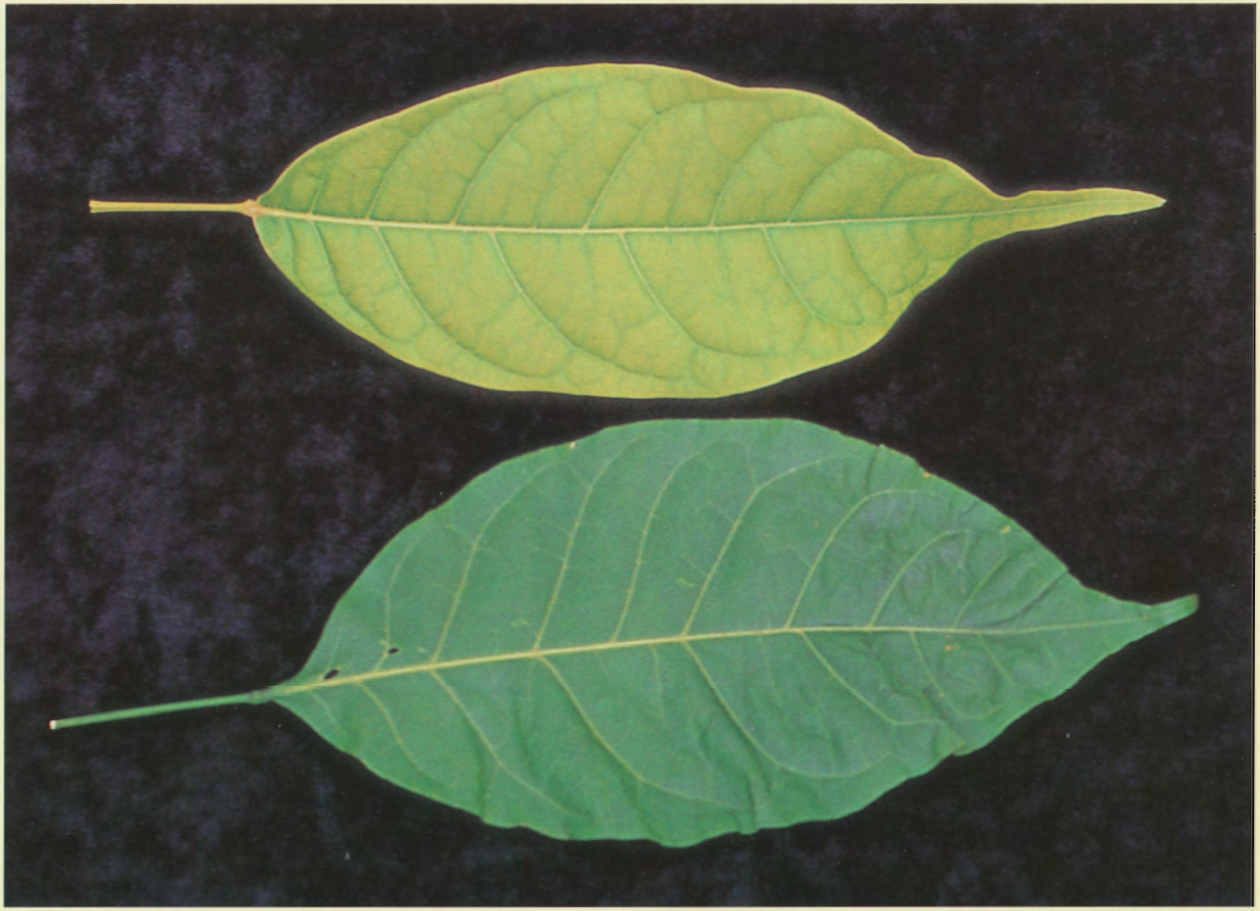

Plate 53: Pale yellow, sulphur-deficient young leaf (top) compared with a dark green, healthy young leaf (bottom).

