A Visual Guide to Nutritional Disorders of Tropical Timber Species:

Swietenia macrophylla and *Cedrela odorata*

M.J. Webb

CSIRO Land and Water, Davies Laboratory,
Douglas, Queensland, Australia.

P. Reddell and N.J. Grundon

CSIRO Land and Water, Tropical Forest Research Centre,
Atherton, Queensland, Australia.

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GPO Box 1571, Canberra, Australia 2601.
http://www.aciar.gov.au
email: aciar@aciar.gov.au

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Introduction

As sources of high-value tropical timbers from natural forests dwindle, there is strong commercial and community interest in producing these timbers from plantations. However, because forestry must compete with other land uses, the sites available for plantation establishment are frequently infertile and/or have been degraded by previous unsustainable land uses. Such sites are often deficient in one or more of the plant nutrients that are necessary to maintain acceptable rates of tree growth. Recent research in the humid tropics has revealed the widespread extent and severity of these nutrient limitations and demonstrated the cost effectiveness of targeted fertiliser applications in increasing growth and wood yield. Nonetheless, the extent of the potential production lost because of nutrient deficiencies is still not widely recognised by many forest managers due to a lack of available information and/or appropriate 'tools' to aid in identifying nutritional problems in tropical trees. The visual symptoms outlined in this book are a first step in alerting plantation managers to nutrient deficiencies they may encounter in the nursery and the field.

The recognition of symptoms on leaves and stems which result from nutritional disorders is a powerful tool in determining nutritional constraints to the growth of trees—especially when little other nutritional information is available. When used in conjunction with other information, such as soil parent material, climate, soil analysis, concentration of nutrients in tissues, site history, and nutrient (fertiliser) trials, it can often lead to rapid diagnosis of major nutritional constraints.

On their own, symptoms can often be the first indication that nutritional constraints to production exist. Recognition of these symptoms can lead to trials or experiments which may confirm the existence of nutritional constraints.

Whilst some symptoms may be the result of any one (or combination) of a number of disorders, others such as iron deficiency often have features that are highly distinctive and are recognisable across a wide range of species.

Although the diagnosis of symptoms can be useful, it should **not** be relied on as the sole system of managing the nutrition of trees. In most cases, by the time symptoms appear, the deficiency is quite severe and substantial losses in potential production may have already occurred.

The manifestation of symptoms depends on two main features of each nutrient: its biological function, and its mobility (the ease with which it is transported) within the plant. Biological function affects certain processes (for example, chlorophyll production, leaf expansion, or stem elongation) and thus will determine the type of symptom produced. Mobility within the plant will determine the most likely location of the symptom—for example, highly mobile nutrients will usually show *symptoms in the older leaves and tissues, whereas* immobile nutrients will usually show symptoms in the younger leaves and tissues. Unfortunately, however, there are some exceptions to these guidelines.

While the symptoms described and illustrated in this book can be used in an empirical fashion (i.e. specific for these species), an understanding of function and mobility of key elements will assist in diagnosing symptoms in other species for which deficiencies have not been documented.

Methodology

This book is the first attempt to document the visible symptoms of nutrient deficiencies for *Swietenia macrophylla* and *Cedrela odorata*. The symptoms have been developed under carefully controlled conditions, mainly in solution cultures in glasshouses, but also in soil cultures in pots and in field studies. The symptoms are primarily derived from young plants less than 8 months old, and while the descriptions in this book will be useful for identification of nutritional disorders in young plants (eg nursery stock and newly planted field plants), the symptoms visible in mature trees may differ somewhat from those in this book.

It was not always (technically) possible to obtain the necessary degree of deficiency (or excess) to induce symptoms for all nutrients for all species, especially for the micronutrients. Therefore, if visible symptoms for a particular element are not included in this book, this omission does not mean that visible symptoms do not exist for that nutritional disorder, but rather that they were not developed under the conditions used in the present study.

Acknowledgments

The authors are pleased to thank Grace Baker and Sue Joyce for technical assistance. We also wish to thank Alan Brown and Richard Bell for valuable comments on the manuscript.

How to Use this Book

Success in getting a useful diagnosis depends on more than just symptom information, so do read the next section, Steps in the Diagnosis of Nutritional Disorders. The more additional information you have at hand, the more likely it is that you will be able to make a reliable diagnosis.

The book has been designed to assist in reducing the number of possible diagnoses to the two or three most likely. It will not necessarily result in an absolute and definitive diagnosis.

There is a key provided for each species as a first step in reducing the number of possible diagnoses. This is not a typical dichotomous key commonly used in symptom identification, but rather, this key may lead to a number of possible diagnoses.

