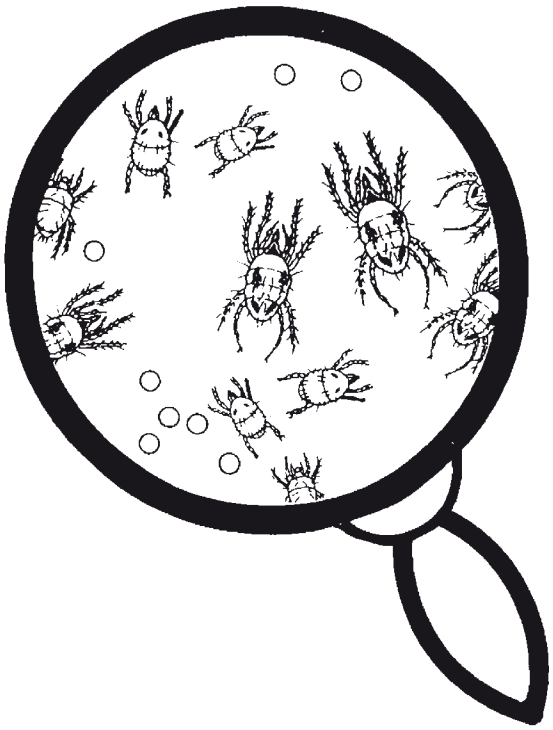
PLANT PROTECTION 4

How to Diagnose Plant Problems



Ruth M. Kerruish

drawings by
Adrienne L. Walkington

PLANT PROTECTION SERIES

PLANT PROTECTION 1

Pests, Diseases and Weeds.

Pests and Diseases

- Insects and allied pests
- Snails and slugs
- Vertebrate pests
- Nematode diseases
- Virus and virus-like diseases
- Bacterial diseases
- Fungal diseases
- Parasitic flowering plants
- Non-parasitic problems

Weeds

PLANT PROTECTION 2

Methods of control.

- Cultural methods
- Sanitation
- Biological control
- Resistant varieties
- Plant quarantine
- Disease-tested planting material
- Physical and mechanical methods
- Pesticides
- Plant Management
- IPM (Integrated Pest Management)
- Organic standards,
- BMP (Best Management Practice)

PLANT PROTECTION 3

Selected Ornamentals, Fruit and Vegetables.

- Annual and herbaceous perennials
- Bromeliads
- Bulbs, corms, rhizomes and tubers
- Cacti, ferns
- Fruit and nuts
- Orchids, palms, roses
- Trees, shrubs and climbers
- Turf grasses
- Vegetables
- Also Australian native plants, Bonsai, Compost, Containers, Garden centres, Greenhouses, Herbs, House plants, Hydroponic systems, Interior landscapes, Manure, Mulches, Nurseries, Plant tissue culture, Postharvest, Potting mixes, Seedlings, Seeds, Soil, Urban bushland, Urban landscapes, Water, Water plants, Xeriscapes.

PLANT PROTECTION 4

How to Diagnose Plant Problems.

- Step 1. The client's enquiry
- Step 2. Identify affected plant
- Step 3. Examine plant parts for signs and symptoms
- Step 4. Visit site, history, questions
- Step 5. Consult references
- Step 6. Seek expert help
- Step 7. Report the diagnosis

PLANT PROTECTION 4

How to Diagnose Plant Problems

Ruth M. Kerruish
with original line drawings by
Adrienne L. Walkington

ROOTROT PRESS ACT

COPYRIGHT

Copyright for material in this book is held by the authors, illustrators and third parties who have made photographs, drawings and product labels available for educational purposes only. Trademarks used in this book to describe firms or their products are trademarks of those firms or the registered proprietor of the trademark and are therefore also protected by copyright. Other material on this website is available for personal use.

Copyright©2006 Ruth M. Kerruish
Copyright©2006 Adrienne L. Walkington
Copyright©Canberra Institute of Technology
Copyright©NSW Department of Industry and Investment
Copyright©State of Victoria. Department of Sustainability and Environment
Copyright©Forestry Tasmania
Copyright©Western Australian Agriculture Authority 2009
Copyright©Yates
Copyright©Ampol Rural
Copyright©D.Olsen

DISTRIBUTED BY:
Qld Textbook Warehouse
PO Box 3220, Brackenridge, Qld, Australia 4017
☎ 07 3261 1300 **Fax** 07 3261 1966
email: info@qtw.com.au
web: www.**qtw**.com.au/

PUBLISHED BY
RootRot Press - ACT
22 Lynch Street, Hughes, ACT, Australia 2605
☎ 02 6281 3650 **Fax** 02 6285 1657

ISBN 1 875907 03 3 (print)
National Library of Australia Cataloguing-in-Publication entry:
Kerruish, Ruth M. (Ruth MacNeil), 1936- .
Plant protection. 4, How to diagnose plant problems.
Bibliography.
Includes index.
1. Plant diseases - Diagnosis - Australia. 2. Garden pests - Australia. 3. Horticulture - Australia. 4. Plants, Protection of - Australia. I. Walkington, Adrienne L. II. Title.
632.90994

ISBN 978-1-875907-04-5 (online)

By the same author:
PLANT PROTECTION 1 : Pests, Diseases and Weeds (with Phillip Unger)
PLANT PROTECTION 2 : Methods of Control
PLANT PROTECTION 3 : Selected Ornamentals, Fruit and Vegetables

DISCLAIMER

This book is **a guide only** to the process of diagnosing plant problems. While the information in this book is believed to be accurate at the time of publication, the author and publisher make no warranties, expressed or implied, as to the accuracy, adequacy or currency of the information presented in this book. The material contained in this book is not intended to provide specific advice.

No reader should act on the basis of anything contained in this book without taking appropriate advice **on their own particular circumstances**.

It should be recognized that there are differences in soils, climates and seasonal conditions, and that pests, diseases and weeds do not occur uniformly across Australia and may spread to new regions within Australia. New pests, diseases and weeds may enter Australia. Advisors and growers will need to adapt information to suit their particular conditions, regions and situations.

Reference to a product or a particular brand of product in this publication (whether the reference appears in an illustration, photograph or in any other form) does not imply the author's or publisher's approval or endorsement of the product or the brand. Similarly, by the omission of certain trade names and some formulated products, either unintentionally or from lack of space, the author or the publisher is not inferring that these products or brands are not approved.

By allowing the use of their product labels and other material, companies do not imply that they are endorsing the contents of the publication. Although efforts are made to have up-to-date material, labels change, and with time the labels in this publication may not be the current version.

The author and publisher do not guarantee the current status of registered uses of any of the pesticides or other products mentioned as these are constantly changing. Users must comply with current pesticide legislation and follow instructions on currently registered labels attached to the container. If information in this book conflicts with that on a current label, follow label instructions.

Websites referred to, or activated in this book are not under the control of the author or publisher who accept no responsibility or liability in relation to their content.

PESTICIDE REGISTRATION, ORGANIC STANDARDS

PESTICIDE REGISTRATION

Registration of pesticides in Australia is the responsibility of the Australian Pesticides and Veterinary Medicines Authority (APVMA).

APVMA assesses and registers these chemicals to ensure that they perform as claimed and are safe for people, animals and the land. **APVMA** also issues permits for off-label uses. Check on the **APVMA** database that the chemicals you use are registered for use:

www.**apvma**.gov.au

and follow the links to **PUBCRIS** (the Public Chemical Registration Information System).

Many registered products are **not available** for home garden use.

CHECK CURRENT REGISTRATION STATUS OF PESTICIDES PRIOR TO USE

ALWAYS READ AND FOLLOW LABEL INSTRUCTIONS ATTACHED TO THE PESTICIDE CONTAINER AT TIME OF USE

ORGANIC STANDARDS

AS 6000—2009. Organic and Biodynamic Products (Standards Australia) outlines minimum requirements to be met by growers and manufacturers wishing to label their products 'organic' or 'biodynamic' within Australia.

Organic Federation of Australia (OFA) is the peak body for the organic industry in Australia

www.**ofa**.org.au

and follow the links to obtain the domestic and export organic standards and certifiers.

Biological Farmers of Australia (BFA)
www.**bfa**.com.au
NASAA Certified Organic
www.**nasaa**.com.au
Organic Growers of Australia (OGA)
www.**organicgrowers**.org.au/

Acknowledgements

The authors would like to express their appreciation of the many people, organizations and companies, whose contributions have made this book possible:

Advice, encouragement	**Bill Kerruish** **Adrienne Walkington**
Horticultural assistance	**Douglas Kerruish**, Kerruish Horticultural Services, ACT. **Phillip Unger**, Canberra Institute of Technology, ACT. **Paul Weiss**, Canberra Institute of Technology, ACT. **Robyn Morgan,** Canberra Institute of Technology, ACT.
Identifying insects	**Kim Pullen**, Entomology, CSIRO, Melbourne.
Identifying plants	**Roger Spencer**, Royal Botanic Gardens, Melbourne.
Computing assistance	**John Kerruish**, Cisco Systems, Sydney. **Stefan Alexander**, Pirion Digital, ACT.
Editing	**Chris McKenna**, formerly Australian Catholic University, ACT. **Erika Kerruish**, Southern Cross University, Lismore. **Bill Kerruish,** formerly Forestry, CSIRO, ACT.
Library assistance	**Diana Kirby,** Canberra Institute of Technology, ACT.
Canberra Institute of Technology	Drawings, diagrams, charts and photographs are reproduced with permission of the Canberra Institute of Technical Education for educational purposes only

Drawings, diagrams, photographs and labels reproduced for educational purposes	**A detailed list of the individuals, organizations and companies who have given permission to reproduce the material for educational purposes only is on the following page.**

ACKNOWLEDGEMENTS *(contd)*

The following drawings, diagrams, photographs and labels are reproduced for educational purposes only with permission of:

Copyright©Canberra Institute of Technology
Page 4.Fig.1.Rose mosaic
Page 5.Fig.2.Christmas beetle, leaf beetle larvae, lerps
Page 6.Vine hawk moth caterpillars, chewing damage by wood moth larvae and caterpillars, stippling caused by spider mites
Page 7.Snail damage, bird damage to apple & roses
Page 8.Hydrangea mosaic, camellia yellow mottle, tulip flower breaking, apple russet ring, bacterial blight of walnut, (leaf spots), bacterial canker (gumming)
Page 9.Powdery mildew on euonymus, rust of snapdragon, brown rot of peach
Page 10.Fungal fruiting bodies in container, sooty mould, slime moulds, fairy rings, vandalism
Page 11.Copper residue on tomato leaf, encrusted salt on container, natural gumming on pittosporum, frost damage to stock, forked carrots, iron deficiency, sunscorch on apple, leaf scorch (moisture stress) on rhododendron, chimera on tulip, genetic ring tomato
Page 12.Cineraria leafminer damage on sowthistle, rust pustules on mallow leaf, fasciation on Paterson's curse
Page 25.Fig.6.Iron efficiency on rhodoendron
Page 41.Fig.8.Rose mosaic
Page 36.Fig.9.Leaf spots on *Gueris*, variegated euonymus, variegated rose flower, ornamental gourd, burr knots on *Prunus*
Page 48.Fungal leaf spots on iris
Page 49.Fig.11.Leafcutting bee injury, hormone herbicide and grapeleaf blister mite damage to grapes, twospotted mite stippling on beans, brown rot on peach
Page 50.Cypress pine sawfly larva, bleached honeysuckle
Page 53.Fig.12.Pest and diseases of roses - petal blight (*Botrytis*), rose mosaic, fungal cankers, powdery mildew on rose petals & leaves, rose scale, crown gall, thrips in flowers, black spot & anthracnose, bird damage, rust on leaves, frost damage to canes, varietal green rose, glyphosate injury to rose, fasciation
Page 72.Fig.15.Sunburnt bark, wood rot fruiting bodies on trees, fruit-tree borer damage
Page 82.Black spot of rose
Page 94.Small citrus butterfly caterpillar, hormone herbicide injury to ash
Page 107.Poor image of mealybugs, blossom end rot, glyphosate injury to hornbeam
Page 108.Witches broom on rhododendron, ringspots on hoya leaves
Page 110.Simazine injury to *Prunus*
Page 123.Callistemon sawfly larvae, powdery mildew on euonymus
Page 124.Autumn colours, snail damage to geranium, gall rust of wattle, grapevine fanleaf virus, pot bound roots, tomato big bud, snail or caterpillar damage to geranium leaves
Page 126.Anthracnose rose & plane tree, early blight of tomato, brown rot on peach shoots, leaf blister of poplar, grapeleaf blister mite damage, oedema on *Peperomia*
Page 127.Acacia-spotting bug symptoms, drought & sunscorch damage to rhododendron leaves, salt injury to *Dracaena*, stem cankers of pelargonium
Page 128.Bacterial canker & shothole on *Prunus*, anthracnose on rose, weevil damage to euonymus, looper damage to geranium, willow sawfly and damage, snail damage and splitting of cabbage
Page 130.Excessive sun camellia, simazine injury to *Prunus*, glyphosate injury to honeysuckle, azalea lace bug symptoms, senescence on rose leaves
Page 131.Oil injury to citrus & *Ficus*, rose mosaic, sunscorch symptoms on *Ficus*, variegated gazania, rose mosaic, plum line on Greengage, hydrangea mosaic, *Kennedia* mosaic, camellia yellow mottle, apple mosaic
Page 132.Rose mosaic, tomato spotted wilt on capsicum leaves, *Odontoglossum* ringspot, peony ringspot, tomato spotted wilt on tomato leaves, oedema on umbrella, rust on plum
Page 133.Lerp damage on eucalypt, grapeleaf blister mite damage, pink new growth on photinia, oriental fruit moth injury to peach, black peach aphids, crusader bug on wattle
Page 134.Bacterial canker leaf fall on stone fruit, lerp defoliation on eucalypt, leaf drop after flowering on camellia, large citrus butterfly caterpillar, webbing caterpillar frass, caterpillar silk, aphid nymph skins, twospotted mite webbing on peas
Page 135.Green peach aphid injury, leaf rolling thrips injury to Callistemon, leaf rolling on apple & rhododendron, leaf cupping on geranium, hormone herbicide injury to grape, plane tree and tomato leaves, glyphosate injury to roses
Page 136.Powdery mildew on rose, rust on antirrhinum, sooty mould on daphne, walnut blister mite symptoms on leaves, slime mould on geranium leaves, camellia leaf gall, *Apiomorpha* galls on eucalypt, poplar gall aphid
Page 137.Doubeheaded hawk moth on hakea, parasitized black bean aphids, black scale, mealybug, whiteflies, diseased grapevine moth caterpillars, larvae of beneficial ladybird, leafblister sawfly larvae in eucalypt leaves, damage by callistemon leafminer, citrus leafminer, cineraria leafminer, azalea leafminer, hakea leafminer & *Lomatia* leafminer
Page 138.Fungal leaf spot of strawberry, bacterial leaf spot of mulberry, herbicide injury to tulip leaves, graft incompatibility symptoms on lilac leaves, bacterial gall of oleander, greenhouse thrips injury to viburnum, variegated pumpkin leaf, senescing rose leaves
Page 139.Leafeating ladybirds & larvae, pear & cherry slug & damage, callistemon sawfly skeletonization, black parasitized whitefly nymphs, leafhopper stippling to mulberry & marigold, whiteflies on *Melianthus*, azalea lace bug symptoms, twospotted mite stippling on frangipani
Page 140.Sclerotum stem rot on daphne, wilting of pumpkin leaves
Page 141.Bacterial canker of plum flowers, petal blight on rose petals, sunscorch on camellia flowers
Page 142.Budworms on snapdragon, earwig damage to dahlia flowers, snail damage to daffodil flowers, tulip flower breaking, stock mosaic, greening of chrysanthemum, sun bleaching of rose flowers, chimera on tulip, natural variegation of rose flowers
Page 143.Greening on *Helichrysum*, cupped hydrangea sepals, grey mould on rose flowers
Page 144.Geranium plume moth caterpillar and exit holes, twospotted mite & webbing on gypsophila, flower wasp, petal blight on white petals, gladiolus thrips injury, sun bleaching of pelargonium petals
Page 145.Anthracnose of pawpaw & banana, tomato spotted wilt on tomato, sunscorch on tomato & capsicum, bird damage to apple, possum damage to lemon
Page 146.Fig.146.Green vegetable bug damage to tomato, San Jose scale on apple, green shoulder of tomato, chimera on apple, brown rot mummies on stone fruit, tomato big bud on tomato, peach leaf curl on nectarine fruit, apple dimpling damage, citrus bud mite damage, twin apples, catface on tomato
Page 147.Brown rot gumming on plums, oriental fruit moth gumming on stone fruit, oriental fruit moth damage, budworm damage to tomato
Page 148.Red scale on citrus, green vegetable bugs on tomato, virus symptoms on watermelon, tomato spotted wilt symptoms on tomato & capsicum
Page 149.Bacterial blight on walnut, grey mould (*Botrytis*) on strawberry, brown rot on peach, powdery mildew on pea pods, stem end rot of mango, blue mould on lemon, frost damage to lemon, blossom-end rot on tomato, apple russet ring, frost injury to plums, cold injury to pumpkin
Page 150.Pear scab, shothole on apricot, apple scab, splitting of tomatoes and plums (environmental)
Page 151.Caterpillar or snail damage to seedlings
Page 152.Damping off in a seedling tray
Page 153.Cabbage white butterfly caterpillar, parasitized aphids, whiteflies, San Jose scale, cabbage aphid injury, etiolated sunflower seedling, hormone herbicide injury to tomato seedlings, bean weevil damage
Page 154.Damaged hakea seed, budworm damage to sweetcorn, faulty tasselling on sweetcorn
Page 155.Bark beetle damage to *Cupressus*, weevil damage to tamarisk, sunburn damage and splitting of tree trunks
Page 156.Stem cankers, cypress canker, hail damage to peach shoots, scalybutt on citrus, weeping base of rowan tree, ivy growing around the base of *Cedrus*
Page 157.Dieback, bacterial canker of stone fruit, splitting of *Acer* trunk, ash suckering from base
Page 158.Fruit-tree borer frass, scale on eucalypt, rose scale, spider egg masses on eucalypt, yellow lichens on *Pistacea*, bacterial canker of stone fruit, wood rot, kino veins in eucalypt
Page 159.Flat limb on apple, split callistemon stems, fasciation on euonymus, swollen basal plate on elm, wood rot fruiting bodies
Page 160.Bacterial gall of oleander, rust galls on wattle, old woolly aphid galls on apple, banksia mite gall, gall on old plum tree, provenance poplar galls, epicormic buds on *Acer negundo,* gumming on plum, pittosporum, *Cedrus*, nectarine
Page 161.Wood moth, auger and longicorn beetle tunnels, termite damage to eucalypt, sirex wasp exit holes, fruit-tree borer damage, San Jose scale on cherry, woolly aphids on apple, steelblue sawfly larvae (spitfires) on eucalypts, tick scales on wattle
Page 162.Lawn mower damage to tree trunk, tier & stake damage, rust galls on wattle, eriophyid mite damage to casuarina, strangling climber, suckering from rootstock, lichens on cherry
Page 164.Fungal fruiting bodies in grass, crown gall on rhubarb and cane fruit, pot bound roots, *Rhizobia* nodules on pea roots, lignotubers on eucalypt
Page 166.Invading Chinese elm roots, azaleas planted too deeply, pot bound roots
Page 167.Root rot symptoms on daphne
Page 170.Galled, forked and split carrots, split potato, grey mould (*Botrytis*) on onion, sclerotinia rot on carrot, slime moulds on onions, green potatoes
Page 171.Club root on Swede turnip, root knot galls on parsnip, bulb aphids on garlic, mealy bugs on daffodil bulbs, termite tunnels in potato
Page 172.Potato tubers with spindly sprouts, common scab & enlarged lenticels on potato, couchgrass growing through a daffodil bulb
Page 173.Soil fungal disease of English daisy
Page 174.Mealybugs on papyrus, frost damage to callistemon, autumn colours
Page 181.Snail damage
Page 182.Hydrangea mosaic
Page 189,Computer image, plant clinic, student examining specimen

Copyright©NSW Department of Industry and Investment
Page 7.Mouse damage to sunflower
Page 9.Strawberry leafspots, lemon scab (M.Senior), rhizoctonia root rot (M.Senior)
Page 10.Leafcutting bee damage
Page 25.Fig.6.Cabbage white butterfly caterpillar (E.H.Zeck); brown rot (M.Senior)
Page 49.Fig.11.Marginal scorch (M.Senior)
Page 62.Fig.14.Hormone herbicide injury (M.Senior)
Page 127.Rhizoctonia collar rot of stock
Page 130.Iron and zinc deficiencies, magnesium and manganese deficiencies (M.Senior)
Page 132.Odontoglossum ringspot (M.Senior), down mildew of grapevine (M.Senior)
Page 135.Peach leaf curl (M.Senior)
Page 136.Downy mildew of grape (M.Senior)
Page 138.Lemon scab (M.Senior)
Page 144.Plague thrips (E.H.Zeck), petal blight
Page 145.Lightbrown apple moth (E.H.Zeck)
Page 147.Codling moth damage to apples (W.G.Thwaite)
Page 148.Codling moth damage (E.H.Zeck)
Page 149.Downy mildew of grape (M.Senior)
Page 150.Lemon scab, black spot of grapevine & freckle (M.Senior), fleck
Page 153.Vegetable weevil (E.H.Zeck), cabbage white butterfly egg (E.H.Zeck)
Page 154.Loose smut of oats (M.Senior), mice damage to sunflowers
Page 158.Pink limb blight
Page 161.Sirex wasp exit holes on *Pinus radiata*
Page 163.African black beetle (E.H.Zeck), whitefringed weevil larvae (E.H.Zeck)
Page 164.Root knot nematode on tomato
Page 167.Phytophthora root rot on citrus
Page 171.Vegetable weevil & larvae (E.H.Zeck)

Copyright© State of Victoria. Department of Sustainability and Environment. They have been reproduced from Marks, G. C., Fuhrer, B. A. and Walters, N. E. M. 1982. *Tree Diseases in Victoria*. Forests Com., Vic.
Page 156.Eucalypt twig canker (D.G.Parberry)
Page 136.Grey mould on callistemon (B.A.Fuhrer)

Copyright©Forestry Tasmania. They have been reproduced from: Elliott, H. J. and de Little, D. W. 1984. *Insect Pests of Trees and Timber in Tasmania*. Forestry Commission
Page 6.Wood moth caterpillar on wattle (H.J.Elliot)
Page 143.Wasp galls on silver wattle (H.J.Elliot)
Page 165.Larvae of the wattle goat moth (H.J.Elliot)

Copyright©Western Australian Agriculture Authority 2009
Page 143.Wasp galls on Geraldton wax (W.Woods & M.Grimm)

Copyright©Yates
Page 169.Optimum bulb diameter, depth and spacing

Copyright©Ampol Rural
Page 137.Citrus leafminer damage

Copyright©D. Olsen
Page 124.Iron deficiency on azalea
Page 131.Rose mosaic

CONTENTS

Copyright ii
Disclaimer iii
Pesticide Registration, Organic Standards iv
Acknowledgments v
Contents vii
Background Briefing *1*
Causes of plant problems *3*
Why identify the causes of plant problems? *15*
The Diagnostic Road Map *21*
Step 1. The client's enquiry *29*
Step 2. Identify affected plant *35*
Step 3. Examine plant parts for signs & symptoms *45*
Step 4. Visit site, history, questions *59*
Step 5. Consult references *77*
Step 6. Seek expert help *87*
Step 7. Report the diagnosis *103*
A diagnostic checklist *113*
Appendixes 1-8 *117*
Selected references *195*
Glossary & acronyms *201*
Index *207*

Background Briefing *1*

Causes of plant problems *3*
What are the causes of plant problems? *4*
Complex causes *5*
Pests & diseases *6*
Parasitic pests & diseases *6*
Non-parasitic pests & diseases *10*
Weeds *12*
Review questions & activities *13*

Why identify the causes of plant problems? *15*
To access information *16*
Manage pests, diseases & weeds *17*
Legislation *17*
IPM & **BMP** Programs *18*
Costs, training, diagnostic tests *19*
Review questions & activities *20*

The Diagnostic Road Map *21*
What is diagnosis? *22*
When to diagnose plant problems *24*
Common or scientific name of pest *25*
How definite does the diagnosis need to be? *26*
How reliable will the diagnosis be? *27*
Case studies *28*
Review questions & activities *28*

Step 1. The client's enquiry *29*
The client *30*
The enquiry *31*
Diagnoses that can be made at enquiry *32*
Summary *33*
Case studies *34*
Review questions & activities *34*

Step 2. Identify affected plant *35*
What is its correct name? *36*
Access to information *38*
Legislation *38*
A normal plant *38*
Reducing the possibilities *38*
List of pests & diseases *38*
Pest information sheet, the pest signature *39*
Diagnosis based on identity of affected plant *41*
Summary *42*
Case studies *43*
Review questions & activities *44*

Step 3. Examine plant parts for signs & symptoms *45*
What is normal for the plant? *46*
Examine plant parts *47*
Signs & symptoms *48*
Complex signs & symptoms *49*
Diagnosis based on signs & symptoms *51*
Summary *54*
Case studies *55*
Review questions & activities *57*

Step 4. Visit site, history, questions *59*
Introduction *60*
Pest information sheet - pest signature *61*
Site map *62*
Site inspection *63*
Patterns of signs & symptoms *63*
Pest calendars & time frames *64*
Soil type, topography & structures *65*
On-site diagnostic tests *66*
History & records *67*
Crop history *67*
Pest, disease & weed history *68*
Environmental history *69*
'20 Questions' *70*
A diagnosis based on a site visit *71*
Summary *73*
Case studies *74*
Review questions & activities *75*

Step 5. Consult references *77*
Books, colleagues & computers *78*
What should I look for? *79*
Host & pest indexes *79*
Pest information sheets *80*
Keys & expert systems *81*
Image matching *82*
Diagnosis based on references *83*
Summary *84*
Case studies *85*
Review questions & activities *86*

Step 6. Seek expert help *87*
How can the experts help me? *88*
Diagnostic services *89*
List of diagnostic services *91*
Diagnostic 'tests' *93*
Types of 'tests' *94*
Signs & symptoms *94*
Microscopy & electron microscopy *94*
Taxonomy *95*
Isolation, culturing & baiting *95*
Indicator plants *96*
Biochemical tests *96*
Serology (ELISA) *97*
DNA fingerprints *97*
Koch's rules *98*
Soil, water & plant tissue analyses *98*
Diagnosis based on expert advice *99*
Summary *100*
Case studies *101*
Review questions & activities *102*

Step 7. Report the diagnosis *103*
Proof of diagnosis *104*
How to report the diagnosis – diagnostic road map *104*
Common errors in diagnosis *106*
Summary *109*
Case studies *110*
Review questions & activities *111*

A diagnostic checklist *113*
Step 1. The client's enquiry *113*
Step 2. Identify affected plant *113*
Step 3. Examine plant parts for signs & symptoms *113*
Step 4. Visit site, history, questions *114*
Step 5. Consult references *116*
Step 6. Seek expert help *116*
Step 7. Report the diagnosis *116*

Appendixes *117*
Appendix 1. Communication guide *117*
Appendix 2. Records *119*
Appendix 3. Signs & symptoms *123*
Appendix 4. Monitor & sample *175*
Appendix 5. Diagnostic tests for specific causes *179*
Appendix 6. Training & practice *185*
Appendix 7. Evaluation *191*
Appendix 8. Control *193*

Selected references *195*

Glossary & acronyms *201*

Index *207*

BACKGROUND BRIEFING

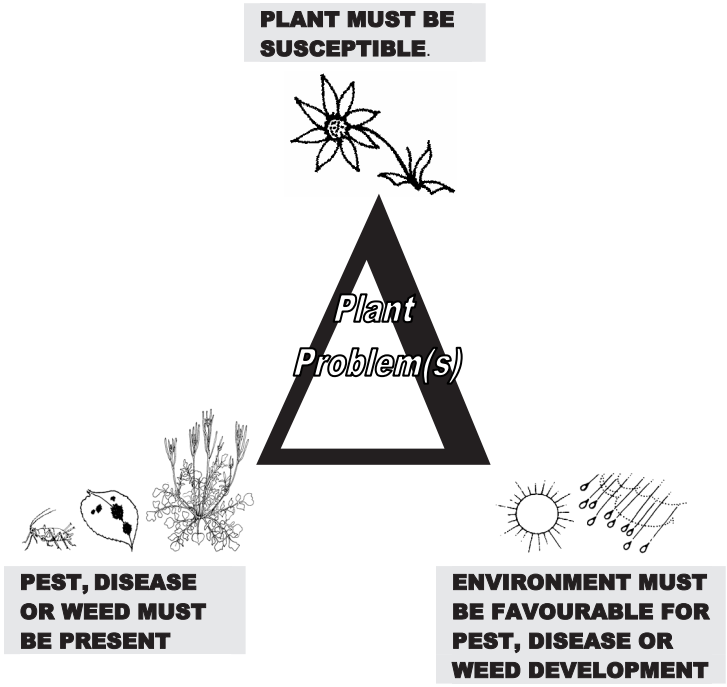
Causes of plant problems *3*

Why identify the causes of plant problems? *15*

This is a **'how to'** book that describes the **process** of diagnosing plant problems. It is not intended for identifying specific pests, diseases and weeds – there are already many resources available for this purpose.

WHO CAN THIS BOOK HELP?	This book will be useful for professional horticulturists, commercial and garden diagnosticians, growers, nursery staff, trainers and students who must be able to diagnose the pests, diseases and weeds associated with the plants they are handling or growing.
WHAT IS IN THIS BOOK?	• **Background briefing** This section will be useful for those with little diagnostic experience. It summarises the **causes** of plant problems and discusses the **reasons** for accurately identifying them. There are **'Review questions & activities'** at the end of each section. • **Diagnosis** In this section of the book the 7 steps involved in diagnosing plant problems are described. Some books in the Plant Protection series list only 5 diagnostic steps, these have now been extended to 7 steps to include the vital steps of the client's enquiry and reporting the diagnosis: Step 1. The client's enquiry Step 2. Identify the affected plant Step 3. Examine plant parts for signs & symptoms Step 4. Site visit, history, questions Step 5. Consult references Step 6. Seek expert help Step 7. Report the diagnosis There are **'Case studies'** and **'Review qestions & activities'** at the end of each step. These are an essential part of training and practise. The case studies are real and have been collected from colleagues, plant clinics and students. So that the case studies can be understood by all, relatively simple examples have been chosen. However, the diagnostic process remains the same. • **Checklist** This is a prompt for the 7 steps in the diagnostic process. • **Appendixes** To allow the reader to focus on the **process of diagnosis**, detailed information on certain aspects of diagnosis has been placed in appendixes: Appendix 1. Communication guide Appendix 2. Records Appendix 3. Signs & symptoms Appendix 4. Monitor & sample Appendix 5. Diagnostic tests for specific causes Appendix 6. Training & practice Appendix 7. Control Appendix 8. Evaluation
PLANT AND PEST NAMES	**Accepted common names** of plants, pests, diseases and weeds are used when available and appropriate. If there is any possibility of confusion, scientific names are used.

Causes of plant problems



What are the causes of plant problems? *4*
- **Complex causes** *5*

Pests & diseases *6*
- **Parasitic pests & diseases** *6*
  - Insects & allied pests *6*
  - Snails & slugs *7*
  - Vertebrate pests *7*
  - Nematode diseases *7*
  - Virus & virus-like diseases *8*
  - Bacterial diseases *8*
  - Fungal diseases *9*
  - Parasitic flowering plants *9*
- **Non-parasitic pests & diseases** *10*
  - Living causes *10*
  - Non-living causes *10*

Weeds *12*

Review questions & activities *13*

WHAT ARE THE CAUSES OF PLANT PROBLEMS?

Diagnosticians must have a good understanding of the causes of plant problems — pests, diseases and weeds

MAIN CAUSES

PESTS AND DISEASES

Because symptoms caused by insects and mites can be confused with those caused by plant diseases, it is sometimes difficult to know whether one is dealing with a pest or disease (see Fig. 1 below). Definitions of these terms are often inconsistent. In this book pests and diseases have been grouped together and re-divided into 2 groups:

- **Parasitic pests and diseases** caused by **living** agents (plants and animals), which damage plants by **obtaining food from them**. Many can spread from sick to healthy plants by a variety of means. Examples of parasitic pests and diseases include:
  - Insects, eg cabbage white butterfly.
  - Snails & slugs, eg common garden snail.
  - Vertebrate pests, eg fruit bats.
  - Nematode diseases, eg root knot.
  - Virus & virus-like diseases, eg rose mosaic.
  - Bacterial diseases, eg crown gall.
  - Fungal diseases, eg black spot of rose.
  - Parasitic flowering plants, eg mistletoe.

Insects are the most numerous and diverse type of plant pest

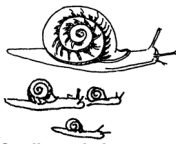
- **Non-parasitic pests and diseases** include:
  - **Living agents** (plants and animals) that damage plants mechanically, or in some way **other than** by obtaining food from them, eg leafcutting bees, dogs, cats, children, fairy rings, lichens, slime moulds. Arguably not a large group.
  - **Non-living agents** that are **not** infectious and do **not** spread from affected to healthy plants. They are almost infinite in number and include:
    - Environment, eg heat, moisture, light, transplant shock.
    - Nutritional deficiencies and excesses, eg iron deficiency.
    - Chemical injury, eg fertilizer burn, spray drift.
    - Mechanical injury, eg mower damage to trees and turf.
    - Genetic abnormalities, eg seed variation.

WEEDS

Weeds, ie unwanted plants, are probably one of horticulture's greatest problems.



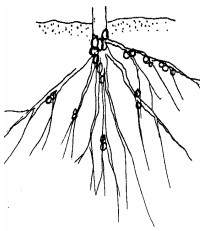
Cabbage white butterfly (*Pieris rapae*) – caterpillars feed on cabbages, stock



Snails and slugs damage a wide range of plants



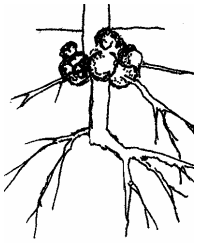
Fruit bats (flying foxes) – can be pests of fruit



Root knot nematode (*Meloidogyne* spp.) – galls up to 20 mm across on roots of many plants



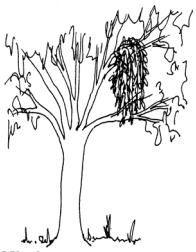
Rose mosaic (a complex of viruses) on roses



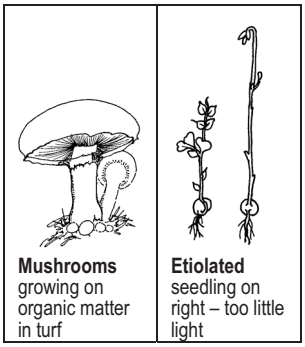
Crown gall (*Agrobacterium* sp.) – galls 20-300 mm across at the crown of Rosaceous plants



Black spot of rose (*Marsonnina rosae*)



Mistletoe on a tree



Mushrooms growing on organic matter in turf

Etiolated seedling on right – too little light



Winter grass, an annual weed

Fig. 1. One example of each of the causes of plant problems.

Complex causes

COMPLEX CAUSES ARE COMMON

When combinations of one or several **parasitic** pests and diseases, and one or several **non-parasitic** factors such as unusual weather, occur on the same plant or in an entire planting, the determination of the real cause(s) of a problem and the relevant importance of each becomes difficult. This is especially so when dealing with **soil and root** problems.

- **Many problems** are of **non-parasitic origin** or have **cultural or environmental** predisposing factors. Their solution requires a thorough knowledge of the conditions under which **plants are growing** and the **treatments** they have received. While important for all plants, this is especially so for **perennial species**, where long term investments are involved.
- **Many plants are affected by one or more pests or diseases at the same time.** For example, citrus trees can be simultaneously affected by aphids, scales and nutrient deficiencies. Eucalypts can be attacked by foliage-feeding insects, leaf spotting fungi and drought simultaneously. It is important to identify each cause. When treatment of a problem is not effective or only partly effective, complex causes should be suspected.
- **Many problems do not immediately suggest their origin.** For example a **primary** cause is something that stresses the plant and starts the decline process, predisposing the plant to **secondary** pests and diseases, which are often blamed for the death of a plant. Examples include:
  - **Citrus fruit bruised** during handling and packing is more readily infected by *Penicillium* blue mould.
  - **Rust galls on wattles** may be invaded by insects which are often thought to be responsible for the development of the galls.
  - **Powdery mildew** may be more severe on plants growing in **reduced light**.
  - **Sooty mould** grows on the honeydew secreted by some sap-sucking insects, eg some species of aphids, lerp insects, mealybugs, soft scales and whiteflies. Control the pest and the sooty mould will slowly disappear.
  - **Some insecticides or fungicides** may injure plants already stressed by high temperatures or lack of water. Some **soil-applied herbicides** may favour seedling diseases caused by a variety of soil fungi such as *Pythium* and *Phytophthora*.
  - **Trees** already stressed by drought **(primary cause)** may become infested with borers (**secondary problem**). The infested trees may eventually blow over in the wind (**tertiary problem**). Borer damage can usually be easily detected, eg galleries filled with frass and/or larvae observed. However, if the diagnostician stops here, the underlying poor environmental factors that stressed the trees in the first place may be missed. It is important to **identify** the **primary** cause of a problem.
  - **Sometimes the cause is found below ground.** Dieback of eucalypts in Western Australia caused by *Phytophthora* root rot is favoured by certain soil characteristics, particularly those affecting drainage. Some trees decline over years then die **suddenly during a dry season** when there are insufficient roots to take up the required moisture. Note that there are many other causes of dieback of eucalypts in Australia including foliage-feeding insects (see Fig. 2 below and page 156).
  - **Others complexes** include the effect of genetic factors, soil conditions and other predisposing or unknown factors that may facilitate plant injury.


Christmas beetles


Leaf beetle larvae


Two species of lerp insects

Fig 2. Foliage-feeding insects associated with dieback of eucalypts north of Canberra.

PESTS & DISEASES

The following is a brief summary of the main types of pests and diseases and some common examples of their **signs** (physical evidence of the pest) and **symptoms** (visible reaction of the affected plant).

Parasitic pests & diseases

INSECTS & ALLIED PESTS



Cabbage white butterfly

Phylum Arthropoda Adult features include:

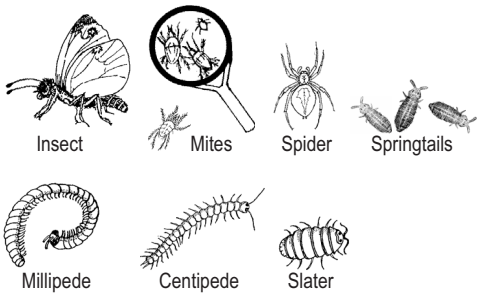
1. Body is divided into segments.
2. Hard outer covering on body and limbs, with flexible joints for movement.
3. Paired limbs.
4. Bilateral symmetry (each side of the body is a mirror image of the other).

Insects

1. Three body segments.
2. Three pairs of legs on thorax.
3. Antennae present (1 pair).
4. Wings either present or absent.

Mites

1. Two body sections.
2. Four pairs of legs.
3. No antennae.
4. No compound eyes, simple eyes present.

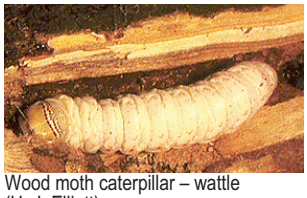


Phylum Arthropoda - Insects & allied organisms, remember, many are beneficial

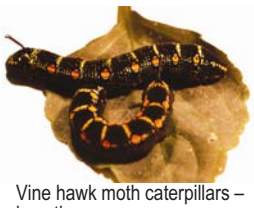
Some insect problems are easy to identify. You can actually see the insect doing the damage. Sometimes, though the insects are not present, eg they have eaten their fill and flown away, they are overwintering somewhere or they are too small to be seen without a hand lens. Some insects like to bore into stems or roots where they can cause damage without being seen.

Signs (physical evidence of the pest)

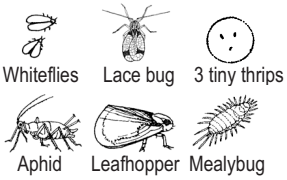
- Insects themselves, nymph and cast skins.
- Spittle on shoots that shelters nymphs of the spittle bug.
- Wax secreted by mealybugs (white cottony material).
- Honeydew produced by some sap sucking insects and the sooty mould growing on it.
- Frass, insect droppings.
- Webbing produced by spider mites, silk produced by caterpillars.



Wood moth caterpillar – wattle (H. J. Elliott)



Vine hawk moth caterpillars – impatiens



Symptoms (visible reaction of the affected plant)

- **In the absence of insects or mites**, symptoms may be observed. The type of feeding damage depends on the type of mouth parts.

Chewing mouth parts

- **Chewing mouth parts** may result in:
  - Chewed leaves, flowers, buds, seeds (caterpillars, beetles).
  - Skeletonization of leaves (pear and cherry slug).
  - Tunnels in leaves (leafminers), fruit (fruit borers), stems and branches (borers).
  - Girdled or dead stems (cutworms, twig girdlers, stem borers).
  - Dieback and general decline of plants due to root damage (soil-dwelling insects) or repeated defoliation (caterpillars, leaf beetles, sawfly larvae).