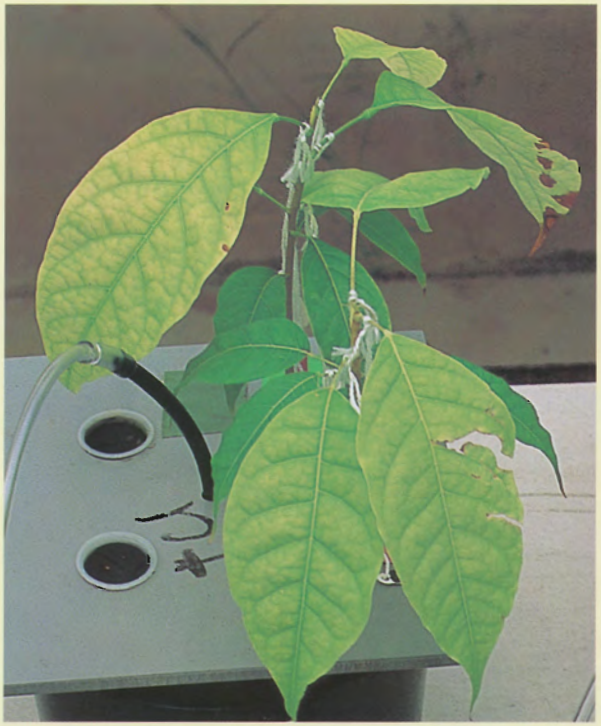

Plate 54: As the severity of the deficiency progresses, the pale yellow chlorosis seen on the younger leaves develops also on the young mature leaves immediately below them.

Plate 55: An older mature leaf from a sulphur-deficient seedling. Note the development of brown necrotic spots near and along the veins in the interveinal areas of the leaf.

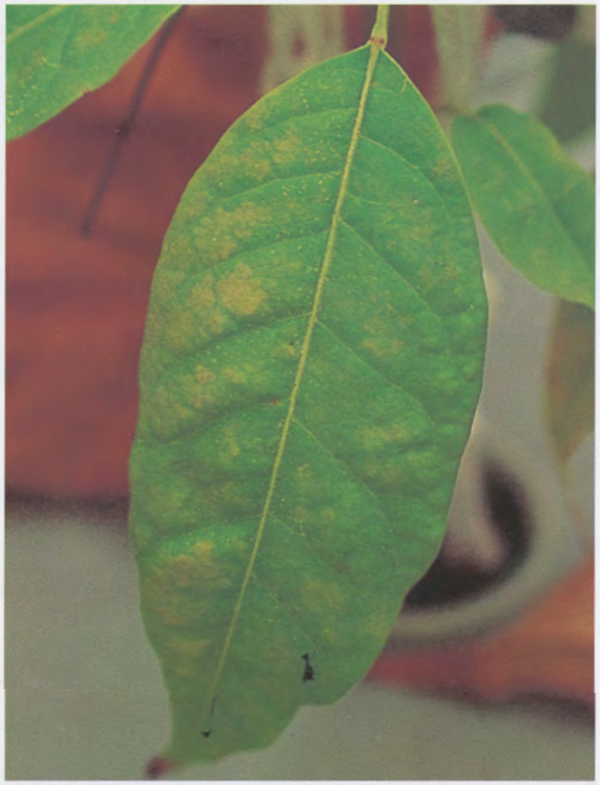

Plate 56: Severe symptoms of sulphur deficiency on an older mature leaf. Note the development of chlorotic patches in the interveinal areas between the major veins.

Plate 57: Seedling suffering very severe sulphur deficiency. Note that all leaves have now become chlorotic, and that the older leaves appear to be paler in colour than the young leaves. (Compare with iron and nitrogen deficiency).

Iron (Fe) Deficiency

Symptoms

The symptoms of iron deficiency appear rapidly, although the seedlings may initially show no reduction in rate of growth. As the severity of the deficiency increases, growth of the young plant slows down and the stem becomes spindly.

The first symptom to appear is a faint yellow interveinal chlorosis in the most recently matured leaves. At this stage the youngest leaves appear a normal and healthy pale green colour and the older leaves a normal and healthy dark green colour (compare with nitrogen and sulphur deficiency). As the severity of the deficiency increases, the interveinal chlorosis becomes characteristic for iron deficiency; the veins remain green as in a normal healthy leaf and the interveinal areas of the whole leaf become an even, pale yellow colour.