A good approach is to identify the location (leaf, stem or growing point) of the symptom and then identify the type of symptom (colour, shape etc). Do this with each of the symptoms present. With this information, follow the keys for each symptom. Take note of ALL of the descriptions that are appropriate. The key will usually lead to a number of possible diagnoses. Read the detailed description of the symptoms for each of the possible diagnoses in the sections following the key, taking into account the 'likely' and 'unlikely' scenarios, to come up with the most likely one or two nutrients that could be responsible for the symptoms observed. At this point it may be necessary to collect additional information or even undertake some experimentation to narrow the possibilities further.

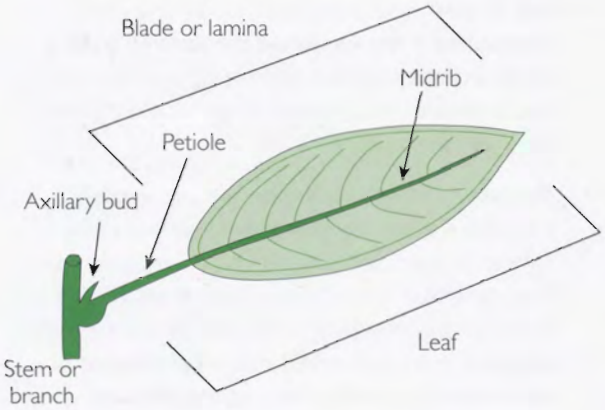
In using this book, it is important to keep the following points in mind:

- Different disorders can have very similar symptoms, and the key may suggest that more than one nutrient be considered.
- Not all symptoms listed in the key for a given nutrient may be present in the affected plant at any one time.
- Not all symptoms under each nutrient may be represented in the key. So use the pictures in the key as examples. Do not exclude a possible nutrient simply because the symptom does not exactly match the example shown.
- The categories listed in the key are not mutually exclusive. A plant may have more than one of the symptoms listed and may even have symptoms that have descriptions which seem in apparent conflict. For example, depending on its severity, iron deficiency can result in a very marked interveinal chlorosis or a chlorosis that is uniform across the veins and interveins. So take note of all symptom descriptions that are appropriate.
- Excessive (toxic) concentrations of some nutrients (or non-nutrients) can cause a deficiency of other nutrients, and the visible symptoms may be a combination of the symptoms of the toxicity of one nutrient and the deficiency of another nutrient.
- Similarly, deficiencies of some nutrients may induce a toxicity of other nutrients.
- Any conclusion based solely on visible symptoms should be considered as a preliminary diagnosis to be confirmed wherever possible by other methods such as soil and plant analyses, pot culture assays, and field experiments.

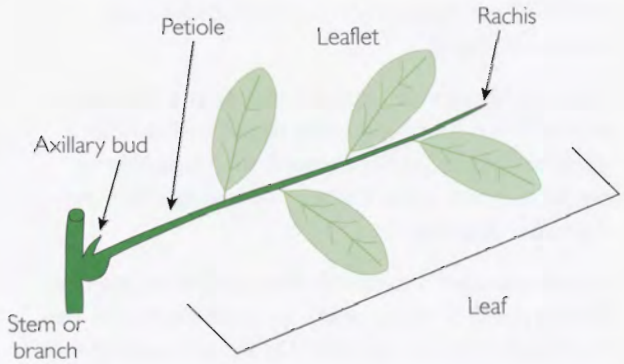
Notes on Terminology

As far as possible, we have tried to be botanically correct in the use of terms without making the book 'unreadable' to a non-botanist. In both *Swietenia macrophylla* and *Cedrela odorata*, all but the first few leaves developed on a young seedling are **compound** leaves. This means that the true leaf is actually divided into leaflets. Usually, the descriptions in this book refer to these leaflets.

The term 'nutrient' has been used in preference to 'element' even though in many other texts on symptoms of nutritional disorders, the terms are used interchangeably.