Piercing & sucking mouth parts

- **Piercing and sucking mouth parts** may result in:
  - Leaf stippling (leafhoppers, mites), distortion (aphids) or rolling, galls, defoliation.
  - Wilting of shoots (various bugs), stunted new growth.
  - Dieback of shoots, twigs or branches (scales).
  - Discolouration of leaves, blossoms and fruit (scale).
- **Rasping and sucking mouth parts** may result in:
  - Leaf silvering (thrips), rolling, curling, galls.
- **Virus diseases** transmitted by sucking insects.



Chewing damage by wood moth larvae – tunnels in wattle roots



Chewing damage by caterpillars – geranium



Stippling caused by piercing and sucking spider mites – French bean

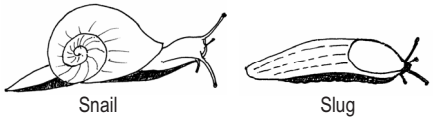
SNAILS & SLUGS



Snail damage – cabbage

Phylum Mollusca

1. Many-celled animals, true digestive cavity.
2. Snails have an external spiral shell into which they can withdraw when alarmed.
3. Slugs have either no shell or a reduced shield-like covering.
4. Both leave distinctive silvery trails.



Snail Slug

Signs

- Snails, slimy trails and messy droppings that are long and curly and adhere to feeding sites, can be seen. They feed at night or on cloudy days. Native species do little damage. Some native snails and slugs are predatory preying on other snails, slugs and earthworms.

Symptoms

- Snails and slugs rasp off portions of plant tissue from a wide range of plants. Young snails may skeletonise the surface of leaves, eg damaged gazania leaves shrivel and it is often difficult to recognize this as snail damage. Snails and slugs may eat from the edge of the leaf as well as from within leaf margins. Slugs also feed on bulbs and other underground plant parts, secondary infections may follow.

VERTEBRATE PESTS



Fruit bat

Phylum Chordata

1. Animals with a backbone.
2. Never more than 2 pairs of limbs.
3. Bilaterally symmetrical.



Common vertebrate pests

Signs

- Presence of the animal or its droppings.

Symptoms

- Birds may eat fruit, seed, seedlings, buds, crops, stored products.
- Mice and rats eat and contaminate crops and may spread disease.



Bird damage – apple



Mouse damage – sunflower (NSW Agric)



Bird damage – roses

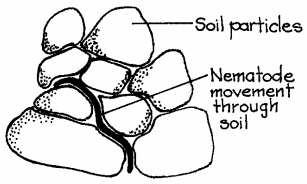
NEMATODE DISEASES



Root knot nematode (*Meloidogyne* spp.)

Phylum Nematoda (round worms)

1. Many-celled animals with a digestive cavity that suck up liquid food through a hollow spear.
2. Mainly microscopic (x 10), some visible to the naked eye. Generally 0.5 - 3.0 mm long, a few species are longer.
3. Generally 'eel-like', adult females of some species are pear-shaped. They move in water films between and around soil particles.
4. Body is unsegmented with no legs or other appendages.



Signs

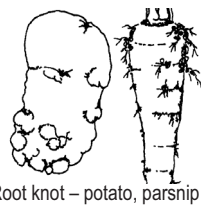
- Remember just because you can see a nematode under a dissecting microscope does not mean that it is the cause of a problem. Many species are beneficial, feeding on decaying roots damaged by other agents, eg non-parasitic nematodes are often found feeding in decaying bulbs.

Symptoms

- **Specific** (distinctive) symptoms include galls, excessive root branching, leaf patterns.
- **Non-specific symptoms** include those similar to moisture and nutrient stress which shows up as leaf yellowing, wilting and stunting of the plant.
- **Nematode-disease complexes** occur when nematode infections are associated with some bacterial or fungal diseases.



Foliar nematode damage – fern, chrysanthemum



Root knot – potato, parsnip



Stem and bulb nematode damage

VIRUS & VIRUS-LIKE DISEASES



Hydrangea mosaic

Viruses

1. Most can only multiply in living cells. Viruses make plant cells produce more virus particles. Some phytoplasmas can be cultured.
2. Are infectious and can spread from one plant to another.
3. Can only be seen with the aid of an electron microscope.
4. Vary in structure and size.



Viroids, (x 100,000) — Viruses (x 10,000) — Phytoplasmas, larger than viruses but smaller than bacteria

Signs

- None. Viruses are too small to be seen with the naked eye or by dissecting or compound microscopes.

Symptoms

- Symptoms are distinctive on some hosts and so disease can be quickly identified. In many cases, though, this is not possible.
- Colour changes, eg flower breaking, greening of flowers, yellowing of foliage (line patterns, mosaics, mottling, ringspots).
- Distortion of leaves or flowers.
- Viruses often weaken rather than kill plants, causing affected plants to be stunted.
- Some virus diseases produce no symptoms, eg carnation latent virus.



Camellia yellow mottle



Tulip flower breaking



Apple russet ring

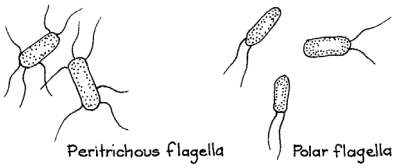
BACTERIAL DISEASES



Bacterial gall of oleander

Bacteria

1. Are small single-celled organisms which can only be seen under high magnification (x 1,000). The ones which attack plants are mostly short, rod-shaped, with one or more flagella which enable them to move through a film of water.
2. Have a cell wall surrounding the cytoplasm but do not have the nucleus found in higher plants.
3. Have no chlorophyll and cannot manufacture their own food. They obtain it from external sources.

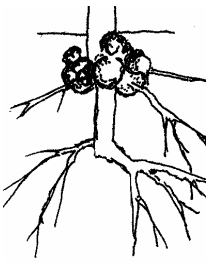


Signs

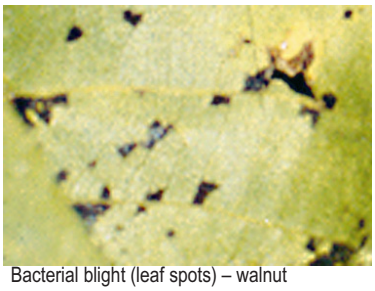
- None. Individual bacteria are too small to be seen with the naked eye. When bacteria are observed on the surface of diseased tissue with a compound microscope, they may be the actual cause of disease or growing on dead tissue killed by some other agents.
- Bacterial ooze may be observed.

Symptoms

- Blights, cankers.
- Galls, gumming.
- Leaf spots, often angular or irregular in shape.
- Rots, often soft and wet. Infected areas look water soaked, have a slimy texture and often smell. If the disease persists the plant tissue may totally disintegrate.
- Wilting followed by death of the plant.
- Leaf yellowing is often associated with bacterial diseases.



Crown gall

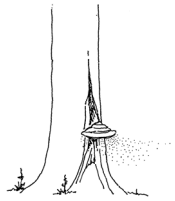


Bacterial blight (leaf spots) – walnut



Bacterial canker (gumming) – stone fruit

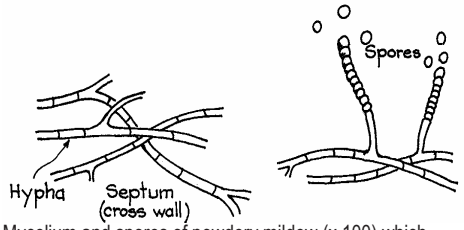
FUNGAL DISEASES



Fruiting body of wood rot (bracket fungus)

Fungi

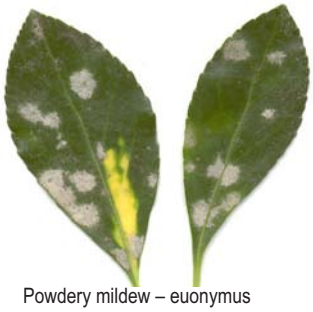
1. Have a very simple plant body (mycelium) with no roots, stems or leaves. This **mycelium** is made up of thread-like filaments called hyphae, which usually can only be seen under a microscope.
2. Contain **no chlorophyll** and so cannot manufacture their own food. They obtain their food from plants or other sources.
3. Reproduce by **spores** (asexual and sexual), which are important in the spread and overwintering of disease.
4. Fungi are by far the most common causes of parasitic plant diseases, particularly the genus, *Phytophthora* in Australia.



Mycelium and spores of powdery mildew (x 100) which grow over the surface of host plants

Signs

- Masses of typically whitish or greyish mycelium and/or spores may be seen.
- Large fruiting bodies such as mushrooms, toadstools and bracket fungi. Microscopic fruiting bodies may form on affected tissue.



Powdery mildew – euonymus



Rust – on undersurface of a snapdragon leaf



Brown rot – peach

Symptoms

- Leaf spots are roughly round with distinct margins and may have concentric rings.
- Leaf and shoot blights, yellowing, defoliation, cankers, galls.
- Flower and fruit rots and spots, scabs, shotholes, wilts.
- Root, crown and stem rots.



Fungal leaf spot – strawberry (NSW Agric)

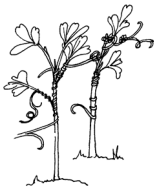


Lemon scab (NSW Agric)



Rhizoctonia root rot – French beans (NSW Agric)

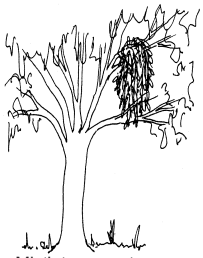
PARASITIC FLOWERING PLANTS



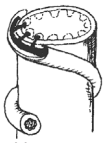
Dodder

Parasitic flowering plants

1. Produce flowers and seeds.
2. Belong to several widely separated botanical families.
3. Parasitism is generally regarded as the result of a degenerative process whereby plant species, which were once free-living and independent, lost their ability to carry out one or more of their physiological functions. They became dependent on the host plant for water and food.
4. Vary in their dependence on host plants.
5. Some are declared noxious weeds in some regions of Australia.



Mistletoe on a tree



Dodder stem twisting around and parasitising its host

Signs

- The presence of the parasitic plant, eg dodder, is sufficient for diagnosis of the disease.

Symptoms

- Dieback, eg mistletoes can kill eucalypts.

NON-PARASITIC PESTS & DISEASES

Living causes



Mushrooms grow around the edge of fairy rings

Living causes (plants and animals) damage plants mechanically, or in some way other than by obtaining food from the damaged plants. They are **not** parasitic, eg leafcutting bees, fairy rings in turf, lichens, slime moulds, sooty mould, liverworts, moss, algae, cats, dogs, earthworms, vandalism!

Signs

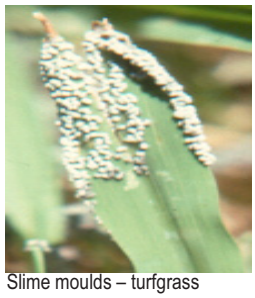
- You can **see** mushrooms, sooty mould, slime moulds.



Fungal fruiting body produced by mycelium growing on organic matter in potting media



Sooty mould – daphne leaves. Growing on honeydew secreted by soft brown scales



Slime moulds – turfgrass

Symptoms

- Leafcutting bee damage, the uneven grass growth of fairy rings.
- Vandalism, dog and cat urine on lawns.



Leafcutting bees cut portions of rose leaves for nest making



Fairy rings – stimulated grass growth in turf due to nutrients produced by fungi growing on organic matter in soil



Vandalism – eucalypt ringbarked by home owner seeking views

Non-living causes



Etiolation

Non-living causes eg cultural and site-related problems, are usually more common and more difficult to diagnose than those caused by parasitic pests and diseases. Many soil-related problems are difficult to identify. Symptoms caused by **non-living causes** are almost infinite.

- **Non-living causes** may directly affect:
  - **A susceptible plant**. Problems arise mainly from the **type of plant** being grown, eg poor location and cultural practices.
    - **Above the soil surface**, eg plants may be affected by hail, frost, wind, sun, rain, light, air pollution, spray drift.
    - **Below the soil surface**, eg plants may be affected by soil compaction, poor drainage, over or under-watering, over or under-fertilizing, poor planting techniques (trees and shrubs) and physical damage to bark or roots. Salinity and herbicide residues may also occur.
  - **The development of a pest, disease or weed**. For example, the severity of fungal leaf spots increases the longer leaves remain wet.
- **Examples of non-living causes include**:
  - **Environment agents**. ***Temperature and moisture*** have the greatest influence on the development of pest and plants. Some of these conditions can be avoided or alleviated, others not. ***Temperature***, eg unseasonable cold, frost or hot weather, sunscorch, low soil temperatures, 'winter kill'. ***Moisture***, eg waterlogging, drought stress, uneven or inefficient irrigation, poor drainage. ***Lack of oxygen***, eg lawn compaction. ***Light***, eg insufficient light may cause seedlings to become long and thin (etiolated), flowering may not occur or be delayed. ***Soil structure***, eg forked roots on carrots, compacted clay soils. ***Wind***, eg stressed plants, abraded fruit, trees blow over.
  - **Nutrient deficiencies and excesses** often show up as yellowing, stunting or death of new growth or older leaves, depending on the missing or extra nutrients. Iron deficiencies are common on azalea and citrus, magnesium deficiency on shrubs during autumn. Excess fertilizer is commonly found in nurseries and gardens.
  - **Acid soil**. Soil pH extremes affect nutrient deficiencies and excesses, eg deficiencies of iron in alkaline soils. Acid soils commonly occur in turf areas.
  - **Salinity** is widespread across Australia.
  - **Pollution of air, soil and water**, eg poor chemical choice, application and drift.
  - **Mechanical injuries**, eg machinery damage to roots, stems, vandals, lightning.
  - **Genetic abnormalities**, eg mutations such as fasciation.

The incidence and severity of non-parasitic diseases are influenced by the severity and length of exposure to the adverse factors

NON-PARASITIC PESTS & DISEASES *(contd)*

Signs

Occasionally non-parasitic problems will leave visible signs, eg

- Chemical residues on foliage, eg copper residues, fertiliser pellets.
- Salt encrustations, eg on the surface of soil or the outside of pots.
- Natural plant exudates, eg gumming on pittosporum.



Copper residue – tomato leaf



Encrusted salts at base of pot



Natural gumming - pittosporum

Symptoms – the real challenge!

Diagnosing non-parasitic plant problems can present real challenges because they include an almost **infinite number of causes**, which can produce an almost **infinite number of symptoms** both externally and internally, above and below ground. Symptoms include:

- **Specific symptoms**. Some non-parasitic problems produce **distinctive** symptoms on plants which make them easy to identify, eg
  - Blisters, eg oedema.
  - Ringspots, eg cold water ringspots on leaves of African violet.
  - Distorted growth, eg forked root crops.
  - Etiolation of seedlings due to insufficient light.
  - Mechanical injury to trunks, roots.
  - Cracking of tree trunks due to stress, splitting of fruit due to water imbalances.
  - Colour changes, eg bleaching of petals due to excessive sun.
  - Russeting of fruit due to frost.
- **Non-specific symptoms** are often caused by non-parasitic agents. Unless the history of a crop is known, it is difficult to accurately diagnose the cause, eg
  - Chlorosis (leaf yellowing) caused by nutrient deficiencies and excesses may be confused with symptoms of herbicide injury, viral, bacterial and fungal diseases or root knot nematodes.
  - Blights, eg frost.
  - Dieback, eg prolonged drought.
  - Reduced vigour, slow growth, eg excess plant growth regulator.
  - Scorches, eg heat waves, frost.
- **Secondary signs/symptoms**. Fruit damaged by sunscorch or frost may be invaded by secondary bacteria or fungi.



Frost damage – stem splitting on stock



Forked carrot roots – stony soil, nematodes or fertilizer damage



Iron deficiency – new leaves



Sunscorch injury with secondary infection – apple



Leaf tip scorch due to lack of moisture – rhododendron



Genetic chimera – tulip flower



Genetic variation – ring tomato

WEEDS

WEEDS



Cardamine

1. Weeds may be defined in many ways but the most apt definition is **'a plant growing where it is not desirable or wanted'.**
2. Most plants including those usually considered beneficial, eg herbs, may be weeds at times. Many plants previously used as ornamentals or crops are today's weeds.
3. Weeds generally reproduce, spread and photosynthesize **efficiently**, surviving under unfavourable conditions.
4. Weeds are a major economic and environmental problem in Australia.



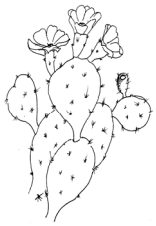
Red-flowered mallow

Signs

- The **presence of the weed itself**, weed seedlings, seeds, roots, bulbs, rhizomes and stolons. Some weeds can be difficult to identify.



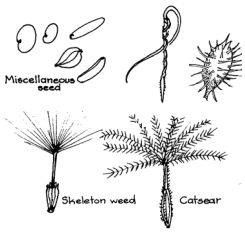
Liverworts



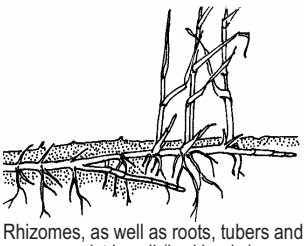
Prickly pear (perennial environmental weed)



Winter grass (annual weed)



Some weed seeds persist in soil (seed banks)



Rhizomes, as well as roots, tubers and corms persist in soil (bud banks)

Indirect effects of weeds

Weeds can be affected by pests and diseases in the same ways as crop plants

- Some are **toxic to stock**, eg Paterson's curse is especially toxic to horses and pigs.
- As **pest and disease sinks**, ie alternate hosts which harbour pests and diseases that can spread into a crop, eg cineraria leafminer (see below).
- Weeds **increase humidity** in a crop, which encourages pests and diseases.
- They compete with the crop for nutrients and water so that the crop appears unhealthy.
- Weed seeds may contaminate crop seed and grain.
- Interfere with machinery and cropping.
- Devalue land due to the presence of difficult-to-control weeds.
- Cause mechanical injury to animals and humans, eg thorny seed.
- Affect appearance of landscapes and containers for sale.
- Reduce biodiversity, taking up valuable cropping areas or bush land.
- Harbour vermin and can be a fire hazard.
- Indicate soil conditions which can be changed to discourage weed growth, eg yellow nutsedge (*Cyperus esculentus*) indicates excessive water perhaps due to broken irrigation pipes.



Cineraria leafminer damage – sowthistle



Rust pustules on leaf undersurface – mallow



Fasciation – Paterson's curse; arguably a genetic abnormality

REVIEW QUESTIONS & ACTIVITIES

1. **Distinguish** between parasitic and non-parasitic plant problems and give 1 example of each:
   1. A parasitic problem is
      Example
   2. A non-parasitic problem is
      Example

2. Name **1 key example** of the following 'causes' of plant problems in **your region**:

Parasitic pests & diseases
- Insects & allied pests, eg
- Snails & slugs, eg
- Vertebrate pests, eg
- Nematode diseases, eg
- Virus & virus-like diseases, eg
- Bacterial diseases, eg
- Fungal diseases, eg
- Parasitic flowering plants, eg

Non-parasitic pests & diseases
- Living, eg
- Non-living, eg

Weeds, eg

3. Which types of pests and diseases are **most common** and often difficult to identify?

4. **Complete** the following and give 1 example of each:
   1. A sign is
      Example
   2. A symptom is
      Example

5. **Recognize** by sight **1 example** of the following:

Pest insect and symptoms:
- Name
- Symptoms

Beneficial insect and what it feeds on:
- Name
- What they feed on

Pest snail or slug and symptoms:
- Name
- Symptoms

Pest vertebrate and symptoms:
- Name
- Symptoms

Nematode disease and symptoms:
- Name
- Symptoms

Virus disease and symptoms:
- Name
- Symptoms

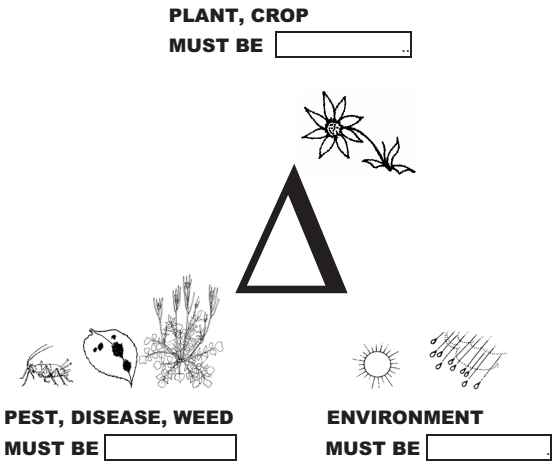
Fungal disease and symptoms:
- Name
- Symptoms

Parasitic flowering plant and its host:
- Name
- Host
- Symptoms

Non-parasitic problem and its symptoms:
- Name
- Symptoms

Weed and its impact:
- Name
- Impact

6. A pest, disease or weed will **only** develop under certain conditions. Fill in the three (3) missing words in the following diagram:



7. Explain how the above pest triangle will help you rule out (**eliminate**) a particular pest or disease as a cause of a current problem?

8. Which of the following generally has the **most** influence on pest **development**? Circle the correct answer.
   1. Light and wind direction
   2. Mulch and soil pH
   3. Temperature and moisture
   4. Soil type

9. Most plant problems are caused by a **single** pest, disease or weed. Circle the correct answer.
   1. True
   2. False

10. **Explain** the following **causes** of plant problems and give **1 example** of each from a crop/situation in your region.
    1. A primary cause is
       Example
    2. A secondary cause is
       Example

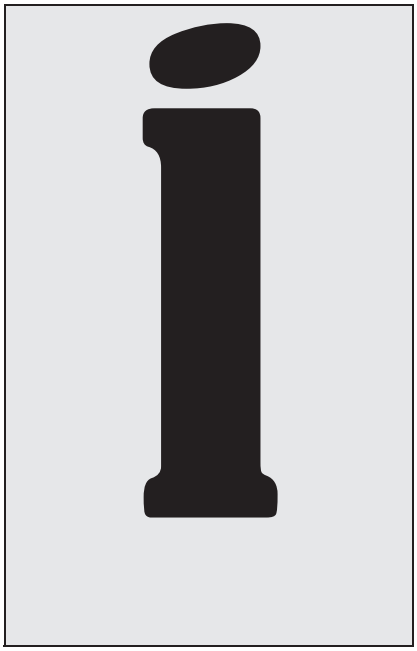
11. What do you think is the **most serious** plant problem in your region?

12. Can you locate and use references relating to the **causes** of plant problems?

13. What **signs and/or symptoms** would you look for if the following problems were suspected? Remember some may be **inside** the plant, or found **away** from the plant, ie in soil, on packing cases, etc.

PROBLEM	SIGNS		SYMPTOMS	
	Below ground	Above ground	Below ground	Above ground
Aphids on roses				
Fruit fly				
Scarab grubs in turf				
Root mealybugs				
Downy mildew on lettuce				
Powdery mildew on apple trees				
Possums				
Iron deficiency on citrus				
Woolly aphid				
Spider mites on French beans				
Phytophthora root rot				
Mistletoe				
Tulip flower breaking				
Latent viruses *in a crop of your choice*				
Damping off				
Borers in wattles				
Over-fertilization of container plants				
Mechanical injury to roots of shrubs				
Drought damage to trees				
Choose your own problem and crop				

Why identify the cause(s) of plant problems?



To access information *16*

Manage pests, diseases & weeds *17*
- Legislation *17*
- **IPM** & **BMP** Programs *18*
- Costs, training, diagnostic tests *19*

Review questions & activities *20*

TO ACCESS INFORMATION

Once you have **identified** the pest, disease or weed you can access pest information sheets, which contain all kinds of information about the problem, eg likely impact on your crop, legal requirements and control.

PEST INFORMATION SHEETS



Pest information sheets contain details of the scientific name, host range, diagnostic descriptions and tests, pest cycle, spread, conditions favouring and recommended control methods. Pest information sheets are sometimes called pest prescription sheets, fact sheets, and various other names.

- The **information** in a pest information sheet is often referred to as the **'pest signature'** and is used to **confirm** the identity of a **suspect** pest, disease or weed. It may also **eliminate** certain possibilities.
- The **degree** to which a suspect pest, disease or weed **matches** its 'pest signature' varies. In some cases a single component is sufficient for an accurate diagnosis, eg a diagnostic test, but in most cases several components are needed.

Pest information sheet

- Common name of pest, disease or weed
- Scientific name
- Causes(s)
- Significance of problem, **legal requirements**
- Host range, plants affected
- Description of signs & symptoms, diagnostic features & tests
- Pest cycle
- Overwintering
- Spread
- Conditions favouring
- Control/prevention, organic standards, Integrated Pest Management, Best Management Practice
  - **Legal requirements**
  - Cultural methods
  - Sanitation
  - Biological control
  - Resistant varieties
  - Plant quarantine
  - Disease-tested planting material
  - Physical & mechanical methods
  - Pesticides

Pest information sheets are described in detail on page 39

MANAGE PESTS, DISEASES & WEEDS

We identify the cause of a plant problem so that we can determine the appropriate action to minimize losses. If the cause is not correctly identified, crop management strategies may be illegal, inappropriate, environmentally unsound, costly, unnecessary or ineffective. Pests must be managed safely and effectively (see page 193). Identifying both the **primary** and **secondary causes** of a plant problem means you have more latitude in the types of treatment you may want to plan and carry out. Recognition of the role that a **primary cause**, eg poor drainage, plays in the development of what may be a **secondary cause**, eg *Phytophthora* root rot, may mean that in the long term, improving the environment may reduce fungicide applications.

Legislation

LEGISLATION



There may be legal and other responsibilities to detect, identify, report and treat some pests, diseases and weeds.

- **Within Australia** some pests, diseases and weeds are **notifiable** and suspected outbreaks must be reported to the appropriate authority to keep areas within Australia free from exotic pests.
- **Control** may be **compulsory** and **methods** of control **prescribed**, eg sanitation techniques, use of disease-tested propagation material, pesticide treatments.
- **There may be responsibilities** within **IPM** (Integrated Pest Management), **BMP** (Best Management Practice) and Organic Standards.
- **Monitoring of certain pests** is required for some species in some regions, eg fruit flies in the Northern Territory.
- **Export/import markets**. Treatment is often necessary for phytosanitary certification.
- **Weed risk assessments** are required for all imported plant material and seeds.
- **Prescribed planting** of resistant varieties, eg phylloxera-resistant rootstock of grapevines in phylloxera regions.
- **Disease-tested planting material** is used in certification schemes for strawberry, cut flowers, potato, grapevines and other crops.
- **Registration and use of pesticides**. Label directions indicate on which **plants** and on which **pests** a registered pesticide must only be used. Many of the newer products control only one or two pests on one or two crops (see Fig, 3 below).
- **Keeping records** of pesticide applications, sources of planting material, eg seeds, parent stock.
- **Analysis** of plant tissue, seeds and food supplies for pesticide residues and genetic contamination.

CROP	DISEASE	RATE	HOW TO APPLY
Young or small citrus and recently transplanted trees	Phytophthora Root Rot Collar Rot	5-10mL/L	Use higher rate under higher disease risk conditions (e.g. for trees in heavy clay soil). Apply each year as a preventative foliar spray, in late winter prior to flowering and again in autumn when fruit are approaching maturity. Spray until leaves are just wet.
Mature citrus (except container grown Mandarin trees)		100-160mL in 12L water per tree	Use 5–10mL/L rate for container grown Mandarin trees. Removal of fruit from affected trees will assist recovery.

A **fungicide** registered for the control of *Phytophthora* on citrus

Examples only

Crop	Pest	Rate	WHP
Apples & Pears	Two-spotted Mite (*Tetranychus urticae*), European Red Mite (*Panonychus ulmi*)	Dilute Spraying 65 mL / 100 L	Harvest 7 days Grazing 28 days

A **miticide** registered for the control of certain species of mites on apples and pears

WEEDS CONTROLLED	RATE	CRITICAL COMMENTS
General mixed weeds (Annual and perennial weeds)	10mL per 1Lwater	**Timing:** Apply when weeds are actively growing. For best results on perennial weeds treat after flowering. Treat woody weeds from flowering to leaf fall (Jan-May). DO NOT spray plants bearing edible berries. **Application:** Uniform and complete spray to wet all leaves. Run off should not occur. 1 litre of spray will cover 10 square metres. The addition of a non-ionic surfactant is recommended at a rate of 1 mL of a 600g/L product (or equivalent) per 1L spray solution.
Woody weeds	15mL per 1L water	

A **herbicide** showing different rates for different weeds

Fig. 3. Examples of labels that indicate the need to identity the pest, disease or weed.

IPM & BMP Programs

WHERE DOES DIAGNOSIS FIT INTO IPM & BMP?

Diagnosis has a high priority in Integrated Pest Management (**IPM**) and Best Management Practice (**BMP**) programs, which are recommended guidelines for managing pests. Prescribed **IPM** and **BMP** programs are available for many commercial crops.

- **IPM** attempts to manage pests, diseases and weeds systematically**.** The crop is managed as a whole and the management of pests is part of the more complex system of producing the crop. **IPM** is not a specific set of rules, there is no central program for every pest.
  - **Where does diagnosis fit into IPM?** Identification of the pest, disease or weed is an essential **3rd step** in **IPM** (see Fig. 4 below).
  - **IPM must be based on sound knowledge** of the pest, its natural enemies, life cycle, thresholds and possible control strategies. It aims to maintain pest populations below that which causes economic and/or aesthetic damage.
  - **If you know what to expect**, you can plan ahead. You will know what monitoring has to be carried out or what soil tests are required. Be able to identify the signs and symptoms you have to look for.
  - **You can maximize the use of non-chemical methods of control**, selecting control methods that cause least damage to the environment and natural enemies. This reduces chemical use.
- **BMP** is **environmentally-sound** management of pests, diseases and weeds.
  - It is a set of **guidelines**, imposing a sense of order and ordered change in an enterprise.
  - It is **site-specific**. Adapting agricultural and horticultural systems to the local environment, rather like **IPM**, which it incorporates.
  - **BMP** requires diagnosticians to undergo **training** and **maintain records** of the actual diagnosis, how it was arrived at and advice given.

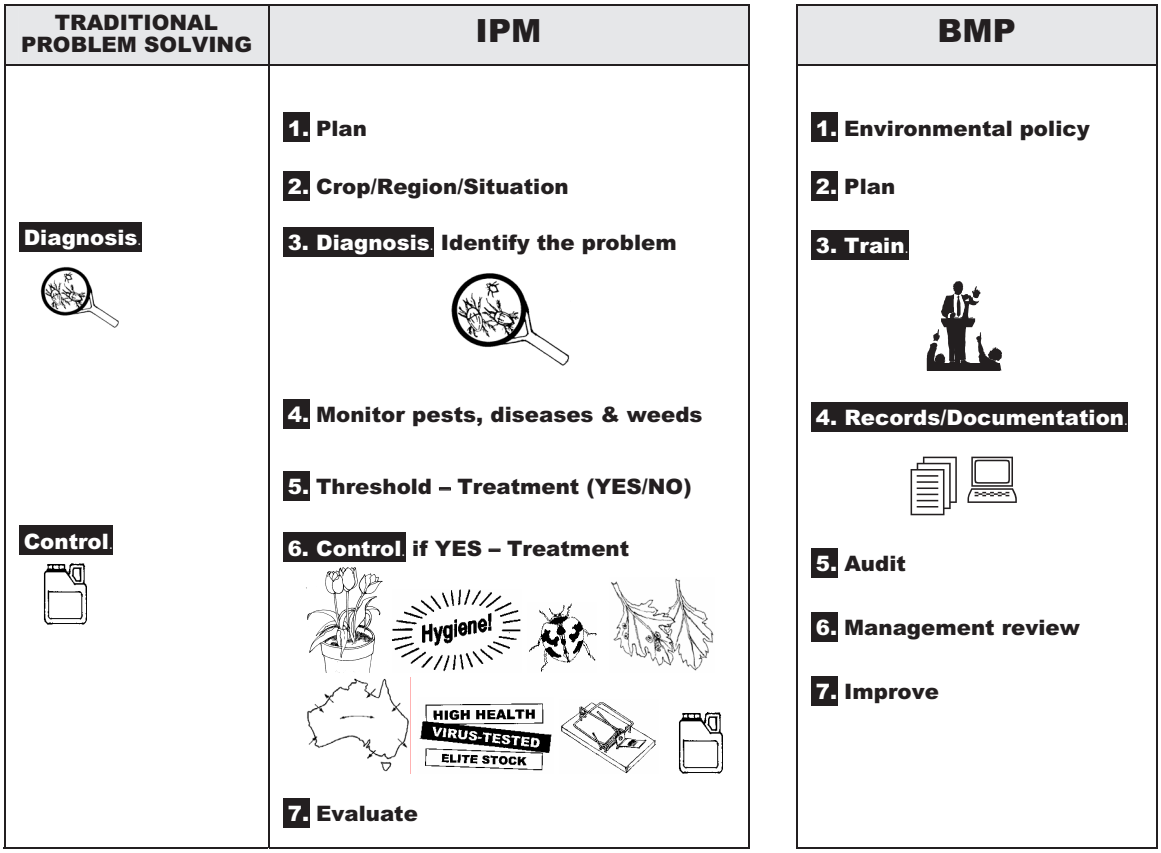


Fig. 4. Steps in IPM and BMP. An accurate identification of plant problems has long been the cornerstone of traditional problem solving and is now an essential part of **IPM**.

Costs, training, diagnostic tests

COSTS AND BENEFITS



Powdery mildew is considered by some to cause greater financial loss worldwide than any other plant disease

The cost of diagnostics can include your own time, seeking expert advice and diagnostic tests. This cost must be balanced against any benefits. Can you reasonably expect to get a useful diagnosis? How much time and effort can be devoted to the diagnosis?

- **Cost of getting a useful diagnosis**.
  - If control measures are **not** mandatory, they must be measured against any economic or aesthetic benefits.
  - Seeking expert help can be costly. Most diagnostic services are user pays.
  - If you are doing your own diagnostics, do you have the time, equipment and the necessary expertise?
  - Free 'Hotlines' are offered by some diagnostic services for some pests and diseases and by plant quarantine (see page 91).
- **Benefits of a correct diagnosis** include:
  - **Saving money** on unnecessary, incorrect or ineffective treatments with environmental benefits, eg avoiding the destruction of beneficial insects.
  - **Improved production**, quality and marketability of produce. Retailers and the public have come to expect this.
  - **Increased profits** in an increasingly competitive environment.
  - **Pre-plant** soil analysis can alert growers to potential problems.
  - **Avoids expensive knee-jerk reactions**, eg immediate unnecessary destruction of plants or crops suspected of having exotic or major pests or diseases. For example, the destruction of experimental wheat crops infected with wheat streak mosaic virus, when the virus disease was already widespread in Australia.
- **Cost of eradicating exotic incursions**.
  - **Likely exotic incursions** are ranked according to the impact of the incursion on productivity, production cost, product quality, environment, human health, amenity values, regional economies and trade.
  - **This pest categorization process** determines the relative industry and government funding of eradication efforts. When an incursion does occur industry and government will have a better idea where resources need to be focused.
  - **Industries participating** in pest categorization include the apple and pear, banana, citrus, strawberry and sugar industries.

TRAINING



New plant varieties and technologies are constantly being introduced. Exotic pests, diseases and weeds seem to arrive in Australia with monotonous regulatory. Some already in Australia may increase in importance with the introduction of new crops and climate change.

- Persons **handling and/or growing plants** should be able to **recognise and identify** current pests and diseases and have some understanding of potential problems. Many exotic pests and diseases enter Australia without being detected and identified for months or years, eg citrus canker, potato cyst nematode, fire ants.
- It is necessary to **keep up to date**.
- Training **needs and opportunities** are outlined on page 185.

DIAGNOSTIC TESTS



When an economically important disease has been identified, it may be necessary to develop a quick and easy diagnostic test.

- **The results of diagnostic tests for citrus greening** are now available within 24 hours enabling the development of new control strategies.
- **Virus infections** may be **symptomless** or may induce symptoms that are easy to confuse with nutritional disorders or pesticide damage. These diseases pose a special risk of being accidentally introduced on vegetatively propagated plant material. Quick and early diagnostic tests are essential for their management.

REVIEW QUESTIONS & ACTIVITIES

To access information

1. Name **2 reasons** why we identify the cause(s) of plant problems.

   1.

   2.

2. Explain the **meaning** of the following terms:

   1. Pest information sheet

   2. 'Pest signature'

3. Provide the following information for **1 economic pest, disease or weed** in your crop/region.

Common name	
Scientific name	
Cause(s)	
Significance of pest, **legal requirements**	
Host range	
Description, signs, symptoms, diagnostic features, tests	
Pest/disease/weed cycle	
Overwintering	
Spread	
Conditions favouring	
Control (IPM, BMP, organic standards) **Legal requirements** Cultural methods Sanitation Biological control Resistant varieties Plant quarantine Disease-tested material Physical & mechanical Pesticides	

4. How might **knowledge** of the life cycle of a pest, disease or weed assist with making decisions about **control**? Describe **1 local example**.

   1. Example

   2. Life cycle

   3. Control options

Manage pests, diseases & weeds

5. Describe local, state or commonwealth **legislation** providing for the control of **1** pest, disease and weed in your region.

Pest, disease, weed	Legislation, regulation
Pest:	
Disease:	
Weed:	

6. Access **3 pesticide labels** and locate the crop and the pest, disease or weed to which it can be applied:

	Plant or crop	Pest, disease or weed
Insecticide label		
Fungicide label		
Herbicide label		

7. Explain the steps in **IPM** and **BMP**:

IPM	BMP
1. Plan	1. Environmental policy
2. Crop, region, situation	2. Planning
3. **Identify problem**	3. **Training**
4. Monitor	4. **Records**
5. Threshold - Control (yes/no)	5. Auditing
6. Control (if yes)	6. Management review
7. Evaluate	7. Continual improvement

8. List **3 common problems** you **expect** to occur in a crop or situation of your choice.

Plant/crop	Expected problems

9. List **3** consequences of **not** correctly identifying pests, diseases or weeds correctly in a crop of your choice.

Plant/crop	Consequences

10. How good are your **diagnostic skills**? List **3** local pests, diseases and weeds that you **can** recognize and **3** that you are **not** sure about.

Can recognize	Not sure about
Pest:	**Pest:**
Disease:	**Disease:**
Weed:	**Weed:**

THE DIAGNOSTIC ROAD MAP

	**STEP 1**. The client's enquiry
	**STEP 2**. Identify affected plant
	**STEP 3**. Examine plant parts for signs & symptoms
	**STEP 4**. Visit site, history, questions
	**STEP 5**. Consult references
XPERT	**STEP 6**. Seek expert help
	**STEP 7**. Report the diagnosis

What is diagnosis? *22*
A few terms *22*
A diagnostic road map – the 7 steps *22*
When to diagnose plant problems *24*
Common or scientific name of pest *25*
How definite does the diagnosis need to be? *26*
How reliable will the diagnosis be? *27*
Case studies *28*
Review questions & activities *28*

WHAT IS DIAGNOSIS?

Diagnosis is essentially a problem-solving exercise involving the initial recognition of a problem, then gathering and sorting information about the affected plants and the nearby environment so that causes can be identified. From prior knowledge or experience and information available, a diagnosis may be possible. If the problem is still unresolved, expert advice may be needed to reach a diagnosis.

A FEW TERMS

It is helpful to have an understanding of terms associated with diagnosis:

- **Host** – a plant on, or in which, a pest or parasite lives. In this book the term **'affected plant'** is used to include host plants and plants affected by non-parasitic agents, eg nutrient deficiencies.
- **Pest** – a term used to include 'any species, strain or biotype of plant, animal or pathogenic agents injurious to plants or plant products' (International Plant Protection Convention). This book follows this convention so the word 'pest' can mean pest, disease or weed unless otherwise specified.
- **Identification** – to identify a plant, pest, disease or weed or other organism by its scientific name and or its accepted/standard common name.
- **Diagnosis** – identification of a disease by investigation of its symptoms and history (Oxford Concise Dictionary).
- **Detection** – to detect the presence of an organism or some other causal agent. In some cases this will provide a basis for diagnosis. However, just because you have detected and identified something does not mean that it is the cause of the problem.
- **Monitor** – a program of sampling, inspecting and recording to detect, locate, identify and quantify potential pests, diseases and weeds and their natural enemies.
- **Tests** – in this book the term diagnostic test or test is used to describe any method or procedure which detects or identifies an organism or causal agent.



- **Pest information sheets** – documents which contain details of the scientific name, legislative requirements, host range, diagnostic descriptions and tests, pest cycle, spread, conditions favouring and recommended control methods. Pest information sheets are sometimes called pest prescription sheets, fact sheets or other names.
- **The 'pest signature' –** the information in a pest information sheet which may be used to **provide, confirm** or **reject** a diagnosis. It may eliminate certain possibilities. The degree to which a suspect pest matches its 'pest signature' varies. In some cases a single component is sufficient for an accurate diagnosis, eg a diagnostic test, but in most cases, several components are needed, eg symptoms and pH test.
- **Proof of diagnosis** – written evidence that confirms or rejects a conclusion. You need to provide **evidence** of how you reached your diagnosis. For some problems this is easy, eg matching a description of a citrus butterfly or spores of a fungus to illustrations and descriptions; for complex causes, this is more difficult.

THE DIAGNOSTIC ROAD MAP

THE 7 STEPS

The diagnostic road map is presented as 7 separate steps and offers a systematic and adaptable approach to making a diagnosis (see Fig. 5 opposite).

