i) Puckering and deformities of young leaves caused by aphid feeding. (Photo: A. Braun)

j) A severely stunted crop of cv. Bustak in Indonesia, which has suffered from heavy aphid infestation.

Plate 19. Cont'd

k) Leaf distortions and thickening caused by broadmites on cv. Beerwah Gold.

l) Intumescence on the lower surface of a leaf of cv. Beerwah Gold, grown in humid conditions in a greenhouse.

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Appendix 1. Glossary, Scientific Names, Abbreviations, Conversions, and Symbols

acidic
(of a solution or soil) containing more free hydrogen ions than free hydroxyl ions, a characteristic which affects the behaviour of many of the chemical species contained in it (see *soil pH*)

alkaline
(of a solution or soil) containing fewer free hydrogen ions than free hydroxyl ions, a characteristic which affects the behaviour of many of the chemical species contained in it (see *soil pH*)

anion
a soluble chemical unit (atom or molecule) which carries a net negative electrical charge

anthocyanin
a red pigment sometimes present in plant tissues. In combination with varying levels of green and yellow photosynthetic pigments, it may produce colours from pale pink to bright orange or dark purple

apex
(adj. *apical*) The shoot or root tip

apical meristem
the tissue in a shoot or root tip which gives rise to new leaves or roots

axil
the acute angle formed by the junction of the stem with a leaf petiole, from where lateral shoots arise

axillary bud
the dormant or undeveloped shoot tip in a leaf axil

cation
a soluble chemical unit (atom or molecule) which carries a net positive electrical charge

cation-exchange capacity
the capacity of a soil to loosely bind cations, determined by the surface area and charge density of particles (e.g. clay, organic matter) contained in a given weight of soil

chlorophyll
the green pigment in plant tissue, which transfers light energy into chemical reactions

chlorosis
(adj. *chlorotic*) Loss of green pigmentation, resulting in a paler than normal colour, either light green, yellow or whitish

dolomite
a mixture of calcium carbonate and magnesium carbonate

exchangeable cation
a cation which is loosely bound to a negatively charged site on the surface of a soil particle, and which may be displaced into solution by another cation which takes its place at the particle surface

fertigation
the application of nutrients by adding them to irrigation water

gypsum
naturally occurring calcium sulfate

internode
the length of stem between two nodes

interveinal
relating to those parts of the leaf blade which lie between the veins

lamina
the leaf blade

latex
the milky sap which exudes from cut surfaces of some species of plants, including sweet potato

leaf blade
the broad, flat part of the leaf which provides most of the photosynthetic surface of the plant

lesion
localised injury (usually necrotic) of the plant tissue

lime
naturally occurring calcium carbonate

major / main veins
thick veins on the leaf blade which branch directly from the midvein or from the point of attachment to the petiole, and radiate outwards to the marginal vein

marginal vein
the leaf vein which runs just inside the margin of the blade and parallel to it

midvein / midrib
the main vein bisecting the leaf blade, from the petiole to the tip

minor veins
secondary and tertiary branches of the major veins

mottle
an uneven or blotchy appearance

mycorrhizae
soil fungi which form an intimate association with plant roots, often to mutual benefit

necrosis
(adj. *necrotic*) Death, affecting any section of the plant tissue, not the entire plant

node
the point on a stem where a leaf is attached

petiole
the leaf stalk which supports the leaf blade. Both the petiole and the blade make up the leaf

photosynthesis
(adj. *photosynthetic*) The process by which plants utilise light energy to synthesise organic material

senescence
(v. *senesce*) The processes leading up to death of a plant part, such as a leaf, or the whole plant

soil pH
a measure of the acidity or alkalinity of a soil. Soil pH may be measured by mixing soil in water (e.g. 1:5 soil:water), or in a solution (e.g. 0.002 M $CaCl_2$). Measured in water, a pH of 6.5–7.5 denotes a neutral soil. Acid soils have pH<6.5, with soils having pH<5 being very acid. Alkaline soils have pH>7.5. The presence of undissolved lime or coral may raise the pH up to 8.2; a higher pH indicates the presence of sodium salts

storage roots
the starchy, edible roots of sweet potato, sometimes referred to as tubers