Simple leaf



Compound leaf

Brief Glossary of Terms

axillary bud
The bud from which a branch grows. It is called an axillary bud because it is in the axil of the leaf. It is this bud which defines a leaf.

abscise/abscission
Detach; fall off.

basal
Near the base of the leaf; i.e. closest to the stem.

chlorophyll
The photosynthetic pigment in plants that gives leaves their green colour.

chlorotic/chlorosis
Leaves (and sometimes other plant tissue) lose their normal green colour and turn yellow or white. Chlorosis is caused by the loss of chlorophyll from the tissue.

compound leaf
The leaf blade is divided into leaflets.

distal
Near the tip of the leaf, i.e. away from the stem.

internodes
The portion of the stem between two nodes.

interveinal
Refers to the tissue between the veins of the leaf.

lamina (leaf blade)
The flattened part or blade of the leaf.

marginal
Occurring on the edges of the leaf.

meristem
The growing point, usually of the stem.

nodes
Points where the leaves (or branches) emerge from the stem.

petiole
The stalk that connects the leaf lamina to the stem.

necrotic/necrosis
Tissues, or patches of tissue, which are dead. Usually such patches are brown in colour and have a dried out, papery appearance.

rachis
An extension of the petiole in a compound leaf. It is equivalent to the midrib of a simple leaf.

simple leaf
The leaf blade is entire and is not divided into separate leaflets.

Steps in the Diagnosis of Nutritional Disorders

Grundon (1987) is one of the few references which describe the steps in diagnosis of nutritional disorders, and what follows is a précis of his suggestions.

Know the healthy plant. Before visible symptoms can be used to assist in the diagnosis of a disorder, it is essential that you know what a healthy plant looks like during all stages of its growth, and how a healthy plant reacts to different environmental conditions of rainfall, temperature and light. For this reason, a description of a healthy seedling is included in this booklet before the visual symptoms of each nutritional disorder are described. This description should be read as the first step in diagnosis of possible nutritional disorders.

Develop a case history. Develop a case history of the problem and the area where the plants are growing. Questions that can be asked to develop a case history include:

- What has been the recent rainfall and temperature? This is especially important if they have been unusual for the locality. For example, unusually heavy rainfall can leach very soluble nutrients such as nitrate from the root zone of recently transplanted seedlings, causing a temporary nitrogen deficiency.
- What is the soil type where the problem occurs? Some soil types are prone to causing particular nutritional disorders. For example, deficiencies of copper and iron are more likely to occur in peat and other soils high in organic matter where the organic matter 'locks up' soluble copper and iron, whereas a deficiency of manganese is most unlikely in peat soils because the low pH makes manganese more soluble and therefore more available to plants. Hence occurrence of a disorder is affected by the soil type rather than the species growing on it, and knowledge of the soil type can eliminate some disorders from consideration. For this reason, soil types where a disorder is unlikely or highly unlikely to occur have been listed in this book under each nutrient.
- Has a soil test been completed on the soil? This information can be most important as it can eliminate certain nutrients from consideration. For example, when the soil is very acidic, with a pH less than 4.5, manganese and aluminium become more soluble and can occur in toxic concentrations in the soil solution. Likewise, when the soil pH becomes very alkaline, with a pH above 8.0, some elements such as zinc become less soluble. Under these conditions, plants may be unable to absorb sufficient quantity for healthy growth, even though there is a large quantity of total zinc in the soil.
- Has fertiliser been applied in the past? If so, what fertiliser was it and when was it applied?
- Has the plant material been chemically analysed; what were the results?

Describe the symptoms. While visible symptoms of deficiency or excess are usually more apparent on the leaves, they can occur on any part of the plant, including the stem, fruit and roots. Because insects, disease or nematodes can cause visible symptoms also, it is essential to note if these are present, and if present to include them in the possible cause of the visible symptoms. When describing the symptoms, pay particular attention to the following:

- The location of the symptom. Does it appear only on the leaves or stem or roots? If it is on the leaves, are they the youngest or oldest leaves or over the whole plant? Does it occur mainly near the tip of the leaf, mainly near the base or over the whole leaf? Does it occur only on the leaf margins or does it occur only in the body of the leaf? Does it occur only between the veins with the veins remaining unaffected, or are the veins the only parts affected?
- The colour of the symptoms. Are they pale green, or a pale or deep yellow (i.e. chlorotic), or brown, or red?
- Is the tissue live or dead (i.e. necrotic)? Here it is important to realise that dead tissue is not always coloured brown, but may be white or even yellow.
- Has the size of the plant or organ changed? Stunted growth is sometimes the only symptom of phosphorus deficiency in some trees.
- Has the shape of the organ changed? Some disorders cause the margins of the leaves to turn upwards and the whole leaf may become cupped.
- Has the orientation of the plant or organ changed? In some disorders the plant or leaves may have a wilted, limp appearance, or the tips of the leaves may become twisted.
- Can you see a pattern to the development of the visible symptoms from mild to severe? The sequence or order in which the visible symptoms appear usually follows a definite pattern as the disorder progresses from mild to very severe. For example, in the early or mild stage of a disorder, pale yellow chlorotic spots may appear near the margins of the leaf, mainly towards the tip or distal portion of the leaf. These chlorotic spots may advance towards the margins and, as the tissue dies, become brown necrotic spots surrounded by a halo of yellow chlorosis. Eventually, as the disorder becomes more severe, the necrotic spots join up to produce a brown marginal necrosis that grows towards the basal portion of the leaf, and advances into the body of the leaf between the veins. By carefully examining a number of leaves on the same plant, or a number of different plants, it is possible to see and describe all stages of the disorder.