- **Some steps in this guide may be bypassed**, **combined or revisited**.
  - Remember, at any step the cause(s) may be identified. With a bit of experience you may be able to answer the client's enquiry immediately!
  - You may decide to send a sample directly to a diagnostic service or one of the various hotlines set up by plant quarantine and grower groups.
  - You may need to use references to identify the affected plant or you may need to send it to a plant identification service.
  - Samples may not be available for examination at the beginning of an investigation, but they could be requested. Additional questions may be asked.
- **Advantages of a systematic, adaptable approach**:
  - Improves the likelihood of a correct diagnosis being obtained efficiently.
  - Embraces new technologies, which improves diagnostics and control methods. New techniques are continually being developed to identify diseases that are difficult to identify by conventional methods.
  - Follows a well established routine in which possible causes can be progressively **eliminated**. With experience, the diagnostic process becomes **semi-automatic** or **instinctive** but control is still retained by the diagnostician (like driving a car).



  - Makes the task of a **novice** diagnostician **less** intimidating, easier and faster by avoiding too many sidetracks.
  - Helps the more **accomplished** diagnostician **avoid** the bias of looking only for the familiar problems and stopping the investigative process too early.
  - Encourages the keep **up-to-date status** required of **IPM** and **BMP** (see page 18).



  - **Ensures records are kept**. Diagnosis involves detective work and information gathering which means taking notes and keeping records of the enquiry, how the diagnosis was arrived at and any advice and information provided. These records provide proof of diagnosis to your client and should follow the diagnostic road map illustrated opposite (see also pages 62, 72, 105, 121).

REDUCING THE POSSIBILITIES	**Diagnosis involves gradually reducing the possibilities** by progressively filtering information (see Fig. 5 below). • An **established routine** is followed in which possible causes are progressively **eliminated**. • This narrowing of the possibilities **reduces** the number of suspect causes which have to be considered. • **At any stage** a diagnosis can be made.

		FILTERING PROCESS
?	**STEP 1**. **The client's enquiry** • The client • The enquiry • Initial perception of problem due to presence of signs & symptoms • If you have not made a diagnosis then	Infinite number of possibilities ▼
	**STEP 2**. **Identify affected plant** • Legislation • Common name, botanical/scientific name • List common problems affecting the plant • Pest information sheets • If you have not made a diagnosis then	Problems that may occur on plant ▼
	**STEP 3**. **Examine plant parts for signs & symptoms** • What is normal for the plant • Examine affected leaves, fruit, etc • Decide if there really is a problem • Preliminary diagnosis • If you have not made a diagnosis then	Problems on leaves, fruit, etc ▼
	**STEP 4**. **Visit site, history, questions** • Gathering information • Site inspection, site map (patterns, calendar, soil type, topography, structures, on-site tests) • History, eg crop, pests, weather • Asking questions of the client • If you have not made a diagnosis then	Time of year, records, weather ▼
	**STEP 5**. **Consult references** • Books, colleagues, computers • Host and pest indexes • Pest information sheets, pest signatures • Keys and expert systems • Image matching • If you have not made a diagnosis then	References ▼
XPERT	**STEP 6**. **Seek expert help** • To obtain, confirm or reject a diagnosis • Select a diagnostic service • Types of tests required • If a diagnosis has been made then	Laboratory tests, specific tests ▼
	**STEP 7**. **Report the diagnosis** • Prepare a permanent record as proof of diagnosis • The report must include: – Any legal requirements – Balance between costs and benefits – What you **did** and **did not** find – The common/scientific name of pest – How definite the diagnosis was – How reliable the diagnosis was – An evaluation of the diagnosis	Report diagnosis to the client

Fig 5. Steps 1–7. The diagnostic road map. Remember that although a diagnosis may be made at any step and steps may be by-passed, combined or re-visited, steps should **not** be omitted without consideration and you **must** always record and report the diagnosis.

WHEN TO DIAGNOSE PLANT PROBLEMS

LEGISLATION



Legislation may require that **certain** pests, diseases and weeds are detected and identified.

- **Quarantine regulations** for state/regional areas and export/import markets require that plants must look healthy, show no visible signs or symptoms and be free of specified pests. This may require continuous or intermittent monitoring during certain seasons.
- **Quality standards** to meet contractual arrangements with buyers.
- **Production and sale of disease-tested planting material**, eg seeds, potato tubers, strawberry runners.
- **Before implementing certain control measures**, eg pesticide applications, release of biological control agents.
- **Expert assistance** may be required to help you comply with legal requirements.

BEFORE YOU 'GROW' THE CROP

Chemical, physical and biological analyses of soil and water are **essential** for particular crops and prudent for many other crops where sites have been repeatedly cropped.

- Before purchasing a property.
- Before selecting and planting crops.
- During the growth of the crop.
- Between crops.

RECURRING PROBLEMS

Know what pests, diseases and weeds to expect in your **crop** in your **region**. In any one crop there are usually recurring pests, eg twospotted mites may always show up first in the same plants in a greenhouse. *Rhizoctonia* may appear on certain plants at the beginning of autumn. This information can be built into your crop management plan. Regional advisors know which problems are expected at particular times of the year.

- **List present and potential problems** for your crop or situation.
- **Obtain pest information sheets** for each problem.
- The **commonest problems really are the commonest problems**. Be able to **recognize** the signs and symptoms of the problems you have to look out for, know what tests you can do yourself and what samples have to be sent for analysis.
- **Decide if monitoring** is necessary, and if so, what has to be monitored.
- **Pest calendars** indicate the time of the year certain problems are likely to occur.
- **A realistic goal for a grower** is to select 6-10 important recurring pests in their crop, learn how to correctly identify them and build up a general knowledge and understanding of them and their control.

EARLY DETECTION AND IDENTIFICATION



The early bird catches the worm.....

Accurate, rapid and early detection of present and potential pests is a critical step in implementing effective control strategies. This will minimize their impact, avoid the possibility of epidemics developing and may prevent recurrences in later plantings.

- **Good diagnostic work** begins **before** or when the **first** signs or symptoms are expected. Once signs and symptoms **appear** it may be too late to apply control measures that season. Many growers diagnose common pest problems but often not until damage is excessive.
- **Regularly monitor** crops for the early detection of pests, diseases and weeds. Scout crops, gardens and quarantine areas regularly. Look under leaves, carry a hand lens and see what you can find. Growers, with today's wealth of information from books, the internet, industry groups and colleagues, should be able to scout their crops and detect key pests (see page 175). **Fungal diseases such as powdery mildews** may cause severe economic loss. Crops can be monitored for early microscopic evidence of fungal growth so that control can be implemented effectively.
- **Early warning services** (predictive pest services) monitor temperature, moisture and other parameters which favour pest development, so that growers can apply preventative measures. **Early Season Diagnostic (ESD)** tools monitor and compare crop vigour and environmental parameters for crops such as cotton so that any problem can be corrected before yield is affected.
- **Soil and water analysis** and seed tests can be carried out before planting.
- **References** can be used to identify weed seedlings.
- **Indicator plants** detect the presence of virus diseases.
- **Eradication of exotic introductions** depends on early detection by diagnosticians capable of identifying a pest not seen before in Australia. Students at Charles Sturt University learn to identify the main exotic threats to Australia's crops as part of their course.

COMMON OR SCIENTIFIC NAME OF PEST

What do you need for your situation?

COMMON NAME	Many pests are known by their common name (see Fig. 6 below). Nothing is wrong with common names except that they can **lack precision**, for example, the same insect may have different common names in different regions. • Common names are often **derived from the appearance** of a pest or disease or the **symptoms they produce** on affected plants. • Common names of many **insects and allied organisms** have been standardised and are called **accepted or standard common names** (Naumann 1993). If there is a possibility of confusion, the common name should be followed by the scientific name. It is not unusual to have common names used incorrectly, eg ferment or vinegar flies (*Drosophila* spp.) are often referred to as fruit flies (*Bactrocera*, *Ceratitis* sp, *Dacus* spp.), which they are not. • Common names for **plant diseases** have been standardized overseas (American Phytopathological Society 1978-1993) but they can still be confusing. In **commercial situations**, common names of **diseases** should be followed by their scientific name. • **Most home gardeners** only need to know the common names of pests. Although several species of aphids infest roses, they only need to know that there are 'aphids' on their roses or that the symptoms on their azaleas are caused by 'thrips' or 'azalea lace bug' or both.
SCIENTIFIC NAME OF THE CAUSE	The scientific name (genus, species, race/strain) of the cause is the only name that can be clearly understood internationally. Scientific names are necessary for many situations including the following: • **Obtaining accurate information** about pests and their control. • **Quarantine, trade**. Monitoring exotic incursions. Which fruit fly species? Is it really a pest species? Pest-freedom may need to be substantiated for export purposes. • **Commercial growers** need to know precisely which organism is causing a problem in their crops. • **Some species within a genus** may not be pest species. Some dodder species are introduced and important weeds; some Australian species are not much of a problem. • **Identification tests**. Some molecular techniques can discriminate between strains, races, and pathovars of species of fungi, bacteria, viruses and nematodes. **Herbicide resistant strains of weeds** and **GMO-contaminated crops** can also be identified. • **Monitoring** for pests in **IPM** programs. • **Selection of biological control agents or pesticides**, eg when beneficial organisms or insecticides are considered. Many beneficial insects will effectively control **only one** pest species and some pesticides only **one pest** species on a **single** crop.

Insects & mites	Diseases	Non-parasitic agents	Weeds
Accepted common names Cabbage white butterfly **Scientific names** *Pieris rapae*   Caterpillar of the cabbage white butterfly (NSW Agric)	**Names of disease** Brown rot of stone fruit Blossom blight & brown rot **Causes** Two fungi **Scientific names** *Monilinia fructicola* *Monilinia laxa* **Strains** Some strains are resistant to some fungicides  Brown rot on peach (NSW Agric)	**Names of disease** Chlorosis **Causes** Non-parasitic, eg iron deficiency  Symptoms of iron deficiency on rhododendron	**Common names** Blackberry **Scientific names** *Rubus* spp.  Blackberry (*Rubus* spp.)

Fig. 6. Some common and scientific names.

HOW DEFINITE DOES THE DIAGNOSIS NEED TO BE?

One should be cautious about being too definite

PRELIMINARY, USEFUL, ACCURATE, DEFINITE OR INCONCLUSIVE?

Pest information sheet
Common name
Scientific name
Causes
Significance
Host range
Description
Pest cycle
Overwintering
Spread
Conditions favouring
Control

Diagnosis may be:
Preliminary
Useful
Accurate
Definite positive
Definite negative
Inconclusive

How definite does the diagnosis need to be? The client or situation determines what is possible or most appropriate. Courts of law and quarantine require different levels of diagnosis than a home gardener.

- The degree to which a suspect pest **matches** the information in the pest information sheet, ie its **pest signature**, will determine the level of diagnosis. In some cases a single component is sufficient for an accurate diagnosis, eg a diagnostic test, but in most cases, several components are needed. It may also **eliminate** certain possibilities.
- Diagnoses may be **classified into different levels**, an example of which is presented below. Levels may comprise of **4 levels** of certainty; a **5th level** recognises that some investigations will be inconclusive.
- **A preliminary diagnosis** is based mainly on knowledge and experience in recognizing previously described signs and symptoms and their similarity to published descriptions and illustrations. A preliminary diagnosis requires a grasp, even if incomplete, of growing plants and the **causes** of **signs and symptoms** produced by pests, their life cycles, how they spread and conditions that favour them.
  - **Experienced diagnosticians** in plant clinics can satisfactorily diagnose 50-70% of the samples submitted. The low percentage is due to the poor quality of some specimens, lack of background information, time constraints, or a perception that an enquiry is unimportant, eg homeowner's potted African violet!
  - **A preliminary diagnosis** can be **confirmed or rejected** by further investigations to produce a useful, accurate or definite diagnosis.
- **A useful diagnosis** is the level at which many diagnosticians operate. **Important components** of the **pest signature** must be consistent with the sample or specimen.
- **An accurate diagnosis** is usually acceptable to plant pathologists, growers, quarantine and courts of law. For an accurate diagnosis **all facets** of the **pest signature** must be present or their absence explained.
  - **For parasitic pests** their presence in, or in association with, the plant must be verified.
  - **For non-parasitic agents** the presence of the causal agents at the appropriate time and place must be established. A site visit and appropriate questions increases the reliability of the diagnosis.
- **A definite diagnosis**.
  - **A definite positive diagnosis** requires the **identification** of both the **causal agent** and the **symptoms** it causes. Most pests and diseases are known and well studied so that descriptions, information about their life cycles and diagnostic tests are available and can be used to confirm or reject a diagnosis.
  - **A definite negative diagnosis** is often all a diagnostician can conclude, ie what the problem is **not** and the diagnostician's report may read 'no evidence of infectious disease'. Suspected problems are **eliminated** because **critical components** of the pest signature are not present, eg a diagnostic test is negative. Many causes may be **eliminated** by noting recent weather, determining soluble salt levels in soil and noting the appearance of roots and internal tissues of stems. A negative diagnosis is still useful. Clients are often pleased to know that symptoms do not confirm the presence of the exotic fireblight disease of apples, hormone herbicide injury or a fungal disease. Such information can allow certain fungicides to be omitted from a spray program.
- **An inconclusive diagnosis**. For a variety of reasons, many investigations will be inconclusive, eg samples are too small, inability to recognise exotic pests or symptoms are non-specific (indistinct), undescribed or of unknown causes. The time and effort devoted to some investigations may not be justifiable and it may be unlikely that a definite diagnosis can be reached.

HOW RELIABLE WILL THE DIAGNOSIS BE?

How much can you expect to do?

YOUR DIAGNOSTIC ABILITY



In many cases diagnosis requires little more than looking at signs and symptoms and having some understanding of the common pests and diseases affecting a crop. At the other extreme there are Diagnostic National Standards for significant high-risk pest threats to specific plant industries, eg banana, sugar, grains, citrus, viticulture and nursery industries, which require a higher level of reliability in diagnosis (see below).

- **Grower diagnosis has many advantages**, including:
  - **Helping growers get to know their crop better**.
  - **Cheaper** than hiring a scout or other experts. With today's wealth of information growers should be able to scout their crops for common pests and diseases.
  - **Speeding** up the diagnostic process and enabling early prevention.
  - **Maintenance of records** for their own benefit and for future use.
  - **Compliance with legislation** and regulations regarding managing the crop and any pests, eg correct use of pesticides, certified planting material, accreditation schemes.
  - **Many common pests, weeds and some diseases are not that difficult** to identify and subsequently control. When insect pests are the problem they are usually obvious and even though mites are very small and can't easily be seen, mite damage is fairly easy to detect once you've seen it a few times.
  - Growers should know **their limitations** and work out how much they want, or can, do.
  - **As a minimum, growers can start the diagnostic process**. Even if they don't conclusively determine the cause themselves, they can usually work through Steps 1 – 5 and assist with reporting the diagnosis (Step 7). Background information relating to site conditions, crop culture and weather speeds up a diagnosis when help from a diagnostic service is necessary.



- **Grower diagnosis can be limited**. Reasons include:
  - **Less reliability**. Growers need to have a level of diagnostic ability and experience.
  - **Time restraints**. If the diagnosis is not straightforward, it requires time to work through the diagnostic process.
  - **Poor quality of specimens**. In poorly collected samples and specimens signs and symptoms may not be representative or obvious (see page 178).
  - **Inadequate equipment**. A dissecting microscope with a top magnification of x40 to x60 is suitable for some insect and mite identification, but not for many disease organisms.
  - **Inadequate reference material**, eg books, fact sheets, computer access, contact with colleagues, industry, organizations. Diagnostic keys can be difficult to use.
  - **BMP** requires **training** to develop some basic skills to do the initial steps of diagnosis – it is not a difficult task but it does require some deductive reasoning (see page 185).

- **Some plant problems are hard to diagnose**
  - **Insect and mite damage can be hard to identify** when these pests are absent, are too small to be seen without a hand lens or it is winter/summer and too cold/hot for activity. Some insects bore into stems or fruit where they can cause damage without being seen. Most horticulturists recognise common insect, mite and disease problems but have occasional difficulties with sporadic pests or the more unusual pests which can sometimes be confused with environmental or cultural problems.
  - **Nematode, virus, bacterial and fungal diseases** are more difficult to identify and may need expert examination and complex testing to detect and identify.
  - **The most difficult plant problems to diagnose** are not usually caused by insect or disease but are **cultural and site-related**. In a natural undisturbed soil, nutrient deficiencies are not often a problem, although there may be exceptions in specific regions. However, in an urban or disturbed soil and in propagation nurseries there may be a high pH and micro-nutrient problems. You are also more likely to see symptoms caused by excessive fertiliser. Take the time to ask questions about the plant's cultural care.
  - **Some plants are susceptible to many problems**. Although most plants in a particular region or situation are only susceptible to a **few** economic pests and diseases, some plants, eg carnations, stone fruits, tomatoes, commonly get multiple problems at once, making diagnosis difficult.

You can **prevent** many problems by beginning with a soil analysis, planting recommended varieties of plants and following proper planting procedures

- **A National Standard** includes **criteria to evaluate the reliability** of a pest record for **living organisms of national importance** (see page 122) and includes:
  - How the samples are collected and information obtained.
  - The credibility of the identifier, their training and experience.
  - Whether standard tests were used and if they were implemented properly in an accredited laboratory which can be relied on to carry out such tests correctly.
  - Whether standard methods of reporting were used.

CASE STUDIES

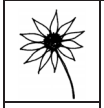
The diagnostic road map

These case studies reflect the importance of using a correct diagnostic process.

1. WHIGH SPECIES OF THRIPS?

	A commercial production nursery wanted to know if the dreaded Western flower thrips (*Frankliniella occidentalis*) had reached their production nursery.
	**Ornamentals**.
	Brought in samples of flowers and leaves with thrips. Examined under a dissecting microscope, but mostly juveniles were found
	-
	Illustrations were located and compared but there was still some doubt.
XPERT	Samples of flowers and leaves with thrips were send to an entomologist who confirmed that it was indeed WFT.
	**Accurate diagnosis** of WFT (*Frankliniella occidentalis).* Provided client with information about the pest and who to contact for advice on its control.

2. WHAT ARE YOUR LIMITATIONS?

	I can identify aphids and other insects. I have a dissecting microscope but can't identify diseases. Why not?
 	Nematode, viral, bacterial and fungal diseases can be a little harder to identify. Symptoms caused by viruses & other diseases are often non-specific and the micro-organisms causing the symptoms can often only be observed using a high powered microscope. Many require complex testing in a laboratory to detect and identify.
	-
	You may not be able to access the necessary books, colleagues and computer sources for information.
XPERT	-
	**Advice** You have to decide how much it is practical for you to do and what you must refer to experts.

REVIEW QUESTIONS & ACTIVITIES

The diagnostic road map

1. List the 7 steps in the **Diagnostic Road Map**.
   1.
   2.
   3.
   4.
   5.
   6.
   7.
2. List at least **3 advantages** of a **systematic process** for diagnosing plant problems.
   1.
   2.
   3.
3. When **diagnosing** a potential problem a horticulturist would:
   1. Identify the affected plant
   2. Be aware of potential problems
   3. Check cultural care
   4. Do all of the above
4. Give **2 reasons** why **'reducing the possibilities'** increases the likelihood of a correct diagnosis.
   1.
   2.
5. Name **2 reasons** why **early detection** of pests, diseases and weeds is important.
   1.
   2.
6. List **2 advantages** of using the **scientific name** rather than the common name of a pest.
   1.
   2.
7. For **2 insect or mite pests** of your choice supply the following information:

Common name(s) of 'pest'	Scientific name Genus/species
1.	
2.	

8. For **2 diseases** of your choice supply the following information:

Common name(s) of disease	Scientific name of cause Genus/species
1.	
2.	

9. For **2 weeds** of your choice supply the following information:

Common name(s)	Scientific name Genus/species
1.	
2.	

10. **Distinguish** between the following levels of diagnosis:

Preliminary	
Useful	
Accurate	
Definite positive	
Definite negative	
Inconclusive	

11. How **reliable** is your diagnosis of pests, diseases and weeds? Give reasons for you answer.

Step 1. The client's enquiry



The client *30*
The enquiry *31*
Diagnoses that can be made at enquiry *32*
Summary *33*
Case studies *34*
Review questions & activities *34*

THE CLIENT

The client is the key to diagnosing many plant problems

Clients include home gardeners, retailers and wholesalers of plants, landscapers, commercial and organic growers, specialist grower groups, arborists and consultants, exporters and importers, industry and government enterprises. A critical part of diagnosis is to understand and satisfy the client's needs and expectations. It is important to differentiate between the **enquirer** (the client) and the **enquiry** (the plant problem). Without a clear understanding of each, incorrect diagnoses and advice may result.

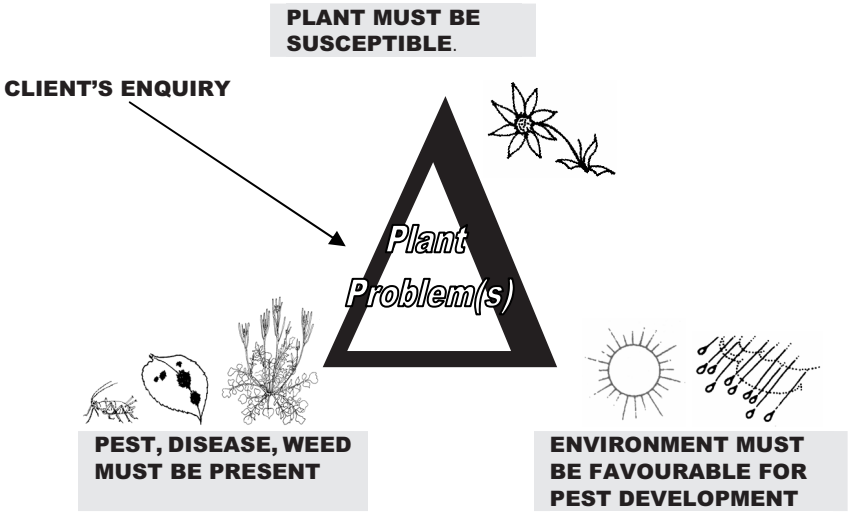
RECORD CLIENT DETAILS 	**The following details must be recorded:** • Date • Name • Company/home gardener • Address • Tel • Fax • Email • For further information see pages 105 and 121.
LISTEN TO THE CLIENT	**You need to be a good communicator** to understand your client and listen to their concerns (see page 117). • It is the **bringing together** of the client's observations and the diagnostician's expertise that decides the outcome of any diagnosis. • **It is the job of the diagnostician** to make a diagnosis, which is as definite and reliable as the client or situation requires. • You have to determine how **significant** the problem is to the client. The loss can be economic, aesthetic or a quarantine matter. • **Clients** often come with an apparently simple enquiry and want a quick fix. This is generally not possible. Don't be rushed into a diagnosis! • **If diagnosticians do not communicate effectively with the client**, they can come up with a perfectly accurate diagnosis of one problem, but not address the main issue of the client's concern. For example, it is possible to come up with an accurate diagnosis of **peach leaf curl on nectarines** from the sample, make control recommendations and walk away with a 'job well done' feeling. Then you discover that the client's real concern was the dieback of several large branches, which was not related to peach curl. Poor communication!
HOW CAN THE CLIENT HELP WITH THE DIAGNOSIS?	**In many situations, the client can provide:** • **Samples**, photographs or digital images of the perceived problem, eg distorted new growth. • **If samples are not available**, they can provide information on the identity of the affected plants and a description of the problem. • **Records** of management practices, pest, disease and weed occurrences and treatments and weather during the current and previous seasons. This information is vital for completing submission forms that accompany samples being sent to a diagnostic service for further investigation. • **Answers to relevant questions**, especially if you are unable to visit the site or access records, eg when the crop or hedge was planted, history of the planting, etc. • **Specialist knowledge**. Some commercial growers, grower groups and home gardeners have considerable knowledge and experience of the plants they are growing and their common pests and diseases.

THE ENQUIRY

WHAT IS THE CLIENT WORRIED ABOUT?

What is the reason for the enquiry? Always address client's concerns, ask questions and make other observations as needed.

- What does the client **think the problem is?**
- **Clearly define the enquiry**. Concerns are wide ranging, eg
  - Is the effect on the crop economic or aesthetic?
  - Does it relate to the identification of an insect, disease or weed?
  - Are diagnostic tests required?
  - Is it to obtain information on a **recurring problem**?
  - Is it to **confirm** a previous diagnosis?
- **Make sure that samples, photographs or digital images** are appropriately **labeled** with information on where, when and how they were taken.



WHAT CAN THE CLIENT EXPECT FROM YOU?

Generally the client expects a diagnosis and advice on prevention and control. Expectations should be discussed and agreed upon prior to proceeding with the diagnosis and periodically reviewed if necessary.

- **What does the client expect** from you? Examples include:
  - Legal requirements, quarantine regulations.
  - Information on any costs involved in the diagnosis.
  - Identification of a plant, weed, insect or a sticky trap catch.
  - Examination of plant material for evidence of pests.
  - Biological information on pests, cultural care of plants.
  - Simple diagnostic testing, eg pH.
  - Information on the need for more detailed investigation by a diagnostic service, eg identification of *Phytophthora*, soil, water or plant tissue analyses, pesticide and other residue tests.
  - Advice on prevention and control.
- **Client expectations** will **vary** depending on whether they are a commercial grower or a home gardener.
  - How definite does the diagnosis need to be?
  - How reliable does the diagnosis need to be?
  - Are common and/or scientific names required?

KEEP RECORDS



Details of the client and the enquiry must be permanently recorded as part of providing proof of diagnosis (see pages 105 and 121).

DIAGNOSES THAT CAN BE MADE AT ENQUIRY

PRELIMINARY DIAGNOSIS	**A preliminary diagnosis** is based mainly on **knowledge and experience**. • One should be **cautious** about being **too definite** about a diagnosis at enquiry unless the problem is obvious, ie striking in appearance and abundant. • **Telephone enquiries** are particularly difficult because there is no sample or photograph. You have to **rely on the client** for all the information relating to the problem, eg identity of affected plants, description of signs and symptoms (see page 117). • Sometimes further investigation is **not** justified, eg if only one plant is affected in a home garden.
CONFIRM OR REJECT A PRELIMINARY DIAGNOSIS	**If the client's enquiry or situation** requires a more definite and more reliable diagnosis, you will need to proceed through further diagnostic steps. Samples and further information would be requested. Examples of this situation include: • Legislative requirements. • Commercial growers. • Quarantine matters. • Certification schemes that provide guaranteed disease-free planting material. • When control of a pest with pesticides has been unsatisfactory, eg possible resistance problems. • A need to know what the problem is **not**, eg that it is not a parasitic pest which can spread from one plant to another, but some environmental or cultural problem. • If a client requires more information about a problem than they originally thought.

SUMMARY

Step 1. The client's enquiry

Each step of the diagnostic process reduces the number of possibilities, eliminating unlikely causes. Listen carefully to the details of the enquiry, so that the client can be provided with an appropriate response.

LISTEN CAREFULLY TO THE CLIENT 	**Record the following details:** • **Client details** – Date – Name – Business/home gardener – Address – Tel – Fax – Email • **Enquiry details** – **Define the problem**. What is the client **concerned** about? Is it a quarantine matter? Is the effect of the problem on the crop economic or aesthetic? Or does it relate to the identification of an insect, disease, fruiting body or weed? Is it a confirmation of a previous diagnosis? – What does the client **think** the problem is? – **What does the client expect from you?** How **definite** does the diagnosis need to be? How **reliable** will the diagnosis be? Does the client require the **common or scientific** name, or strains of the pest? Are diagnostic tests required? – **Samples, photographs and digital images** must be appropriately **labeled** with information on where, when and how they were taken. • **Diagnoses made at enquiry** – Usually only a preliminary diagnosis is possible.
FURTHER STEPS	Many diagnosis will require further investigation: Step 2. Identify the affected plant. Step 3. Examine plant parts for signs and symptoms. Step 4. Visit site, history, questions. Step 5. Consult references. Step 6. Seek expert help. Step 7. Report the diagnosis.

CASE STUDIES

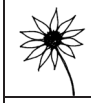
Step 1. The client's enquiry

These case studies indicate that a preliminary diagnosis of some problems of striking appearance and abundance can be made at enquiry.

1. WILL MY WEEPING CHERRY TREE DIE?

?	**A very cross customer** wants to know why the leaves of their expensive weeping flowering cherry trees are brown and shriveled.
	-
	-
	-
	-
XPERT	-
	**Preliminary diagnosis**. The problem is caused by 'pear and cherry slugs' which skeletonize the leaves that then shrivel and die *(see page 139)*. Trees look unsightly. This is a key problem that occurs every year. The 'slugs' pupate in soil and emerging adult sawflies re-infest the tree. Affected trees do not usually die. Nurseries note: Advise customers if a serious pest affects the plants they intend to purchase.

2. YELLOW PASSION FRUIT?

?	**Home gardener's** passionfruit produced lovely fruit for years. Recently noticed that some of the fruit are yellow in colour. Client is concerned that they have been doing something wrong.
	-
	-
	-
	-
XPERT	-
	**Preliminary diagnosis**. Passionfruit vines are grafted onto vigorous rootstock with tolerance to soil diseases. It seems that the rootstock (which produces yellow fruit) has produced shoots which are growing amongst the main vine.

REVIEW QUESTIONS & ACTIVITIES

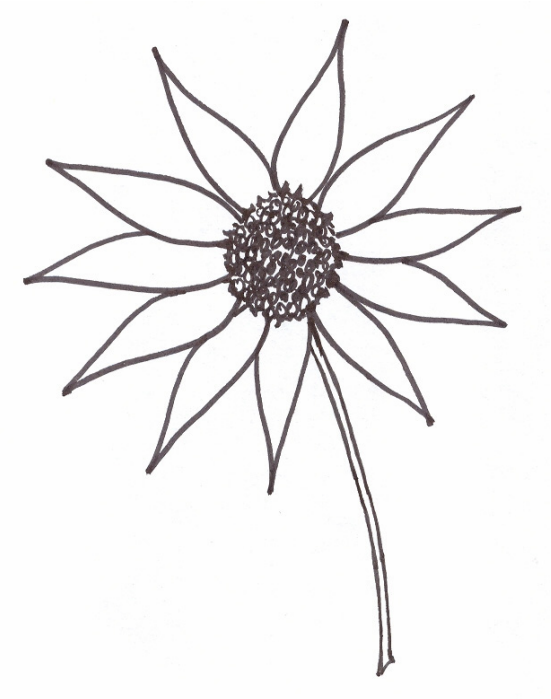
Step 1. The client's enquiry

1. Fill in the following for a diagnosis of your choice:

THE CLIENT Date Name Business/home gardener Address Suburb, town, postcode Tel Fax Email	
THE ENQUIRY • What is the client **worried** about? Identity of plant, weed, insect, fruiting body. Effect on crop – economic, aesthetic. • What does the client **think** the problem is? • What does the client **expect** from you? Common/scientific name/strains. Preliminary/definite diagnosis. How definite and reliable a diagnosis? • **Attach label** to sample (plant, soil, photo) with information on where, when and how it was taken.	?

2. Provide **3 reasons** for keeping **permanent records** of the client's enquiry.
   1.
   2.
   3.
3. Name **3 reasons** why **telephone** enquiries are very difficult for diagnosticians.
   1.
   2.
   3.
4. Describe **3 ways** in which the client can **help** you with your diagnosis.
   1.
   2.
   3.
5. List at least **3 common causes** of plant problems in your region at this time of the year.
   1.
   2.
   3.
6. **Practice** diagnosing selected plant problems at **enquiry** participating as:
   1. The client
   2. The diagnostician

Step 2. Identify affected plant



What is its correct name? *36*

Access to information *38*

- Legislation *38*
- A normal plant *38*
- Reducing the possibilities *38*
- List of pests & diseases *38*
- Pest information sheets, the pest signature *39*

Diagnosis based on identity of affected plant *41*

Summary *42*

Case studies *43*

Review questions & activities *44*

WHAT IS ITS CORRECT NAME?

Plant identification is an important part of diagnosis

COMMON AND BOTANICAL NAMES

Knowing your plants is an essential starting point for diagnosis. Plants may have a range of botanical (scientific), common and marketing names. Is the plant **really** what your client or label says it is?

Most plants have one to several common names

- **Common names** One plant may have several common names and the same common name may be used for different plants. This is confusing. Bindii is a problem weed in nearly every state/territory of Australia:
  - **Common names**: Bindii, caltrop, cat-head, catshead, common dubbeltjie, goat head, gokhru, kanti, Malta Cross, puncture vine, yellow vine.
  - **Botanical name**: *Tribulus terrestris*.

All plants have a genus and species

- **Botanical names** Plants are named according to rules and recommendations in two books, the International Code of Botanical Nomenclature (**ICBN**), and the International Nomenclature of Cultivated Plants (**Cultivated Plant Code**). Nomenclature (naming of a plant) is based on the first **published** description. The names of plants or groups are based on **types**, which are mostly dried herbarium specimens with **published** descriptions. These have **botanical names**.
  - If possible, **know** the botanical name, ie genus and species, so you can reliably receive information from and give advice to the client (Fig 7 opposite).
  - Is the name the **current** botanical name? A plant has only one correct botanical name which is always in Latin (except for the cultivar). This is the only one that can be clearly understood internationally and is generally the key to information about the plant (Lumley & Spencer 1991, Spencer 2002, 2003). When diagnosing plant problems you should aim to identify the affected plant by its botanical name, ie genus, species, variety/cultivar, and, if needed, provenance.
  - The botanical name of a plant may **change** when new knowledge has caused changes in taxonomy, eg **DNA** studies. **Misidentification** may occur when species introduced to cultivation are wrongly named and the name remains uncorrected for some time, becoming accepted. An Advisory Panel on Nomenclature and Taxonomy has been set up by the Royal Horticultural Society (**RHS**) to help solve such problems. There is a database and associated publications to serve this need, eg the free **RHS** Plant Finder.

Variations from the normal form of the species of horticultural interest, are known as cultivars, also there may be hybrids

- **Is it the correct cultivar or variety?** It is even more difficult to keep track of cultivars with many quickly falling out of favour. The Australian Cultivar Registration Authority (**ACRA**) is the source of correct cultivar names and usage. The cultivar, variety or provenance is often useful as some may be more or less susceptible to particular pests or diseases. Cultivar names should be placed after the botanical (Latin) name for the plant, but for a variety of reasons, retail nurseries may omit the botanical name.
- **Many horticulturists identify plants** by trying to match a plant or plant part to a picture, but some may be able to use keys to identify plants to family, genus and species (see also page 179).
- **What identification is appropriate for your client's needs?** Is the common name sufficient for the situation? The common name of a plant may be sufficient if it is distinctive, eg sweetcorn, however, knowledge of the cultivar is often still necessary. When there is any likelihood of confusion, the botanical name must be included. Advisors should aspire to using botanical names – even the family is a start.
- **References** are listed on page 196.

MARKETING NAMES AND OTHER DIFFICULTIES

The advent of Plant Breeders Rights (**PBR**) and branding with trade marks has resulted in a shift in emphasis from botanical and common names to legally protected **marketing** names (Fig.7 opposite). 'Made-up' trade names lead to all kinds of confusion. In addition the system has to accommodate aberrations such as:

- Synonyms, hybrids and genetically modified plants.
- Plants derived from perpetuated juvenile foliage (some conifers), self-sustaining prostate varieties (some wattles), virus infected plants (*Abutilon*), clonal selection of aberrant growth (witches' brooms), various seed-raised individuals, lines achieved by repeated self-fertilisation and graft chimeras.

KEEP RECORDS



Details of the affected plant's names together with any information accessed about the plant must be permanently recorded as part of proof of diagnosis (see pages 62, 72, 105 and 121).

DIFFICULTIES WITH HOST IDENTITY

Difficulties with host identity may mean that diagnosis may take longer and be inconclusive. You will not be able to access a list of possible problems or associated references.

- **If host is known** but **not** well studied, select a closely related species with caution.
- **If host identify is uncertain or unknown**, diagnostic services can assist with plant identification. A **pest index** may be useful.
- **Some plants are easily misidentified**, eg proteas/waratahs, deciduous plants when not in leaf, bare-rooted nursery stock. Clients often bring in samples with only a few leaves, or without flowers or seeds.
- **New crops**. As many growers look to new crops to improve profits, it is imperative to be able to recognize different cultivars and learn their cultural needs and their susceptibilities to pests, diseases and weeds. Sometimes it is not possible to identify **cultivars** with certainty.
- **Most is known about crop species**, but there are still many problems of pasture, forest, ornamental and Australian plants that have not been fully investigated.

WHICH OTHER PLANTS MAY NEED TO BE IDENTIFIED?

List types of other plants growing near (around, over or under) crop plants.

- If it is a **pest or disease** problem and you want to apply an insecticide or fungicide, in addition to knowing the name of the host, you must also know the botanical or common names and types of **other plants growing near them**, including both desired and weed species.
- If it is a **weed** problem, both the weeds and surrounding plants must be correctly identified before herbicide recommendations can be made.
  - Find out the **botanical or common names** and **types** of other plants growing near weeds, eg whether the crop is broadleaved or grass-like, annual or perennial.
  - **If herbicides** are to be applied to **weed seedlings**, recognize the different stages of weed growth.

SITUATION	WEEDS CONTROLLED	RATE	HOW TO APPLY
In established **grass** lawns, including **bent, buffalo, couch, fescue, kikuyu, paspalum, ryegrass**	**Broadleaf weeds** including bindii, catsear, clover, creeping buttercup, creeping oxalis, cudweed, dandelion, dock, fleabane, Jo Jo. lamb's tongue, wireweed and clovers		*Example only*

Synonyms (of the scientific name)	Scientific names and cultivars	Some market names
Genus *Corymbia* Species *citriodora* Synonym ***Eucalyptus*** *citriodora* Common name Lemon-scented gum Genus *Argyranthemum* Species *frutescens* Synonym ***Chrysanthemum*** *frutescens* Common name Marguerite Daisy, etc	Genus *Nandina* Species *domestica* Cultivar **'Nana'** Common name Dwarf Nandina Genus *Zelkova* Species *serrata* Cultivar **'Green Vase'** Common name Japanese Elm Genus *Grevillea* Species *rosmarinifolia* Cultivar **'Nana'** Common name Dwarf Rosemary Grevillea	TM indicates an unregistered trade mark ® indicates a registered trade mark Φ indicates that the name is protected under Plant Breeders Right (PBR) Genus *Lonicera* Species *nitida* Cultivar 'Maigruin' Market name **Honey Hedge Lime™** Genus *Pittosporum* Species *tobira* Market name **Miss Muffett®** Genus *Acacia* Species *cognata* Market name **'Limelight'Φ** Genus *Callistemon* Market name **'Hot Pink'Φ**

Fig. 7. Some names that appear on retail plant labels. Look at **both sides** of the label for the genus, species, cultivar and market name.

ACCESS TO INFORMATION

Correct identification of affected plants means that information about its culture, its pests and diseases can be accessed.

LEGISLATION



The status of a crop may differ depending on the situation, eg commercial crops, public parks or home gardens.

- **For quarantine and trade purposes**. Knowledge of the relationship between Australian plants and those belonging to other geographic regions is vital to preventing exotic introductions. **Weed risk assessment** is carried out for all imported plants.
- **Registration and use of pesticides and bio-pesticides**. Most insecticides and fungicides are only registered for use on certain plants. Some are **not** registered for use on edible crops, some can only be applied at certain **stages of crop growth**. So you may need to identify different stages of plant growth, eg seedlings, pre- and post-flowering, fruiting, post-harvest, dormant rootstock, mature plants.

CROP	DISEASE	STATE	RATE	HOW TO APPLY
Almonds	Leaf curl Shothole			Spray at **budswell** before and within one week of **bud opening**, etc
Apples	Black spot (scab)			Spray at **green tip** stage, etc
Apricots and cherries	Shothole Freckle			Spray at **early budswell** prior to earliest stage of bud movement, etc

Example only

- **Sale of plants.** Assist customers in purchasing correctly named plants suitable for their garden and the surrounding environment. The customer is **entitled to expect** that the botanical name is included somewhere on the label.

A NORMAL PLANT

To diagnose abnormalities you need to know what a normal healthy plant of the same variety and age looks like in your region. Most **horticultural references** are organized by **host**, so once the name of the plant is known, you can look up references or ask someone about its culture. Is it naturally variegated? Is it supposed to be a dwarf variety? Are stems naturally hollow?

REDUCING THE POSSIBILITIES

Hundreds of pests and diseases may occur in your area - a formidable number to choose from. However, **most plants** are only susceptible to a few economic pests. By identifying the affected plant you can:

- **Reduce potential problems to a manageable number**. You have immediately reduced the number of possible problems from hundreds to those that typically occur on that species or variety. For example, if the host is a rose, you can narrow down the possible problems to the 20 or so pests and diseases that affect roses.
- **Learn how to distinguish one problem from another** on a particular plant (pages 52 and 53).

LIST OF PESTS & DISEASES

Roses

Virus diseases
- Rose mosaic

Bacterial diseases
- Crown gall

Fungal diseases
- Anthracnose
- Black spot
- Powdery mildew
- Downy mildew
- Petal blight
- Rust

Insects, mites
- Aphids
- Plague thrips
- Rose scale
- Twospotted mite

Non-parasitic problems
- Iron deficiency
- Herbicide injury

You can access lists of the common pests and diseases of your crop. This list offers suggestions of what your plant problem might be, but any diagnosis must ultimately be **proved** by appropriate diagnostic techniques.