Scientific names for plant species mentioned

barley	*Hordeum vulgare*
beet	*Beta vulgaris*
cassava	*Manihot esculenta*
citrus	*Citrus* spp.
ginger	*Zingiber officinale*
green bean	*Phaseolus vulgaris*
maize	*Zea mays*
peanut	*Arachis hypogaea*
potato	*Solanum tuberosum*
soybean	*Glycine max*
sugar beet	*Beta vulgaris*
sunflower	*Helianthus annuus*
sweet potato	*Ipomoea batatas*
taro	*Colocasia esculenta*
tobacco	*Nicotiana tabacum*
wheat	*Triticum aestivum*
yam	*Dioscorea* spp.

Abbreviations

ACIAR	The Australian Centre for International Agricultural Research
µM	micromolar concentration
CEC	cation-exchange capacity
CIP	International Potato Center
cm	centimetre
cmol(+)	centimoles of positive charge
cv.	cultivar
DTPA	diethylenetriaminepentaacetic acid
EC	electrical conductivity
EDTA	ethylenediaminetetraacetic acid
g	gram
ha	hectare
kg	kilogram
L	litre
m	metre
M	molar concentration = mole/L
me	milliequivalent
mg	milligram
MJ	megajoule = million joules
mm	millimetre
dS	decisiemen
Mt	megatonne = million metric tonnes
PNG	Papua New Guinea
S	Siemen
t	metric tonne = 1,000 kg
TSP	triple superphosphate
VAM	vesicular-arbuscular mycorrhizae

Conversions

Units of measurement used in literature have been converted to standard units for inclusion in this text. Following are the standard units and their synonyms or conversions to other commonly used units.

cmol(+)/kg	=	me/100g
mg/kg	=	ppm = µg/g
dS/m	=	mS/cm = millimhos/cm
1 kg K/ha	=	1.20 kg K_2O/ha
1 kg P/ha	=	2.29 kg P_2O_5/ha

Symbols denoting chemical elements

Throughout most of the text in this booklet, chemical elements are referred to by their chemical symbols. However, the names of chemical compounds are written in full. Following is a list of the elements mentioned and their corresponding symbols.

Symbol	Name
Al	Aluminium
B	Boron
C	Carbon
Ca	Calcium
Cl	Chlorine
Cu	Copper
Fe	Iron
H	Hydrogen
K	Potassium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
Na	Sodium
O	Oxygen
P	Phosphorus
S	Sulfur
Zn	Zinc

Appendix 2. Key to Nutrient Disorders

This key is intended as a quick reference to help determine which disorders are the most likely cause of the symptoms observed. It is recommended that the user then refer to the detailed descriptions of each suspected disorder.

This key uses symptoms visible on the above-ground parts of the plant only. Some disorders may be keyed out through a number of routes, depending on which symptoms are expressed most clearly in the crop being investigated. Nutritional disorders may induce a variety of symptoms, which may be expressed to a greater or lesser degree (or not at all) in certain cultivars, or under certain environmental conditions. Hence, a number of symptoms may be described for each disorder. It is not necessary that each of these is observed; the presence of any one, or combination, of the described symptoms may indicate the disorder.

In addition to nutritional disorders, reference is made to a few pathogenic diseases, whose symptoms may be easily confused with those of a nutritional disorder. The key is not intended to give a comprehensive diagnosis of pathogenic disorders.

A **1.** Symptoms are most severe on the young leaves or shoot tip. ..... **B**

2. Symptoms affect older leaves, or the whole plant equally. ..... **G**

B **1.** Shoot tips are dead. ..... **C**

2. Shoot tips are not dead. ..... **D**

C **1.** Young leaves have conspicuous interveinal chlorosis, with green major and minor veins contrasting sharply with the yellow to whitish interveinal tissue; severely affected leaves may be entirely chlorotic or have brown patches; leaves are of normal shape and texture. ..... ***Iron deficiency*** p.75

2. Young leaves are thickened and brittle, often puckered or chlorotic; leaf tip and lateral lobes may be curled under. ..... ***Boron deficiency*** p.79

