A Guide to IDENTIFYING NUTRITIONAL & PATHOLOGIC DISORDERS of PINUS RADIATA

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by

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A limited number of colour photographs are available at current costs on request for some of the nutritional and pathologic disorders described in this Paper.

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INTRODUCTION

Disorders in *Pinus radiata* D. Don can be caused by incorrect mineral nutrition, poor soil structure, unsuitable climatic factors, pathogens and management effects. To establish why a tree or group of trees changes colour, has poor growth or dies, is often difficult or impossible, but, if the cause can be found, some disorders can be corrected. Symptoms must be assessed in conjunction with the stand history, climatic, and soil factors. Where a significant area of forest is affected, confirmation of symptoms by foliar chemical analysis is essential and possible pathogens should be identified if present.

Mineral nutrient imbalances can be diagnosed by an assessment of visual symptoms, the chemical analysis of foliage and soil, pot and field fertilizer trials and by assessing the response to the direct application of specific chemicals to trees. These methods are largely complementary and diagnoses for significance or extensive areas are usually not based on one method alone. Some nutrient deficiencies produce very distinctive symptoms and hence a decision about the cause can be reached with some certainty. However some nutrient deficiency symptoms are similar and so cannot be conclusive. This may occur when two elements are connected with the same growth process or processes within the plant. For example, manganese and iron are both associated with chlorophyll formation and a deficiency of either of these elements produces chlorotic symptoms in pines which are hard to separate (Truman, 1972). Also, field symptoms of manganese *toxicity* and manganese *deficiency* are very similar.

Fungal infections are usually accompanied by the presence of hyphae and often by fruiting bodies and spores. Finding evidence of a known pathogen assists correct diagnosis *but does not always mean that the primary cause of the problem has been established.* In particular nutrient deficiency situations, poor drainage or drought stress may weaken groups of trees to such an extent that the natural resistance of the plant is substantially lowered, enabling infection to occur.

A preliminary key to relate symptoms in *P. radiata* to nutritional deficiencies and other biological disorders has been devised. It is meant as a guide and should not be regarded as a complete list of *P. radiata* disorders. Details of sampling methods together with the climatic and site data required are included as an aid to confirmation of the disorder.

NUTRIENT DEFICIENCIES

The most widespread nutrient deficiencies encountered in New South Wales *P. radiata* plantations are phosphorus, sulphur, boron and calcium although deficiencies of other nutrients may cause problems in some specific situations. In other parts of Australia, nutrient deficiencies of zinc, potassium and copper are also important. The geology of an area is a very useful indicator of nutrient status and other soil characteristics, as summarized in Table 1. It is not meant to imply generally that a forest growing on a particular soil parent material will necessarily have a nutritional problem. However, if symptoms do appear and the basic geology can be identified, the possible causes can be grouped immediately.

TABLE 1. SOIL PARENT MATERIALS AND THEIR POTENTIAL NUTRIENT DEFICIENCIES FOR *PINUS RADIATA*

Geological type	Possible deficiencies	Comments
A. *Unconsolidated sediments*		
Coastal sands	Phosphorus, calcium and nitrogen	In New South Wales, severe phosphorus deficiency sometimes occurs.
Loess soils or inland dunes	Phosphorus, zinc, manganese and copper	Zinc, manganese and copper deficiencies are rare in New South Wales, but common on these soils in southern States. These soils often have very high sulphur status.
B. *Sedimentary*	Phosphorus and calcium	In New South Wales, soils derived from sedimentary rocks include those which are fertilized routinely with superphosphate. Generally the younger the geological strata, the lower the phosphorus status. Soils derived from sedimentary rocks in order of *increasing* natural phosphate status are: Jurassic → Triassic → Permian → Devonian → Silurian → Ordivician.
C. *Igneous*		
Granites — not strongly weathered (Red earths)	Sulphur and boron (usually near adequate)	There may be sporadically occurring sulphur and boron problems especially in the second rotation, and some *Diplodia* infection related to sulphur deficiency.
Granites — strongly weathered (Podzolics — solodics)	Sulphur and/or boron, phosphorus and calcium	These are poor soils due to the degree of weathering and many respond to superphosphate. It can be expected that foliar pathogens such as *Diplodia* or *Dothistroma* will be found associated with these soils. Problems associated with poor soil physical factors may also be encountered.
D. *Extrusives*		
Basalt-Diorite	Sulphur and/or boron	These soils are generally very rich in all nutrients but have low sulphur and boron availability. Pine growth is usually very good but dieback due to sulphur and boron deficiencies may lead to a very high proportion of stem deformities. Cation imbalances can also occur, the most common effect of which is the temporary yellowing of needles typical of magnesium deficiency, induced by a super abundance of calcium or potassium. *Diplodia* and *Dothistroma* are common.