- Get to **'know'** the pests, diseases and weeds likely to affect your crop in your region. A realistic goal for a grower is to select 6-10 important recurring problems in their crop and obtain information about them. **Prioritize** (list 1-10) them according to their economic or aesthetic significance, quarantine importance, etc.
- This list may enable you to **eliminate** pests and diseases that do not need to be considered. This can be just as important as knowing what it is, eg it is **not** rust on walnut because walnut is not a host for rust.
- **Knowing which species** or cultivars are susceptible to the common problems in your region will assist with plant selection.
- **Although lists of common problems are helpful**, remember that both country and urban environments are constantly **changing** and exotic introductions are a regular occurrence. Some pests may occur **out of their normal environment** in protected sites, eg in greenhouses, courtyards. Under some circumstances, some pests and diseases may attack unusual hosts, eg black scale has been found on potatoes, brown rot may attack quince. Be familiar with **new crops** and their associated pests. Contact quarantine for recent pest introductions in your region.
- If a host is not listed, selecting a closely related species may be useful but be cautious.

PEST INFORMATION SHEETS

The pest signature



Pest information sheets provide information on a pest's biology, including its correct scientific name, significance and how it can be controlled.

- If possible **obtain a pest information sheet** for each present and potential pest, disease or weed in your crop or region.
- Pest information sheets are sometimes called a pest prescription sheets or fact sheets and are available in sheet form, online or as CD-ROMs (see page 195).
- The **information** in a pest information sheet is often referred to as the **'pest signature'** and is useful in the identification of **suspect** causes. The **identity** of the suspect pest can be confirmed by the **degree** to which it matches the 'pest signature'. The result varies. In some cases a single component is sufficient for an accurate diagnosis, eg type of spores present or a diagnostic test, but in most cases, several components are needed to complete the diagnosis. It may also **eliminate** certain possibilities.

Pest information sheet

'Pest signature'

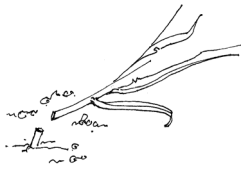
Common name
Scientific name
Causes
Significance
Host range
Description
Pest cycle
Overwintering
Spread
Conditions favouring
Control

CONTENTS OF A PEST INFORMATION SHEET

- **Recognized common name(s)** of the pest, disease or weed.
- **Scientific name**. Knowing the scientific name of a pest is important if you are to obtain information from the internet, literature and diagnostic services.
- **Cause(s)**. Is the problem **caused** by a virus, bacteria, fungus, nematode, insect or something else, eg drought or a combination of factors?
- **Significance of problem to client**.
  - **Status of pest**. Are there **legal responsibilities?** Is it a notifiable quarantine pest, or a recent introduction? Is it a major/minor, established/ sporadic, or an Australian/exotic pest? Is it a noxious or other type of weed, eg a nuisance or sleeper weed, or a Weed of National Significance (**WONS**)?
  - **Has a pest, disease or weed risk assessment** been carried out? Is it a high risk area?
  - **What is the potential to cause economic loss?** The economic or aesthetic effect on the crop may differ from region to region. Powdery mildew of euonymus may be irrelevant to plant health in one landscape, but it would certainly matter to a garden centre displaying euonymus in its sales area.
  - **Whether you are a commercial grower or a home gardener** will influence the need for a definite and reliable diagnosis.
  - **Other considerations**. Some plants and weeds are poisonous, eg Paterson's curse is toxic to horses and pigs. Some plant diseases can make plants poisonous, eg peanuts infected with *Aspergillus flavus* contain aflatoxin which is toxic to humans.
- **Host range**. **Plant species affected**. Some pests and diseases affect many species, eg twospotted mite. Others, such as black spot of rose, only infect roses.
- **Description of signs and symptoms**. Know which plant parts are affected, eg above or below ground (leaves, roots), internal or external (inside fruit, bark beetles). Signs, symptoms and diagnostic features are described, eg insects can be measured, fungal spores described. On-site and laboratory **diagnostic tests** may be available, eg pH and **ELISA** tests, **DNA** technology.



Sign. Cutworm in soil. Check with description in pest information sheet



Symptom. Stem base chewed by cutworm. Seedling falls over



On-site tests

Identifying plants, weeds
Detailed soil, water & plant analyses
Microscopic examinations
Culturing fungi
Virus testing

Laboratory tests

- **Pest cycle**. Know **when and where damaging stages** of the pest are likely to occur. Knowledge of pest cycles indicates vulnerable stages when control measures are likely to be most effective.

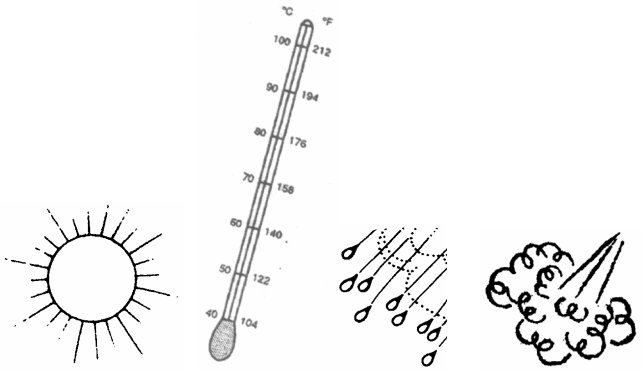
PEST INFORMATION SHEETS *(contd)*

– **Overwintering**. Overwintering can also mean 'oversummering'. These terms indicate when, where and in what stage a pest carries over from one season to the next.

– **Spread**. It is vital to know how a pest is spread, ie by wind, flying, water, propagation, etc. What is the **pattern** of occurrence in the crop and surrounding area? Where does it occur in Australia?

– **Conditions favouring**.

- **Environmental factors** influence the incidence and severity of **parasitic** pests and diseases but remember they may also **directly** damage the plant.
- **Site conditions**, eg soil type, topography, aspect, buildings, drainage.
- **Crop history**, eg previous cropping, treatments, fertilisers, irrigation.



Are there **IPM**, **BMP** or **Organic Standard** programs available for this pest in your crop?

– **Control**. The above information will help you work out what advice would be appropriate and effective; sometimes no action may be in order. Explaining why a problem occurs may be all that is required to allay client concerns. Could previous treatments have caused plant damage? Lack of appropriate treatments may have favoured the problem in the first place. There may be **legislative** requirements. **IPM** programs may provide threshold values for your pest below which treatment may not be recommended.

- **Cultural methods**. Each plant has its own cultural requirements.
- **Sanitation**. Water free of disease organisms is essential for **all** stages of plant production, including potting media producers as well as plant propagators.
- **Biological control**. Know the names of any natural enemies of a pest which might provide some control and reduce pesticide use. Have biological control agents been released?
- **Resistant varieties**. Are cultivars of your plant or crop available which have some resistance to your pest problems?
- **Plant quarantine**. Check state/territory/Commonwealth regulations.
- **Disease-tested planting material**. Where did the planting material, growing media and containers come from? Some pests and diseases are carried in association with seed, cuttings, bare-rooted nursery stock. Weed seed, weed parts, nematodes and soil fungi may be transported in soil.
- **Physical & mechanical methods**. Hand weeding or hoeing on a hot day may have damaged surface roots of annual seedlings.
- **Pesticides**. Check registered uses of all pesticides prior to use. **Labels specify** the plants and the pests to which a pesticide may be applied.

DIAGNOSIS BASED ON IDENTITY OF AFFECTED PLANT

Reducing the possibilities

PRELIMINARY DIAGNOSIS	**If you can identify the plant**, you can access a list of pests likely to affect it; you can also access relevant pest information sheets (see Fig. 8 below). Previous knowledge and experience of the affected plant may enable you to make a preliminary diagnosis. • This list only offers **suggestions** of what your plant problem **could** be.
CONFIRM OR REJECT THE PRELIMINARY DIAGNOSIS	**If the client's enquiry** requires a more definite diagnosis you will need to proceed through further diagnostic steps, eg examining plant parts for signs and symptoms, site visits, consulting references or seeking expert help.

Identify plant

ROSES
Rosa spp.

List of pests and disease (not exhaustive)

ROSES

Rosa spp., *Rosa hybrida*
Rose family (Rosaceae)

Parasitic

Virus and virus-like diseases
ROSE MOSAIC

Bacterial diseases
Crown gall (*Agrobacterium* spp.)

Fungal diseases
Anthracnose
Black spot
Damping off
Downy mildew
Grey mould, blossom blight
Powdery mildew
Rust
Stem cankers

Nematode diseases
Root knot nematodes

Insects and allied pests
Aphids
Caterpillars
European earwig
Fuller's rose weevil
Mites
Plague thrips
Rose scale

Vertebrate pests

Non-parasitic
Environment
Leafcutting bees
Nectar scarabs
Nutrient deficiencies, toxicities
Pesticide (fungicide, herbicide, insecticide) injury
Senescence

Different or additional problems may occur when a plant is grown out of its natural habitat, or if new exotic pests have arrived in Australia.

Pest information sheet (one for each problem)

The 'Pest signature'
(summary only)

ROSE MOSAIC

Common name Rose mosaic
Cause Several viruses
Scientific name Various
Significance Usually minor
Host range The most common viruses, apple mosaic and *Prunus* necrotic ringspot mainly infect plants in the rose family
Description No signs. Symptoms include mottles, line patterns, ringspots. Diagnostic tests are available if there is a need to know which virus is involved.



Overwintering In roots, canes and buds of infected plants.
Spread by propagation, pollen. Symptoms are mostly uneven on leaves (exceptions include line patterns which may have a mirror image as above). Affected leaves are scattered on the plant. Affected plants are scattered throughout the crop but all plants may be affected if all are from the same parent stock.
Conditions favouring Usually first noticed in spring on new growth of new plantings. Common in home gardens but commercial growers propagate from certified virus-tested stock.
Prevention/Control.....

Fig. 8. A list of pests and diseases for roses and a pest information sheet for rose mosaic. This illustrates how the identification of an affected plant allows you to access information which will help you with diagnosis.

SUMMARY

Step 2. Identify affected plant

Each step of the diagnostic process reduces the possibilities, eliminating unlikely causes. Recall the original enquiry (Step 1). We now need to correctly identify the affected plant so relevant information can be accessed.

WHAT IS ITS CORRECT NAME? 	**Identify your client's plant** as accurately as you can, tactfully putting aside any mis-identifications offered by the client. Be wary of common names. Many diagnoses fail because of an initial misidentification of the affected plant. • Do you need the **botanical** or **common name** or **both**? Diagnosticians should aim to know the genus and species. Remember botanical names may change. Common names are acceptable for home gardeners. • The name of the cultivar and the family to which the plant belongs is often useful. • 'Marketing' or trade names can be confusing. • It may be necessary to check references such as **ICBN**, **RHS** Plant Finder, **ACR**. If proof of identification is required, plant material can be sent to a botanic garden or diagnostic service (Step 6). • Horticulturists **mostly identify plants** by image-matching, but some may be able to use keys to identify plants to family, genus and species (see page 179). • **Adjacent plants** may need to be identified.
ACCESS INFORMATION	**Identifying the host plant** can open the door to a wealth of information. • **Be aware of legislation** and why plant identification is important for quarantine, trade and contact with other industries or organizations. • **What does the plant normally look like?** Identifying a plant to genus, species and variety enables the diagnostician to understand how the plant should grow under normal conditions. • **Reducing the possibilities** Because most plants are only susceptible to a few pests, unlikely suspects can be eliminated, saving time and money. There may be different pests at each stage of plant growth, eg codling moth only infests fruiting apples. – Access a **list** of known and potential pests and diseases to which your crop is susceptible in your region. If the plant is not listed, select a closely related species with care. – Access a **pest information sheet** for each present and potential pest listed for your crop. They will provide information to help you identify and effectively control the problem. • **Be aware of possible difficulties in diagnosis** if the affected plant cannot be identified with certainty. • **Diagnosis based on identity of an affected plant** is at best preliminary and must ultimately be proved by further investigation, eg moving to Steps 3, 4, 5 or 6.
FURTHER STEPS	Step 3. Examine plant parts for signs and symptoms. Step 4. Visit site, history, questions to ask. Step 5. Consult references. Step 6. Seek expert advice. Step 7. Report the diagnosis

CASE STUDIES

Step 2. Identify affected plant

These case studies emphasize the importance of identifying the affected plant.

1. WHITE CARROTS? A well known case study

	**A fresh sample by mail** with a letter. Concern that the carrot seed planted had produced some carrots which were white.
	Little doubt about the identity of the affected plants! One was a carrot, the other a parsnip!
	One carrot and 1 parsnip both approximately the same size which at first glance appeared to be very healthy.
	-
	-
XPERT	-
	**Useful diagnosis** The 'white carrot' is actually a parsnip, possibly due to parsnip seed mixed in with carrot seed. Seeds of both are very small and easily mixed up.

2. 'CEDARS' AND 'CEDARS'

	**A telephone enquiry.** Lots of black furry caterpillar-like things about 2 cm long all over garden, some coming onto verandah. What are they and are they harmful?
	Client not sure where they come from.
	No sample. Preliminary diagnosis of **white cedar moth caterpillars**.
	As these caterpillars only infest white cedar, asked if the client or their immediate neighbours had a white cedar tree. **Answer:** Definitely not. Requested a sample.
	Illustrations **confirmed** the preliminary diagnosis. Hairs can cause severe irritation. So why no white cedar trees? The client thought white cedar trees were conifers.
XPERT	-
	**A useful diagnosis** of white cedar moth caterpillars and their itchy hairs. Advisor also explained that the white cedar tree is *Amelia azadarachin,* not a conifer

3. LEGAL OBLIGATIONS?

	**Fresh samples** of foliage of ***Pistacia*** brought for **confirmation** as an environmental weed in a Landcare area.
	Only leaves were available, 3 possibilities: ***Pistacia chinensis*** with **alternate** 10-12 leaflets, strong odour when crushed. ***Rhus*** with 4-7 (usually 5) **opposite** pairs of Elliptical leaflets each 4-10 cm long. ***Tree of heaven*** with up to 20 pairs of **opposite** leaflets (each 12 cm long), base Asymmetric, entire except for teeth near base. At each tooth there are 1 or more glands which produce an unpleasant odour when crushed. Leaves up to 50 cm long.
	Consulted books and colleagues to confirm identification of plant. Not as easy as it seems. Odours were not much help.
XPERT	-
	**Useful diagnosis** of **tree of heaven,** noxious weed in some parts of Australia, possibly toxic to stock. Check local legal obligations.

4. 'BENEFICIAL' GALLS ON ROOTS

	Client brought in some roots of a 10 metre high alder tree (*Alnus* spp.) which had been chopped down because of 'crown gall' on the roots. Client wanted confirmation.
	Assumed that it was an **alder tree**. Checked what the roots of an alder tree would look like normally and for the causes of galls (about 8 cm across). *See page 46*.
	Examination revealed mycorrhizal galls which alder trees normally have on their roots and are necessary for tree health.
	-
	Checked references to **confirm** that the shape and type of mycorrhizal galls were consistent with those found on alder trees.
XPERT	-
	**Useful diagnosis**. **Beneficial** mycorrhizal gall on alder. Suggest avoid knee-jerk reactions. A little knowledge is a dangerous thing!

5. IT IS PROBABLY WEBBING CATERPILLAR

	**Client** concerned about the lack of flowers and small bits of 'sawdusty' material on a large public planting of *Astartea*.
	***Astartea***. List of pests not readily available. Possibly webbing caterpillars. Related to tea-trees (*Leptospermum* spp.) in the Myrtaceae family.
	Samples confirmed old webbing caterpillar damage. Caterpillars shelter in frass during the day & feed at night *(see page 134)*.
	-
	References available on webbing caterpillars. But lack of flowers may also be due to lack of pruning. Requested a sample.
XPERT	-
	**Useful diagnosis** of webbing caterpillar damage. This pest must be controlled and the plant correctly pruned, if flowers are to be obtained.

6. IT IS NOT LIKELY TO BE WOOLLY APHID

	Caller complains about 'fluffy white stuff" in the throat of a few **agapanthus** in a group of about 20. They were advised that is was woolly aphid, but wanted a '2nd opinion.'
	**Agapanthus**. Unlikely to be woolly aphids as they only infest apple, crabapple, hawthorn, rarely pears, some cotoneaster species, rarely liquidamber.
	From the description, possibly mealybugs. If the client wanted to be sure a sample would be needed *(see page 137)*.
	-
	Samples **confirmed** the identity of mealybugs from illustrations (white, with waxy secretions and filaments). The host range of woolly aphid was also confirmed.
XPERT	-
	**Useful diagnosis**. Mealybugs.

REVIEW QUESTIONS & ACTIVITIES

Step 2. Identify affected plant

1. From **2 plant labels** of your choice provide the following details:

	Plant label 1	Plant label 2
Common name(s)		
Botanical name(s) (genus, species)		
Variety, cultivar(s)		
Strain, race		
Trade, market name		
Synonyms		

2. If you **don't know** or are not sure of the name of a plant, list 3 ways you could find out.
   1.
   2.
   3.

3. Collect **3 plants** unknown to you and identify them using references, eg books, colleagues, computers.
   1.
   2.
   3.

4. Name **3 reasons** why diagnosticians need to know the name of the affected plant.
   1.
   2.
   3.

5. List the common **pests and diseases** affecting a plant of your choice under the following headings.

Common name **Genus/species/cultivar**
Parasitic pests & diseases
Virus & virus-like diseases
Bacterial diseases
Fungal diseases
Nematode diseases
Insects and allied pests
Vertebrate pests
Non-parasitic pests & diseases

6. **From a list of pests and diseases** affecting the following plants, indicate which problems you would expect to find in Australia. Circle the correct answer.

Roses	a. Rust, black spot, anthracnose. b. Powdery mildew, downy mildew c. Aphids, scale, mites d. All of the above.
Eucalypts	a. Rust b. Downy mildew b. *Phytophthora* root rot d. All of the above
Grapevines	a. Downy mildew b. Powdery mildew c. Fig longicorn d. All of the above
Tomatoes	e. Corn earworm f. Green vegetable bugs g. Tomato spotted wilt d. All of the above
Garlic	a. Rust b. Root knot nematodes c. Bulb & potato aphid d. All of the above.

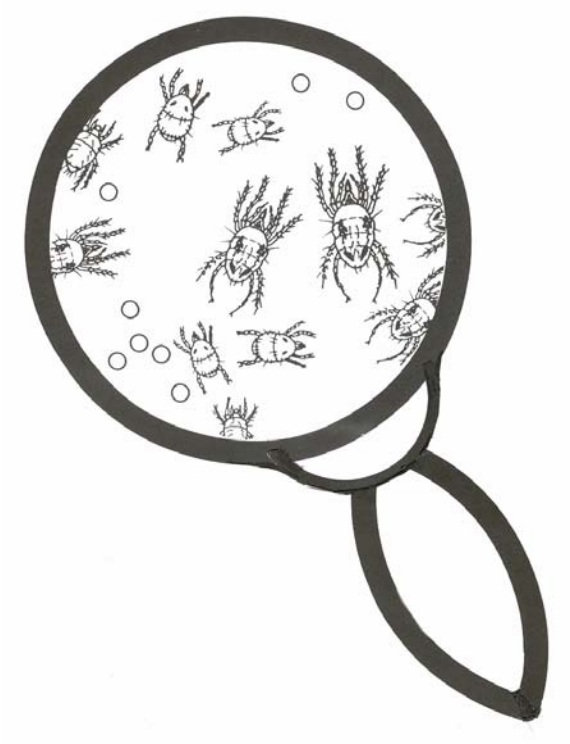
7. **Explain** the following:
   1. Pest information sheet
   2. Pest signature

8. Fill in the following **pest information sheet** for a pest, disease or weed of your choice.

Common name
Scientific name
Cause/
Host range/Plants affected/Situation
Significance
Description (signs, symptoms, diagnostic tests)
Pest/Disease/Weed cycle
Overwintering
Spread
Conditions favouring

9. **From 3 pesticide labels** locate the crop or plants to which the product be applied.
   1.
   2.
   3.

Step 3. Examine plant parts for signs & symptoms



What is normal for the plant? *46*

Examine plant parts *47*

Signs & symptoms *48*

Complex signs & symptoms *49*

Diagnosis based on signs & symptoms *51*

Summary *54*

Case studies *55*

Review questions & activities 57

WHAT IS NORMAL FOR THE PLANT?

IS THERE REALLY A PROBLEM?

Few plants are completely problem-free

Some apparent problems may be normal features of the species.

- **Once the affected plant is identified**, the next step is to describe what may be **abnormal**. And this can only be determined if the diagnostician knows what the plant looks like normally (see Fig. 9 below).
- **Plant characteristics are variable**. What is perfectly healthy for one plant may be an indication of a serious problem for another.
- **It is necessary to have a yardstick** against which an affected plant can be compared. This yardstick is knowing what a normal healthy plant of the same species, variety and age looks like growing under the same conditions. This is gained from a knowledge of:
  - Its life history and knowing what it looks like at various stages of growth. This applies not only to its external appearance but also its internal anatomy.
  - How it responds to stress; its cultural and environmental requirements.
  - The effect of seasonal conditions, such as rainfall, temperature and light, on the appearance of nutritionally healthy plants.
  - Its susceptibility to pests and diseases.
  - Its susceptibility to herbicide injury, nutrient deficiencies and toxicities.
- **Some plants may appear abnormal** to someone **unfamiliar** with the normal characteristics of the crop, eg
  - Normal autumn colours of many deciduous trees and shrubs.
  - Whether a plant is meant to be a dwarf variety.
  - Lemon drop poinsettia (*Euphorbia pulcherrima* 'Lemon Drop') has yellow bracts rather than the more familiar red, white or pink of most poinsettias causing concerns about the plant's nutrition.
  - **But** these examples do **not** prove that the plant is healthy. The poinsettia could **still** a have nutrient deficiency, and possibly other problems.



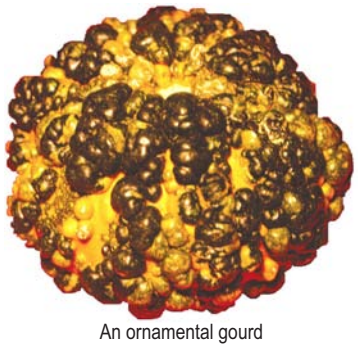
Spots on *Gueris* leaves



Variegated *Euonymus*



Variegated rose with crimson stripes and splashes of colour



An ornamental gourd



Burr knots on *Prunus*

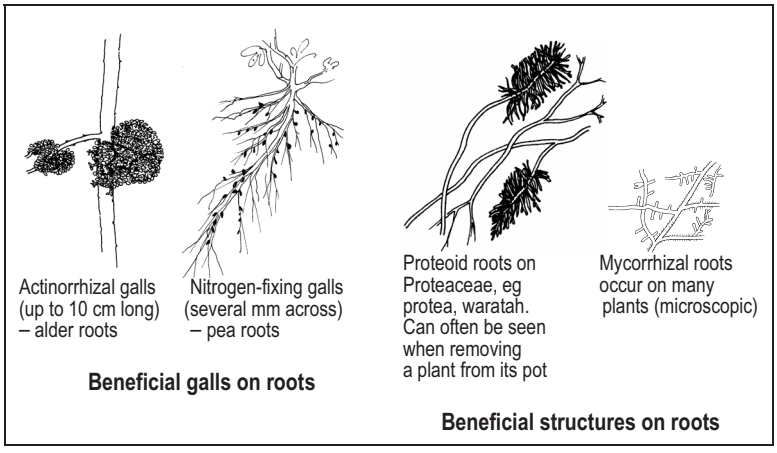


Fig. 9. Examples of normal plant features.

EXAMINE PLANT PARTS

We have identified the affected plant and know what a healthy plant looks like. The presence of certain signs and/or symptoms indicate that there is a problem. **Take plenty of time** in this initial phase of diagnosis.

LOCATION OF SIGNS & SYMPTOMS

Examine plant parts for **signs**, eg aphids, and/or **symptoms**, eg rots. Examine first visually then under a hand lens or dissecting microscope. Then, if available, under a high powered microscope. Look at the early stages of the problem. If monitoring or tissue testing is being carried out, examine parts of the plant where signs and/or symptoms may be expected.

- **Plant parts**. Signs and symptoms may be located on one or several parts of the plant or spread over the whole plant.
- **Above and below ground**. Problems on **above ground** parts may be caused by insects, diseases, poor site location, air pollution, volatile herbicide formulations, weather.
  - **Leaves** often have the most noticeable symptoms. However, the cause of the leaf symptoms may be located in the twigs, branches, trunk and roots or in the soil or water.
  - **Problems on below ground parts** may be caused by insects feeding, root rots, chemical injury, transplant shock, poor planting methods, site-related stress, restricted rooting area, soil compaction, poor drainage, over or under watering, over or under fertilizing!
- **On the surface or inside plant parts**. Each plant part should be examined internally as well as externally. Cut open fruit and stems, tease out flower petals and buds.
- **The whole plant**. Walk around the plant. Observe symptoms close up then from a distance. What do you see that looks abnormal?
- **Away from the plant**. Sometimes the cause of a problem is found in the soil, eg nematodes, insects, *Phytophthora*, in the mulch and plant debris, eg insects, snails, disease organisms, in water, eg *Pythium*, or on packing cases, eg insect pupae.

RECORDS



Describe and record all visible signs and symptoms that make you believe there is a problem. In many instances **more** than one cause may be involved, and each cause may produce one to several signs and symptoms, eg insects, chewing damage. Use standard recording sheets (see pages 62, 72, 105 and 121); records may include samples, specimens or photographs and a site map.

- **Check your observations with co-workers** to find out if they can add to them or if they disagree with any of them.
- **Keeping records formalises observations** and avoids a hasty diagnosis.

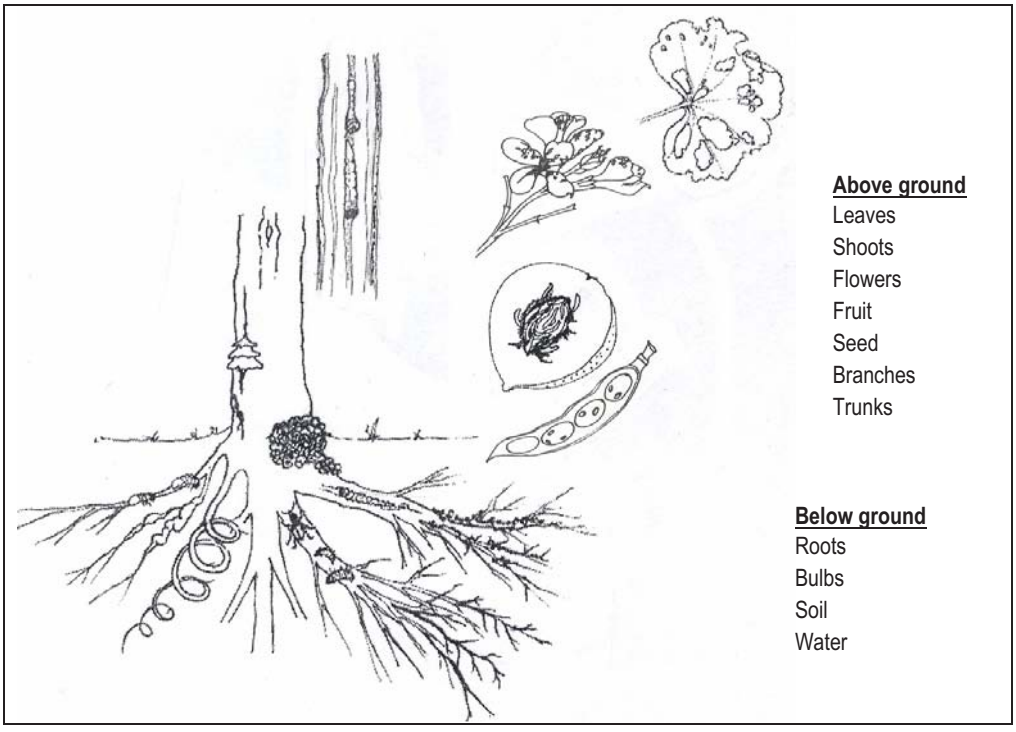


Fig. 10. Plant parts which may be affected.

SIGNS & SYMPTOMS

Do you know what to look for? Signs and symptoms make us aware that a **problem may exist** and may offer clues as to the cause of the problem. A knowledge of the **signs and symptoms** produced by the various **causes** of plant problems can speed up the diagnostic process considerably. This comes with experience and if you are new to diagnostics the information in Appendix 3 (pages 123-174) will be helpful.

SIGNS





Signs are the physical evidence or the actual presence of the cause of plant problems. Use a hand lens or dissecting microscope to get a close up view.

- **Signs** may be very obvious, enabling the pest to be identified.
  - **Insects and allied pests**. Signs include immature or adult insects and mites, frass, cast skins, honeydew, silk, wax and spittle. If they are the cause of a problem, they can be easily seen. Remember to check the undersurfaces of leaves.
  - **Some fungal diseases** can be readily recognized, eg powdery mildews, rusts, wood rot fruiting bodies. Growers are generally not equipped to identify most viral, bacterial and many fungal diseases. Diagnostic techniques and tests are often difficult to do and require equipment not available outside diagnostic laboratories.
  - **Residues** of fertilisers or pesticides on leaves can sometimes be seen.
  - **Weeds** such as couchgrass in garden beds are very obvious.
- **Just because you can see the pest**, eg aphids, and they are easy to identify, do not rush into thinking that this is the only problem as it rarely tells you the whole story.
  - **Finding a nematode** does not necessarily indicate a nematode problem, it may be a beneficial species.
  - **Insect pests may be present** but not in enough numbers to be the primary cause of a problem. A chewing or sucking insect may feed on pest insects and mites.
  - **If signs are absent** additional time may be required to diagnose the problem.

SYMPTOMS



Fungal leaf spot on iris (*Cladosporium iridis*) – often called 'eye spot'

Symptoms are the visible external or internal reactions of the affected plant and are useful in diagnosis. **They are clues that you can see**. They indicate that something may be wrong. Symptoms are usually named according to the appearance of the affected plant, eg galls, gumming, rots.

- **Symptoms do not directly identify the cause** of a problem **or its location on the affected plant**, especially if symptoms are caused by root damage or poor soil conditions. Many problems cause similar symptoms, eg **leaf spots** may be caused by fungal or bacterial diseases, contact herbicides or other agents.
- **Symptoms may be:**
  - **Specific (distinctive)** and enable a pest or disease to be identified with reasonable certainty, eg anthracnose of rose, leaf cutting bee damage.
  - **Non-specific**, eg leaf yellowing and browning of leaf tips and margins are common. Often the only way to arrive at a correct diagnosis is make a site visit and gather information (Steps 4 and 5) then, if necessary, seek help (Step 6).
  - **Localized**, eg leaf spots. However, they may occur over large areas of the leaf to the extent that leaves may brown and die.
  - **Systemic**. Many viruses are systemic. Some bacterial and fungal vascular wilt diseases spread internally throughout the plant and interfere with water and nutrient uptake. Water conducting tissue will appear brown when stems are cut across or longitudinally.
- **Sometimes symptoms are easier to observe** than **signs**. For example, the hairiness (erinose) produced by grape leaves as a result of grapeleaf blister mites sucking plant sap is easily observed, while the tiny eriophyid mites themselves are only visible under high magnification. Some species of actively flying leafhoppers leave stippled feeding tracks on leaves after they have fed and left.
- **Non-parasitic causes** usually do not have signs and their symptoms may be non-specific so that diagnosis is often reliant on diagnostic testing, gathering information from a site visit, crop records and asking questions.
- **Knowledge of how symptoms differ** is the fine-tuning that diagnosticians develop as they improve their observation and reporting skills.
- **Many plant diseases** can reduce crop production by 10-15% without disease being apparent.

Complex signs & symptoms

COMPLEX SIGNS & SYMPTOMS

Many plant problems are caused by a combination of parasitic and non-parasitic problems. These complex causes have been discussed in some detail previously (see page 5). The following examples are illustrated in Fig. 11 below.

1. **One symptom One cause**, eg
   - **Symptom.** Large smooth scalloped leaf edges caused by leafcutting bees.
2. **One symptom Many causes**, eg
   - **Symptom.** Marginal leaf scorch may be caused by drought, salinity, too much water, wind, etc.
3. **Complex symptoms Two causes**, eg
   - **Symptom 1.** Parallel leaf veins caused by hormone herbicide injury.
   - **Symptom 2.** Blisters on leaf uppersurfaces and erinose (hairiness) on leaf undersurfaces caused by the grapeleaf blister mite.
4. **Complex signs & symptoms One cause**, eg **twospotted mite** (*Tetranychus urticae*). If suspected look for:
   - **Signs.** Mites, frass, eggs and webbing on leaf undersurfaces (use a hand lens).
   - **Symptoms.** Leaf stippling or speckling due to mites sucking plant sap.
5. **Complex signs & symptoms Two causes**, eg
   - **Signs.** Spores of the brown rot fungus.
   - **Symptoms.** Holes in fruit caused by caterpillars of the oriental fruit moth.
6. **Complex signs & symptoms Several causes**, eg
   - **Signs.** Wood rot fruiting bodies.
   - **Symptoms.** Sunburnt bark on north-west side of trunk, tree blown over by wind.



1. One symptom/One cause – leafcutting bee damage due to nest building activities



2. One symptom/Many causes – marginal leaf scorch due to drought, salinity, too much water or wind (NSW Agric)



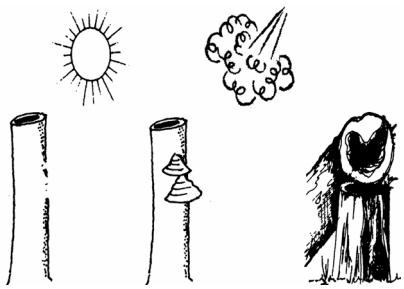
3. Complex symptoms/Two causes – hormone herbicide injury (parallel veins) and grapeleaf blister mite damage to grape leaf



4. Complex signs & symptoms/One cause – the sap sucking of twospotted mites produces leaf stippling. Mites, webbing and eggs can be seen on leaf undersurfaces



5. Complex signs & symptoms/ Two causes – holes caused by oriental fruit moth caterpillars provide entry points for the brown rot fungus



6. Complex signs & symptoms/Several causes – primary cause (sunscorch damage to trunks), secondary cause (wood rot) and tertiary cause (wind blows the weakened tree over)

Fig. 11. Complex signs and symptoms. Factors affecting above ground parts have been chosen for simplicity, however, they occur just as frequently on below ground parts.

ADVANTAGES OF SIGNS & SYMPTOM



Sign – cypress pine sawfly larva

Signs and symptoms let us know there may be a problem. Observing them can provide the **fastest** means of diagnosing some plant problems. Few diagnostic tests are as quick as visual examination of a rose plant for signs of powdery mildew or aphids.

- **For those without access to diagnostic facilities** this is often the main method of diagnosis and with some experience a preliminary diagnosis can be made.
- **A grower** who can diagnose plant problems accurately from early signs and/or symptoms can quickly implement control measures.
- **A knowledge of the common pests** that affect the crop and the presence of **specific** (distinctive) signs and symptoms is a major step in making a preliminary diagnosis.
- **Signs and symptoms help** to distinguish one problem from another on a particular plant (see page 53). Growers will find it is easy to distinguish between leaf diseases caused by different disease organisms, eg powdery mildew and rust of rose. Pest management programs for particular crops often include photographs of the signs and symptoms of the pests and diseases which attack different plant parts.
- **Growers can scout and monitor** their crops for signs and symptoms. For example, levels of mite infestation can then be compared with known thresholds above which treatment is necessary (see page 175).

DISADVANTAGES OF SIGNS & SYMPTOMS



Non-specific symptom – bleaching of honeysuckle foliage. Can you suggest likely causes? See page 130.

A preliminary diagnosis based on observed signs and symptoms indicates something is wrong but **not** necessarily the cause of the problem or its location on the plant, especially those caused by root damage or poor soil conditions.

- **Less reliable**. Although potentially simple, identification by eye alone is not always possible or reliable. Diseased roots are more difficult to inspect than foliage.
- **Infinite numbers of symptoms**. There can be no precise description of all symptoms covering all plants.
- **Similar symptoms** may be caused by **many different causes**, eg virus symptoms may be confused with nutrient problems, herbicide injury, damage by sap sucking insects.
- **Non-specific symptoms are widespread**, eg **dieback** may be associated with:
  - **Parasitic pests and diseases** such as *Phytophthora* root rot, borers, soil nematodes, wood rot, foliage-feeding insects, **or by**
  - **Non-parasitic agents**, eg drought, waterlogging, frost, shallow soil **or**
  - **Any combination of these**.
- **Some plants** are affected by multiple problems simultaneously so that symptoms are indistinct and difficult to recognise, eg tomatoes, stone fruit.
- **Lack of prior knowledge and experience** of the common pest problems in your crop delays even a preliminary diagnosis.
  - **The point** at which signs and symptoms become **apparent** depends to some extent on the observer's ability to recognise them.
  - **Signs and symptoms are not static** but may change with the season and the developmental stages of the pest and the affected plant. Many immature stages of insects and weed seedlings can be difficult to identify.
- **Individual plants**, depending on their genetic make-up, may vary in their response to attack.
- **Image-matching** may lead to mis-diagnosis, especially if observed signs and symptoms are **not specific**, ie they are **not** distinctive enough to match with a photograph.
- **Diseases** are harder to diagnose from signs and symptoms than weeds and insects.
- **If signs and distinctive symptoms** are **not present** additional time may be required to investigate the problem.
- **Once signs and symptoms appear** in some crops it is often too late to obtain effective control.
- **Absence** of signs and/or symptoms may **not** indicate pest or disease-freedom, eg
  - **Latent infections** do not result in the expression of symptoms, a common situation with viruses and some fungi such as anthracnose in fruit. Diagnostic testing rather than recognition of the disease from signs and symptoms is needed for a definite diagnosis.
  - **Delayed symptoms**, eg conifers take months to brown after drought.
  - **Insects may have left the scene**, eg leafhoppers have flown away.
  - **Seeds** and other propagation material often carry diseases and pests internally.
  - **Soil and/or root problems** cannot be seen.
  - **Signs of pests** may occur away from damaged plants, eg rat droppings.
- **Poor quality of specimen and samples** may make it difficult to identify signs and recognize symptoms. Samples may have been delayed in the mail (see page 178).
- **Secondary pests and diseases** may be incorrectly diagnosed as a **primary** cause, eg poor soil drainage predisposing a plant to secondary root rot.

DIAGNOSIS BASED ON SIGNS & SYMPTOMS

PRELIMINARY DIAGNOSIS	**A knowledge of the common pests and diseases** that affect your crop and the presence of **distinctive** signs and symptoms on certain plant parts, may allow you to make a preliminary diagnosis. Pests and diseases that affect roses and photographs of their signs and symptoms of them are shown on pages 52 and 53. • Remember, observing **symptoms** is **not** the same as identifying the **cause** of a problem.
CONFIRM OR REJECT THE PRELIMINARY DIAGNOSIS	**If the client requires** a more definite and reliable diagnosis you will need to proceed through further diagnostic steps. • **If a parasitic problem is suspected**, observed signs and symptoms can be compared with published illustrations and descriptions in books or on the internet. The identity of samples or specimens of some insects or disease organisms can be confirmed by microscopic examination. – **Larger insects** can be easily measured and their features compared with published descriptions for a useful diagnosis. Smaller insects and mites can be examined under a hand lens or dissecting microscope. Many unfamiliar insects and mites will need to be sent to a diagnostic service for identification. – **Some large fungal fruiting bodies**, eg wood rot brackets or mushrooms, can be difficult to identify with certainty. As some species are poisonous and others cause serious wood rots, expert advice may be needed. Some are the fruiting bodies of beneficial mycorrhizal fungi. – **Some diseases caused by fungi** can be identified by the presence of plant symptoms. Close observation with a hand lens or dissecting microscope is needed for the observation of mycelium, fruiting structures and spores and may be sufficient for a **useful** diagnosis. In other cases the use of a microscope with higher magnification is required. **For most diseases** caused by viruses, bacteria, fungi and nematodes, expert advice will be required. – **There may be a series** of signs and symptoms that identifies a particular problem. For example, the observation of mites, nymphs and eggs on leaf under-surfaces and stippled leaf upper-surfaces, is sufficient for a **useful** diagnosis of spider mites (see Fig. 11, page 49). • **If a non-parasitic problem is suspected**, and if symptoms are **not** distinctive, as is often the case, a site visit, crop records and on-site diagnostic tests may be required (Step 4). • **In both cases** it may still be necessary to seek expert help. If samples are being sent to a diagnostic service ensure that the submission form accompanying the sample is filled in to the best of your ability.

Table 1. Roses - signs and symptoms of some common pests and diseases.