3. Young expanding leaves may have necrosis on the lateral margins; leaves immediately below may be dead or abscised; older leaves may have circular chlorotic or necrotic spots. ..***Calcium deficiency*** p.72

D **1.** Young leaves are paler than older leaves. ..... **E**

2. Young leaves are not chlorotic. ..... **F**

E **1.** Young leaves have conspicuous interveinal chlorosis, with green major and minor veins contrasting sharply with the yellow to whitish interveinal tissue; severely affected leaves may be entirely chlorotic or have brown patches; leaves are of normal shape and texture. ..... ***Iron deficiency*** p.75

1.1 Necrotic spots are present, particularly on older leaves. Iron deficiency symptoms may be induced by ... ***Manganese toxicity*** p.37

1.2 Red or purple pigmentation is present, on older leaves or leaves of all ages. Iron deficiency symptoms may be induced by ..... ***Zinc toxicity*** p.65

2. Young leaves show general chlorosis, or clearing of small interveinal islands which may form necrotic pits. Older leaves show a diffuse interveinal chlorosis, with darkest green near main veins and colour fading gradually into interveinal zones; these leaves may be puckered or drooping. ..... ***Manganese deficiency*** p.54

3. Chlorosis is general on young leaves, but distinctly interveinal on mature leaves. Young leaves are very small, elongated, and may be curled but not puckered. ..... ***Zinc deficiency*** p.83

4. Chlorosis on young leaves may be diffusely interveinal or general; young leaves are thickened and brittle, and may be puckered. Older leaves are not chlorotic. ..... ***Boron deficiency*** p.79

F 1. Young leaves may be puckered, deformed, or very small, but not thickened and without interveinal pitting. The leaf blade may have holes, especially near the midrib, and the young leaves may have a silvery appearance, compared with the mature leaves.

1.1 The symptoms affect adjacent plants similarly, although they may be more severe in one part of the field than another. ..... ***Copper deficiency*** p.58

1.2 The symptoms affect some plants more than others. There may be healthy plants adjacent to severely affected plants. Veins may be paler than the rest of the leaf. ..... ***Virus disease***

2. Young leaves are small, and may be curled but rarely puckered. Upper internodes may be very short, but not in all cultivars.

2.1 Branching is increased giving a bushy appearance. Some plants may be much more affected than others, even adjacent plants. The symptom may appear more severe after dry weather. ..... ***Little- leaf disease*** p.91

2.2 Branching is not excessive. Adjacent plants are similarly affected. Young leaf shape is elongated, with lateral lobes reduced in extent and pointing forward. ..... ***Zinc deficiency*** p.83

3. Young leaves are thickened and brittle, may be puckered and have tips and lateral lobes curled under. May have corky growth of tissue over the veins. Upper internodes usually shorter than normal; the shoot tip and axillary buds may be necrotic. .. ***Boron deficiency*** p.79

4. Young expanding leaves have necrotic lateral margins. Leaves below them may be dead, but older leaves are less affected. Older leaves may have circular brown or russet necrotic spots. ..... ***Calcium deficiency*** p.72

G 1. The whole plant is pale green, with a generally stunted appearance and small, dull leaves. ..... **H**

2. Chlorosis or necrosis is only or most severe on mature to old leaves. ..... **K**

3. No above-ground symptoms other than poor establishment of the crop, wilting or death of plants at an early stage. ..... **O**

H 1. Red or purple pigment is present on the young leaves. ..... **I**

2. No red or purple pigmentation is present on the young leaves. ..... **J**

I 1. Pigment is present on the veins and petioles of young leaves (upper or lower surface); cultivars which are normally purple-tipped have purple veins on maturing leaves which are losing general pigmentation. No pigmentation is present on oldest leaves. ..... ***Nitrogen deficiency*** p.45

1.1 The crop does not respond to either nitrogen or sulfur fertilizers. Some mature leaves may have necrotic patches in interveinal tissue or at the margins. ..... ***Molybdenum deficiency*** p.63

2. Pigmentation on the young leaves is more on the margins than veins. Oldest leaves are also pigmented, especially on the margins and tips. On mature leaves, veins may be paler than the interveinal tissue. ..... ***Sulfur deficiency*** p.50