The final diagnosis. When as much information as possible has been gathered, use one of the keys in this book to identify possible nutritional causes for the symptoms.

Notes of caution

An absence of a symptom does not necessarily mean that nutrient constraints are absent. For example, P deficiency can cause severe growth reduction without the development of other visible symptoms. Similarly, plants grown in soils of generally low fertility may appear healthy in all respects (visual appearance, nutrient concentrations, photosynthetic capability) but still have reduced growth rates.

Some symptoms in trees can be caused by agents other than nutrient deficiencies, such as insects and other herbivores, environmental stresses (temperature, wind, water), salinity, toxicities of nutrient and non-nutrient elements, pathogens, pollutants, pesticides and herbicides, and genetic factors (Dell *et al.* 2001). The possibility that these factors may also be present must be considered when assessing the cause of a particular visible symptom.

References

Dell, B., Malajczuk, N., Xu, D. and Grove, T.S. 2001. Nutrient disorders in plantation eucalypts. 2nd edition. Canberra, ACIAR Monograph No. 74. 188 pp.

Grundon, N.J. 1987. Hungry crops: a guide to nutrient deficiencies in field crops. Brisbane, Queensland Department of Primary Industries. 246pp.

Other Useful Resources

The following bibliography refers to either photographic or written descriptions of symptoms of nutritional disorders in trees, but not necessarily *Swietenia macrophylla* or *Cedrela odorata*. Many other references to symptoms of nutritional disorders in trees are listed in Grundon *et al.* (1997).

Bergmann, W. (ed) 1992. Colour atlas of nutritional disorders of plants: visual and analytical diagnosis. Jena, Gustav Fischer. 386pp.

Grundon, N.J., Robson, A.D., Lambert, M.J. and Snowball, K. 1997. Nutrient deficiency and toxicity symptoms. In: Plant analysis: an interpretation manual. Second edition. Collingwood, Victoria, CSIRO Publishing, 37–51.

Kamala, B.S., Angadi, V.G., Parthasarathi, K. and Rai, S.N. 1986. Symptoms of deficiency of trace elements and the associated changes in peroxidase isoenzyme pattern in the seedlings of teak, mahogany and eucalyptus. Van Vigyan, 24, 49–55.

Swietenia macrophylla King

aguano
araputango
arawakan
big leaved mahogany
broad leaved mahogany
Honduras mahogany
large leaved mahogany
mahogany
mahokani
mara
mongo

Symptom Key

No apparent symptoms on leaves

N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B	Mo	Mn Tox	Al Tox

Symptoms based on

Symptoms based on leaf colour: overall

Pale green/ yellow/white (chlorosis)

N P K Ca Mg S Fe Zn Cu Mn B Mo **Mn Tox** Al Tox

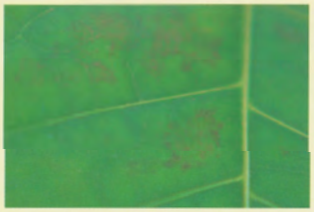
Key pages 16-19

Brown patches or spots – dead (necrotic)

N P K Ca Mg S Fe Zn Cu Mn B Mo **Mn Tox** Al Tox

Key pages 20-21

Brown spots – alive (not necrotic)



N P K Ca Mg S Fe Zn Cu Mn B Mo **Mn Tox** Al Tox

Pink

N P K Ca Mg S **Fe** Zn Cu Mn B Mo Mn Tox Al Tox

Dark green

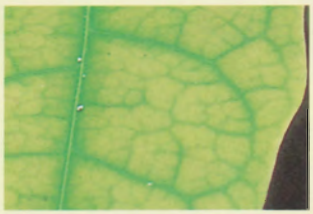
N P K **Ca** Mg S Fe Zn **Cu** Mn B Mo Mn Tox Al Tox