Signs have been highlighted in grey

PESTS/DISEASES	PLANT PARTS – SIGNS & SYMPTOMS			
	Flowers/Buds	Leaves/shoots	Canes	Crown/Roots
Virus diseases				
Rose mosaic		Mosaic, line patterns, ringspots		
Bacterial diseases				
Crown gall				Galls at crown
Fungal diseases				
Anthracnose		Discrete spots		
Black spot		Black/brown feathery spots, yellowing, leaf fall	Black/brown feathery spots on young canes	
Downy mildew		**Downy mildew on under-surfaces** Irregular areas die	Purple-brown spots	
Petal blight	Pink spots or brown flecks on white petals, white spots on dark petals			
Powdery mildew	**White fluffy mildew on buds and petals**	**White mildew on both leaf surfaces** Distorted leaves	**White mildew around thorns**	
Rust		**Red or black spores on undersurface** Yellow specks on upper surface		
Stem cankers (various species)			Cankers, dieback	
Insects, allied pests				
Aphids (various species)	**Aphids, honeydew, nymph skins**	**Aphids, honeydew, nymph skins** Leaf distortion		
Caterpillars (various species)	**Caterpillars** Small holes in buds which are partly eaten out			
Rose scale			**Scales, mostly on older canes, are white**	
Thrips	**Thrips** Petals brown			
Twospotted mite		**Twospotted mites, eggs, webbing on undersurfaces** Stippling		
Weevils (various species)	**Small dark weevils** Holes in petals	Leaf edges unevenly chewed	Patches eaten from green canes	
Vertebrate pests				
Birds, possums, etc		Possums may eat new growth	Cockatoos tear fleshy young canes in spring	
Non-parasitic				
Environmental				
Frost			New canes blacken in spring	
Sunscorch		Scorched leaves, leaf burn		
Nutrient problems				
Deficiencies		**Iron** – new leaves, interveinal yellowing. **Magnesium** – older leaves, distinctive patterns		
Chemicals				
Copper sprays – too frequent application or rate too high		Leaf yellowing, leaf fall		
Rogor®, other organophosphate insecticides – excessive use		Leaf burn, leaf fall		
Sulphur – concentration too strong, hot weather		Leaf burn		
Glyphosate injury		New leaves feathery or with non-specific yellowing		
Other problems				
Leafcutting bees		Leaf edges smoothly scalloped		
Nectar scarabs	**Nectar scarabs** Petals brown			
Genetic	Green flowers Variegated flowers	Yellow leaves – no chlorophyll	Fasciation	
Senescence		Silvering of older leaves – end of season	Galls on canes of old roses especially climbers	
Other problems include replant problems		Poor growth		

Flowers, buds	Leaves/shoots	Canes	Crowns/roots



Petal blight (*Botrytis cinerea*)



Rose mosaic



Stem canker – Hath not thy rose a canker, Somerset? (Henry VI, Shakespeare)



Fungal cankers following hard pruning at the crown prior to transplanting



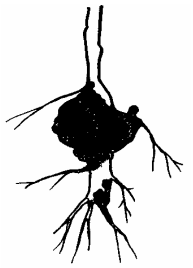
Powdery mildew on petals



Powdery mildew – distorted leaves



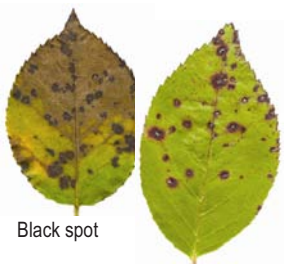
Rose scale. *Left:* Female scales. *Right:* Male scales



Crown gall



Plague thrips



Black spot

Anthracnose

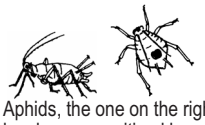


Cockatoo damage to canes

The below ground component of a rose plant is important. Because of the difficulty of seeing roots and soil below ground level, diagnosis from signs & symptoms is difficult (see Roots, soil pages 163-168, Whole plants pages 173-174).



Nectar scarab (6-10 mm long)



Aphids, the one on the right has been parasitized by a wasp



Rust. *Left:* Orange/brown spores on leaf undersurface. *Right:* Blurry yellow spots on leaf uppersurface



Frost damage to tender new canes in spring



Green rose (*Rosa virififlora*)



Feathery spring growth due to spray drift of glyphosate during dormancy



Fasciation

Fig. 12. Signs and symptoms of pests and diseases of roses.

SUMMARY

Examine plant parts for signs & symptoms

Each step of the diagnostic process reduces the possibilities and eliminates unlikely causes. Recall the original enquiry (Step 1). Having identified the affected plant (Step 2) you have access to a list of potential pests and pest information sheets (pest signatures) for each problem.

EXAMINE THE PLANT



The presence of signs and symptoms combined with the knowledge of **common** problems that affect the plant, and the **parts** of the plant on which they occur, reduces the number of possibilities.

- **What is normal for the plant?** Plant characteristics vary. The **yardstick** is knowing what a normal healthy plant of the same species, variety and age looks like growing under the same conditions. Describe any signs and symptoms that you think might indicate a problem.
- **Examine affected plant parts** for **signs** and **symptoms**. Examine visually then under a hand lens or dissecting microscope and, if necessary, under a high power (compound) microscope, which may require specialist assistance.
  - **Location on plant**. Which plant parts are affected? Are there signs and symptoms only on the leaves and shoots or are they spread over the whole plant? Are they on **above or below ground parts**. Dig up plants.
  - **Examine each plant part internally as well as externally**. Cut them open.
  - **If appropriate, look at the plant as a whole**, close up and from a distance. What is the overall health of the plant?
  - **Record** your observations.
- **Signs & symptoms**.
  - **Signs** are physical evidence of the cause of the problem, they can be seen and often identified. Not all insects seen, or nematodes found, are pests. Also the presence of a pest in low numbers may not damage the plant sufficiently to warrant treatment.
  - **Symptoms** are the visible reactions of the affected plant. They are clues!
  - **Learn to recognize** the signs and symptoms of problems commonly affecting your crop.
  - **If signs and symptoms** are **specific (distinctive)** the problem can often be easily diagnosed. If **non-specific** then diagnoses are more lengthy and difficult.
  - **Complex** signs and symptoms are common and often the cause of mis-diagnosis.
  - **Absence** of signs and distinctive symptoms may mean that more time is needed to investigate the problem.
  - **Secondary pests and diseases** may be incorrectly diagnosed as a **primary** cause, eg poor soil drainage predisposing a plant to secondary root rot.
- **Diagnosis based on signs & symptoms**.
  - **A preliminary diagnosis** can be tentatively made if signs and symptoms are distinctive and can be matched to published illustrations and descriptions.
  - **If that is all that is required** the diagnosis can be reported (Step 7). If a more definite diagnosis is required proceed to Steps 4, 5 or 6.

FURTHER STEPS

Step 4. Visit site and have a look at the problem in the field, access history, ask questions.
Step 5. Consult references.
Step 6. Seek expert help.
Step 7. Report the diagnosis.

CASE STUDIES

Step 3. Examine plant parts for signs & symptoms

1. BE WARY OF TELEPHONE DESCRIPTIONS

?	**Telephone enquiry**. Is the nest in the corner of their outdoor loo a **European wasp nest** or not? It sounded suspect so the client was advised to contact their local European wasp advisor. Three months later when the same client rang about another problem, they were asked about the wasp nest. They had been advised that it was a paper wasp nest and not to worry. Being uneasy and because even paper wasps can sting, a visit was arranged. It was indeed a football-sized European wasp nest! European wasps will nest in wall cavities & under floors, not just in the ground. Their nests are quite distinctive but the wasps themselves can be confused with native flower wasps, honeybees and other insects when observed away from their nests.
XPERT	Expert help **had been** sought.
	Useful diagnosis. European wasp nest. Even experts can mis-diagnose a telephone enquiry. We ordinary mortals are even more likely to do so!

2. POWDER ON LEAVES OF ASH TREE

?	A **landscaper** is worried that the undersides of leaves falling from ash trees are covered with whitish, powdery material. Is it powdery mildew?
	Golden ash (*Fraxinus excelsior* 'Aurea') List of pests & pest information sheets available.
	Examined leaves visually, the white powder looked like whiteflies. Checked under dissecting microscope to observe the distinctive pupae of ash whitefly.
	-
	Consulted reference to match the **pupal pattern** which distinguishes it from other whiteflies. Recent introduction to Australia.
XPERT	-
	Accurate diagnosis. Ash whitefly. Client was provided with written proof of identity which included illustrations of the distinctive pupae, other information on its occurrence. It is **not** a notifiable pest.

3. POWDERY OR DOWNY MILDEW

?	Horticulturists talk about powdery and downy mildews. How do I know the difference on leaves?
	Only **some plants** are susceptible to these diseases and **very few** get both. So accessing a list of problems for your plant is a good start.
	Advice. It is easy to spot powdery mildew on some hosts, white powdery fungal growth develops on **both** upper and lower leaf surfaces. Downy mildew develops **only** on the lower leaf surface, under humid conditions. It may be necessary to place suspect leaves in a plastic bag to encourage spore production. Spores can then be examined microscopically. **Powdery mildew** can be confirmed with a dissecting microscope. Bend a leaf in half and look at it edge-on. You will see tiny chains of spores like a string of beads. *See page 136.* **Downy mildews** have more complex spore patterns and will probably need identification by a plant pathologist.
	Check if fruit or other parts are affected. If unsure you may have to consult a diagnostic service. Downy and powdery mildews can be difficult to identify on some hosts. Old lesions can also be difficult to recognize late in the season.

4. LEAVES STIPPLED - WHAT IS IT – MITES?

?	Client brought in many samples of French bean leaves which were yellowish and shriveling. Plants are dying.
	French bean. List of problems and pest information sheets available.
	Leaves are stippled due to sap sucking activities. Examination of leaf undersurfaces revealed large number of mites, some with 2 large dark spots on the back, nymphs with 6 legs, also eggs. Possibly twospotted mite (*Tetranychus urticae*). *See pages 49, 139.*
	-
	References indicated significant variation within spider mite species so that the 2 large green spots on the back may not be a reliable diagnostic feature for identifying *T. urticae.*
XPERT	-
	Preliminary diagnosis. Spider mites. Twospotted or bean spider mite are common pests of beans. Commercial growers require a definite diagnosis from an entomologist.

5. PATTERN OF DEAD AREAS ON LEAVES

?	Contractor caring for a large public planting of plane trees. Had been advised that the scorched leaves were probably caused by 'anthracnose' but could be drought stress or frost. Which is it?
	London plane (*Platanus hybrida*). 20-30 years old. List of pests & pest information sheets available.
	With drought stress, brown areas are along the **outer margins** of leaves (marginal scorch). With anthracnose, brown areas develop **along leaf veins** & may be more of a reddish brown. Frost injury quickly scorches whole leaves. In all cases, leaves brown and fall. *See page 126.*
	References indicate that anthracnose tends to occur in wet springs, drought stress after hot dry windy conditions with inadequate irrigation. Frost injury after late spring frosts.
XPERT	-
	Preliminary diagnosis of marginal leaf scorch probably due to drought stress, not anthracnose.

6. LEAF YELLOWING ON CITRUS

?	Home gardener concerned about yellow leaves on 20 year-old lemon trees. Brought samples. End of winter. Concerned that it could be injury from glyphosate recently-applied.
	Lemon – Eureka. A list of problems that occur on lemons & pest information sheets available.
	On examination it is the **older leaves**, last season's leaves, that show yellowing with a distinctive pattern typical of magnesium deficiency. It is **not** glyphosate injury because that would show in the new leaves.
	-
	Accessed illustrations of symptoms of magnesium deficiency on the older leaves of citrus. *See page 130.*
XPERT	-
	Useful diagnosis. Magnesium deficiency.

7. UNUSUAL HOST FOR BROWN ROT

?	Commercial client presented a sample of an apple covered with brownish coloured mould. Thought brown rot only affected stone fruits, but it seemed to be also on apples.
	**Apple**. List of pests & pest information sheets available.
	The mould certainly looked like brown rot. *See page 49.* Microscopic examination of spore structures matched illustrations of the brown rot fungus.
	-
	Checked references for the complete host range of brown rot and illustrations.
XPERT	-
	**Useful diagnosis**. Brown rot usually only occurs on apples when grown close to stone fruits & when skin is injured. It is unlikely to be a problem on apples. May also occur on pears & quince in similar situations.

8. ROSE FLOWERS TURNING BROWN

?	The owner of a large rose garden about to open for inspection as part of an Open Garden Scheme was concerned that the white rose flowers were being ruined by lots of small insects. Could we identify them and offer advice on control?
	**Roses**. List of pests & pest information sheets available.
	**Nectar scarabs** are attracted to white flowers. They are 6-10 mm long, brownish with long hind legs. Occur in swarms, feed on pollen and damage flowers by pushing around among the petals. Checked for thrips which were also present. Showed client how to shake them out onto a white surface for observation under a hand lens.
	-
	Description and illustrations of nectar scarabs matched the suspect insects. *See page 53.*
XPERT	-
	**Useful diagnosis.** Nectar scarabs were the main cause of the problem. Difficult to control in gardens open to the public.

9. WHITE FUNGUS ON ROOTS

?	**A cactus grower** was concerned when on repotting some succulents a white fluffy 'fungus' was observed on the roots of most of them. Brought samples.
	**Succulents.** List of pests & pest information sheets available for succulents generally.
	Above ground parts appeared healthy. Examination of the roots revealed that they were heavily infested with mealybugs.
	-
	References were obtained to confirm the diagnosis of root mealybugs to show the client. *See pages 137, 171.*
XPERT	-
	**Useful diagnosis.** Root mealybugs suck sap from roots, heavy infestations cause plants to lack vigour. They can attack a wide range of indoor potted plants, particularly those grown in relatively dry potting mixes.

10. BUDWORMS & CARNATIONS

?	**Commercial grower** concerned about holes in flower buds and chewed flowers. Was thought to be the corn earworm (*Helicoverpa armigera*). Is this so?
	**Carnation**, other cut flowers. List of pests & pest information sheets available.
	Examination revealed caterpillars which, when compared to illustrations, were thought to belong to the genus *Helicoverpa* but the exact species was uncertain.
	-
	Illustrations of the *Helicoverpa* caterpillars were accessed. *See pages 142, 147, 154.*
XPERT	Commercial growers should submit specimens to an entomologist for a definite identification.
	**Useful diagnosis.** *Helicoverpa* spp. The corn earworm (*H. armigera*) has several common names including cotton bollworm, tomato grub, tobacco budworm. The native budworm is *H. punctigera*.

11. SMALL 'GALLS' ON VEGETABLE ROOTS

?	**Home gardener** concerned about small galls on the roots of peas, beans and tomato plantings. Plants appear to be **healthy**. Brought many samples in.
	**French beans and peas** belong to the Family Fabaceae which have **nitrogen-fixing bacteria** in galls on their roots. They can also be attacked by root knot nematodes. Microscopic examination revealed corky tissue of nitrogen-fixing galls.
	**Tomatoes** belong to the **Solanaceae** family which do **not** have nitrogen-fixing nodules on their roots. Examination of the tomato galls under a dissecting microscope revealed nematodes.
	-
	References were accessed to demonstrate the difference to the client. *See page 164.*
XPERT	**Commercial growers** of tomatoes would require a detailed nematode identification and assay to determine severity and whether treatment was necessary.
	**Preliminary diagnosis**. The peas and beans would look healthy because they need the nitrogen-fixing galls. Small populations of root knot nematodes may not cause ill-effects on plants. Advice provided on minimizing future problems.

12. DISCOLOURED CAMELLIA LEAVES

?	**Home gardener** presented samples of unhealthy-looking camellia leaves from bushes about to flower.
	***Camellia japonica***, an evergreen shrub which loses some leaves every year after flowering in spring. Some leaves may stay on a camellia for up to 2 years before falling.
	Leaves were clean – no sign of insects or disease, just disolcoured.
	**Pattern on plant**. When questioned regarding whether the discolouration was on older, younger or on all leaves, the client indicated it was only on **older** leaves.
	-
XPERT	-
	**Preliminary diagnosis**. Natural senescence, not to worry.

REVIEW QUESTIONS & ACTIVITIES

Step 3. Examine plant parts for signs & symptoms

1. **What is normal** for the following plants that could be mistaken for a pest or disease?

Plant	Normal features
Eucalypts	
Roses	
Zucchini	
Citrus	

2. Distinguish between a **sign and a symptom**, give **1** example of each on a plant of your choice.
   1. Sign
      Example
   2. Symptom
      Example

3. Explain the **difference** between specific (distinctive) and non-specific symptoms. Give **1** example of each.
   1. Specific symptom
      Example
   2. Non-specific symptom
      Example

4. Give 3 reasons why symptoms **may not be a reliable** means of diagnosing plant problems.
   1.
   2.
   3.

5. Give 2 reasons why root problems are **difficult to diagnose** from signs and symptoms.
   1.
   2.

6. Examine **3 'diseased' plants** of your choice with and without a hand lens or dissecting microscope, and record your observations.

Plant	Signs	Symptoms

7 Provide the following information:

Cause of problem	Plant parts affected	Signs	Symptoms	Would you be able to identify the problem from signs & symptoms alone? Give reasons for your answer.
Fruit fly				
Powdery mildew of grapes				
Downy mildew of grapes				
Phytophthora				
Christmas beetles				
Oriental fruit moth				
Corn earworm				
Black vine weevil				
Citrus red scale				
Wood rot				
Longicorn borer injury				
Excess water, poor drainage				
Drought, insufficient water				
Compacted soil				
High soil pH, salinity				
Hormone herbicide injury				
Glyphosate injury				
Twospotted mite injury				
Excess nitrogen				
Iron deficiency				
Sunscorch				

8. Access a **list of pests and diseases** for a plant of your choice.

9. Access a **pest information sheet** for a pest, disease or weed of your choice.

10. Name **2 causes** of the following **signs and symptoms**. Could you distinguish one cause from another?

Affected plant	Signs & symptoms	Possible causes	Distinguishing features
Apples	'Grubs' in fruit	1.	
		2.	
Azaleas	Leaf stippling	1.	
		2.	
Eucalypt	Dieback	1.	
		2.	
Flowers	Browning of petals	1.	
		2.	
Citrus	Leaf yellowing	1.	
		2.	
Grapevine	Whitish fuzz on leaf undersurfaces	1.	
		2.	
Palms	Leaf stippling	1.	
		2.	
Peach	Curly leaves	1.	
		2.	
Peas	Small gall on roots	1.	
		2.	
Pelargonium	Chewing damage	1.	
		2.	
Pumpkin	Wilting	1.	
		2.	
Roses	Leaf yellowing	1.	
		2.	
Seedlings	Damping off	1.	
		2.	
Tomato	Creamy blotches on fruit	1.	
		2.	
Wattle	Brown areas on leaves	1.	
		2.	
Crop of your choice	Symptom of your choice	1.	
		2.	
Crop of your choice	Symptom of your choice	1.	
		2.	

Step 4. Visit site, history, questions



History

Questions?

Introduction *60*
- Pest information sheets - pest signature *61*
- Site map *62*

Site inspection *63*
- Patterns of signs & symptoms *63*
- Pest calendars & time frames *64*
- Soil type, topography & structures *65*
- On-site diagnostic tests *66*

History & records *67*
- Crop history *67*
- Pest, disease & weed history *68*
- Environmental history *69*

'20 Questions' *70*

A diagnosis based on a site visit *71*

Summary *73*

Case studies *74*

Review questions & activities *75*

INTRODUCTION

The diagnosis of many pest, disease or weed problems should only be made after a visit to the property and a careful examination of the crop and adjacent areas. When a site visit is not possible, information can be obtained by accessing records and asking considered questions.

THE SITE VISIT

Site inspection
- Patterns
- Time frames
- Site conditions
- On-site tests

History
- Crop
- Pest
- Environmental

'20 Questions'

The most difficult plant problems to diagnose are **not** usually caused by insects or diseases but are site-related with cultural or environmental predisposing factors. Their solution requires a thorough knowledge of the conditions under which plants are growing and the treatments they have received.

- **Symptom patterns** coupled with knowledge of the **time frame** for their development are two of the most important clues for **distinguishing** between **parasitic and non-parasitic** causes.
- **Always determine if the site** is suitable for the crop.
- **Prepare a rough site map**.
- **Monitoring and sampling** may be necessary (see page 175).
- **On-site diagnostic tests** may be carried out.
- **Diagnostic tests in a laboratory** may be required,
- **Records** are kept by experienced growers, facilitating the tracing of crop history, pest occurrences and treatments, and environmental events. Many causes may be **eliminated** by checking recent weather.

WHEN ARE SITE VISITS NECESSARY?

A site visit is desirable when trying to diagnose:

- **Non-parasitic problems**, eg environmental factors, irrigation and temperature effects, nutritional and fertilizer needs, soil problems.
- Problems affecting **tree** and other **perennial crops**, where long term investments are involved and symptoms may take a long time to become obvious.
- The **primary** cause of a plant problem. The diagnostician is often confronted with complex causes, signs and symptoms (see pages 5, 49). Working out exactly how much damage is due to different factors can be difficult, but **it is the job of the diagnostician** to do so.

KEEPING RECORDS, CHECKLISTS



Details of the site visit must be **permanently recorded** as part of proof of diagnosis (see pages 62, 72, 105 and **121**).

- **Have a standard form or system** to record observations and information gathered such as identity of the affected plant, signs and symptoms, patterns of signs and symptoms, time frames, soil type, diagnostic tests, history of the crop, pests and treatment and the environment and questions asked.
  - **Checklists** help with this (see page 119).
  - **Diagnosis for crop problems** indicates the type of information that needs to be collected from a site visit. www.cbit.uq.edu.au
  - **Submission forms** have space for information collected from a site visit (see page 121). If expert advice is considered necessary then you already have the information they request.
  - You can make up your own recording system.
  - Remember to keep a copy.
- **Digital images** are an excellent means of recording field observations. However, clients may still need to collect samples for further investigation by themselves or by a diagnostic service (see page 175).

Pest information sheets

'Pest signature'

THE SITE VISIT AND THE PEST INFORMATION SHEET	The pest information sheet contains information about a pest and includes the patterns of occurrences and conditions under which it can occur in the field. How your suspect problem occurs in the field can be **matched** to that described in the pest information sheet. These linkages are illustrated in the simple example of wood rot shown in Fig. 13 below. A site visit is a desirable way of gathering this information but if this is not possible then you will need to ask many detailed questions.

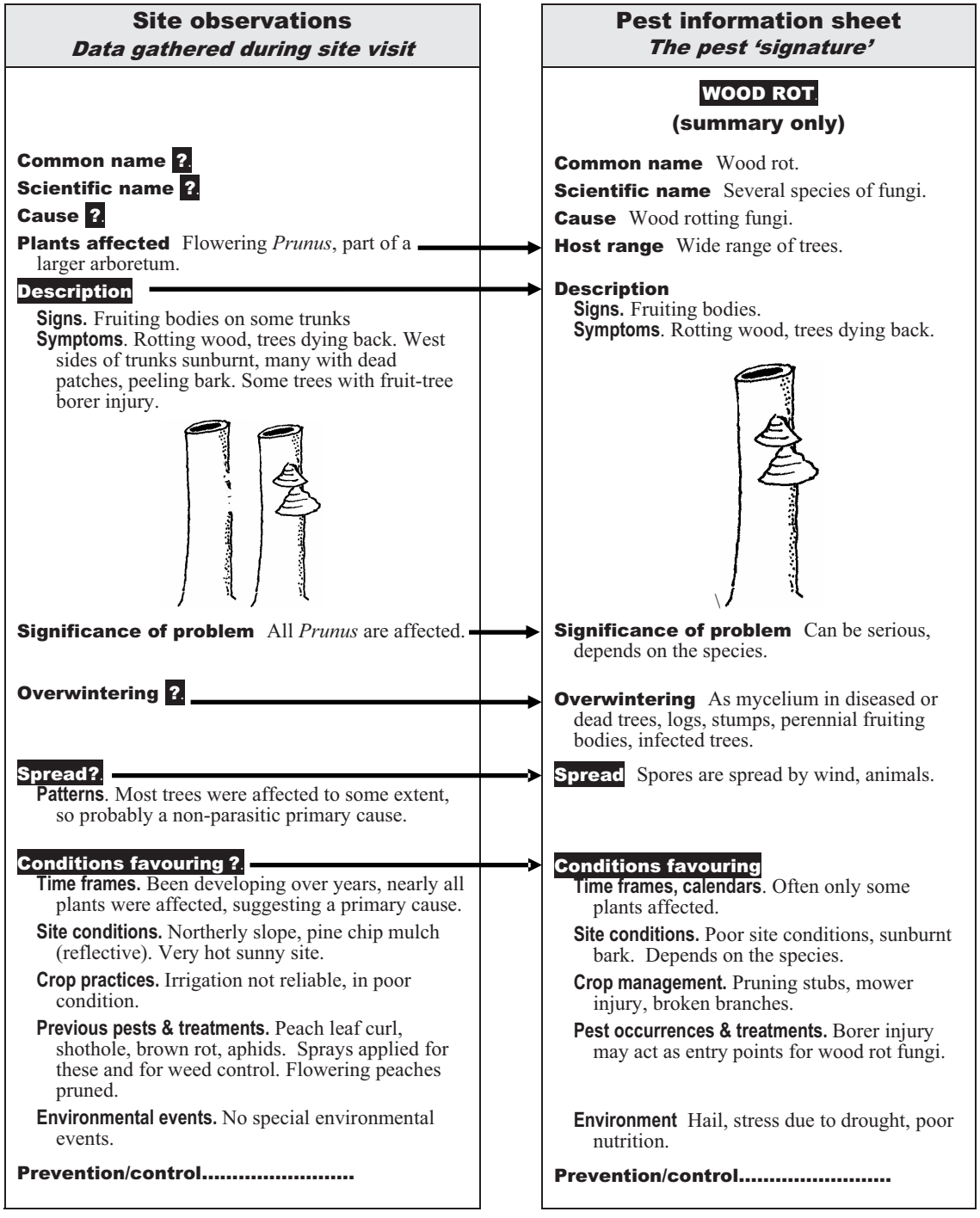


Fig. 13. An example linking site observations with a pest information sheet for wood rot (see also page 72).

Site map

WHAT IS A SITE MAP?

A site map may help you confirm or eliminate possibilities, as illustrated by this simple case study (Fig, 14 below). A rough site map should be prepared for every site visited. If you can't visit the site ask your client to prepare a site map. Consideration should be given to including the following features where relevant:

- Pattern of affected plants in the crop or on the site.
- Aspect (north-south), prevailing winds, wind breaks.
- Soil type, contours, elevation, slope.
- Irrigation and drainage patterns.
- Fertiliser and pesticide application patterns, drift, chemical stores.
- Buildings, fences, power lines, construction activity.
- On-site and laboratory tests, where and when they were carried out.
- Environmental monitoring, if relevant.
- Adjacent areas, eg grazing, edible crops, dams, native vegetation, picnic areas.

Step 1. Client's enquiry. Home gardener with vegetables showing symptoms of spray damage. Insisted that spray drifted from a neighbour who regularly sprayed their fruit trees and weeds in their lawn. Wanted confirmation of their diagnosis. Site visit was arranged. See pages 105 and 121 for details that must be recorded.

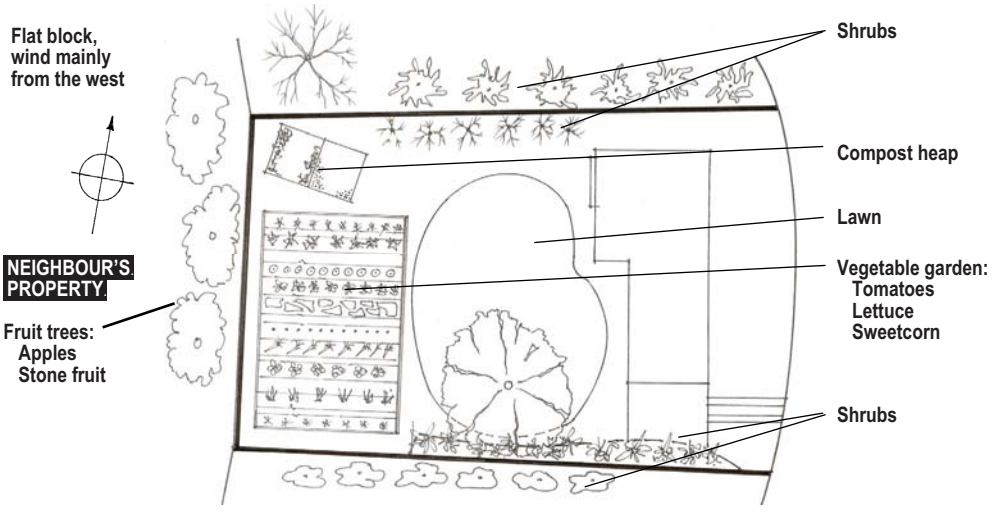
Step 2. Identify affected plants. Tomato, French bean, pumpkin.

Step 3. Examine plant parts. Typical hormone herbicide injury. All new growth on tomato, pumpkin and French beans was affected. Leaves are curled and twisted with reduced area of green tissue and thickened veins.



(NSW Agric)

Step 4. Visit site, history, questions. All broadleaved vegetables (tomato, French bean, pumpkin) were affected, but not narrow-leafed ones (sweetcorn or onions) or any surrounding broad-leafed trees and shrubs. If damage had been caused by drift one would expect damage downwind from the neighbour, ie on the sides of trees and shrubs and strips or patches through the vegetable patch, but this was not so, suggesting that drift from the neighbour was an unlikely cause of the problem. What had been put on the vegetable garden? Insistent that no sprays had been applied but fertilisers and compost used. Fertilisers were an unlikely a source of the problem, so attention turned to the compost. Contents included food scraps, autumn leaves and grass clippings. Persistent questioning revealed that the lawn had been sprayed with a hormone herbicide (MCPA, dicamba) to control broadleafed weeds some time ago (exact date elusive). These herbicides can persist for some time depending on weather, longer under conditions of low temperatures and low soil moisture.



Step 5. Consult references. Checked references for information on persistence of MCPA and dicamba.

Step 6. Seek expert help. Detailed analysis of the compost and soil in the vegetable garden was not justified for this situation.

Step 6. Report the diagnosis. A preliminary diagnosis that contaminated grass clippings was the likely cause of the symptoms on the vegetables.

Fig. 14. An example of a diagnostic report that includes a site map.

Patterns of signs & symptoms

The **patterns** caused by parasitic pests and diseases differ from those caused by non-parasitic agents. View pattern development stepwise starting with **plant parts**, **individual plants** then the **whole crop** and finally the **surrounding plant community**. The only means of identifying many problems is to observe the pattern of symptom development and know whether their development is consistent with that of the particular species. There are always exceptions. Patterns may change with time (see page 64).

	Parasitic pests & diseases (scattered patterns of occurrence)	**Non-parasitic agents** (even pattern of occurrence)
RULES OF THUMB – THERE ARE ALWAYS EXCEPTIONS	Many leave **signs**, eg insects, eggs, mycelium, and produce **symptoms**, eg leaf spots, chewed leaves. • Pests such as aphids, whiteflies and mites usually infest a few isolated areas and spread at varying rates. They take time to build up in numbers and cause damage. For the most part parasitic agents are slower in causing symptoms than non-parasitic causes. • Signs and symptoms are **not** uniformly distributed on all species, plant parts, whole plants, the crop and surrounding plant communities. The damage is scattered on leaves, flowers, plant or crop. • Disease symptoms caused by viruses may be similar to the those of nutrient deficiencies or herbicide injury. Viruses would be implicated if the pattern on affected leaves were uneven, only a few leaves were affected on the plant and affected plants were scattered throughout the crop.	**Most** will leave **symptoms**, only a **few** leave **signs**, eg visible pesticide residue on leaves. • Symptoms caused by herbicide and fertilizer injury and the environment (temperature, rainfall, late frosts), are **uniformly** distributed on exposed parts of susceptible plants. • There is usually a **clear demarcation** between injured and healthy tissue on a plant, eg spray drift. • Plant damage in relatively straight lines at regular spacing may be due to overlapping fertilizer or spray applications. Equipment may be malfunctioning/improperly calibrated. • Greenhouse environments may vary even in nearby areas; check if the problem is associated with a particular part of the greenhouse. • Damage may be **acute and appear suddenly**, eg a number of different plants in a given area all with deformed leaves on the west side may be due to spray drift.
SPECIES AFFECTED	**Host range**. Signs and symptoms may be limited to **one** cultivar, species, closely related species, genus, or family. There are many exceptions, eg twospotted mite and *Phytophthora* root rot attack many species.	**Plants affected**. Depending on the agent, damage may be widespread, affecting different species and perhaps the surrounding plant community, eg herbicide injury, prolonged drought. Some species are more vulnerable than others.
PLANT PARTS, WHOLE PLANTS	Signs and symptoms are usually **scattered** on the plant part or on the plant, eg • Parasitic pests and diseases **progressively** attack plant parts such as leaves or flowers, not all portions simultaneously. However, many foliage diseases will be more severe on the lower parts of plants which remain moist for longer, favouring infection. • If the problem is localised to a particular branch or section of the plant it is unlikely to be caused by weather or chemical application.  Scattered leaf spots  Scattered symptoms on plant	Symptoms occur **uniformly** on plant parts or on the whole plant. • May cause **complete failure of a plant** including leaves, flowers and roots. • If all leaves of a **certain age are affected**, it is likely to be non-parasitic, eg iron deficiency on azaleas causes new growth to yellow.  Marginal scorch  Sunscorch on exposed side  Iron deficiency on new leaves
THE CROP **Site maps** showing distribution of affected plants in the crop	**Small regular or irregular areas** of affected plants in a crop may be caused by soil-borne fungi, nematodes, insects or vector-borne virus diseases. Exceptions include cucumber mosaic virus in narrow-leafed lupin crops, which stunts all plants 'mimicking' a herbicide application. 	All plants in the affected area may be affected by spray drift or frost. A pattern that starts on one side of a planting and gradually disappears as you move away from the affected area, is typical of spray drift. Low lying areas with poor drainage may favour some soil diseases. 
SURROUNDING PLANT COMMUNITY	Check out the 'neighbourhood', eg • Overhanging trees or hanging baskets infested with soft scales will drip honeydew onto plants causing them to blacken due to growth of sooty mould. • Scales on wattle in surrounding bushland may continually re-infest citrus orchards.	Symptoms on different species nearby may suggest, eg • Major environmental factors, eg frost, drought. • Improper herbicide use. • Pollution. • Site conditions.

Pest calendars & time frames

Successful diagnosis depends on knowing when pests, diseases and weeds will appear on particular plants or in particular situations. Pest calendars assist with anticipating occurrences, monitoring and management (see Table 2 below).
Symptom development may be **delayed**. Trees, because of their size and deep roots, are often slow to respond to stress, declining slowly over years. Extended periods of below average rainfall and extreme heat can weaken woody plants. Some smaller specimens may die in their first year while larger ones may become susceptible to borer infestation and exhibit dieback a few years later. Weather can have a detrimental effect in hours, days, weeks or years.

	Parasitic pests & diseases	Non-parasitic agents
CALENDAR 	Pest calendars indicate when parasitic pests are likely to appear and when monitoring should be carried out.	Management practices of fertilising, irrigation, pesticide applications occur at certain times of the year. Attempt to link practices with the development of symptoms.
TIME BETWEEN CAUSE OF PROBLEM AND APPEARANCE OF SYMPTOMS 	• **Days, weeks**. Signs and symptoms develop over a short period, eg powdery mildews. • **Months, years**. Symptoms may be delayed, eg trees infected with *Armillaria* root rot may die slowly over 2-5 years. Drought or excessive rain may hasten decline.	• **Days**. Symptoms appear at **one point in time** and tend **not** to progress. Damage may be acute and appear suddenly, eg overnight, killing tissue quickly without a yellowing stage. A frost event on daylilies may cause exposed leaves to die but leaves which emerge after the event would be symptom-free. Over-mature cabbages split overnight. Contact herbicide injury is obvious the next day. • **Weeks, months, years**. The effect of consecutive drought years, soil gradient changes, road works, construction of walls, may take years to show up in trees. Herbicide injury not show up for months, eg on new spring growth (see page 53).
SIGNS AND SYMPTOMS MAY CHANGE WITH TIME	Signs and symptoms may continue to progress depending on the particular problem. • Insects have different developmental stages, eg eggs, larvae and adults. • Fungal rust galls on wattles may be invaded by insects. • Fungal wilts may cause leaves to die one at a time until the whole plant dies.	Symptoms appear suddenly and remain in a particular spot or on a particular plant. • Sunburnt areas of leaves may be invaded by secondary bacteria or fungi confusing the diagnosis of the **primary** cause.
PATTERNS MAY CHANGE WITH TIME	Signs and symptoms start in one area and **continue** to spread to healthy plants.	Symptoms usually do **not continue to spread** either throughout the individual plant or onto unaffected plants, eg herbicide drift.

Table 2. Pest calendar for roses in the ACT. There can be seasonal variations and some problems are sporadic, eg birds, locusts, heat waves, sudden heavy frosts.

Pests/Diseases	JAN	FEB	MAR	APRI	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PESTS												
Aphids	■									■	■	■
Rose scale	■	■	■	■	■	■	■	■	■	■	■	■
Thrips	■	■	■								■	■
Twospotted mite	■	■	■	■								■
DISEASES												
Anthracnose	■	■	■	■						■	■	■
Black spot	■	■	■	■						■	■	■
Downy mildew										■	■	■
Powdery mildew	■	■	■	■						■	■	■
Petal blight	■	■	■	■					■	■	■	■
Rust	■	■	■	■								■
Rose mosaic	■	■	■	■					■	■	■	■
Stem cankers	■	■	■	■	■	■	■	■	■	■	■	■
NON-PARASITIC AGENTS												
Magnesium def.		■	■	■								
Herbicide injury	■	■	■	■					■	■	■	■

Soil type, topography & structures

Each plant has its own cultural requirements. Unsuitable sites makes plants vulnerable to fluctuating soil moisture, pests and diseases and other stresses. Soil and water analysis are useful tools in determining site suitability.

	Parasitic pests & diseases	Non-parasitic agents
SOIL TYPE	• **Nematode populations** are related to soil properties and can act as indicators of soil conditions. • **Scarab larvae** overwinter in moist soils with some organic matter. • The severity of some **soil fungal diseases** is increased in soils low in organic matter. *Phytophthora* spores overwinter more successfully in soils low in organic matter and micro-organisms.	• **Soil drainage**, compaction, organic matter and pH influences the success or failure of plants. • **Clay soils** contain an adequate supply of most nutrients but can easily become waterlogged. • **Sandy,** time-worn soils are often leached and deficient in many nutrients and organic matter but have good drainage. • **In neutral to slightly acid soils** most nutrients are readily available to plants. • **In undisturbed bushland**, nutrient deficiencies are only important in specific regions. **Soil maps** show soil conditions across Australia, with specific and local variations, eg deficiencies of copper, iron and zinc. • In cultivated soils, high pHs (alkalinity), low pHs (acidity), nutrient deficiencies and excesses can occur. Over-fertilization is not uncommon. • Nutrient disorders or soil herbicide applications may show a pattern associated with soil type.
TOPOGRAPHY, ASPECT 	• Visit **low lying areas** after good rain where water might be standing and humidity higher. Diseases will favour these areas. Poorly drained, wet soils may result in root rots in susceptible plants. • **Examine** the various components of irrigation systems for leakages. • Check areas where **foliage** is lush as some pests are favoured by luxuriant plant growth. • Poor weed control and dense canopies are ideal places for diseases to flourish.	• **What is the slope** of the site? Slight differences in elevation or drainage may result in scattered trees declining due to a raised water table. • How does water **move over** the area? • **Waterlogged soil** may result in poor growth and kill plants due to lack of oxygen, various toxins, nutrient and other problems. • **In frost-prone areas** 'ponding' of cold air may occur at the lower parts of the property. • **Aspect** can be critical for some crops.
STRUCTURES 	• Nearby **buildings** and **fences,** often modify the environment (temperature, moisture, air movement) around plants, which may favour certain diseases. • **Vegetation** around homes, field margins and ponds can harbour diseases and insects. • **Telephone poles**, **fence lines** and **dams**. A spray operator may apply herbicide to a crop but omit areas surrounding these areas allowing pest or disease-hosting weeds to flourish.	• Buildings, roads and pathways may **restrict** root growth, affect drainage or contribute pollutants. • **Brick walls** and colorbond fences may radiate heat. Courtyards can become very hot, more sheltered and airless causing scorching from reflected heat. • **Exposure to rain**. House eaves, trees, etc can cause herbaceous ornamentals to miss out on natural rain fall.
CONSTRUCTION WORK  	• Some root fungi, eg *Phytophthora* root rot, may be introduced to disease-free areas of bushland and nurseries in soil adhering to shoes and equipment.	Road building and construction activities can cause major soil disturbance. • Changed soil gradients affect drainage patterns and root growth. • Feeder roots of trees and other plants in the upper 15 cm of soil may be damaged. • Some species are particularly susceptible, eg oak trees. Older trees are more prone to stress. • Damage may be obvious in months or not appear for years, eg after prolonged drought. • Large amounts of excavated soil placed over root areas reduces soil aeration. Similarly piles of soil placed around the base of tree trunks may result in collar rots. • Changing the soil profile by bringing heavy clay sub-soil to the surface may induce compaction and nutrient deficiencies in new landscapes. • New developments may shade sun-loving plants.

On-site diagnostic tests

Most growers can do a range of on-site tests themselves with reliable testing equipment.

- **Observation** of signs and symptoms on affected or indicator plants often **precedes** on-site diagnosis tests. With recurring problems, tests may need to be made **before** symptoms are apparent.
- A **site map** shows where on-site tests have been done and where samples have been taken for laboratory testing.
- **On-site tests** can provide indications of whether more detailed and accurate laboratory tests are required.
- Some on-site tests can be expensive, and you still have to **interpret the results**, which in some cases may require considerable skill and experience. While on-site tests are very helpful they are often only part of the diagnostic process.
- They must be **easy and quick to perform**, with quick answers. For some problems, eg parasitic diseases, tests are mostly done in laboratories.
- A **positive test result on its own**, does not mean that you have found the cause of a problem. A negative result may eliminate some problems from consideration.