Primary Diagnosis —

The overall impression of a *P. radiata* stand is important when making the first assessment of a potential nutritional problem. Easily definable visual symptoms occur in acute stages of deficiency. In cases where different nutrients affect the same part of the tree, symptoms may relate to more than one nutrient. One nutrient symptom can mask deficiencies of another. There may also be confusion where multiple problems, each of varying severity, exist. In these situations, symptoms become modified and chemical analyses become essential but are correspondingly more difficult to interpret.

Reduction in growth because of limited moisture can also reduce nutrient uptake (particularly nitrogen). This can lead to the incorrect assessment of the problem as one of nitrogen deficiency. In the same way, primary or secondary infections by pathogens can cause symptoms similar to nutrient deficiencies. Fungal infections can manifest themselves as sporadic occurrences where trees are under stress from other causes such as nutrient deficiencies, limited moisture or an interaction of the two. Recent weather conditions need to be taken into account as symptoms may be accentuated by extremes of moisture availability and heat, or extended series of frosts. A guide to the most common deficiency symptoms is given in Table 2.

TABLE 2. *PINUS RADIATA* NUTRIENT DEFICIENCY SYMPTOMS (modified from GENTLE AND HUMPHREYS, 1967)

Probable deficiency	Age of severest onset of symptoms	Symptoms
Phosphorus	6–15 years	Thin crown, grey green colour. Needles may be short, the tips yellow and sometimes fused. Within the stand, growth is very uneven and there will be a range of symptoms.
Nitrogen	6–15 years	Fine branching of trees and foliage which turns a uniform yellowish green, becoming yellow under severe conditions.
Calcium	15 years +	Tip dies back, side branches sprout giving a hedged, flattened appearance to the top of the tree. There may be abundant cone production and copious resin bleeding near terminal bud.
Potassium	4–8 years	Chlorosis occurs mainly in the lower lateral branches, the younger upper branches remaining unaffected, while the leading shoot remains apparently healthy. Onset of chlorosis rapid in spring but by the end of autumn, yellowing

TABLE 2 (continued)

Probable deficiency	Age of severest onset of symptoms	Symptoms
		not so marked and remaining foliage more even in colour. Needles only last 1½ to 2 years instead of 3 to 4 years, then yellow and fall.
Sulphur	1–15 years	Overall yellowing of trees with yellowing most pronounced at base of needles. In severe cases lesions and resin bleeding on stems.
Magnesium	3–6 years	Needle tips appear golden yellow as if dipped in paint. In some seasons yellowing occurs on stem needles.
Boron	1–7 years	Terminal shoots and leader die back with bright orange-red colouration. Buds fail to flush and the main stem forks and becomes deformed. Pith is black or dark brown. Young pith is flecked with brown; older pith is pitted with dark areas. Resin bleeding from bud. It is noticeable that patches of trees are affected and the planting lines appear uneven. It is most severe on eroded soils.
Zinc	3–6 years	Terminal needles are greatly reduced in length and clustered at end of shoot (rosetted).
Copper	3–10 years	Symptoms not specific but there may be dark blue-green foliage, distorted branches and bushiness. Prostrate growth in extreme cases.
Manganese	3–10 years	Paleness of the foliage, especially towards the top of the trees, and most recent growth extremely short, somewhat curved.

If symptoms or poor growth are observed and nutrient imbalance is suspected, chemical analysis can be used as a guide. For this, foliage samples are usually taken at a standard time (the dormant period) from within the evenly-lighted top third of the crown (Appendix 1). A low foliar concentration of a nutrient does not necessarily arise from absolute soil deficiency of that element; some other factor such as a strong affinity of the soil for the element may be limiting uptake. Final verification rests on the correction of the problem by application and subsequent uptake of the nutrient concerned.