J **1.** Veins are paler than the interveinal tissue; this may be obvious only on mature or older leaves. ..... ***Sulfur deficiency*** p.50

2. The entire leaf blade is uniformly chlorotic. Oldest leaves become mostly or entirely yellow before browning off. ..... ***Nitrogen deficiency*** p.45

2.1 The crop does not respond to either nitrogen or sulfur fertilizers. Some mature leaves may have necrotic patches in interveinal tissue or at the margins. ..... ***Molybdenum deficiency*** p.63

K **1.** Chlorosis or necrosis is not accompanied by discrete necrotic spots. ..... **L**

2. Chlorosis is accompanied by discrete necrotic spots. ..... **M**

L **1.** Young leaves are dark green; yellowing of the oldest leaves may be patchy, asymmetric or interveinal and is accompanied by irregular necrotic patches. Older leaves may have purple pigmentation, becoming red and orange as the leaves senesce. ..... ***Phosphorus deficiency*** p.20

1.1 Poor crop establishment and root growth. Soil is acidic (pH<5.0 measured in water).
Phosphorus deficiency may be induced by ..... ***Aluminium toxicity*** p.88

2. Yellowing of the interveinal sectors between main veins is present on the oldest leaves, and is accompanied by marginal to interveinal necrosis; younger leaves may show light green interveinal chlorosis, with darker green retained around both major and minor veins. ..... ***Potassium deficiency*** p.25

3. Symptoms progress gradually from young mature leaves to oldest leaves. Sectors between main veins become pale green, while the veins are flanked with a zone of greener tissue. On older leaves, the interveinal tissue may become yellow or develop necrotic patches, or the leaf may be entirely yellow and wilted. Red pigment may be present on older leaves. The stem near the tip may be thin and twining. ..... ***Magnesium deficiency*** p.29

3.1 Poor crop establishment and root growth. Soil is acidic (pH<5.0measured in water).
Magnesium deficiency may be induced by ..... ***Aluminium toxicity*** p.88

4. Chlorosis is well developed on mature leaves, but not necessarily the oldest leaves. The chlorosis is diffusely interveinal, mottled or general, and may be accompanied by drooping, puckering or localised necrotic lesions. Youngest leaves may be deformed, puckered or undersized. ..... ***Copper deficiency*** p.58

5. Light green to white chlorosis of small interveinal islands on mature leaves; may affect only a few leaves, and only part of the leaf blade, and does not progress to general yellowing or leaf senescence. ..... ***Copper toxicity*** p.68

6. Leaves have irregularly scattered chlorotic spots (not a regular interveinal distribution), which are roughly circular, and approx. 2–7 mm across. Spots may be surrounded by purple pigmentation. ..... ***Feathery mottle virus*** p.91

7. Oldest leaves become necrotic, initially around the margins but rapidly spreading, causing early death. Necrosis may be preceded by a narrow front of yellowing. Whole crop stunted, and with a tendency to wilt. ..... ***Salinity*** p.40

M **1.** Necrotic lesions are initially small (1–2 mm), dark, and scattered over the interveinal tissue. They may proliferate and merge to form irregular patches of interveinal necrosis. General yellowing of the entire blade occurs on the oldest leaves, immediately preceding senescence. Young leaves may have pale green chlorosis due to induced iron deficiency. ..... ***Manganese toxicity*** p.37

2. Necrotic lesions are most frequent and largest midway between the main veins. ..... **N**

N **1.** Necrosis extends around the leaf margin, and may spread from the initial lesions to engulf large areas of the blade. Necrosis is usually preceded by a front of yellowing. Dead leaves may be retained on the stem. ..... ***Salinity*** p.40

2. Interveinal necrotic spots usually precede the spread of necrosis around the leaf margin. They may expand and fuse, but the surrounding tissue does not become yellow or necrotic until the leaf is about to die. Dead leaves are readily shed. .... ***Boron toxicity*** p.34

O **1.** Saline soil, often irrigated semi-arid land, possibly showing surface crusting or salt deposition around hollows ..... ***Salinity*** p.40

2. Acid soil, having pH <5.0 (measured in water). ..... ***Aluminium toxicity*** p.88