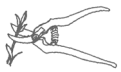
	Parasitic pests & diseases	Non-parasitic agents, weeds
ON-SITE DIAGNOSTIC 'TESTS' 	Numerous on-site diagnostic 'tests' can detect the presence of insects and a few diseases. • **Insects** can be **detected** and caught by trapping, then **identified** by taxonomy. Catches can be counted over time either by the grower or sent to a diagnostic service for identification and counting. – **Sticky traps** catch flying insects, eg thrips, whiteflies. – **Lures** attract fruit flies, many moths, eg codling moth, lightbrown apple moth, oriental fruit moth and budworms *(Helicoverpa* spp.). – **Plant parts.** Various stages of insects can be counted on leaves and other plant parts. For example moths of budworms (*Helicoverpa* spp.), eggs and caterpillars can be detected and counted in sorghum heads, as can predatory assassin bugs, lacewings, ladybirds. Control thresholds vary according to the value of the crop and the cost of control. – **Potato slices** attract fungus gnat larvae. – **Scarab grubs** under turf can be counted. • **Snails and slugs** can be trapped and counted. • **Soil and water tests**, eg – *Phytophthora* and *Pythium* tests, although available as field tests, are mainly done in laboratories. • **Plant tissue testing**, eg – **ELISA** tests for some virus, bacterial and fungal diseases are similarly mostly done in laboratories. • **Others**, include: – Resistographs for trees diagnosis. – Indicator plants. – Grow-on tests.	Many problems can be **anticipated** by **pre-plant** soil and water analysis. Sometimes one plant nutrient deficiency combined with a very high or very low pH can complicate symptoms. It is best to first check the pH of the soil before trying to remedy any nutrient deficiency. Alternatively get a laboratory leaf analysis to determine the nutrient problem. Simply applying heavy doses of fertilizer is not the answer and may cause other problems. • **Soil tests** – **Chemical analysis**, eg pH, salinity, nutrient levels, pesticide residues. – **Physical analysis**, eg soil type, compaction, moisture movement of water through soil, hydraulic conductivity. • **Water testing** – **Chemical analysis**, eg pH, salinity, nutrient levels, nutrient run-off, fertigation, pesticide residues. – **Irrigation rates**, pooling of water, drainage. A standard field test for drainage involves making a 40 cm deep hole and filling it with water. The water level should drop 7-8 cm every half hour. • **Plant tissue analysis,** eg nutrient levels, pesticide residues. • **Environmental monitoring,** eg temperature, rainfall, humidity, evaporation rates, light, pesticides, pollution. • **Weed mapping**. Weeds and weed seeds in soil can be mapped and counted.

HISTORY & RECORDS

Experienced growers keep records of plant conditions and management practices. This enables them to trace the history of a particular crop, pest occurrences, treatments and environmental events. Check whether any management practices have recently changed as these may have contributed to the problem. Remember, many problems are due to complex causes rather than a single cause. Although 'history' has been divided into that of the crop, pests and the environment, there is much interaction and overlap.

Crop history

Gather as much information about the crop as possible. A review of cultural practices may reveal some that are linked to the current problem. The following are examples of some which could have impacted on crop health.

	Parasitic pests & diseases	Non-parasitic agents
TRANSPLANT HISTORY	• **Previous crops**, eg carnations planted into pasture infected with *Fusarium*, which can attack both crops.	• An unhealthy 10 meter tall tree can be a puzzle until you discover that the tree was transplanted 2 years ago. • Large plants transplanted during hot summer weather are likely to show signs of stress. • Check if recently transplanted seedlings were weeded as this can disturb developing roots. During warm, dry conditions, some may die.
TEMPERATURE, IRRIGATION **Too much and too little**	• **Some pests and diseases** are favoured by **overwatering** that, when accompanied with mild temperatures, results in lush foliage. Nurseries tend to over-irrigate, producing conditions that favour certain diseases, eg *Botrytis*, damping off.	• **Temperature**. Most plants will only grow, flower and ripen fruit within a limited range of temperatures. • **Irrigation**, both too much or too little. Have you measured how much plants actually receive? Consider the always important question of **timing and duration**. An irrigation system that is present and seemingly functional may not have been working during the hottest portion of summer, when the observed damage took place.
FERTILIZER RECORDS **Almost always too much**	• **Certain pests and diseases** may be favoured by lush foliage due to **over-fertilization**, eg oriental fruit moth which damages shoot tips and fruit of stone fruit. Check fertilizer records.	• **Check fertilizer application rates**, test water and media for both pH and soluble salts. • The **same amount of fertilizer** applied to one crop without any problem may have detrimental effects on the following crop. Continual applications may result in increasing concentrations in the soil. • Check for excessive piles of granular fertilizer.
MULCH 	• **Certain pests** may be favoured by mulch. Mulch which has been in place for a long time can provide protected sites for pests, eg black vine weevils, rodents. Minimum or no-till cultivation results in a mulch of the remnants of the previous crop and may also favour some pests.	• Check **type** of mulch, eg fresh pine bark and some sawdusts may contain phenols which may inhibit plant growth for a few weeks. Was it aged or composted prior to use? • Check **source** of mulch. Does it contain weed seeds or rhizomes? Mulch from chipped eucalypt trees in urban areas is often biodegraded by fungi that produce spectacular fruiting bodies. • Can water **penetrate** the mulch? If mulch is thicker than 8-9 cm, irrigation and rain may not penetrate.
PRUNING 	• **Bacteria and fungi** may invade pruning wounds. Fungi may invade pruning stubs on rose canes if the pruning was carried out during **wet** weather.	• Were plants pruned at the **correct** time? Pruning banksia roses in winter will remove flowering shoots. • Were plants pruned **correctly**? Rosemary pruned into old wood will not re-shoot.

Pest, disease and weed history

Know what to expect

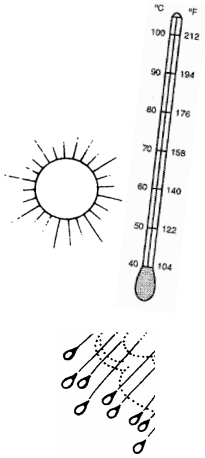
Access records of pest occurrences and their treatments. These can be an important source of information for making a diagnosis. The following are examples:

	Parasitic pests & diseases	Non-parasitic agents
PREVIOUS OCCURRENCES	• **What parasitic pests and diseases** have already occurred in your crop and/or in your region? • **Do you know why** these problems occurred on your crop and how they were introduced? • Do you know **what to expect and when** it will occur? If not, the following will help: – **Having a list** of parasitic problems which may affected your crop. – Making sure you have the relevant **pest information sheets**. – Being able to recognize **different stages of host growth** and knowing that different problems affect plants at different stages of growth – Being aware that the **incidence and severity** of a disease is influenced by environmental factors that affect **both** the **disease organisms** and the **host**.	• **What non-parasitic problems** have already occurred in your crop and/or in your region? • **Do you know why** these problems occurred on your crop? • Do you know **what to expect and when** it will occur? If not, the following will help: – **Having a list** of non-parasitic problems which may affect your crop. – Making sure you have the relevant **pest information sheets**. – Being aware that the **incidence and severity** of non-parasitic diseases is influenced by the **severity** and **length of exposure** to the adverse factors. – Knowing if **nutritional deficiencies** or toxicities occurred in the past? – Whether there has been **competition from weeds** or other plants?
PREVIOUS TREATMENTS 	• **What control treatments** have been used in the past? • **Is lack of appropriate sanitation** contributing to disease in propagation and growing areas? This could include conditions of propagation and growing areas, weed control, source of water and media, disposal of waste plants and media. • Have **bio-control agents** been released or been purchased? • **Herbicides** may predispose plants to some soil diseases.	• **Check treatments** within **IPM**, **BMP** and Organic Growing programs. • **Individual plants** within a species may lack vigour or show variable performance. • Has there been **recent applications of pesticides** around the plants or close by? Herbicides will likely cause symptoms on a number of species if there has been aerial drift. Pesticides may injure both above and below ground plant parts. Did heavy rain occur after an application which might have washed it downhill? • **Is there any evidence of plant recovery** and/or new growth, from affected plants which might suggest a non-parasitic cause? • Toxic substances in soil or in air.
PREVIOUS TESTS	• **What tests for fungal diseases** have been carried out previously? • Is there a **record** of results which might be useful?	• Have soil or water analyses been carried out previously?
SOURCE OF PLANTING MATERIAL & MEDIA 	• Check the **source of planting material**. Some pests and diseases are carried in, on, or in association with seed, cuttings, bare-rooted nursery stock. Use disease-tested planting material if available. • Check source of **growing media, soil and containers**. Soil deliveries may introduce weed seeds, nematodes and soil fungi. • *Phytophthora* diseases can be spread from nurseries via contaminated containers and tube stock.	• Check the **source of planting material**. Are you receiving the variety your ordered? This applies to both vegetative material and seeds. Propagation by **seeds** results in greater variation in yield, flower colour, and other characteristics than by vegetative propagation. Continually **saving seed** from the same crop may introduce unwanted variability. Albino pea seedlings may result from this practice. • **Check source** of soil, potting mixes as they may contain toxic residues. • Containers and tube stock **held** for long periods in nurseries will be slow too establish.
HOST SUSCEPTIBILITY	• Are the species/varieties grown **very susceptible**? Could more resistant ones be selected? eg *Photinia serrulata* is susceptible to powdery mildew while other species are not.	• **Similarly** some genera, species, cultivars and provenances, are genetically more or less susceptible to frost, heat or other non-parasitic agents.

Environmental history

Know what to expect

Many plant problems are caused by an unsuitable relationship between the plant and its environment. **Temperature and moisture** have the greatest influence on both plant growth and pest development. Early warning services predict outbreaks of pests and diseases and when extreme weather events might be expected, eg frosts, hail. **AusVit** predicts outbreaks of downy and powdery mildews, *Botrytis*, mites, lightbrown moth on grapevines, based on weather data indicating the need for treatment. Importantly for diagnosticians, these services can also provide a record of past environmental events. Many environmental agents produce **non-specific** symptoms which, unless environment records are kept, make them difficult to diagnosis. The following are examples of how the environment can affect the development of pests and the host plant.

	Parasitic pests & diseases	**Non-parasitic agents** (direct effect on plants)
TEMPERATURE & MOISTURE 	All parasitic pests and diseases will only infect and damage plants under certain conditions of **temperatures and moisture**, eg peach leaf curl will only develop during cold, wet weather during leaf emergence in spring followed by warm humid weather during early blossoming. • **Temperature**. Extreme cold can directly injure or weaken a plant, allowing pest and disease organisms to develop, eg – **Sunburnt or frosted fruit** are commonly invaded by secondary disease organisms (see page 149). • **Moisture**. Humidity and over or under watering, summer drought, excessive rainfall, can predispose plants to disease. – **High atmospheric moisture** favours foliar and stem diseases. Moisture influences start of the fungal growth and protect the fungus from drying out until infection of the host occurs. The longer the foliage and stem stays moist the more infection occurs. Early warning services use this information to time spray applications measures to control apple scab (*Venturia inaequalis*) which is a serious disease of apples in spring under moist conditions. – **High soil moisture** favours root rot diseases such as *Phytophthora*, and damping off diseases of seedlings.	All plants have optimum temperature and moisture requirements. Different conditions may be required for planting out, growing, flowering, pollination, ripening and postharvest. They can be quite precise, eg the optimum temperature for ripening most tomatoes in a ripening room is 20°C. • **Immediate microclimate around the plant**. Does the site receive normal rainfall, sunlight, exposure to wind, protection from frost, etc? Environments within a greenhouse may vary even in adjacent areas. What was the weather like when the problem appeared? • **Short-term weather extremes**, ie those occurring within the last few months. – **Temperature. Late spring frosts** may damage plant cambium inhibiting plants from growing beyond initial bud break (flowering and leafing out). Frost damage to fruit may be immediately obvious or not apparent until the fruit enlarges (see page 149). Tender rose canes and developing buds may also be damaged (see page 53). **Early autumn frosts** may damage flowers of some plants. **High temperatures** may cause wilting, fruit shrivelling and scorch leaves and flowers. **Low or very high temperature** may inhibit growth. – **Moisture**. Plants such as turfgrass, tender perennials are susceptible to poor irrigation or dry weather. – **Combinations** of early hot, dry weather in a given season can have major effects. • **Long-term weather extremes**, ie those occurring continuously over the **previous 1-5 years** such as drought or excessive rainfall, low or high temperatures, should be factored into the diagnosis, especially of perennial species, eg drought-sensitive trees. • **Did heavy rain occur after a pesticide application?** Herbicides may be washed downhill to damage non-target plants.
SUN/SHADE EXTREMES, LIGHT	• Shady parts of shrubs favour certain pests and diseases, eg greenhouse thrips. • Reduced light may favour some powdery mildews.	• Can be critical for survival of many plants. Japanese maples prefer protected sites and are prone to leaf scorch in hot, sunny, windy sites. • Note the light situation, eg full sun, partial or full shade, and compare to the plant's needs.
WIND 	• Strong winds can injure or weaken plants, allowing pest and disease organisms to invade.	• **Wind** may dry out tissue of broadleaved evergreen shrubs in winter and burn tender perennials in summer. Wind may bruise citrus and other fruit. Leaves may be tattered. Trees may 'lean'. • **Wind in combination with high soil moisture** is a problem for trees. The soil loses its strength, can't hold the roots in position and the tree may blow over.
OTHERS	• Fruit damaged by hail may be invaded by disease organisms.	• Hail may injure fruit, lightning may split tree trunks.

'20 QUESTIONS'

Whether you visit the site or not, **always ask considered questions**. However, questions are particularly important if you cannot visit the site, if the enquiry is made by telephone, letter, email or if there is no specimen, photograph or digital image.

Asking the right questions is an important skill especially when the client is not volunteering much information. Do not necessarily accept the first answer to questions, they may not be accurate. Check consistency of answers to eliminate false possibilities.

THE CLIENT



Probe the client's mind for information. If a diagnostician does not talk to the client directly, a perfectly accurate diagnosis of **one** problem may be made, without addressing the client's main concern.

- Re-examine the client's enquiry. What does the client think the problem is?
- Ask the client for help with accessing records and other information. In most situations the client or co-workers can provide a history of the site and the associated plant materials, which will ultimately help in diagnosis.
- Often one must rely heavily on a review of management practices to link these with the timing of symptom development.
- Communicating with some clients can be difficult, but always avoid embarrassing them (see page 117).

QUESTIONS & ANSWERS



The trick is to ask the right questions to get the answers you want. Asking the right questions helps you eliminate some problems and 'zero in' on others. Checklists are useful guides but in some instances may be too formal and need to be varied, otherwise they can **lead you to a conclusion** when the diagnosis should be **inconclusive**.

- **Questions to ask** must include enquiries about patterns of symptoms, time frames, site conditions, diagnostic tests, history of the crop, pest occurrences, treatments and the environment. Are weather warning services available?
  - **A checklist** can help you frame your questions. You can vary, omit or add some questions as required. Questions can be asked in the order that best suits the client's enquiry (see pages 113 and 116).
  - Have any **tests been done previously**? Is there a record of results which could be helpful? **If samples** are being sent to a diagnostic service, carefully complete the **submission form** accompanying the samples to the best of your knowledge (see page 121).
  - **The types of questions** will vary depending on the client, crop, the problem (insect, disease etc) and legal responsibilities (quarantine, notifiable pests, pesticides).
  - **You may need to ask questions** about **signs** and **symptoms** previously noticed which are not now obvious. Were they recorded?
  - **Failure to ask some basic questions** early in the diagnostic process is often the reason for a faulty diagnosis, eg are the plants in the ground or in containers?
  - Even when you **do** ask the correct questions, they may not result in an open-and-shut case. Questions usually reveal more possibilities for consideration.
  - One need **not** necessarily know the answers to **all** the questions.
- **Questions will vary** depending on whether you:
  - **Visit the site with the client** who can answer questions and provide records. While some problems are relatively easy to determine on-site, it helps to have the client there to provide important background information. It also gives the diagnostician a better understanding of the client's concerns and expectations.
  - **Visit the site without the client**. This is a disadvantage but you will be able to add your own visual impressions and take samples and photographs.
  - **Cannot visit** the site, when your questions will need to be more precise and thorough.
- Remember, it may **not** be possible to get satisfactory answers to some of your questions. You may just be able to offer several possibilities, ie an inconclusive diagnosis.

RECORDS



Use a **permanent** recording system or a form that is appropriate for your situation to keep records of the following:

- The questions you asked and the answers received.
- The submission forms which accompanied any samples sent to a diagnostic service.

A DIAGNOSIS BASED ON A SITE VISIT

TO PROVIDE, CONFIRM OR REJECT A DIAGNOSIS

Site inspection
- Patterns
- Time frames
- Site conditions
- Assessment
- On-site tests

History
- Crop
- Pest, disease, weed
- Environmental

'20 Questions'

A preliminary diagnosis depends on knowledge and experience in recognizing certain previously described signs and symptoms and their similarity to published descriptions and illustrations. The identity of samples or specimens of some insects or disease organisms can be confirmed by microscopic examination. However, this is **not** possible for many problems. Some will **require a site visit** to identify likely causes. Site visits are particularly valuable for identifying **primary causes** of problems resulting from **non-parasitic agents**, eg site conditions (see Fig, 15 page 72). A site visit may not come up with a definite diagnosis but you should be able to come up with a short list of possible causes.

- **Patterns of signs & symptom** coupled with knowledge of the **time frame** of their development, are two important clues for distinguishing between parasitic and non-parasitic agents. Many causes may be **eliminated** by noting recent weather, checking the pH of the soil or water and noting the appearance of roots and internal tissues of stems.
  - **Looking at a plant or a crop as a whole** can contribute to the diagnosis. Step back to consider overall crop health in more detail. **Compare** affected with non-affected areas, is there a link between soil type and severity of the problem? What do you see that looks abnormal?
  - **Ask how quickly signs and symptoms developed**. When did the symptoms start? Try to link this to weather records.
- **Site conditions** may indicate likely causes. Draw a rough **site map**.
- **On-site tests** may confirm or reject some causes, depending on the problem. **Samples** may need to be collected and sent to a diagnostic service. Complete the submission form, which must accompany the samples, as best you can
- **Check history** of the crop, pest occurrences and treatments and environmental events. If pattern development, time frames, site conditions and history all point to a **non-parasitic agent** such as a adverse weather conditions or pesticide drift, then try to link symptoms with site conditions and crop records or with **information submitted** with a specimen, eg reports of pollution, weather events, pesticide applications.
- If you cannot pinpoint anything seek expert advice.

STEP 1. **The client's enquiry.** Several flowering trees dying in a small arboretum. A site visit was arranged. See pages 105 and 121 for details that must be recorded.

STEP 2. **Identify affected plant.** Flowering *Prunus*, eg peach, Japanese flowering cherry.

STEP 3. **Examine plant parts for signs & symptoms.** West sides of trunks sunburnt, many with dead patches, several with wood rot fruiting bodies and some with fruit-tree borer injury. Many showing signs of dieback.



Sunburnt bark



Wood rot fruiting bodies



Wood rot fruiting bodies



Fruit-tree borer damage. Note frass at tunnel entrance – caterpillars feed on bark and may ringbark branches

STEP 4. **Visit site, history, questions**

Patterns. Most trees were affected to some extent indicating a possible non-parasitic primary cause.

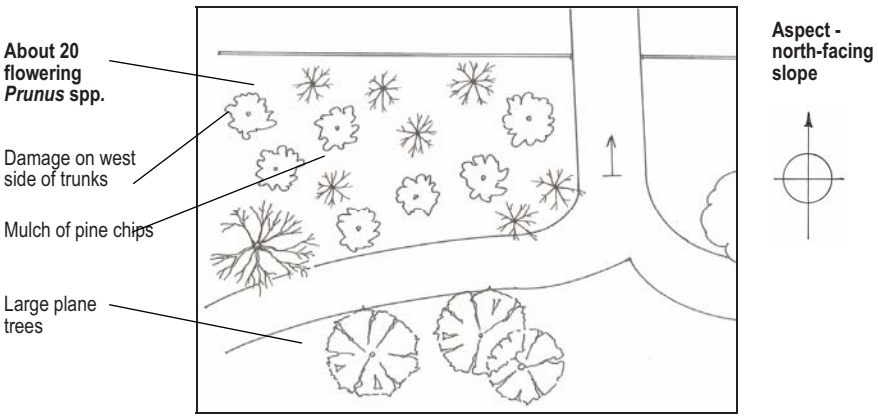
Time frames. Been developing over years.

Site conditions. North facing slope, pine chip mulch (reflective), plants exposed to sun all day in both summer and winter (deciduous trees); a very hot site.

On-site tests. Not relevant.

History. ***Crop history*** – intermittently irrigated, system in poor condition. ***Disease pest & weed occurrences & treatments*** – glyphosate and simazine herbicides applied to control weeds; copper fungicides to control peach leaf curl, brown rot and shothole; pyrethrum insecticide to control aphids.

Questions. Revealed that irrigation was intermittent.



STEP 5. **Consult references**. Fact sheets for wood rot on fruit trees.

STEP 6. **Seek expert help**. Not required. Samples submitted enabled a diagnosis of wood rot to be made but this was not considered to be the primary cause of the problem.

STEP 7. **Report the diagnosis**. Primary problem is sunburn, followed by wood rot fungi and fruit-tree borer infestation, resulting in death of trees. Information obtained from the site visit matched the 'pest signature' for wood rot (see page 61).

Fig. 15. Example of a diagnositic report based on a site visit.

SUMMARY

Step 4. Visit site, history, questions

Each step of the diagnostic process reduces the possibilities and eliminates unlikely causes. Recall the original enquiry (Step 1). Having identified the affected plant (Step 2) you have access to a list of potential pests and pest information sheets. You have examined the plant (Step 3) and may have tried to match signs and symptoms from descriptions in the pest signature (Step 5). You may or may not have made a diagnosis (Step 7). A site visit, crop records and questions may confirm or reject any preliminary diagnosis. Depending on how definite the diagnosis needs to be, expert advice may still be required.

REDUCING THE POSSIBILITIES



A site visit will provide information on conditions which might favour either a parasitic or non-parasitic problems. Remember there may be complex causes to the current problem. Knowing the type of plant, its present site conditions and management history is the key to making a diagnosis even if further specialist assistance is required.

- **A site inspection**
  - **Patterns of signs and symptoms**. Is the problem restricted to one species or does it attack several? Are all the plants of that species affected? What is the pattern of symptoms on leaves, the whole plant, the crop and the surrounding plant community? Patterns can reveal whether it may be a parasitic **or** non-parasitic problem.
  - **Calendars and time frames** also help to indicate parasitic **or** non-parasitic problems. Pest calendars indicate when they are likely to occur. Problems that develop 'overnight' usually indicate a non-parasitic event, eg frost, hail, sunscorch.
  - **Consider site conditions** with the potential to affect the plant directly or favour any pest problem. Draw a site map.
  - **On-site tests** may be required.
- **History, access records**
  - **Crop history**. Check present and past cultural practices. Is the present problem linked to crop management practices, eg recent applications of fertilizers, irrigation schedules?
  - **Disease, pest and weed history**. Know what to expect. Access records of pest occurrences and any treatments carried out. What is the importance of parasitic pests compared to any non-parasitic factors?
  - **Environmental history**. Has the weather been unusually hot or cold, wet or dry? How has it affected the crop and any pests that might have developed?
- **'20 Questions'**
  - **Ask the right questions** to get the information you need to help you solve the problem. Questions should aim to bring out 'clues' which can lead to a diagnosis.
  - **A checklist** can be a good starting point (see page 113).
- **Diagnosis based on-site visit**
  - A preliminary diagnosis can be confirmed or rejected by a site visit.
  - If a more definite diagnosis is required, seek expert help.

FURTHER STEPS

Step 5. Consult references.
Step 6. Seek expert help.
Step 7. Report the diagnosis.

CASE STUDIES

Step 4. Visit site, history, questions

Site visits make a valuable contribution to a diagnosis involving non-parasitic or complex causes

1. INCONCLUSIVE DIAGNOSIS

?	**Nursery concerned** that up to 90% potted up roses of some cultivars dying. A new problem. Concerned that it is a disease.
	Some **rose cultivars** were doing better than others, but some plants of all cultivars were dying irrespective of supplier.
	Plants were dying, roots were poor. Death rates varied between suppliers and cultivars. **Site observations & questions** revealed irrigation, fertilizer, spraying schedules were unlikely to be a problem. **Pattern** of dying plants & poor growth across the nursery was generally in blocks and clear cut, indicating a likely non-parasitic problem. Variation in plant mortality from different suppliers may indicate potting mix problems in the nursery or improper handling in the nursery. Could they have been left to dry out? Significant damage can occur in a few hours, exposure of roots even in mild weather may cause damage.
	
XPERT	**Inconclusive diagnosis** Staff insistent that they were **not** allowed to dry out. Although there are potting mix standards, potting mix problems are not uncommon. Supplier may be new to the industry, ingredients may have been improperly composted. Suggest getting a media analysis from supplier or getting one done yourself. Difficult to assess because of time since the event.
	

2. REPEATED CROPPING IN THE SAME AREA

?	**Samples** of unhealthy peach seedlings were brought in, unfortunately without the roots. Clients indicated that they thought the problem was due to the source of the seed. Requested samples of plants with roots.
	**Peach seedlings** to be used as rootstock. List of pests & pest information sheets available.
	**Small to large galls** on all seedlings. The problem is probably crown gall (*see page 164*).
	**Questions** revealed that there were galls on all plants in the field. Also that similar nursery stock had been grown in the same beds for at least the last 3 years.
	**Checked source** of seed about likelihood of infected peach seed. Seed was supplied fresh from the cannery and unlikely to be contaminated.
XPERT	-
	**Useful diagnosis**. Crown gall probably due to the same beds being used each year. Populations of crown gall bacteria gradually increase without adequate treatment.

3. DIEBACK IN CONIFERS – 2 PROBLEMS?

?	**After a telephone** enquiry about conifers on a country property failed to reach a conclusion a site visit was arranged.
	A 'forest' of approximately 800 ***Cupressocyparis leylandii* 'Green Spire'** several years old. Many trees affected.
	Some showed browning due to water stress, others showed gumming and splitting of bark on which were tiny black spots (fungal fruiting bodes), possibly cypress canker.
	Irrigation appeared inadequate given the size of the trees and the past few years of drought.
	References confirm the canker as probably cypress canker *(see page 156)*. Conifers do not 'wilt' but brown months after a drought.
XPERT	However, bark samples should be sent to a diagnostic service for detailed microscopic examination of the fruiting bodies.
	**Preliminary diagnosis** based on symptoms which a diagnostic service could confirm. Replacement or further plantings should have some resistance to cypress canker.

4. SITE CONDITIONS

?	**Home gardener** with a dying mature MopTop hedge. Several shrubs have died and others not looking healthy. A site visit was arranged.
	***Robinia pseudoacacia* 'Inermis'** (Moptop) grafted onto false acacia (*Robinia pseudoacacia*).
	**No pests or diseases observed.** The hedge was in a hollow at the bottom of a slope where water collected. The soil was wet. Questions revealed that a new irrigation system had been installed for the large lawn and annual bed areas 3 years ago. On digging a hole water collected almost immediately. Robinias do not grow well in waterlogged soils.
	
XPERT	-
	**Useful diagnosis**. Excess irrigation to lawn and flower beds drains down the slope to the hedge. Roots were literally drowning.

5. ON-SITE TEST FOR PHYTOPHTHORA?

?	Client concerned that large numbers of eucalypt tube stock planted in memorial park about 2 years ago were dying. Concern that it could be *Phytophthora*.
	Various ***Eucalyptus* spp**. A site visit was arranged. Many tube stock were dying and others looked unhealthy. Explained that soil samples could be sent for testing, but that even if *Phytophthora* was isolated from affected tube stock this would not confirm that it is the sole cause of the problem, other factors, eg poor drainage, waterlogging, soil problems could be involved. So many tube stock were affected it was unlikely to be *Phytophthora*. Area was well drained. Check management records for planting dates, fertilizing, spraying. No irrigation but one would expect most of the tube stock to establish. Glyphosate and a pre-emergent herbicide had been applied several weeks previously. There are no guards around the tubes to provide some protection from drift. Roots can also be injured.
	
	
XPERT	
	**Inconclusive diagnosis**. Likely cause is herbicide injury. Many trees and shrubs less than 2 years old are very susceptible to herbicide injury. Exercise care!

6. COMPLEX PROBLEM

?	**Country property** with large plantings of 3-4 year old oak trees planted out 1 year ago. Signs of decline, some had died. A site visit was requested.
	**Evergreen oak** (*Quercus ilex*). A list of pests & pest information sheets available.
	No obvious pests or diseases. Trees heavily low pruned causing many to shoot from the base. The pruning cuts could have provided entry points for secondary infections.
	Hardy, well suited to the site, been grown in the area for years. Drippers not blocked. Organic fertilizer around stems may have caused collar rots. **Questions** revealed that many had been sprayed for aphids.
	-
XPERT	-
	**Useful diagnosis.** Excessive pruning, spray damage, and excessive mulch around stems all contributed to the decline of the trees. Advice provided on future care.

7. PEST, DISEASE & WEED HISTORY

?	**Commercial grower enquiry**. Unhealthy cut flowers in polytunnels.
	Many species of **cut flowers**.
	All plants looked unhealthy, growing slowly.
	Site visit **not** possible. **Patterns –** plants of all species were affected so unlikely to be a parasitic problem. **Questions** asked about application of fertilizers, irrigation, pesticides. A pre-emergent herbicide had been applied several weeks previously.
	Checked **pesticide label** for information regarding plants to which it could be applied and the conditions under which it can be applied.
XPERT	-
	**Useful diagnosis.** Probably pre-emergent herbicide injury due to its application in a warm enclosed environment where vapours could remain for some time after application.

8. ENVIRONMENTAL HISTORY

?	**Home gardener enquiry**. A dying honeysuckle hedge adjacent to a public park. Client thinks local council spray units have been spraying herbicide along fence lines. Need to visit site.
	20 metre honeysuckle hedge (*Lonicera japonica*).
	**Symptoms observed on-site**. Blighting and dying back of growth probably due to the combined effect of recent very cold and wet weather.
	**Patterns**. All plants affected. Customer was **not** convinced. Symptoms did **not** look like those of herbicide injury. Probably winter injury on straggly overgrown, un-pruned honeysuckle.
	**Contacted the local spray service** who indicated that **no** herbicides had been applied in that area for at least 1 year. The client could go on a **'No Spray'** list.
XPERT	-
	**Useful diagnosis** of cold, wet, winter weather injury. Client was very happy. Clients are often pleased to know what the problem is **not**.

REVIEW QUESTIONS & ACTIVITIES

Step 4. Visit site, history, questions

1. **Make a site visit**. Access or prepare a form or system to record observations made on the site visit.

2. **Collect samples** to bring back for further examination or send to a diagnostic service. Fill in an appropriate submission form to accompany the samples.

3. If a **non-parasitic** problem is suspected, which of the following is likely to be most useful?
   1. Examining specimens and comparing observations with illustrations and descriptions.
   2. Referring to the information attached to a specimen, eg pesticides used, location, climate, weather, soils and crop records generally.

4. Which of the following **predisposing** factors could prove difficult to identify?
   1. Provenance.
   2. Drainage.
   3. Soil compaction.
   4. All of the above.

5. Prepare a rough **site map** which may include location of affected plants, irrigation, shading, proximity to parking lots and buildings, pesticide stores, sprayed areas, construction activities, on-site tests and where samples had been collected.

Site inspection

6. If **all** plants of **different** species are affected by a problem, is the problem most likely to be caused by:
   1. Diseases and insects.
   2. Insects and mites.
   3. Conditions of the site or weather.
   4. All of the above.

7. Indicate which of the following patterns would most likely be caused by a **parasitic** or by a **non-parasitic** agent.

Pattern of plants showing symptoms	Parasitic	Non-parasitic
Even patterns of yellowing on **all** leaves on **all** plants of the **same** species		
Uneven patterns of yellowing on **some** leaves on **some** plants of the **same** species		
All plants of **different** species		
All plants of **same** species, other species not affected		
Single tree in an **orchard**		
Only a **few** plants all of the **same** species in a planting		
Clear cut line of symptoms in a crop of **one** species		
Your choice		
Your choice		
Your choice		

Site inspection

9. Which of the following are useful in distinguishing between a parasitic and non-parasitic causes when symptoms are similar?
   1. The time of year they occur
   2. Time between cause and effect
   3. Rate of spread
   4. Whether signs & symptoms change with time
   5. Management practices
   6. All of the above

10. Which of the following would usually be considered short or long term causal events?

	Short term	Long term
Flooding		
Saline soils		
Successive dry years		
Herbicide drift onto non-target plant		
Soil compaction		

11. Describe **2 on-site tests** you could carry out on a crop of your choice.

History

12. Access **records** of the crop. What information would you look for?
    1. Variety planted
    2. Source of planting material and media
    3. Previous crops
    4. Irrigation
    5. Fertilizers
    6. All of the above

13. How does the **relationship** between soil pH extremes relate to the availability of certain micro-nutrients? Describe **2** examples.
    1.

    2.

14. Access **records** (for the past 12 months) of pest, disease and weed **occurrences** in a crop of your choice.

15. Access **records** (for the past 12 months) of pest, disease and weed **treatments** in a crop of your choice.

16. Access **records** of rainfall, temperature and any unusual weather events (over the last 12 months) and identify the effect of any **one** on a crop and a pest, disease or weed
    1. Crop

    2. Pest, disease or weed

'20 Questions'

17. Shrubs planted out about 2 years ago are showing signs of decline, some have died. What 4 questions could you ask that might help you reach a diagnosis?
    1.

    2.

    3.

    4.

18. Seedlings of pansies and a range of other flowers planted in beds for display in a flower show have not grown as well as expected. What 4 questions could you ask that might help you reach a diagnosis?
    1.

    2.

    3.

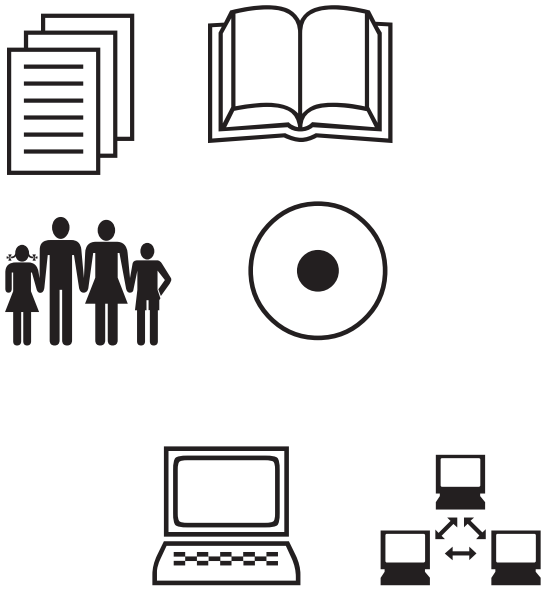
    4.

Diagnosis based on site visit

19. From a site visit what can you expect to be able to do?
    1. Identify the primary cause of a problem
    2. Make or confirm a diagnosis
    3. Eliminate a number of possibilities
    4. All of the above.

20. What are some of the **clues** that might indicate herbicide damage rather than a parasitic disease?

Step 5. Consult references



Books, colleagues & computers *78*

What should I look for? *79*

- Host & pest indexes *79*
- Pest information sheets *80*
- Keys & expert systems *81*
- Image-matching *82*

Diagnosis based on references *83*

Summary *84*

Case studies *85*

Review questions & activities *86*

BOOKS, COLLEAGUES & COMPUTERS

Use references at any stage of diagnosis

The horticulturist with good books and internet access, along with willing and competent colleagues, is at a decided advantage. Locating a publication or web site relevant to the enquiry can bring a wealth of knowledge to the diagnosis. Once you gain some **experience** you will use your references quickly.

PAPER TRAIL



Commonwealth/State/Territory Departments of Agriculture/Primary Industry/Forestry provide Australians with reliable and well researched pest information sheets (Fact Sheets) for a wide range of economically important pests, diseases and weeds. Those dealing with issues of national importance are usually free-of-charge. Others include Wild Life Notes, Farmer Alert, Grain-Guard, Hort-Guard. Many are also available as CD-ROMs or via the internet.

- Books on pests, diseases and weeds (the causes of plant problems) can be purchased.
- **IPM** and **BMP** programs are available for some commercial crops and mostly produced by industry organizations, eg **NIASA**, cotton, etc.
- Plant disease reference collections, still or video images, are being used in many areas for disease diagnosis.

COLLEAGUES



Colleagues are an important resource.

- **Industry organizations** are the major source of information for commercial growers.
- **Specialist hobby growers** can be a valuable source of information for home gardeners.
- At the other end of the spectrum **diagnostic networks** have been set up between diagnostic services.
- Network with your colleagues at the appropriate level.

COMPUTERS



CD-ROMs and web sites enable horticulturists to search for information themselves and are a great resource for problem solving.

- **Search State and other websites** for information available for your **plant** or **pest** by scientific and/or accepted common names. Remember, common names can be misleading.
- Many States also provide **on-line pest management recommendations**, some websites offer training in diagnostics (see page 195).
- There are Australian and overseas websites for **particular pests**, eg grapeleaf rust, whiteflies, vine weevils.
- **Subscribe to websites** which help keep you up-to-date. **Outbreak** is a quarantine website which notifies you of new pest and diseases. www.outbreak.gov.au
- Search for **Australian references**. Many pests which occur overseas do not occur in Australia.
- **To reduce information overload**, some industry-supported programs focus on key aspects linked to profitability of a particular crop, eg Ricecheck is based on only **eight** key practices.
- **Not everything** on the internet is accurate, so choose sites carefully (see page 83).
- **An important reference** is *Horticulture Sites on the World Wide Web*. cur. edn, Book and CD-ROM (available from GrowSearch, Cleveland, Qld).

RECORDS



Keep a **permanent** record of the references you have used as part of the proof of your diagnosis (see pages, 62, 72, 105 and **121**).

- **References and records must be organized** in such a way that they can be quickly accessed during future diagnoses (see page 119).

WHAT SHOULD I LOOK FOR?

Once you have **identified** the plant or the pest it is easy to obtain information describing them, providing the crop and its associated pests have been previously described in detail. It is **not so easy** to access information on less well known plants, uncommon pests or non-parasitic problems.

Host & pest indexes

Information is commonly searched for either by the name of the affected plant, ie a **host index** and by the pest, ie the **pest index**.

HOST INDEX



A host index lists plants in alphabetical order either by their scientific or common name. Hosts may firstly be grouped into fruit, vegetables, ornamentals, nursery plants, etc. Under each plant (host) is a **list of pests**. Ideally there should be a host index for each region.

- **Information on the pests of commercial crops** is now available in both book and computer form, eg cotton, Asian vegetables, mango, banana, ornamentals, vegetables. These are mostly produced by industry associations as **IPM, BMP**, organic standards and other Quality Assurance programs.
  - **These programs list the pests** associated with the crop and provide a pest information sheet for each problem. Descriptions and illustrations of signs and symptoms can be compared with the signs and symptoms of a suspect problem. In most cases you may pinpoint contributing factors.
  - **Host indexes, only offer suggestions** as to a suspect problem, which must ultimately be proved by specific references or a diagnostic service.
  - **Some indexes list only the common** or key pests and diseases, others are more detailed and organized into pest and disease groups, but even with those there may sporadic pests, such as plague locusts, that are not on the list.

Roses Pest & diseases

Virus diseases
Rose mosaic (a complex of viruses)
Bacterial diseases
Crown gall (*Agrobacterium* sp.)
Fungal diseases
Black spot (*Marssonina rosae*)
Powdery mildew (*Sphaerotheca pannosa*)
Downy mildew (*Peronospora sparsa*)
Petal blight (*Botrytis cinerea*)
Rust (*Phragmidium mucronatum*)
Insects & allied pests
Aphids (various species)
Rose scale (*Aulacaspis rosae*)
Twospotted mite (*Tetranychus urticae*)
Non-parasitic problems
Iron deficiency
Herbicide injury

PEST INDEX



A pest index usually lists pests alphabetically according to their scientific or accepted common names. Pest indexes are important if you:

- **Need to access pest information sheets** for a particular pest, disease or weed to help with confirming or rejecting a preliminary diagnosis.
- **Need to know** the scientific name of a pest or disease, eg green peach aphid (*Myzus persicae*). Diseases often need to be searched for by the scientific name of their cause, eg *Monilinia fructicola* which causes a brown rot disease of stonefruit.
- **Do not know** or are uncertain of the name of the affected plant, or if it is known but not well studied.

List of pests	List of diseases	List of weeds
Aphids	Black spot	Bindii
Black vine weevil	Blights	Bitou bush
Ferment flies	Charcoal rot	Paterson's curse
Fruit flies	Downy mildews	Serrated tussock
Lerp	*Phytophthora* root rot	
Mealybugs	Powdery mildews	
Mites	Rusts	
Scales	Wood rot	
Whiteflies		

Pest information sheets

PEST INFORMATION SHEETS

Pest signature

Pest information sheets are a vital source of information about any pest, disease or weed and are described in detail on page 39.

- **They usually include** illustrations or photographs, describe diagnostic features and tests, identification keys, pest calendars and expert systems. They will indicate the significance of the problem and its economic cost. You may be able to access some directly via the internet.
- **Pest information sheets** will also provide information on **legislative requirements**, eg notification of quarantine pests and prescribed treatments.
- **The illustrations and descriptions** are useful for **distinguishing** between pests with **similar symptoms** on the **same plant**.
- **Remember**, the degree to which a suspect pest **matches** the information in the pest information sheet, ie its **pest signature**, may determine how definite the diagnosis is. In some cases a single component is sufficient for an accurate diagnosis, eg presence of fungal spores or a diagnostic test, but in most cases several components are needed. It may also **eliminate** certain possibilities (see also pages 26 and 61).