FUNGAL PATHOGENS

Fungal pathogens attack individuals or groups of trees regularly or sporadically throughout pine plantations. They can cause symptoms which may be confused with those of nutrient deficiencies. Some diseases infecting groups of trees, as opposed to occasional individuals, are found on particular soil types (such as those with low sulphur/boron availability) and these may be considered secondary nutrient deficiency symptoms. However not all disease situations fall into this category. Brief descriptions of the most common fungal diseases of *P. radiata* in New South Wales are given in Table 3. The fruiting bodies referred to in this Table are best seen with the aid of a 10x hand lens.

TABLE 3. FIELD DESCRIPTION OF COMMON FUNGAL PATHOGENS

Pathogen	Symptoms
Needle infecting diseases	
Dothistroma septospora (Dorog.) Morelet (syn. *D. pini* Hulbary)	Orange red colouration on trees from the base up, killing older needles first. The disease first appears as chlorotic spots on the needles. These spots, which may appear translucent, later turn red or brick red, and may form bands around the needles, leading to the name 'red band'. However, red bands alone are not sufficient to indicate *Dothistroma,* since similar bands may appear with other needle cast fungi. Within the reddish zones, small brown to black pustules of irregular shape burst through the epidermis, and these produce vegetative spores which are the principal means of dispersal. The needles die distally (i.e. from the needle base) from the lesion and the fungus is most infective whilst the needle remains on the twig. There may be several flushes of infection in a growing season. In *P. radiata,* infection seldom occurs on trees older than 14 years but in *Pinus ponderosa* Laws. and some other species it may be severe at any age.
Lophodermium pinastri (Schrad. ex Hook.) Chev.	Yellowing of stem needles and older age classes of needles, followed by browning. Favoured by wet conditions during the late and early growing periods. The fruiting bodies (ascocarps) of the fungus appear as small, elliptical, shining black structures just below the surface of the needles. These ascocarps, when mature, open by a narrow central slit, and become strongly arched, exposing the closely packed glistening white tops of many club-shaped asci. Each ascus contains eight thin, threadlike spores which are forcibly shot into the air when ripe. Most asci develop on fallen leaves in the litter. A few are usually found also on dead needles still on the tree. Dispersal is by wind. There is also a vegetative stage (pycnidia) which appears as very small, shining black spots which contain hyaline bacillar-like conidia. Another useful characteristic of *Lophodermium pinastri* is the formation of black bands (diaphragms) across the needles, though this feature is not always present.

TABLE 3 (Continued)

Pathogen	Symptoms
Naemacyclus nivues (Pers. ex Fr.) Fuckel ex Sacc.	Yellowing of stem needles followed by browning under some conditions. Favoured by dry conditions. The fruiting structures (ascocarps) are whitish, waxy and rectangular in appearance. The ascocarp opens by a rupturing of the hypodermal layer to give the appearance of two white hinged lids or flaps. These, when open, expose the white glistening heads of club-like asci containing thread-like ascospores. There are no black bands on the needles such as found associated with *Lophodermium*. This fungus is mostly found on senescing needles.
Diplodia pinea (Desm.) Kickx	Tip curl, dark reddish colouration of leading shoot and/or laterals. Stem browning occurs and the area behind the leader tip often appears purple-brown. Can cause dieback of seedlings and poor form in older trees if leading shoot is affected. The fruiting bodies (pycnidia) are small, black, and burst through the epidermis of needles, shoots, bark and cone scales and are common in the axils of the leaves. These fruiting bodies produce large numbers of brown, single celled spores which are dispersed by wind, rain and insect attack. The fungus is common on slash.
Root rot diseases	
Phytophthora cinnamomi Rands.	This fungus is not known to cause any serious pine dieback in New South Wales. Where dieback does occur it is associated with poor drainage conditions and the symptoms are usually similar to water stress. "Little leaf" syndrome may also occur — short, sparse and discoloured needles.

MANAGEMENT PRACTICES AND EFFECTS ON DISORDERS

Various nutrient deficiencies can be induced by management practices either as a result of increased growth (growth dilution) or increased availability of other nutrients. It may be expected that in instances of intensive site preparation, fertilization or weedicide treatment, various symptoms may appear.

Some interactions which have been observed in New South Wales are —

1. Induced nutrient deficiencies (e.g., magnesium) produced by growth stimulation after application of phosphatic fertilizers (Newnes S.F., Mullion Range S.F., Wingello S.F.).
2. *Diplodia/Dothistroma* infection following sulphur deficiency induced by experimental nitrogen (ammonium nitrate) fertilization (Nundle S.F.).
3. Boron deficiency after mounding on poorly drained basalt soils (Buccleuch S.F.).
4. Distortions produced by hormone spraying (Nundle S.F., Canobolas S.F., Dog Rocks S.F.).