When the deficiency is very severe, the interveinal areas often turn almost white and only the major veins remain pale green. By this stage, the characteristic symptoms of interveinal chlorosis have appeared on both the young maturing leaves and the new expanding young leaves, and even some of the older mature leaves may begin to show some interveinal chlorosis. The newly developing young leaves often turn a distinctive pale pink colour when the deficiency is very severe.

Occurrence likely

- Alkaline or calcareous soils with high pH (7.4 – 8.5) where levels of soluble iron are low.
- Waterlogged or compacted (wet) calcareous soils (including roads made from coral rubble).
- Coarse-textured soils low in total iron (eg bleached white sands).
- Peat soils where organic matter ties up soluble iron.
- Acid soils with very high levels of soluble manganese, zinc, copper (either natural or from excessive applications of copper-based fungicides), or nickel (eg serpentine soils) which depress the uptake of iron by plants.

Occurrence highly unlikely

- Acid to neutral mineral soils that are not high in soluble manganese, zinc, copper or nickel.
- Flooded non-calcareous soils.
- Mineral soils high in organic matter (but not peat soils).

Plate 58: Young seedling showing the very early stage of iron deficiency. Note the first stages of a pale yellow interveinal chlorosis on the youngest mature leaf.

Plate 59: Iron-deficient leaf showing the characteristic interveinal chlorosis that develops as the severity increases. The pale yellow interveinal chlorosis is spread evenly over the whole leaf blade with the green veins standing out against the yellow background in this youngest mature leaf.

Plate 60: Older leaves from plants shown in Plate 59. Note the lack of distinctive symptoms; only a slight chlorosis is apparent at this early stage of development of the symptoms.

Plate 61: Seedling showing more severe symptoms of iron deficiency. The characteristic interveinal chlorosis now appears on both the expanding and recently matured leaves. The older mature leaves show only a slight chlorosis and have become pale green.

Fe

Plate 62: Severe interveinal chlorosis on the youngest mature leaf. At this stage only the main veins remain green.

Plate 63: Leaves separated to show the change in intensity of the symptoms with age of leaf. Note the pale green youngest leaves, pale yellow younger mature leaves, and the green older mature leaves.

Plate 64: Close-up of leaves showing the pattern of development of the characteristic interveinal chlorosis associated with iron deficiency. The youngest mature leaf (far left) shows the patchy development of the yellow interveinal chlorosis in the early stage of symptom expression. The older leaves (to the right) show increasing intensity of the yellow chlorosis until the interveinal areas have turned almost white and the main veins have turned pale green. The leaf at the top of the plate is from a healthy seedling.

Fe

Plate 65: Young developing leaf on a seedling showing symptoms of severe iron deficiency. Note that the interveinal chlorosis has become very pale, almost white in colour.

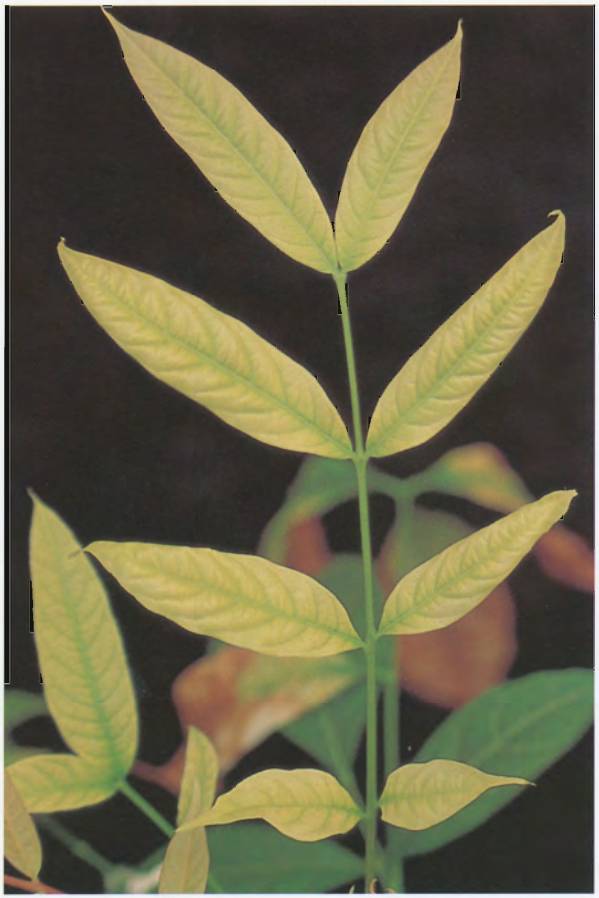

Plate 66: Iron-deficient leaf showing the almost total loss of colour, even in the main veins, that occurs when the deficiency is very severe.