Pest information sheet

- Common name of pest, disease or weed
- Scientific name
- Causes(s)
- Significance of problem, **legal requirements**
- Host range, plants affected
- Description of signs & symptoms, diagnostic features & tests
- Pest cycle
- Overwintering
- Spread
- Conditions favouring
- Control/prevention, organic standards, Integrated Pest Management, Best Management Practice
  - **Legal requirements**
  - Cultural methods
  - Sanitation
  - Biological control
  - Resistant varieties
  - Plant quarantine
  - Disease-tested planting material
  - Physical & mechanical methods
  - Pesticides

Pest information sheets are described in detail on page 39

Keys & expert systems

Various keys and expert systems are used to identify pests, diseases or weeds, optimize production and provide early warning services (disease prediction services). In most cases keys are followed by **descriptions and illustrations** that can be used to check that this approach has led to the correct identification.

TYPES OF KEYS, EXPERT SYSTEMS



Keys used to identify organisms include:

- **Traditional either/or keys** which present the user with **two choices** at each step. The choices may be in the form of a description, illustration or photograph.
- **Computerised interactive/multi-access keys**, whether they are published on CD-ROM or the internet, are easier to use and are more intuitive and user-friendly than either/or keys. They are also better suited for diagnosing complex problems.
- **Various expert systems capture the knowledge of an expert** and make it available in an IT system. They also are user-friendly.

WHAT ARE KEYS & EXPERT SYSTEMS USED FOR?

Uses include:

- **Identifying plants, weeds, pests and diseases.** Many simple keys are based on morphology, ie the structure of the organism that can be seen with the naked eye, a hand lens or a microscope. These are used to identify:
  - **Plants**, including grasses, weeds, weed seedlings, seeds, parasitic flowering plants, eg eucalypts of southeast Australia (**EUCLID**), Crop Weeds of Australia, Declared Plants of Australia, Suburban Environmental Weeds, Blackberries.
  - **Insects**, mites, snails and slugs, nematodes, bacteria, fungi, eg **fruit flies**; the **BugMatch Series** for identifying insects on citrus, cotton and grapes; **OZPest** for identifying urban pests; **WeedBiocontrol** for identifying insects used to biologically control weeds; **NemaSYS** which is a resource center on major Australian nematodes.
  - **Pests and diseases of particular crops or situations**, eg mites in soil, cotton pests, pests of pip and stone fruit, turf pests and turf pest damage.
  - **Specific (distinctive) symptoms** on plants, eg those caused by nutrient deficiencies and excesses or by Christmas and leaf beetles on eucalypts when the insect causing the damage is absent.
  - **Reactions** to various tests.
- **Optimizing crop management**. These may include early warning services for selected diseases, monitoring and control. Examples include:
  - **Canegrub** – a best practice management tool for the Australian sugar industry.
  - **Cropwatch Online** – an identification guide for grapevine diseases.
  - **DELTA** (Description Language for Taxonomy) – used by the Western Australian Herbarium and CSIRO Entomology.
  - **EXNUT** – an expert management system for irrigated peanut production.
  - **HERBASYS** – a herbicide advisory system.
  - **PALMS** – a database for palms.
  - **Rice IPM** – a training and support tool for pest management in rice.
  - **TURFPLAN** – an expert planning system for turf managers.
- **Training students and personnel** in diagnosis.
  - **Diagnosis for Crop Problems** is an interactive tool which teaches diagnostic skills. It provides an authoring package to build problems scenarios and a player to run the scenarios (Centre for Biological Information Technology (CBIT), University of Queensland, www.cbit.uq.edu.au). **Diagnosis for Crop Problems** has its own website, www.diagnosis.co.nz. which provides more information and includes a demonstration version.

Image-matching

One picture is worth a 1000 words!

TRADITIONAL DIAGNOSIS GOES MODERN

Traditional diagnoses has been based on **visual observations of signs and symptoms** expressed by the infected plant.

- **Computers** have given a new dimension and accuracy to image-matching. An internet search is often done for **images** of a pest, disease or weed.
- **Good images** of plants, weeds, insects, symptoms, patterns of affected plants in the field, can help with diagnosis in certain situations. Images taken at different times can show the progression of signs and symptoms. Videos can assist with this.
- **Images** are more useful for **above ground problems** than those associated with roots and soil.
- **Distance diagnostics** involves sending photographs through the mail, or digital images via email to be displayed on computers or larger screens, for detailed examination. Microscopic images of tiny insects, fungal mycelium and spores can also be taken and forwarded to experts, if you have the correct equipment.
- **Diagnostic services** are more able to interpret images.
- **Image matching** can be used to explain to your client how you reached your diagnosis.
- However, there can be **traps** with image-matching (see pages 83, 107, 108).

A SIMPLE EXAMPLE

Some websites guide users through a series of images until a diagnosis is made. **CropWatch Online** is an identification guide to diseases of commercial grapevines in Australia (www.cropwatch.com.au/). The University of Minnesota extension website enables home gardeners and nursery professionals to diagnose plant diseases and manage them effectively (www.extension.umn.edu). Having accessed the websites, simply follow the links, which may vary considerably depending on the crop and if several regions are included. A series of images may include:

Click the appropriate links

1. Choose and click a **plant type**, eg **fruit**.
2. Click on the specific **fruit**, eg **apple**.
3. Choose the **part of the plant** showing symptoms, eg **leaves**.
4. Click on the **sign or symptom** that matches your pest or disease.
5. Once you diagnose a problem by matching it to an image on the web page, **clicking on the image** may link you to a pest information sheet.
6. See if you can match your suspect pest to the **pest information sheet** (pest signature).

Type of crop	Ornamentals	Fruit	Vegetables	Field crop

Which fruit crop?	Apple 	Banana	Cherry	Peach	Etc

What part of the apple tree is affected?	Leaves 	Flowers	Fruit	Trunk	Roots

What signs & symptoms match your specimen?	Powdery mildew	Spots  Black spot	Scales	Etc

Pest information sheet available	Black spot (apple scab) How much of the suspect problem can you match with the pest information sheet, ie a pest signature?

DIAGNOSIS BASED ON REFERENCES

Most diagnoses include references of one type or another

PROVIDE, CONFIRM OR REJECT A DIAGNOSIS

A preliminary diagnosis can often be made from descriptions and illustrations of **specific** (distinctive) signs and symptoms. For problems less easily diagnosed and where a definite diagnosis is required, further reference checks are necessary to indicate the best way to proceed, eg

- More detailed **microscopic examinations** of fungal spores or tiny insects may confirm your diagnosis. You may be able to do that yourself, or do some simple tests.
- **Pest information sheets** can provide the information required for matching all, or as many as feasible, of the specific components of a **pest signature**, eg host range, signs and symptoms, diagnostic tests, patterns of, time and place of occurrence, site conditions and crop records.
- Remember, laboratory tests or expert advice may still be required.

CAUTION WITH REFERENCES

Just because you have consulted books, colleagues or computers, does not mean that that your diagnosis has been confirmed; it may still be inconclusive, particularly if it is a complex problem.

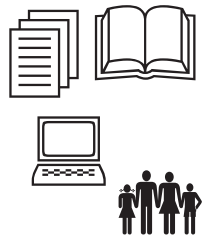
- **Good references** are essential and are based on reliable information produced by qualified researchers. Although **recent** references are preferred and some **must** be up-to-date, eg pesticide and quarantine information, older references may describe a problem more extensively.
  - **Diagnostic references** may **not** include recent exotic introductions. It may take years for some pests to be recognized and identified after their arrival in Australia, eg potato cyst nematode in Western Australia. Others, such as poplar rust, which attack leaves, are easily seen, spread quickly and are soon identified.
  - **Control references** may not include current recommendations, especially in regard to registered pesticides.
  - **Do not rely on a single website, textbook or colleagues**, eg internet blog sites are an unreliable source of scientific information.
  - **Overseas sources** are helpful, but use with caution as many problems listed do **not** necessarily occur in Australia, or if they do, not in your region.
  - **Be wary of hearsay accounts** especially when not backed up with recorded information or specimens.
- **For little known hosts and pests** there may be few if any references, so that there may be no list of pests, or if there is, your pest may not be included. Pest information sheets may not be available.
- **Keys and expert systems** should be used as **guides only** and it may be necessary to back any diagnosis by further investigations or testing. Some keys are used by **growers**, others by **experts**. To use a key one needs to know the **vocabulary** of plants, insects or diseases. Distance diagnosis by experts can speed up the process.
  - **Complex causes of plant problems** create variability in signs and symptoms which is often the reason why keys may not work. This is why site visits are often necessary.
  - **Either/or keys** can be difficult for the non-expert to use. It is easy to go wrong, eg you make the **wrong** choice, or **can't** make a choice for various reasons:
    - Organisms are unfamiliar, too small or broken.
    - Key may only include the more common pests and symptoms, your pest may be little known and not included. You may be trying to key out a mite in a key to insect orders.
    - There are large groups of organisms or plants in the key.
  - **Interactive keys and expert systems**:
    - Are better for complex causes and non-specific symptoms.
    - Only a limited number of interactive keys and expert systems are available.
- **Image matching** seems easy and quick, **but**
  - **Identification based** on image-matching **alone** may lead to **mis-diagnosis,** subsequent incorrect treatment, lost time and money (see pages 106, 107).
  - **A good diagnostician** will use images in the **overall context** of the problem. This is critical when symptoms are **not distinctive enough** for a useful identification.
  - **In many instances** more than one cause may be involved, or the one diagnosed may be a secondary or tertiary problem. Site visits may be necessary.
  - **Image-matching is better** used for identifying **insects and plants**, than **diseases** which produce non-specific symptoms, eg leaf yellowing (see page 125).
  - **Samples** are still needed for diagnosing many problems, eg culturing bacteria and fungi, diagnostic tests for virus diseases, soil and water analyses.
  - **When in doubt** about a diagnosis, seek expert advice.

SUMMARY

Step 5. Consult references

Each step of the diagnostic process reduces the possibilities, eliminating unlikely causes. Recall the original enquiry (Step 1). Having identified the affected plant (Step 2) you have access to a list of potential pests and pest information sheets (a pest signature) for each problem. You have examined the plant (Step 3) and visited or asked questions about the site (Step 4) and have tried to match the pest signs and symptoms and information about the site with illustrations and descriptions in the pest signature (Step 5). You may or may not have made a diagnosis (Step 7).

REFERENCES



Access and use references **at any stage** of the diagnostic process.

- **Books, colleagues, computers**
  - Paper trail, eg books, leaflets.
  - Colleagues, eg industry organizations.
  - Computers, eg websites, CD Roms.
  - Keep records of references used for future use and as proof of your diagnosis.
- **What can I find out?**
  - **Host and pest indices** preferably for your region.
  - **Pest information sheets** conveying specific information about a particular pest, ie the **pest signature**. They may include pest calendars, diagnostic tests and the availability of early warning services (predictive pest services).
  - **Keys and expert systems** which help identify plants, pests and diseases. They must be used with care where complex causes are thought to occur.
  - **Image-matching** is useful in diagnosis providing signs and symptoms are specific (distinctive) and easily recognized.
- **Diagnosis based on references**
  - The preliminary diagnosis can be confirmed or rejected. Use references to provide proof of identity or eliminate suspects.
- **Use references with caution**
  - **Always check** that diagnostic and control references are providing up-to-date information.
  - **Overseas references** are often not applicable to Australia.
  - **Image matching** can lead to **mis-diagnosis** where signs and symptoms are not specific (distinctive), as may occur with many diseases.
  - **Either/or keys** can be difficult to use. Multi-access/interactive keys and expert systems are more user-friendly.
  - **Popular/hearsay** accounts, especially when not backed up with recorded data or specimens, are likely to be inaccurate.
- **If uncertainty** about the diagnosis persists, you can either report the diagnosis (Step 7) to the extent that you can, or if a more definite diagnosis is required, seek expert help (Step 6).

FURTHER STEPS

Step 6. Seek expert advice.
Step 7. Report the diagnosis.

CASE STUDIES

Step 5. Consult references

These case studies indicate the range of references available and their limitations.

1. DIAGNOSIS CAN BE HAZARDOUS?

	**Home gardener** produced a bottle with an unusual 'worm' in it and wanted to know its name and if it was 'good' for the garden.
	-
	At first glance it didn't look very worm-like and on closer examination, the scales and forked tongue looked distinctly snake-like!
	-
	Snakes have scales on their body, a forking tongue, eyes, & slides on its belly. Worms have a segmented body giving it a ringed appearance, no eyes and 'crawls' by lengthening its front part, pushing through soil then pulling the hind part up. Snakes are vertebrates, worms have no backbone.
XPERT	
	**Useful diagnosis**. Baby snake, possibly brown snake. For a specific identification it would need to be sent to a herpetologist.

2. HUMAN ERROR, ACCESSING RECORDS

	Successive batches of nursery seedlings not growing as they should. Client thought it was **damping off** problems. This problem had occurred twice in a row.
	**Wide range of seedlings** in the nursery.
	**Non-specific** symptoms of a nutrient problem. Unable to match them to a specific deficiency.
	**All seedlings** were affected indicating it was likely to be a **non-parasitic problem** rather than damping off.
	**Records of calculations** for preparing mix checked, no error found. It was decided to work with staff preparing a batch of mix. It was found that the **volume** of the mixing vessel was actually half that used in the calculations!
XPERT	-
	**Useful diagnosis.** Human error in preparing mixes. The mix had twice as many nutrients as necessary, the cause of the poor growth.

3. WEEDS WITHOUT FLOWERS

	Client brought in samples of plants from a paddock for identification. Was it Paterson's curse? Plants were in early stages of growth, no flowers.
	Plants identified as **Paterson's Curse**. Seedling, pre-flowering plants and mown weeds (due to their abnormal habit) can be hard to identify. Herbicide control is more effective when plants are in the rosette stage rather than when they are fully developed and flowering, so identification of early stages is important.
	
	-
	Identification was confirmed from noxious weeds leaflets.
XPERT	-
	**Useful diagnosis**. Paterson's curse is toxic to horses & pigs. Client advised to check if there were legal obligations for control in their region.

4. N0 MATCHING PEST SIGNATURE

	**Landscaper** with beds of stock plants with splitting and breakdown of stems just above ground level.
	**Stock**. Lists of pests & pest information sheets available.
	Looked like a collar rot. Examined specimens microscopically but found no fungal organisms *(see page 11)*.
	-
	**Unable to match** problem with a pest signature of problems affecting stock. Client willing to send sample to a diagnostic service.
XPERT	**The diagnostic service** indicated that it was frost damage which had been invaded by secondary yeast fungi.
	**Useful diagnosis**. Frost injury at soil line. Questions revealed that plants were mulched after planting which in cold areas may increase frost damage.

5. REFERENCES NOT HELPFUL

	Client enquiry accompanied with specimens of deformed hydrangea flowers.
	**Hydrangea**. List of problems & information sheets available.
	All or some florets were **cupped** on some flowers only *(see page 143)*. Possibly a **parasitic problem**. No obvious pests or diseases found. Some cultivars have cupped florets, greening can cause similar symptoms. A few mites were observed.
	Questions revealed that about half the plants were affected. Plants were 35 years old, problem been observed the last 1-2 years.
	Illustrations and descriptions could not be found that matched the problem. Suggested seeking expert help. Client unwilling to accept the cost.
XPERT	-
	**Inconclusive diagnosis** Cupping of florets may be due to the sap sucking activities of mites. For a more definite diagnosis expert help is needed.

6. HERBICIDE INJURY?

	Sample of what looked like herbicide injury to roses. Client concerned because glyphosate was used near rose beds.
	**Roses.** List of problems and information sheets available.
	**Leaf samples** showed vein-clearing which can be a symptom of some types of pesticide injury but not usually glyphosate.
	**Questions** revealed that only a **few shoots** were affected on a **few plants**, indicating that it was probably a **parasitic** problem.
	Several viruses infect roses and are referred to as 'rose mosaic'. Coloured illustrations of one matched the suspect leaves *(see pages 107, 135)*.
XPERT	-
	**Useful diagnosis.** Rose mosaic virus. Client was provided with a pest information sheet for rose mosaic. Partner off the hook!

REVIEW QUESTIONS & ACTIVITIES

Step 5. Consult references

1. List at least **2 precautions** when using each of the following:

References (books, colleagues, computers)
Keys
Image-matching

2. If possible, **use a computerized system** to diagnose at least **1** plant problem of your choice.

3. Access at least **1 reference** for each of the following:

	Books/Leaflets	Colleagues	Internet/CD rom
Identification of a weed			
Identification of a plant			
Identification of a parasitic flowering plant			
Identification of an insect			
Identification of a disease			
Identification of disease symptoms			
Host index			
Pest index			
Pest information sheet			
An either/or key			
An interactive/multi-access key			
A diagnostic test			
Forms for recording observations & information from a site visit			
A checklist to help with diagnosis			
A submission form which would accompany samples sent to a diagnostic service			
An early warning service (predictive pest service)			
How to collect and label specimens and samples			
A training program in diagnosis			

Step 6. Seek expert help



How can the experts help me? *88*

Diagnostic services *89*
- List of diagnostic services *91*

Diagnostic 'tests' *93*
- **Types of 'tests';** *94*
  - Signs & symptoms *94*
  - Microscopy & electron microscopy *94*
  - Taxonomy *95*
  - Isolation, culturing & baiting *95*
  - Indicator plants *96*
  - Biochemical tests *96*
  - Serology, ELISA *97*
  - DNA fingerprints *97*
  - Koch's rules *98*
  - Soil, media, water & plant tissue analyses *98*

Diagnosis based on expert advice *99*

Summary *100*

Case studies *101*

Review questions & activities *102*

HOW CAN THE EXPERTS HELP ME?

The trick is knowing when to call in expert help

By definition an expert is someone with knowledge and experience on a particular topic. To the home gardener this might be someone who has made a hobby of growing a particular plant, but at the other end of the spectrum, if there are legal responsibilities or high value crops are affected, the expert must be formally trained and accredited.

WHAT EXPERTS CAN DO





Many diagnostic tests

You have made a **preliminary diagnosis** from signs and symptoms and site observations and questions, but the client's enquiry requires a **more definite diagnosis**. Experts and diagnostic services can:

- Provide information on how to **collect, package and dispatch samples** to them.
- Provide a **submission form** to accompany any samples sent to them.
- **Provide, confirm or reject a diagnosis** which is as definite and reliable as required. Diagnostic services can provide rapid and accurate identification of some pests and a variety of management options.
- Provide a **permanent record** of the diagnosis as **proof of identity**.
- **Provide proof of identity** by performing appropriate tests or procedures, eg
  - **Samples and specimens can be examined** using techniques not available to growers, eg entomologists can use high powered microscopes to identify insects or mites and provide their scientific name.
  - Discriminate between **strains and races** of species of fungi, bacteria, viruses, nematodes and other disease organisms. Also identify resistant strains of weeds.
  - Water, soil and plant analysis, **ELISA** tests, **DNA** tests.
  - Provide advice on the suitability of **on-site** diagnostic kits.
  - Subject likely **non-parasitic problems** to experimental proof. This can be difficult. How do you prove conclusively that it was a non-residual herbicide applied 4-6 months ago that caused the yellowing of foliage the following spring? You may have records of the application and be able to access references which say it is possible, but the client may still be sceptical. Are tests likely to provide evidence? Experts are more likely to be able to explain the occurrence.
- **Assist with interpretation** of signs and symptoms, information gathered from a site visit and any previous on-site tests in a more expert way, ie matching the signs and symptoms and collected data to a pest information sheet, ie its pest signature.
- **Provide disease-testing services** for certification schemes, eg for orchids, potatoes and strawberries.
- **Help you comply with legislative** or quality assurance requirements, eg quarantine, trade. Explaining the need for **scientific names** for these problems, eg different species of fruit fly or *Phytophthora*.
- **Help you to access information** on:
  - **Pests** and pest information sheets for key pests, diseases and weeds.
  - **Scouting and monitoring**.
  - The availability of **early warning services** (predictive pest services).
  - **Specific crops**, eg the **IPM** and **BMP** programs available for crops such as grapevines. **NIASA** (Nursery Industry Accreditation Scheme Australia) may also provide information on the use of fertilisers, pesticides, companion planting, beneficial insects and quarantine strategies.





IMPROVE SKILLS IN DIAGNOSIS



Regular consultations with experts can add to your skills.

- Some diagnostic services provide **training** in diagnostics.
- Working within a **plant clinic**, if properly organised, is very helpful and allows you to continually up-date your skills.
- Make a habit of **following up** any problems that are inconclusive.
- Further training opportunities are described on page 185.

KEEP RECORDS



Keep the permanent record of diagnostic advice provided by the expert as proof of diagnosis and future reference, eg how and by whom the problem was identified (see page 119).

DIAGNOSTIC SERVICES

Diagnostic services and expert help provide rapid and accurate identification of some pests, providing a variety of management options. Improved diagnostic services and assistance in planning and decision-making is one of the objectives of the national strategy for the management of pesticides.

LEGISLATION



Diagnostic services and experts may have legal obligations to:

- Provide **accurate up-to-date advice** on scouting, monitoring, identifying, reporting and controlling pests, noxious weeds, vertebrate and other pests. **Quarantine** has responsibilities to scout, detect, monitor and report suspected exotic or illegal pests to prevent their spread into and within Australia.
- Advise on **appropriate management**, eg compulsory use of resistant varieties, disease-tested planting material, phytosanitary or pesticide treatments.
- Detecting residues of pesticides and fertilizers for compliance with Organic Standards.
- **Accreditation and quality assurance schemes**, eg **NIASA** and various **BMP** and **IPM** programs include requirements for scouting, detecting and monitoring specified pests in certain crops.

HOW DEFINITE WILL THE DIAGNOSIS BE?

Hopefully the diagnosis is as definite as required. However, the diagnosis may still be only **preliminary** or it may be **inconclusive** (see page 26). Further investigations may be necessary.

RELIABILITY

How reliable is the diagnostic service?

- **Commercial diagnostic services must meet certain standards** and be independently assessed, demonstrating their professionalism. Recognized standard diagnostic techniques and tests must be used (see pages 27, 122).
- **Diagnostic national standards** are being developed for significant high risk pest threats to economic crops, eg banana, sugar, grains, viticulture and nursery industries. **If collecting** a permanent record of a living organism, certain information must be recorded (see page 122).
- **Seeking professional assistance** may result in high costs for a pretty simple diagnosis but it is usually quick and reliable.

HOW DIAGNOSTIC SERVICES ARE ORGANIZED

Diagnostic services may focus on particular types of tests or crops.

- **Some offer comprehensive diagnostic skills**, having a range of specialists, eg plant pathologists, entomologists, nematologists, botanists and soil scientists. From the client's point of view the multidisciplinary diagnostic service or plant clinic is ideal (see also page 120).
- **Problem-orientated services**. Some specialise in insect or weed identification, diseases or nematode counts. Others analyze soil, water and plant tissue for nutrient and pesticide residues. Many media and fertilizer companies have testing capabilities. There are specialists in seed testing and tree root identification. Some specialist tests, eg **DNA** testing, are offered only by a few laboratories.
- **Crop-orientated services** deal with specific crops. Some crops have their own diagnostic services, eg turf, grapes, cereals, nurseries, citrus, tree diseases, with websites for updates on pest situations and current publications.
- **Diagnostic networks**. With the introduction of Quality Assurance (**QA**) frameworks, a network of laboratories may operate together. If submitted samples produce a negative result in one expert area, they may be forwarded to other laboratories, or extension agents may be contacted. Site visits may be necessary.
- **Workshops** are offered on diagnosis, you should attend if possible (see page 185).

CONTACTING DIAGNOSTIC SERVICES



Access to diagnostic services is **improving** all the time and includes:

- **Face-to-face consultations** with diagnosticians are available for both commercial growers and gardeners.
- **Enquiries can be mailed** to both commercial and garden advisory services, including columns in local, regional newspapers and magazines.
- **Telephone** advice is available from most commercial and garden advisory services (see page 117). A correctly labelled sample may be requested.
- **Email**. Images of insects and diseased plants obtained by camera or microscope can be emailed to a diagnostic laboratory. Distance imaging is useful for both commercial growers and home gardeners. It removes the problem of specimen deterioration in the mail and quarantine restrictions, speeding up diagnoses and management responses. However, there are **limitations**, eg for a definite diagnosis of some bacterial or virus diseases, soil and water problems, it is necessary to submit samples to a laboratory. A site visit may be necessary for tree and soil problems.

HOW CAN I HELP THE DIAGNOSTIC SERVICE?



Always contact the diagnostic service first and check the following:

- The **services offered**. Can they provide the service you require?
- What **tests** may be done, their cost and how long they will take.
- **How to obtain their submission form** from the website or through the mail and fill it in as best you can (see page 121). This will give the diagnostic service the information they need to provide a correct diagnosis. This must accompany the sample. Inadequate information regarding treatments, weather and soil types, may result in an incorrect or incomplete diagnosis.
- **Collect, package and dispatch samples** correctly (see page 178). If a diagnosis is negative, correctly prepared samples may be forwarded to other laboratories for further tests.

COST



Commercial diagnostic services, private or government, are usually 'user pays'.

- **Seeking professional assistance can be costly** but can result in the saving of thousands of dollars. The expense of using diagnostic services must be balanced against the legal and commercial cost of not using them. Diagnostic services also provide advice on prevention and control. It may not be cost-effective for the home gardener to send one ailing plant for expert advice.
- **Free** specialist diagnostic services are available for some problems in some areas, eg
  - Quarantine Hotline services.
  - Broomrape identification in grain crops (GrainGuard in WA).
  - Research projects, eg identifying viruses present in cowpea, faba bean and canola crops.
  - Garden advisory services attached to local horticultural colleges, are often free for home gardeners as are some TV and radio garden shows.

WHY SOME GROWERS DO NOT USE DIAGNOSTIC SERVICES

Growers may avoid using diagnostic services for a variety of reasons (not always logical), including:

- **Cost** (see above).
- **Diagnostic services not always available** or too far away. No matter how accessible these services become there are always some who feel they are not accessible enough.
- **Lack of confidence** in using electronic methods to gain advice or filling in submission forms which accompany samples.
- **The length of time** needed to prepare and send samples and for results to come back. This is getting better with improved testing techniques, increased competition and distance diagnosis. For some problems response can be instantaneous by email or by fax. Some bacterial tests may take 1-5 days to complete, viral testing is more variable. For the commercial grower, time is critical.
- **Concern about financial backlash** if a disease is known to exist on a property, there may be hostility from neighbours. Control methods may be legally enforceable but financially detrimental. They could go broke!
- **Distrust of professional services**, which are thought to have made mistakes in the past. If you are going to test one diagnostic facility against another, the samples submitted to each must be as identical as possible. Each laboratory should receive half of each plant sampled the **same** day, otherwise diagnosis and advice may vary. Some errors in diagnosis are the result of poor timing of sample collection, incorrect collection, packaging and mailing.
- **Over-confidence in ones own diagnostic ability**. It is easier to identify weeds and insects than diseases. Identifying many diseases is seldom simple. Diseased roots are usually more difficult to inspect than foliage because soil often obscures the symptoms and several fungal diseases can cause similar symptoms. If you are going to attempt in-house diagnosis of the more difficult problems you will need to have:
  - **Sophisticated equipment**. Some growers assume they already have the required diagnostic equipment; they may have a dissecting microscope with a magnification of x40 to x60 which is suitable for insect and mite identification but **not** for most plant disease organisms.
  - **Someone in the business** with time, expertise and a willingness to learn. A realistic goal for a grower may be to select 6-10 important recurring diseases in their crop, learn how to identify them and send the remainder to a diagnostic service.

List of diagnostic services

Home garden advice may be provided by your local horticulture college, botanic gardens, garden centres and garden clubs. Talkback radio, Gardening Australia TV and newspapers all provide further opportunities for gardeners to seek advice. Pre-recorded telephone messages about seasonal problems and fact sheets available on-line are a big help for gardeners. However, **a pest still needs to be correctly identified**. Some garden advisory services are offered in conjunction with commercial services.

Commercial diagnostic services are offered by private consultants, industry associations and state departments of primary industry. Diagnostic services for specific crops may be available, eg grape, cotton and turf. For some crops there may be a 'One Stop Shop for Your Crop' via the internet, eg CropWatch Online for grapevines. Local councils offer advice on noxious weeds and vertebrate pests, bees, possums. The following are examples of some commercial diagnostic services:

AUSTRALIA-WIDE

GrowSearch Australia

GrowSearch Australia is an information service for producers of ornamentals, horticultural and nursery crops. www2.dpi.qld.gov.au/growsearch
PO Box 327, Cleveland, Qld 4163
☎ (07) 3821 3784, 3824 9555 **Fax** (07) 3286 7618
email growsearch@dpi.qld.gov.au

Plant quarantine

Freecall 1800 020 504

Plant Health Australia is the peak national coordinating body for plant health in Australia. There are links to the websites below at www.planthealthaustralia.com.au/

PaDIL (Pest and Diseases Image Library) provides high quality images of exotic organisms, assists with diagnostics, trains and encourages public awareness in quarantine. www.padil.gov.au

APPD (Australian Plant Pest Database) is a nationally coordinated database of plant pests and diseases. There is restricted access.

EPPH (Exotic Plant Pest Hotline) enables members of Australia's plant production sectors and plant health services to report suspect exotic plant pests. They should also be reported to your local Dept of Agriculture or Primary Industries.
Free call Hotline 1800 084 881

National Pest and Disease Outbreaks
You can subscribe to receive free updates on national pest and disease outbreaks as information becomes available. www.outbreak.gov.au/

Turf Consultants

SportsTurf
☎ (03) 9574 9066 **Fax** (03) 9574 9072
email info@sportsturf.com.au
www.sportsturf.com.au

Globe Australia
☎ (02) 9791 1111
email sales@globeaustralia.com.au
www.globeaustralia.com.au

Australian Golf Course Superintendants Assoc. (AGSCAtech)
☎ (03) 9548 8600 **Fax** (03) 9548 8622
email info@agcsa.com.au
www.agcsa.com.au/

NORTHERN AUSTRALIA

Northern Australia Diagnostics Network (NADN)

includes NT, north WA and north Queensland. Research develops sustainable technologies for protecting Australia from exotic and endemic pests and aims to increase pest resistance to pests. Based at the University of Queensland. www.tpp.uq.edu.au/

Communication officer
CRCTPP [Cooperative Research Centre (CRC) for Tropical Plant Protection (TPP)]
Level 5 John Hines Building
The University of Queensland, Qld 4072
☎ (07) 3365 4776 **Fax** (02) 3365 4771

AUSTRALAIN CAPITAL TERRITORY

XCS Consulting

A European Wasp and Insect Identification Service.
☎ (02) 6162 1914

NEW SOUTH WALES

Plant Health Diagnostic Service (PHDS), NSW Agric

Services offered include plant pest and disease identification, soil, water and plant analysis and testing for chemical, pesticide and antibiotic residues.

Elizabeth MacArthur Agriculture Institute
Woodbridge Road, Menangle, NSW 2568
☎ (02) 4640 6428 **Fax** (02) 4640 6415
email phds.menangle@agric.nsw.gov.au

Orange Agricultural Institute
Forest Road, Orange, NSW 2800
☎ (02) 6391 3800, 1800 675 821 **Fax** (02) 6391 3899
email phds.orange@agric.nsw.gov.au

Yanco Agricultural Institute
80 Trunk Road, Yanco, NSW 2703
☎ (02) 6951 2611 **Fax** (02) 6951 2719
email phds.yanco@agric.nsw.gov.au

Wagga Wagga Agricultural Institute
Pine Gully Road, Wagga Wagga, NSW 2650
☎ (02) 6938 1999 **Fax** (02) 6938 1822
email phds.waggawagga@agric.nsw.gov.au

Plant Disease Diagnostic Service

Royal Botanic Gardens
Mrs Macquarie's Road, Sydney, NSW 2000
☎ (02) 9231 8186
www.rbgsyd.gov.au

NORTHERN TERRITORY

Dept. of Primary Industry, Fisheries and Mines

Entomology A range of entomological services is provided to growers, government departments, householders, home gardeners and the general public.
☎ (08) 8999 2257 **Fax** (08) 8999 2312

Plant Pathology Plant disease diagnosis, monitoring and advisory services and disease management.
☎ (08) 8999 2264 **Fax** (08) 8999 2312

Weeds
☎ (08) 8999 2380

Address
Berrimah Farm
Makagon Road, Berrimah, NT 828
GPO Box 3000, Darwin, NT 801
www.nt.gov.au/dpif

QUEENSLAND

Dept. of Primary Industries

Grow Help Australia provides a comprehensive range of diagnostic services to growers of nursery, flower, ornamental and other horticultural crops.

Grow Help Client Service Officer
PO Box 327, Cleveland, Qld 4163
☎ (07) 3824 9526 **Fax** 07 3286 3094
email growhelp@dpi.qld.gov.au
www2.dpi.qld.gov.au/horticulture

Grow Help Laboratory
80 Meiers Road, Indooroopilly, Qld 4068
☎ (07) 3896 9590 **Fax** 07 3896 9533

Nematode diagnostic services
Biological Crop Protection
3601 Moggill Road, Moggill, Qld 4070
☎ (03) 3202 7419 **Fax** (03) 3202 8033
email biolcrop@powerup.com.au

SOUTH AUSTRALIA

SA Research & Development Institute (SARDI)

Diagnostic Services offered include disease and insect identification for all horticultural crops. Details of causes of disease and guidelines for control may be provided when required. Samples may be posted or delivered.
www.sardi.sa.gov.au/horticulture

Diseases ☎ (08) 8303 9562

Post to:
SARDI Horticulture Pathology
Diagnostic Service
Plant Research Service
Locked Bag 100,
Glen Osmond, SA 5064

Deliver to:
SARDI Horticulture Pathology
Diagnostic Service
Plant Research Centre
Gateway 2A
Hartley Grove,
UMBRAE, SA 5064

SOUTH AUSTRALIA *(contd)*

Insects ☎ (08) 8303 9540

Post to:
SARDI Entomology
Diagnostic Service
Main Building, Waite
GPO Box 397,
Adelaide 5001

Deliver to:
SARDI Entomology
Diagnostic Service
Main Building
Waite Road
UMBRAE, SA 5064

TASMANIA

Dept. of Primary Industries, Water & Environment

Diagnostic Services offer comprehensive range of services including ELISA and pathogen testing (TASAG). www.dpiwe.tas.gov.au

Diagnostic Services
St Johns Avenue, Newtown, Tas 7008
☎ (03) 6233 6845, 6233 6833 **Fax** 6278 2716

VICTORIA

Dept. of Primary Industries

Crop Health Services offers a comprehensive range of diagnostic services for plant diseases and pests and will provide management recommendations as appropriate. Also provides disease-tested planting material of potatoes, strawberries and other crops and monitoring services **(Cropwatch)** www.dpi.vic.gov.au/

Crop Health Services
621 Burwood Highway, Knoxfield, Vic 3180
Private Bag 15
Ferntree Gully Delivery Centre, Vic 3156
☎ (03) 9210 9356 **Fax** (03) 9887 3166

WESTERN AUSTRALIA

Department of Agriculture

AGWEST Plant Laboratories provides a range of services including seeds certification, weed and insect identification and plant disease diagnosis. **Grain Guard** is a free specialist diagnostic service for some pest species, eg broomrape in WA. www.agric.wa.gov.au

AGWEST Plant Laboratories
3 Baron-Hay Court, South Perth, WA 6151
☎ (08) 9368 3721 **Fax** (08) 9474 2658
email agwestplantlabs@agric.wa.gov.au

DIAGNOSTIC 'TESTS'

In this book the term **diagnostic test** or **test** is used to describe any method or procedure which establishes the presence of an organism or causal agent. A wide variety of tools are available to interpret or diagnose plant health problems. Examining weather records, conducting various tests, testing soil and culturing plant tissues all play important roles in getting to the bottom of a problem. A grower should know the different types of tests a diagnostic service can offer. Remember, knowing the type of plant, its present site conditions and management history is the key to making many diagnoses.

EFFECTIVE DIAGNOSTIC TESTS

Ideally an effective diagnostic test will:

- **Be simple, accurate, rapid and safe** to perform, yet sensitive enough to avoid 'false positives'. Some are rapid and accurate but others may take a long time to provide a result, eg culturing some fungi. Some need lots of test material.
- **Be reliable**. Test material may be contaminated with various organisms or with a deep seated infection like a wilt fungus which can frustrate efforts to isolate pure cultures. Traditional test procedures of culturing and microscopy can therefore be **less reliable** than those based on newer techniques, which are less easily affected by subtle changes.
- **Provide early and quick detection** of some diseases before symptoms are apparent. If plant material has to be guaranteed free of specified diseases for quarantine purposes or the production of certified planting material, speed is essential.

ON-SITE AND LABORATORY TESTS

There are an increasing number of easy-to-use on-site diagnostic tests for virus, fungal and bacterial diseases that give a result within minutes.

- **In Australia** diagnostic test kits are mostly used in diagnostic laboratories rather than on-site.
- **Some on-site tests** are **not** as detailed or as accurate as laboratory tests, and remember the on-site test still has to be **interpreted** accurately in the context of the overall situation (see page 66).
- **Most diagnostic test kits** are manufactured **overseas** by a few companies, eg Hydros Inc. (www.hydros.cc/), Neogen Europe Ltd (www.neogeneurope.com/), and Agdia Inc. (www.agdia.com/). Most have to be refrigerated and have a use-by date.

CAUTIONS WITH TESTS

Over-reliance on a single test can mean that some causes may be missed in complex situations or that the wrong organism is diagnosed simply because the true organism is outside the scope of the test.

- Some tests may only **detect or identify**, they may **not** provide any quantitative assessment. **Root knot nematodes** can be detected and identified but must then be assayed to see if numbers are sufficient to warrant treatment.
- **Success in using diagnostic test kits** is only as accurate as the samples taken. As disease organisms are not usually evenly distributed throughout the plant, follow instructions for sampling carefully.
- **Small amounts of a disease invasion** are often not significant and no action may be required. **Exceptions** include quarantine pests, eg citrus canker, and plant material for use in certification schemes, eg virus diseases of potato.
- Tests for many **less well-known** organisms are not available because the markets are too small.
- Tests to identify **particular** problems, eg bacteria, fungi, are described on pages 179-184.

MATERIAL WHICH CAN BE TESTED

Obtain **directions from the diagnostic service** for **collecting, packaging and dispatching samples** so that they arrive in a satisfactory condition (see pages 177, 178). Ensure their submission form is completed. Material which can be tested includes:

- **Soil and water**, which are the most commonly requested analyses.
- **Plant material**, eg leaf tissue, seeds, food supplies, parent stock for certification schemes such as strawberry, cut flowers, potatoes and grapevines.
- **Air may be analyzed** for pollutants.


Soil sample


Water sample


Seeds, bulbs


Plant tissue analysis

Types of diagnostic 'tests'

SIGNS & SYMPTOMS

If signs and symptoms are **specific** (distinct) many growers will be able to diagnose some pests, diseases and weeds.

- Some pests and weeds are easy for the grower to identify.
- Some diseases produce **specific** (distinctive) symptoms enabling the grower to make a preliminary diagnosis.
- However, many diseases, and some pests produce **non-specific** (indistinct) signs and symptoms which are difficult for a grower to recognize. Most nematodes and many viral, bacterial and fungal diseases can only be identified if samples are sent to a laboratory for detailed examination or diagnostic tests.
- Experts are more skilled in **recognising** and **interpreting** signs and symptoms.
- Signs and symptoms are described in detail on pages 48-50 and 123-174.



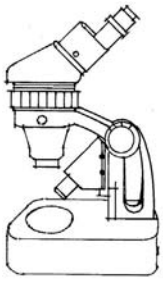
Distinctive sign – caterpillar of the small citrus butterfly



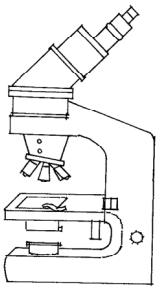
Distinctive symptom – hormone herbicide injury to ash

MICROSCOPY & ELECTRON MICROSCOPY





Dissecting stereo-microscope



Binocular compound microscope

Microscopic **morphological** examination of some insects, fungi and other organisms, enables them to be definitely identified. Direct microscope examination of diseased material has the advantage of **detecting** disease organisms that **cannot** be cultured artificially, eg powdery or downy mildews, or where culturing is not possible due to recent fungicide applications.

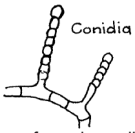
- **A hand lens** (x 10) is useful for examining leaves for insects and mites and visible signs of disease organisms. Growers may also have a **dissecting stereo-microscope** with a top magnification of x40 to x60, which is suitable for identifying many insects and mites but **not** for many disease organisms. These examinations could **precede** sending samples, correctly prepared and labeled, to a diagnostic service.
- **Binocular compound microscopes** (x100, x200, x400) are mainly used in diagnostic laboratories for basic **fungal** identification. The higher magnification is essential. Small fragments of rotted tissue can be teased out, stained and examined under the microscope.
- **Electron microscopy** is only available in diagnostic laboratories. It is necessary for identifying the shape of virus particles (rods, bullets or sphericals) in plant sap or ultra-thin plant segments. For some viruses though, the shape of particles is not a reliable means of identification. Electron microscopes are also used for more detailed examination of insects, mites, nematodes, bacterial and fungal organisms in infected plant material.
- **Limitations**. Techniques which rely on microscopy depend on the quality of the specimen and the extent to which the samples are representative of the problem.