5. Nursery deaths induced by frost after excessive nitrogen fertilization (Jenolan S.F.).
6. Nursery deaths induced by frost after overcropping and resultant lack of boron (original diagnosis of boron deficiency in New South Wales at Kunama nursery, Bago S.F., winter, 1956).

When forest stands are being assessed for various disorders, information of the following type is required and could be collected in the following form. (Not all details will be available).

FIELD DATA ON FOREST DISORDERS

Stand Details —

1. Forest:
2. Compartment No.:
3. Age Class:
4. Site height (m):
5. Stocking (high, low, patchy):
6. Thinned (when):
7. Uniformity of growth in stand:

Site Details —

8. Geology (granite, sediment, basalt, etc.):
9. Age/weathering (age of sediment, degree of weathering):
10. Soil depth (cm):
11. Depth to impermeable layer (cm):
12. Quantity of stone:
13. Drainage (standing water, mottling):
14. Soil type (kraznozem, solodic, podzolic, etc.):
15. Slope:
16. Aspect:
17. Position on slope:
18. Elevation:
19. Other comments (e.g., frost hollow, exposed site, wind tunnel, etc.):

Individual Tree Symptoms —

20. Needle colour:
21. Needle length:
22. Needle age class/stem affected:
23. Proportion and section of tree affected:
24. Dieback of leader:
25. Dieback of laterals:
26. Specific fungal markings:

27. Tree distortion:
28. Needle clumping:
29. No. of needle age classes retained:
30. Obvious damage from other sources (possums, birds, insects, hail, frost, windthrow):
31. Bleeding of resin (resinosis):
32. Other comments:

General —

33. Size of affected area (ha):
34. Boundaries of affected area (ridges, gullies, etc.):
35. Recent weather (drought, flood):
36. Previous treatments and when: (fertilizer, herbicide, fungal sprays, etc.)
37. Give details of (36) e.g., type of fertilizer, type of herbicide:

Generalized Key to Symptoms Of Disorders In *PINUS RADIATA* (see also Tables 2 and 3).

Primary symptom	Probable cause
A1. Brown or orange-red needles on a significant percentage of tree and/or dead topping (if not go to A2).	
B1. Patches of stands with brown needles often from base up.	
C1. Trees of all ages affected noticeably on dry ridges. Seasonal, usually after a period of low rainfall.	*Drought*
C2. Poorly drained areas, all age classes affected.	*Phytophthora infection*
C3. Usually affecting suppressed trees in stand. Dead topping with needles retained.	*Sirex wasp*
C4. Areas of stand turning orange red to red brown from base up, trees usually under 15 years old. Probably on basalts, poor granites or soils high in nitrogen (fertilized farmland). Related to low sulphur/boron situations. Brown needles have red bands.	*Dothistroma infection*
B2. Scorching of needles.	
D1. Coastal situations with one side of tree affected — flagging.	*Salt toxicity*
D2. Scorch from base up, groups of trees affected especially in hollows.	*Frost*
D3. One side of tree affected, distortions may be present.	*Herbicides*

Primary symptom	Probable cause
B3. Dieback of patches of trees less than three years old, usually from top of tree down. Soils derived from basalts or highly weathered granites. At periphery of dieback, expect further zone of deformed trees with dead tips or side branches. Area most usually affected is in a gully and may be related in some instances to poor drainage. (*May expect secondary infection of *Diplodia* or *Dothistroma* on surviving trees.)	*Sulphur/boron deficiencies**
B4. Dieback of growing tips repeatedly giving rise to stunted bushes, rounded trees, and often, in otherwise highly productive stands, a high proportion of multiple leaders. Soils are basalts, weathered granites or eroded soils. Dead areas in stands (see B3). Dead topping may be spread through stand giving a pepper pot appearance.	
E1. Black or dark brown pith near site of death. Shepherd's crook.	*Boron deficiency*
E2. Resinosis with or without E1.	*Sulphur/boron deficiencies*
E3. Wilting effect on side branch giving Shepherd's crook with or without E1 and E2.	*Diplodia infection*
A2. Yellowing of needles (if not go to A3)	
F1. Overall pale yellowing.	
G1. Thin crown, fine branches, generally slender trees. Yellowing or pale green appearance of all needle age classes, stand affected relatively uniformly. Coastal sands and some heavily weathered granites.	*Nitrogen deficiency*
G2. Not finely branched, probably more patchy in stand. Usually very productive stands. Basalts and granites.	*Sulphur deficiency (see also above)*
F2. Yellowing from base of tree up. Usually on deep sands. Seasonal. Rare in New South Wales.	*Potassium deficiency*
F3. Yellowing of single needle age classes, starting with oldest. On inspection yellowing may be severe on distal half of needle.	
H1. Older age classes and stem needles brown to yellow. Black shiny elliptical fruiting bodies, opening by central narrow slit.	*Lophodermium infection*