Plate 67: Seedling showing symptoms of extreme iron deficiency. The young expanding leaves have lost almost all colour; the recently matured leaves are strongly chlorotic, and even the older mature leaves are developing the interveinal chlorosis characteristic of iron deficiency.

Fe

Plate 68: Newly emerging leaves on a seedling with extremely severe iron deficiency often develop a distinctive pale pink colour.

Plate 69: Old mature leaves from the plant in Plate 67 showing the development of the mottled yellow interveinal chlorosis and green veins that is the characteristic symptom of early stages of iron deficiency.

Zinc (Zn) Deficiency

Symptoms

Zinc deficiency reduces the rate of growth of seedlings so that they eventually become very stunted, with short internodes and spindly stems.

The first foliar symptoms to appear develop on the younger leaves as a 'scalloped' marginal chlorosis that advances rapidly across the blade until the whole leaf becomes almost white with only the main vein remaining green. In the younger newly emerging leaves, the yellow chlorosis begins at the leaf margin but advances inwards between the secondary veins. As these leaves become more mature, the chlorosis is followed by a marginal brown necrosis that also advances inwards, mainly between the secondary veins.

As the severity of the deficiency increases, the newly emerging leaves exhibit a new pattern of symptom expression. Tissue that has a 'water-soaked' appearance develops in the regions between the veins, particularly in the area near the stalk of the leaf. These 'water-soaked' areas die rapidly and become necrotic, turning pale brown.

When the deficiency is severe, the newly emerging leaves wither and die soon after expanding, leaving the petioles attached near the tip of the stem. By this stage, the internodes near the tip of the shoot have become very short, giving the stem a stunted appearance.

Occurrence likely

- Strongly alkaline soils, especially those with free lime, where the availability of zinc is depressed.
- Sandy-textured soils where total zinc is low.
- Soils derived from parent materials low in zinc (eg granites, gneisses).
- Some soils which are very low in organic matter.
- Some organic soils where zinc can be tied up in forms less available to plants.
- Soils where erosion or management practices have exposed subsoils with low levels of total zinc.
- Acidic, coarse-textured soils where soluble zinc has been leached by heavy rainfall.
- Soils where frequent heavy applications of phosphorus, copper, manganese and iron have occurred and uptake of zinc is inhibited by high levels of these elements in the soil.
- Flooded or compacted soils (possibly because of high levels of available iron and manganese).
- Soils high in fine clay or silt.

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

Occurrence highly unlikely

It is difficult to define a natural soil type that would generally be regarded as never being zinc-deficient. For example, in Vanuatu, some basaltic soils may be high in total zinc but similar soils in other parts of the South Pacific may be very low.

Thus, zinc deficiency is unlikely to occur in:

- Acidic soils formed from parent materials rich in zinc (eg basic igneous rocks such as basalt).
- Soils with a reasonable organic matter content.
- Soils where foliar zinc sprays or fungicides that contain zinc have been applied regularly to crops.
- Soils close to zinc mines where management operations cause zinc minerals to contaminate the surrounding regions.

Plate 70: A generally healthy young seedling showing the early signs of zinc deficiency as a marginal chlorosis on the young leaf (arrowed).

Plate 71: Leaves separated from zinc-deficient seedling to show the development of symptoms on leaves of different age. Note the appearance of marginal chlorosis on the young expanding leaves but the more pronounced chlorosis on the younger mature leaves. Note also the apparently healthy green of the oldest mature leaves.

Plate 72: Close-up of young expanding leaf with developing symptoms. The chlorosis starts at the margins and then moves inwards between the secondary veins.

Plate 73: Close-up of older leaves from a zinc-deficient seedling showing more widespread chlorosis and mottling than in Plate 72.