Red tinge

N P K Ca Mg S Fe Zn Cu Mn **B** Mo Mn Tox Al Tox

Symptoms based on leaf colour: pattern of chlorosis

Veins green; interveinal areas strongly chlorotic



N P **K** Ca **Mg** S **Fe** **Zn** Cu Mn B Mo **Mn Tox** Al Tox

Veins green; interveinal areas mildly chlorotic

N P K **Ca** **Mg** S Fe **Zn** Cu **Mn** B Mo Mn Tox Al Tox

Veins green; interveinal areas weakly chlorotic

N P K Ca Mg **S** **Fe** Zn **Cu** Mn B Mo Mn Tox Al Tox

Symptoms based on leaf colour: position of chlorosis

Basal

N P K Ca **Mg** S Fe **Zn** Cu **Mn** B Mo Mn Tox Al Tox

Distal

N P K **Ca** Mg S Fe Zn Cu Mn B Mo Mn Tox Al Tox

Marginal

N P **K** Ca Mg S Fe **Zn** Cu **Mn** B Mo Mn Tox Al Tox

Lobed

N P K **Ca** Mg S Fe **Zn** Cu Mn B Mo Mn Tox Al Tox

Body of leaf

N P K Ca **Mg** S Fe Zn Cu Mn B Mo **Mn Tox** Al Tox

Uniform over leaf

N P K Ca **Mg** **S** **Fe** **Zn** **Cu** Mn B Mo **Mn Tox** Al Tox

Symptoms based on leaf colour: necrosis

Basal

N P K Ca Mg S Fe **Zn** Cu Mn **B** Mo Mn Tox Al Tox

Distal

N P **K** **Ca** Mg S Fe Zn **Cu** Mn **B** Mo Mn Tox Al Tox

Marginal

N P **K** **Ca** Mg S Fe **Zn** Cu Mn **B** Mo Mn Tox Al Tox

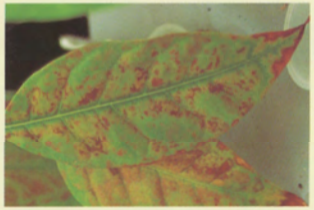
Lobed

N	P	K	**Ca**	Mg	S	Fe	**Zn**	Cu	Mn	B	Mo	Mn Tox	Al Tox

Body of leaf

N	P	K	**Ca**	**Mg**	**S**	Fe	Zn	Cu	**Mn**	B	Mo	**Mn Tox**	Al Tox

Necrotic areas between veins



N	P	**K**	**Ca**	**Mg**	**S**	Fe	**Zn**	Cu	Mn	**B**	Mo	**Mn Tox**	Al Tox

Symptoms based on leaf shape and condition

Wavy edges

N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B	Mo	Mn Tox	Al Tox
		K								B			

Twisted tips

N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B	Mo	Mn Tox	Al Tox
								Cu		B			

Flaccid

N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mn	B	Mo	Mn Tox	Al Tox
			Ca					Cu		B			

Rapid death of new leaves

N	P	K	**Ca**	Mg	S	Fe	**Zn**	Cu	Mn	B	Mo	Mn Tox	Al Tox

'Water-soaked' areas

N	P	K	Ca	Mg	S	Fe	**Zn**	Cu	Mn	B	Mo	Mn Tox	Al Tox

Symptoms based on stems and growing point

Short and stout

N **P** K **Ca** Mg S Fe Zn Cu Mn B Mo Mn Tox Al Tox

Thin/spindly/ leggy

N P **K** Ca **Mg** **S** **Fe** **Zn** Cu Mn B Mo Mn Tox Al Tox

Death of growing point or meristem

N P K **Ca** Mg S Fe Zn Cu Mn B Mo Mn Tox Al Tox

Abscission of leaves

N P K **Ca** Mg S Fe **Zn** **Cu** Mn B Mo **Mn Tox** Al Tox

Shortened internodes

N P K Ca Mg S Fe **Zn** Cu Mn B Mo Mn Tox Al Tox

Healthy Seedlings

Healthy mahogany seedlings usually have an unbranched stem that grows rapidly to reach 30 cm to 40 cm in 12 weeks. The first 5 to 10 leaves to develop are simple leaves, followed by compound leaves carrying firstly 3 leaflets and later 5 to 7 leaflets.

The young leaves are often pale brown to golden brown with a soft texture. As they mature, the young leaves turn pale green and may have a mottled appearance. When they are fully expanded the leaves are an even dark green with a glossy, shiny appearance. Thus a healthy seedling generally has pale brown to pale green younger leaves and glossy, dark green older leaves.

The roots of a healthy seedling are extensively branched, the younger roots being pale brown to white while the older roots are dark brown. The roots tips have no signs of malformation such as being club-shaped or with brown or black necrotic lesions.