Primary symptom	Probable cause
H2. Older age classes and stem needles brown to yellow. Whitish waxy, rectangular shaped fruiting bodies.	*Naemacyclus infection*
H3. Bright yellow stem needles or younger needles, often appearance of needle ends dipped in paint. Probably seasonal, especially spring.	*Magnesium deficiency*
F4. Youngest needles yellow to white. Very sudden change. (A rare occurrence as usually found on alkaline soils).	*Iron deficiency*
F5. Needles yellow to white as above — all soil types.	*Triazine or Triazole herbicide spraying*
A3. Yellowing or brown needles not most obvious symptoms Trees generally remain green or grey green.	
I1. Thin crowned trees causing stem and branches to be obvious especially in younger trees. Fused needles and rosetting on some trees. Poor and very uneven growth. Generally on sedimentary rocks, poor granites or coastal sands. In less severe stages, may be yellowing on needle tips. Range of symptoms occurs in one stand. Most severe stage in older trees will be death of older needles and top of tree.	*Phosphorus deficiency*
I2. Trees generally older than 15 years. Repeated dieback of trees leading to flattened appearance. High coning may occur. Soils usually similar to phosphorus deficient sites.	*Calcium deficiency*
I3. Rosetting — lateral branches short and at an acute angle, with short needles. Only late-formed needles of current year retained. No recorded instances in New South Wales.	*Zinc deficiency*
I4. Dark blue-green foliage, distorted branches and bushiness. No recorded instances in New South Wales.	*Copper deficiency*
I5. Paleness of foliage, especially towards top of tree. No recorded instances in New South Wales.	*Manganese deficiency*

TREATMENT OF DIAGNOSED PROBLEM

Even if the actual cause of a problem can be ascertained unequivocally, it is often not worthwhile to carry out a treatment. There are various courses open and these are specifically management decisions. Some possible alternatives are as follows:

1. On areas of small extent, for example small area erosion sites where *P. radiata* growth is very stunted, no treatment need be considered. This would also apply to some of the pathogens, such as *Lophodermium.*

2. Plantation diseases which do not need treatment are *Lophodermium* and *Naemacyclus* since reduction in increment is usually very small and recovery is rapid.

3. Some deficiency symptoms such as those associated with magnesium deficiency may occur in some seasons but do not appear seriously to affect tree growth. After recognition of the problem these symptoms can effectively be ignored.

4. Other nutrient deficiencies such as phosphorus, can be overcome by phosphate fertilizer applications. The sites being presently treated are usually soils on recent sediments (Triassic, Permian). It is not feasible to fertilize some sites where phosphate deficiency is recognized because of soil phosphate sorption problems or because the costs are too high.

5. Important foliar fungal diseases such as *Dothistroma* can be treated successfully by such means as aerial spraying and this would usually be done if defoliation was severe.

SUGGESTED FURTHER READING

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APPENDIX 1

Procedure for sampling pine foliage —

Where possible, pine foliage is sampled in May–June (late autumn–early winter). The samples are taken from the full extension of the previous 12 months' growth on the second main whorl beneath the leading shoot. Where necessary (e.g., with very young trees), all shoots on this whorl are included but generally one branch is selected. All the needles on the shoot are removed in order that the sample for analysis is fully representative of a full year's growth. This operation is carried out immediately after removing the shoot from the tree. The sample is placed in a paper bag, labelled and stapled. The bag is then placed in a forced-draught oven at 70°C for 36 hours. If the air circulation in the oven is poor and more than 36 hours drying are required, it is important to ensure that the excess time is kept to a minimum. Otherwise changes, such as loss of nitrogen, can occur in the material if drying is prolonged.