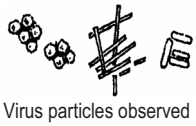
Insect antennae observed using a hand lens or dissecting microscope



Nematodes observed using either a hand lens or dissecting microscope



Spores of powdery mildew seen under a dissecting or compound microscope

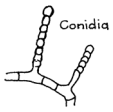


Virus particles observed using an electron microscope

TAXONOMY







ELISA Testing Service

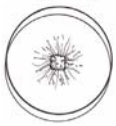


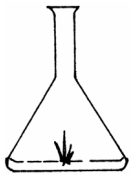
Taxonomy is the **naming, describing, and classification** of plants and animals to enable taxonomists to distinguish between organisms. The Swedish scientist, Carolus Linnaeus (1707-78) developed the system, which bears his name, of dividing up the plant and animal world into categories based on their **structure** (morphology) to arrange them in a hierarchical order using the Swedish army as a model. To avoid confusion, Latin, the international language of the time, was used to **name** plants and animals. Taxonomy involves **identifying** plants and animals. In commercial situations, scientific names are essential (see pages 25, 36 and 179).

- **'Tools' available** to the taxonomist include:
  - **Morphology** of affected plants, pests and diseases.
  - **A wide range of tests**, eg ELISA tests for viruses.
  - **DNA** techniques which have transformed the approach to taxonomy and complement the work of those who use morphological features.
  - **Keys and expert systems**, which are more reliably used by diagnostic services.
- **To make the most of these tools** and enhance diagnostic capacity, experts need:
  - **Fast computers** to handle the large amount of information generated by the analysis of **DNA** sequences, the **morphological features** of plants and diagnostic **tests**.
  - **To network**. Taxonomists regularly exchange information and specimens with each other. The purpose being to determine taxonomic relationships among plants, pests and micro-organisms using authenticated **type** specimens, which can later be drawn upon to confirm or reject a suspect identity.
  - **To be aware that changes in taxonomic status** are almost inevitable given that taxonomy is an interpretative science. Different conclusions may be drawn by different people from (apparently) the same structures. Taxonomic decisions of individual workers are sometimes revised by their peers resulting in name changes. Even the most detailed taxonomic analysis is open to interpretation and a diversity of opinions may arise when natural plant groups are named.
  - **To develop easy-to-use interactive keys and expert systems** enabling common plants, pests and diseases to be easily identified. This is happening.

ISOLATION, CULTURE & BAITING







There are various techniques for isolating and identifying certain bacterial or fungal disease organisms. The process can take days or weeks. Some can be recorded permanently by camera with or without the aid of a microscope so that test material is not destroyed.

- **Direct isolations** from plant parts are a reliable way to detect and identify certain bacterial and fungal disease organisms. Pieces of infected plant tissue are placed on agar or other media and any organisms that grow from them are identified under a microscope by a taxonomist. Most sampling and testing of fungal diseases for nursery accreditation schemes is to determine the **presence or absence** of *Phytophthora*.
- **Direct isolation followed by further culture** on general or selective media is used to obtain pure cultures of a range of disease organisms for microscopic identification, eg *Phytophthora*, *Pythium, Cylindrocladium, Rhizoctonia.*
- **Potato tissue plantlets** grown in culture tubes can be used to establish and monitor disease development in the roots and other underground plant parts.
- **Baiting** media, soil or water for *Phytophthora, Pythium*, *Rhizoctonia,* involves floating plant material, eg lupin baits, on the surface of a representative sample of soil, media or water and observing them for signs of fungal invasion and rotting which indicate the presence of disease organisms. The baits are removed, examined microscopically and the fungus cultured on selective media and identified.
- **Moist incubation of plant material**. Hyphae and spores may be produced from infected plant material when placed in a plastic bag, enabling them to be identified, eg downy mildews.

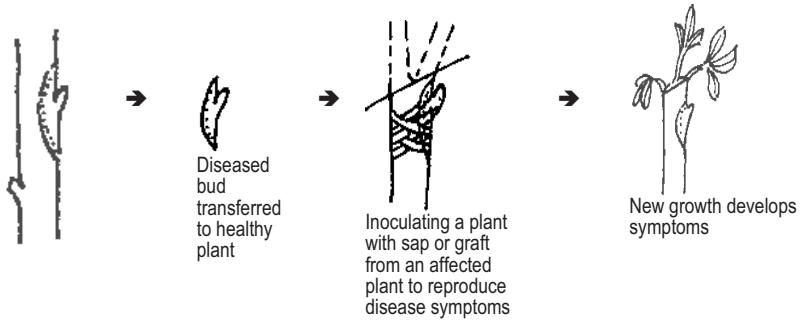
INDICATOR PLANTS

Some herbaceous plants are used as indicator plants. Leaves of tobacco and petunia readily show **specific** (distinctive) symptoms when infected with certain plant viruses. A virus can be transferred from a **diseased host plant** which does **not** show distinctive symptoms, to a **healthy indicator species** which **does** show distinctive symptoms. This can be done by budding, grafting, mechanically rubbing the plant with sap, or by one of its vectors. Indicator plants should be highly sensitive so that inoculum levels are kept below the threshold at which epidemics are initiated. Diagnostic foliage symptoms can be observed in 2-4 weeks or years, depending on the virus and the indicator host. This technique is used in:

- **Certification schemes**, eg for detecting the presence of virus in parent stock and producing disease-tested planting material for strawberry, cut flowers, potato, pome and stone fruit, grapevines.
- **Implementing quarantine strategies** to keep countries free from exotic diseases.
- **Detecting low populations of root knot nematodes**. Susceptible plants, eg tomato seedlings, are grown in soil samples for about 1 month and then the root system is removed and examined for galls.
- In greenhouses for **detecting the presence of thrips** that can transmit tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV).
- **Predicting disease outbreaks** in susceptible crops, eg rose bushes planted at the end of grapevine rows indicate when to spray for powdery mildew.
- Indicator plants may be used **in combination** with virus test kits.



Thrips (< 3 mm long)



BIOCHEMICAL TESTS



There are many biochemical tests carried out in laboratories which are **simple and efficient**. They are mainly used to identify **bacterial and fungal pathogens** for Quality Assurance (**QA**) and **accreditation schemes**. These tests are precise; species and sub-species can be identified.

- **Rapid identification methods** are based on the micro-organism's:
  - Ability to utilize various substrates.
  - Chemical and nucleic acid composition.
  - Reactions with dyes.
  - Capability of causing disease (pathogenicity).
  - Susceptibility to certain viruses or bacteriophages.
  - Other reactions.
- **BIOLOG** is an automated identification system based on the differential use of **95 different carbon sources**. Increased respiration by the **carbon-using** bacteria is indicated by a colour change. The source of the carbon could be alcohol, sugars, organic or amino acids. Each of the carbon-using micro-organisms has a metabolic fingerprint which is compared with **previously recorded fingerprints** already in the database.
- **Isozyme analysis** is based on the occurrence of different forms of the **same enzyme**. Closely related variants of the same enzyme may demonstrate that sufficient genetic variation exists within a species to support its division into separate species.
- **Some of these biochemical tests** are routinely used to settle taxonomic disputes and fingerprint patentable bacteria and fungi. They can also be used to detect and identify disease organisms and trace their spread.
- **Like most other diagnostic tests they have their limitations**.
  - They are **expensive** and are mainly used by consultants for quality assurance and accreditation schemes.
  - Relatively **large quantities of organisms** are needed compared with **DNA** methods; this is not a problem for fungi that can be grown on artificial media.

SEROLOGY, ELISA

Immunology



Virus protein injected into rabbit

TASAG ELISA and Pathogen Testing Service, Tasmania

An example of the many diagnostic services offering ELISA testing

ELISA (Enzyme-Linked Immunosorbent Assay) is a serological test for the rapid detection of some viral, bacteria and fungal organisms that cannot be easily identified by other routine tests. All warm-blooded animals have an immune system that produces antibodies in response to foreign substances introduced into the animal. A rabbit injected with a relatively harmless plant virus, produces antibodies specific to that virus. A small amount of blood is drawn from the rabbit, the virus-specific antibodies purified and then used in an **ELISA** diagnostic test kit. If the disease organism is present a coloured compound is released.

- **ELISA** tests are relatively rapid, safe and easy to use for testing large numbers of plant samples. **ELISA** tests are mainly carried out in **laboratories**. A few on-site kits are available for growers to monitor low levels of disease in the field. Some commercial growers use 'Alert Fungal Disease kits' to detect certain soil fungi, including *Phytophthora*, *Pythium* and *Rhizoctonia*. An **ELISA** test is now available for bacterial leaf and stem rot of pelargonium (*Xanthomonas campestris* pv. *pelargonii*).
  ELISA tests:
  - **Are the mainstay** of plant certification schemes where **only** disease-tested plants must be selected.
  - **May allow diseases to be treated earlier**, eg soil-borne diseases which are difficult to identify may become worth treating.
  - Can **detect and identify** the presence of known disease organisms **before** symptoms are obvious, or that can **only** be cultured in living cells.
  - **Can detect** some diseases, eg *Ralstonia* (*Pseudomonas*) *solanacearum* of potato and tomato, which often take days for confirmation using other techniques. If the **ELISA** test is positive a sub-sample can be forwarded to a laboratory for confirmation.
- **Limitations** include:
  - **Are not as sensitive** as some other methods, eg **DNA**.
  - **Serology is only useful** for identifying **previously described** disease organisms for which antibodies are available.
  - **Efficiency** of the test and results depends on the **quality** of the specimen.

DNA FINGERPRINTS



Phytophthora - IDENTIKIT™

A DNA test for *Phytophthora*

A **DNA** fingerprint can be described as a genetic photograph of a plant or animal. In general, every cell in every living thing contains **DNA unique** to that individual and is the blue-print for its development. The **DNA** of an unknown organism can be analyzed for its unique sequence (**fingerprint**). So that the sequence can be easily seen visually as a gel, a process called the Polymer Chain Reaction (**PCR**) multiplies a short segment of **DNA** over a million times. The fingerprint of an unknown organism cab then be compared with those of **known** organisms to seek a match. **DNA** technology is used in laboratories to:

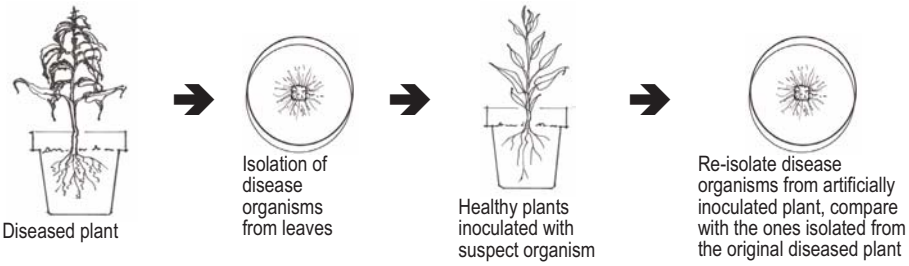
- **Complement the use of structural features** to identify exotic pests.
- **Rapidly and reliably** detect and identify unknown viruses, micro-organisms that can only be cultured in living cells and difficult-to-diagnose soil-borne diseases. Those with a long latent period between infection and development of symptoms may become worth treating if fungicides can be applied earlier.
- **More accurately identify and improve monitoring** of previously unidentified species of *Phytophthora, Armillaria, Fusarium* and other fungi.
- **Detect, identify and monitor** resistant and non-resistant strains of a fungus to fungicides at the start of any growing season. Living spores in the air can be detected and identified even before infection takes place.
- **Detect low infection levels** in small samples. **DNA**-based detection systems exhibit higher levels of sensitivity than conventional techniques, eg visual examination, selective media, seedling grow-out and serological tests.
- **Screen planting material**, eg seeds, cuttings, in certification schemes to limit spread of certain diseases.
- **Identify plants**, guarantee the authenticity of seeds, propagation material and plants being purchased and protect plant breeders' rights.
- **Develop new tests** for specific disease organisms.
- **Assist quarantine**, eg preventing importation of exotic *Phytophthora* species.
- **Determine the distribution** of exotic diseases during eradication campaigns.
- **Establish an economic threshold**, ie predicts crop loss and need for treatments.
- **Limitations**. **DNA** fingerprinting **does not** indicate the **capability** of a previously unknown organism to produce disease in plants, ie its pathogenicity.

KOCH'S RULES

Proof that the **bacteria** or **fungi** does actually cause the disease

A 100% positive diagnosis requires the identification of **both** the disease and the causal agent. An **unknown** parasitic organism must be 'tested' using Koch's rules to make sure that it is capable of causing the disease. Koch's rules establish the **disease-causing capability** of an unknown organism (its pathogenicity).

- **Koch's rules** must be satisfied before it can be accepted that a particular microorganism isolated from a diseased plant is the **cause** of the disease and not some unrelated contaminant (Agrios 1997). Koch's rules apply specifically to parasitic fungal and bacterial organisms that can be isolated from diseased plants and grown in pure culture. In principle, they can be used to prove the cause of all types of diseases:
  1. The organism must be **consistently** associated with the disease symptoms.
  2. The organism associated with the symptoms must be **isolated** in pure culture and its characteristic features ascertained.
  3. Healthy plants of the same species and cultivar inoculated with the suspect organism will become infected and **reproduce symptoms** similar to those on the plant from which it was isolated.
  4. The organism should then **be re-isolated** in pure culture from the artificially inoculated diseased plant. If the re-isolated organism is the same as the one isolated from the original diseased plant then Koch's rules have been satisfied and the organism has been proved to be the cause of the disease.
- **When are Koch's rules used?**
  - For diseases which **have not** been recorded in literature previously, Koch's rules are necessary to prove that the bacteria or fungus really does cause the disease.
  - These principles have been universally accepted as final proof for the cause of a disease and were always followed when a disease was first described.
  - **Koch's rules are seldom used today** because many of the causes of plant diseases are now well documented so that most of the more common ones can be identified with relative certainty without having to go through Koch's rules.



SOIL, WATER & PLANT TISSUE ANALYSES







Detailed analyses of soil, water and plant tissue are usually laboratory-based. Organic certification depends on regular testing for pesticides and fertilizers. **Records** of the results of analysis must be kept for **comparison** with future tests. Examples of analyses and other tests include:

- **Soil/media analysis**
  - Chemical analysis, eg pH, salinity, nutrient levels, pesticide residues.
  - Physical analysis, eg soil type, dryness, benefits of mulching.
  - Disease analysis, eg nematode identification and counts, identification of *Phytophthora, Pythium, Rhizoctonia* and other fungi.
- **Water analysis**
  - Chemical analysis, eg pH, nutrient levels, fertigation, salinity, pesticide residues.
  - Disease analysis, eg *Pythium, Phytopthora.*
- **Plant tissue analysis**
  - Chemical analysis, eg nutrient and pesticide levels.
  - Pesticide resistance, eg weeds.
  - Disease analysis, eg virus, bacteria, fungi.
- **Air analysis**, environmental monitoring, eg pollution, pesticide residues, dust levels. Information can be relayed from field sites to laboratory for analysis and use in disease prediction services.
- **Grow-on tests** are useful to confirm certain **non-parasitic disorders** such as frost where plants recover after initial exposure, or **parasitic problems** which may persist into new growth.
- **Controlled environment experiments** where temperature and other environmental parameters are controlled.

DIAGNOSIS BASED ON EXPERT ADVICE

PROVIDE, REJECT OR CONFIRM A DIAGNOSIS

When a more definite and reliable diagnosis is required appropriate specialist help or diagnostic services should to be consulted. Examples of such situations include legal disputes, quarantine, commercial growers involving considerable financial risk, certification and accreditation schemes. It is important to be clear about the following:

- That **representative samples** have been correctly collected, labelled and forwarded with a completed submission form to an appropriate specialist or diagnostic service.
- How **definite** the diagnosis should be (see page 26).
  - A **preliminary** diagnosis is based mainly on knowledge and experience in recognizing previously described signs and symptoms and their similarity to published descriptions and illustrations.
  - A **useful** diagnosis is the level at which many diagnosticians operate. Important components of the pest signature must be consistent with the sample or specimen.
  - An **accurate** diagnosis is usually acceptable to plant pathologists, growers, quarantine and courts of law. For an accurate diagnosis all facets of the pest signature must be present or their absence explained.
  - A **definite positive** diagnosis requires the identification of **both** the causal agent and the symptoms it causes. Most pests and diseases are known and well studied so that descriptions, information about their life cycles and diagnostic tests are available and can be used to confirm or reject a diagnosis.
  - A **definite negative** diagnosis of what the problem is **not**.
  - For a variety of reasons the diagnosis may be **inconclusive**.
- How **reliable** the diagnosis should be (see page 27). Where a highly reliable diagnosis is required it is important to check:
  - **The diagnostician's** accreditation and level of training.
  - **The accreditation of the laboratory** which will carry out the tests.
  - **That standard tests** will be used to identify the pest or disease organism.
  - **That standard methods** will be used to collect the samples. Information must include location, date and type of the record/pest collection/observation.
  - **That standard reporting methods** will indicate the way in which the identification has been **recorded**.
- **That a permanent record** of an expert's investigation, including results of any tests and conclusions drawn, will be produced.

SUMMARY

Step 6. Seek expert help

Each step of the diagnostic process reduces the possibilities, eliminating unlikely causes. Recall the original enquiry (Step 1). Having identified the affected plant (Step 2) you have access to a list of potential pests, diseases and weeds, and pest information sheets (pest signature) for each problem. You have examined the plant (Step 3) and may have tried to match the pest signs and symptoms with illustrations and descriptions in the pest signature (Step 5) and may or may not made a diagnosis (Step 7). A site visit and questions (Step 4) may have helped to refine your diagnosis but you may still only have managed a preliminary diagnosis.

Xperts	**To provide a more definite diagnosis** requires expert assistance. • **How can the experts help me?** They can: – Provide information on how to **collect, package and dispatch** samples. – Provide a **submission form** to accompany the samples. – Provide, confirm or reject a preliminary diagnosis which is as **definite** and as **reliable** as it needs to be. – Provide a **permanent record** of the diagnosis as proof of identity. – Assist with **interpreting** test results. – Assist with **legislation compliance**, eg quarantine regulations, accreditation scheme requirements, pesticide use. – Provide **information** on lists of possible problems, pest information sheets, diagnostic tests, availability of warning services, monitoring, collecting and dispatching samples, prevention and control. – Assist in **improving** diagnostic skills, training courses may be available. • **Diagnostic services** – Services provided **vary**. Contact a service that provides what you want. – Provide information on **sample collection and submission forms**. Advice from diagnostic services is only as good as the samples and information provided. – Provide a diagnosis which is as **definite** as it needs to be. – Provide a **reliable** diagnosis. Diagnostic services should be accredited and standardized tests carried out by qualified and accredited diagnosticians. – Provide a **permanent record** of the diagnosis which must be presented in a manner which is readily understood by the client. – Can assist with **legislation**. – Most are **user-pays**, some are free. Check the cost. – Some growers are **reluctant** to use diagnostic services. • **Types of diagnostic tests** include: – Signs and symptoms. – Microscopic examination of tiny insects, mites, fungal mycelium, spores and plants. – Taxonomy for the correct classification and naming of plants and animals. – Isolation and culture of bacterial and fungal micro-organisms. – Indicator plants for detecting the presence of viruses. – Biochemical tests for bacterial and other diseases. – Serology (**ELISA**) tests mainly for virus, bacterial and fungal diseases. – **DNA** fingerprinting for insects and disease organisms. – Koch's rules – good basic principles but replaced by modern techniques. – Soil, water and plant tissue analyses. – Be cautious about an over-reliance on tests, there may be complex causes. • **Diagnosis based on expert advice**. Was a definite diagnosis made? If uncertainty still exists, you can either: – Report the diagnosis as it stands to your client (Step 7), **or** – Pursue the diagnosis further, eg discuss further tests with the diagnostic service, or send further samples to another diagnostic laboratory (Step 6).
FURTHER STEPS	Step 7. Report the diagnosis.

CASE STUDIES

Step 6. Seek expert help

These case studies of complex problems were passed onto experts with varying results.

1. HOTLINES - FIREBLIGHT?

?	Concern by a member of the public that the apparent dying back of ash tree in nature strips might be caused by fire blight (*Erwinia amylovora*).
	**Ash** (*Fraxinus excelsior* 'Aurea'). List of pests does not include fireblight which is not known to occur in Australia. Fire blight occurs on plants in the rose family, eg apple, pear, quince, plum, hawthorn, service berry, also persimmon & walnut.
	**Symptoms** of fireblight include blackening of shoots and leaves and a curling of affected shoots often characterized as a shepherd's crook (a diagnostic symptom). Observed symptoms did not match.
	-
	References confirmed the host range and symptoms of fire blight. If the plant was a host for affected by fire blight the quarantine hotline would be contacted.
XPERT	Diagnostic tests for fire blight were standardized when there was a suspected outbreak in Melbourne's Botanic Garden.
	**Definite negative diagnosis**. Ash is not a host for fireblight.

2. NO DIAGNOSIS BUT ACTION NEEDED

?	Enquiry about large galls on many poplars in public plantings and why several hundred trees were being removed including many without galls.
	*Populus deltoides* hybrids.
	Large galls on stems *(see page 160)*. Tops were dead or dying and there seemed to be a risk of them falling. References inconclusive, expert advice was sought.
	A site visit was required to appreciate the extent of the problem.
	References suggested that galls may be caused by a bacterial disease but diagnostic testing would be needed.
XPERT	**Diagnostic service** unable to find a specific cause, however, all the poplars with trunk galls were of the same **genetic** source.
	**Inconclusive diagnosis** Probably a combination of drought and stem weakening caused by the galls. Removal of all trees was necessary because of their poor condition and risk to public safety.

3. HERBICIDE-RESISTANT RYEGRASS

?	**Group of farmers** asked about the resistance of weeds such as annual ryegrass (*Lolium rigidum*) to glyphosate. Is it serious?
	General enquiry. There are farms with whole fields infested with resistant ryegrass. Also occurs along irrigation channels, fence lines and orchards.
	-
	-
	There is plenty information on the Weedscience website (www.weedscience.org).
XPERT	If resistance is suspected, it can be confirmed by appropriate diagnostic tests.
	**Resistance is serious** and is due to intensive use of glyphosate, little or no tillage & no other effective herbicides used.

4. PHOTINIA & BORE WATER

?	**Client** brought several specimens of very unhealthy photinia plants from a large planting. Growth was poor or non-existent.
	*Photinia glabra* 'Rubens'.
	Yellow foliage with no new growth. Internodes are very small indicating poor growth since planting.
	**Questions** revealed the hedge was planted 4 years ago into mushroom compost. This year a complete fertilizer was applied. Irrigated by bore water. Water analysis was recommended.
	References revealed that photinia is classified as being very sensitive to salinity.
XPERT	**Bore water analysis** revealed that salinity was much too high for the species.
	**Useful diagnosis** Bore water as the cause of the problem. A difficult problem. Is it possible to mix town water with the bore water or grow more tolerant plant species?

5. TREE STUMP – WHITE ANTS

?	**Client** brought in pieces of tree stump with insects in it and wondered if they were white ants?
	**Eucalypt** tree felled about 10 years ago.
	Examination revealed typical termite tunnels and worker termites *(see page 161)*, but un sure about the species. Some species are more likely to damage house timbers.
	-
	Much literature on termites but identification can be difficult for the non-expert.
XPERT	**Domestic pest control** business was consulted, but specimens could have been sent to an insect identification service.
	**Accurate diagnosis** of *Coptotermes* spp. which can invade houses. The pest control company would recommend a complete property inspection.

6. EUCALYPTS – MUNDULLA YELLOWS

?	Concerns from farmers in the Mundulla area of NSW about leaf yellowing on bush eucalypts. What is the cause – drought, *Phytophthora*, salinity?
	**Eucalypts**
	Yellowing of new foliage and slow dieback over years. However, there is almost an unlimited number of causes of leaf yellowing on eucalypts.
	-
	-
XPERT	**Researchers** took up the problem and suggested that its cause was iron deficiency due to an inability to take up iron in increasingly alkaline soils.
	**Preliminary diagnosis** made by researchers that Mundulla yellows was caused by an iron deficiency. Severe iron deficiency can cause dieback on other susceptible species usually under high soil pHs. Research is continuing.

7. DYING PITTOSPORUM

?	A supplier of *Pittosporum* to landscapers is concerned about individual or groups of *Pittosporum* planted out in hedges dying over a period of time.
	*Pittosporum tenuifolium* 'James Stirling'. List of pittosporum problems & pest information sheets available.
	Examined stems and roots. This species is susceptible to attack by the black vine weevil, but there was no evidence of larvae, adults or damage. Roots look unhealthy, some darkish. **Preliminary diagnosis** suggesting that it may be *Phytophthora*. Client happy to pay cost of $80 to send to a diagnostic service.
	**Questions** revealed irrigation was adequate but that there may be a tendency to over-irrigate. Flat ground, poor drainage.
	-
XPERT	The diagnostic service confirmed the presence of *Phytophthora cinnamomi* on all samples and provided information on prevention and control *(see page 105).*
	**Accurate diagnosis** of *Phytophthora*. However, *Phytophthora* may be a secondary problem favoured by a primary cause of over-wet soil and poor drainage.

8. WHERE WAS THE CROP PLANTED?

?	**New commercial grower** with a query about dying carnations.
	**Carnations**, various cultivars. List of problems & pest information sheets available.
	Roots, stems and leaves were examined. Suspected root rot of some type.
	**Questions** about cropping revealed the carnations had been planted into pasture.
	References indicated that several root rotting fungi could attack carnations, but it was not possible to identify which one. Client needed a definite identification so samples were sent to a diagnostic service.
XPERT	Diagnostic service advised that the fungus attacking the carnation was *Fusarium avenaceum*.
	**An accurate diagnosis** of *Fusarium avenaceum*. The carnations had been planted into infected pasture land.

REVIEW QUESTIONS & ACTIVITIES

Step 6. Seek expert help

1. Give **1 example** for each of the following ways a diagnostic service can **assist** you:

	Example
Identify a host plant	
Identify a pest, disease or weed	
Interpret signs & symptoms	
Interpret information	
Comply with legislation	
Microscope examinations	
Diagnostic tests	
Increase your knowledge of your crop	

2. Name **1 diagnostic services** that you could use for problems that occur in your crop and the tests you are likely to require?
   1. Problem
   2. Diagnostic service
   3. Tests

3. Describe the **steps** you would take to ensure the diagnostic service received a quality sample (see page 178).
   1.
   2.
   3.
   4.

4. Access a **sample submission form** from a website and fill it in for a problem of your choice.

5. Which **pests and diseases** can be identified from the following tests?

	Pest and diseases
Signs & symptoms	
Microscopy, electron microscopy	
Classification, keys, taxonomy	
Culturing, baiting	
Indicator plants	
Biochemical tests	
ELISA	
DNA technology	
Plant, soil, water analyses	

6. Which **tests** would a diagnostic service perform to **confirm** the identity of the following problems? You may need to refer to pages 179-184.

	Diagnostic tests
Phytophthora	
Powdery mildew	
Nematode populations	
Species of fruit fly	
Insect	
Nutrient deficiency	
Salinity	

Step 7. Report the diagnosis



Proof of diagnosis *104*
How to report the diagnosis – diagnostic road map *104*
Common errors in diagnosis *106*
Summary *109*
Case studies *110*
Review questions & activities *111*

PROOF OF DIAGNOSIS

Written evidence of a diagnosis

A formal diagnosis should include written proof of how the diagnosis was made. For some problems this is easy, eg matching a description of a citrus butterfly, spores of a fungus to descriptions or a diagnostic test; for others it may be more difficult, eg where complex causes are involved.

HOW TO REPORT THE DIAGNOSIS – DIAGNOSTIC ROAD MAP



The **diagnostic road map** is a framework for reporting the diagnosis (Fig. 16 opposite).

- **Produce a permanent record** of the enquiry, diagnosis and recommendations given to the client, so events can be reconstructed to support your diagnosis (see pages 62, 72, 105 and 121).
  - **Not every enquiry requires every step** to be implemented. Reports for insect or weed identification are less likely to involve all steps and the reporting forms will vary accordingly.
  - **Many diagnosticians** will have their own reporting forms.
  - **Both you and your client** should have a written copy. If your advice is sound but the client's implementation is **not**, you have some form of protection against litigation.
  - **Explain** any scientific or specialist terms to the client.
- **What should be in the report** includes the following:
  - **Proof of diagnosis**, ie evidence of how the diagnosis was made. Follow the diagnostic road map.
  - Any **legal** requirements, eg quarantine, prescribed treatments.
  - What you **did** find, ie signs of powdery mildew.
  - What you did **not** find. This can be just as important as knowing what was found, eg nursery accreditation schemes include testing for the presence of *Phytophthora* and its absence is obviously greeted with relief.
  - **Photographs** and **site maps** may be included where relevant.
  - **Common or scientific names** of the affected plants, and pests, diseases or weeds.
  - How **definite** was the diagnosis, was it preliminary, useful, accurate or definite? If the client is a home gardener with only on a few roses, then a preliminary diagnosis based on visual signs and symptoms would be sufficient. Most commercial growers would require a more definite diagnosis. If uncertainty about a diagnosis persists, then report the diagnosis to the extent that it has been made.
  - How **reliable** was the diagnosis? Was the person who made the diagnosis trained and experienced to do so? Was the examination or test carried out using standard tests? If in a diagnostic laboratory, was it accredited and was the sample of the required standard and quality.
  - **Balance between** costs and benefits might also be included.
  - **If necessary, or requested**, include recommendations for action, eg legal requirements, need for further investigations, improved management (see page 193).

A PLANT DISEASE DIAGNOSTIC REPORT FORM

CLIENT'S ENQUIRY (Step 1)

Client details

Date
Name
Business/gardener
Address
Suburb, town, postcode
Tel
Fax
Email

Enquiry details

A supplier of plants is concerned about the cost of replacing plants which had died after planting out. Client thought the problem might be caused by black vine weevils. Client was also concerned that the problem might have been introduced on the nursery stock or in the media.

The request was for a diagnosis and advice on what to do.

CROP, LANDSCAPE, NURSERY (Step 2)

Pittosporum tenuifolium 'James Stirling' in a landscaped area.

SIGNS & SYMPTOMS OBSERVED (Step 3)

Whole plants die – it is an ongoing problem for the supplier. A student advisory service indicated that no sign of black vine weevil damage could be found but rotted roots suggested there could be a fungal root rot and recommended samples be sent to a diagnostic service. Cost would be $80 to $100 (2006). Client was more than happy to do so and an appropriate diagnostic service was contacted. **3-4 whole plant samples** were appropriately labeled, packaged and forwarded, with the submission form, to the diagnostic service.

SITE OBSERVATIONS, RECORDS ACCESSED (Step 4)

Information supplied by client. Gaps are left in hedges. Once a plant starts to die it dies quite quickly. Clients are upset. Hedges are usually irrigated and there is a suggestion in this instance, that irrigation may be excessive. **A site map** was not made. **No on-site tests** had been carried out.

REFERENCES CONSULTED (Step 5)

No details of the references used to identify the species of *Phytophthora* involved were supplied by the diagnostic service. **Pest information sheets** were provided for the client.

EXPERT HELP (Step 6)

Examinations carried out Using specific media the soil was tested for the presence of major soil-borne fungal pathogens. A species of *Phytophthora* was found but microscopic examinations revealed that it was not the dreaded *Phytophthora cinnamomi* which causes serious dieback in many plant species. However, any *Phytophthora* species can be pathogenic to some degree, particularly to stressed or young plants.

THE DIAGNOSIS (Step 7)

Proof of diagnosis. The diagnosis was **useful**. A trained plant pathologist performed standardized tests in a accredited laboratory. No information was supplied on whether the problem might have been introduced in the container or whether it would have been present in the soil.

CONTROL / RECOMMENDATIONS

Advice on control was provided, accompanied with a Fact Sheet on *Phytophthora*. Information was also provided on the mode of action of phosphorous acid which was recommended for the control of *Phytophthora*. Phosphorous acid is presently considered to have a mixed mode of action – in addition to having some direct toxicity at certain concentrations towards *Phytophthora*, it increases the affected plant's resistance to the fungus. Phosphorous acid is systemic but is not a naturally occurring substance. Remember to check the current registration status of a pesticide prior to use. Always read and follow label instructions attached to the pesticide container at time of use.

Fig. 16. A condensed example of a diagnostic report for a disease. The client provides the information for the first 4 steps (which is the information requested in a submission form) and the diagnostician fills in the next 3 steps and makes recommendations (see also page 121).

COMMON ERRORS IN DIAGNOSIS

Even doctors make mistakes and their patients can talk! Although some pests and diseases are mis-identified, undetected, or unknown, it is possible to minimize errors. Remember, the commonest problems associated with particular plants are really the commonest. Look for the obvious. Diagnosticians are continually learning and there is always room to improve. The following brings together errors commonly made during the diagnosis.

THE MOST COMMON ERRORS

Avoid trying to be **too definite** about a diagnosis. You may not have the necessary proof, especially when samples are very small, eg 1-2 affected leaves, or the identity of the affected plant itself is not clear.

- The **most common** error in diagnosing plant problems is to consider the **first cause** detected to be the one and only problem. The most important cause may not be visible or only have symptoms but no signs.
- The **second** most common error is trying to identify a **single cause** of a plant problem. Many problems are **complex**, eg
  - Failing to identify the **primary cause** and focusing too much on **secondary causes**, eg tree borers attacking stressed trees, *Penicillium* fungi infecting bruised oranges, weeds invading thinned turf or pasture. Sometimes the secondary problem, eg weeds, needs immediate attention, and the primary cause may require longer term strategies.
  - **Symptoms** may be the result of **complex causes** instead of one isolated environmental factor or pest. So diagnosis may require several attempts before the total problem is understood. It is not uncommon to return to earlier steps and work through the process again.

FAILURE TO USE SYSTEMATIC METHODS

In the absence of a systematic approach, a novice diagnostician may find the task of diagnosing plant problems intimidating.

- **A systematic process reduces the possibilities** and eliminates the unlikely. A diagnosis may fail due to initial misidentification of the affected plant, or not seeking advice when necessary.
- **Don't make assumptions**. You may observe hundreds of harlequin bugs feeding on the foliage and flowers of vegetables and ornamental plants in your region. Later when someone calls and says that insects are eating 'everything' you may correctly (or incorrectly) conclude that these client's insect pests are harlequin bugs.

FAILURE TO KEEP ADEQUATE RECORDS



Failure to keep records means you have no proof of your diagnosis for yourself or your client. This can lead to client dissatisfaction, time-consuming negotiations with specialist laboratories and you will have no reference material of your own the next time the same problem crops up. Record keeping also avoids hasty diagnosis.

- **BMP** requires diagnosticians to maintain records of the actual diagnosis, how it was arrived at and advice given.
- **Record keeping** is the basis of good diagnostics. Keep records in a place where they can be readily accessed (see page 119).
- Good records provide protection against **litigation**.
- If relevant, **include** specimens, photographs and site maps in your diagnostic report.
- **If you feel uncomfortable** about putting it all in writing then question whether you should be giving the advice.

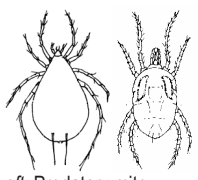
FAILURE TO RECOGNISE NORMAL PLANTS OR BENEFICIAL ORGANISMS

Learn to recognize what plants look like under normal growing conditions.

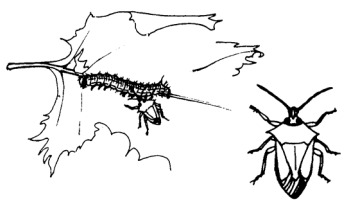
- **Beneficial insects** are common and may be mistaken for insects which damage plants, eg predatory mites for pest species. A hand lens or dissecting microscope and appropriate reference material is needed to tell the difference.
- **Finding a nematode** does not indicate that it is the primary cause of any visible damage, it may just be feeding on organic matter.
- **Beneficial microscopic fungi and bacteria** can only be identified by experts.



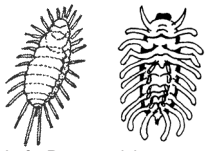
Pest shield bugs.
Left: Green vegetable bug
Right: Bronze orange bug



Left: Predatory mite.
Right: Spider mite



Predatory shield bug (*Oechalia scheilenbergii*) feeds on vine moth caterpillars (sucks insect juices). Most shield bugs are pests of plants



Left: Pest mealybug
Right: Predatory mealybug ladybird larva. Both insects are white, about the same size and are easily confused

POOR CLIENT INTERACTION



It is **not** enough to say that if the client is unhappy with your diagnosis, then it is their problem. It is not, it is yours.

- You may **not** have understood the client's initial enquiry, explained or offered proof of your diagnosis, or explained clearly the options and costs open to them. If you have done all these things properly in Steps 1-7, and the client is **still** unhappy then it **may** be the client's fault!
- Do not **under-estimate your client's knowledge** if they are experienced growers.

NOT TAKING ENOUGH TIME



Don't be rushed into thinking about the cause of a problem just to satisfy an impatient client. To avoid this pitfall, take time to actually write down your observations. Complete record forms as you proceed, not at a later date.

- Diagnosticians are commonly faced with the demand for an instant diagnosis.
- To identify the cause when no signs are present may require additional time. An accurate diagnosis takes **time**.
- There is nothing wrong with saying **'I don't know'** or 'I'm not sure' but these should be followed by **'but I will find out'**. Explain that this might involve collecting samples, checking references, a site visit or calling in expert help.

LACK OF SKILLS



Diagnosing plant problems **requires** that you can recognise plant species and some signs and symptoms that pests and diseases may produce (see page 123).

- We all have limitations, know yours.
- Good diagnosticians have lots of experience and skill. These can readily be acquired (see page 185).

INADEQUATE INFORMATION OR EQUIPMENT

It is **not** unusual to have to make a preliminary diagnosis without all the information you would like.

- However, it is possible you may have **missed** important clues. Check back through the diagnostic steps. Do not be trapped into a diagnosis when the information to support it is doubtful or lacking.
- Major reasons for not diagnosing problems include **inadequate** samples, deterioration of samples during shipment and lack of information accompanying the sample.
- Dissecting microscopes and lighting may be **inadequate** for examining some problems.

TRAPS OF IMAGE-MATCHING

Identification based on **image-matching alone** can lead to misdiagnosis, incorrect treatment, lost time and money.

- This is especially so when **symptoms** are **not** specific or distinctive enough for a definite diagnosis, eg marginal scorches caused by salinity, wind burn, drought or wind, dying of plants due to *Pythium* and *Rhizoctonia* root rots, poor watering. Such problems really require further investigation.
- The images themselves may **not** show the signs and symptoms clearly.
- A good diagnostician will use image-matching in the **overall context of the problem**. Images may be used when the advisor is showing a customer **proof** of the problem.



Poor image – can you accurately identify the signs and symptoms shown in this picture?

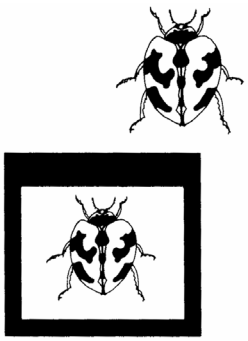


Image-matching – clear picture of a transverse ladybird – easy to identify



Leafcutting bee damage – rose



Blossom end rot – tomato

Specific symptoms – easy to identify



Non-specific symptom – leaf yellowing on hornbeam (*Carpoprinus* sp.). Depending on how important the problem is, a site visit may be required and records accessed – symptoms were caused by spray drift of glyphosate

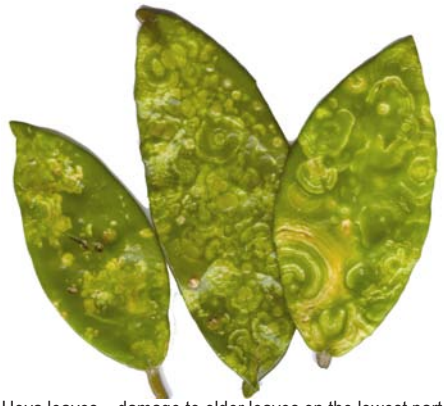
DIFFICULTY IN DIAGNOSING SOME PLANT PROBLEMS

Diagnosing some problems can be very difficult. Examples include:

- Some **plants** are difficult to identify, eg weeds, grasses, conifers and plant varieties.
- Problems on **some hosts** can be difficult to detect and identify, eg stone fruit, tomato, trees, turf.
- **Some common pests and diseases** can be also be difficult to identify, eg old powdery mildew lesions on hebe, photinia.
- **Diseases** caused by bacteria, fungi or viruses are **hard to identify** and are often confused with **nutritional problems** and damage caused by **sap sucking insects**. Soil, water or plant analysis may be needed.
- **Non-specific symptoms** are difficult to interpret, eg leaf yellowing caused by some diseases and nematodes resembles that of poor site, plant competition, low fertility, root-feeding insects, soil compaction, and other types of stress! Often a site visit and records of crop practices and weather are needed.
- The **most** difficult problems to diagnose are often not parasitic pests or diseases but are **cultural and site-related**.
- Symptoms may **differ** from those of published descriptions and illustrations, eg rose mosaic may produce a wide range of leaf patterns, not all may be illustrated.
- Sometimes disease organisms are in the **soil**, so that laboratory tests are required.
- **Introduced** pests, diseases and weeds may be present in Australia for many years prior to being detected, identified and described.
- **Complex** causes are notoriously difficult to identify.
- Damage which took place **a long time ago**, perhaps years previously, eg feeding or egg laying damage to *Callistemon* stems which then split as they grew (see page 159).
- The following are examples of **symptoms which are distinctive** but which still led to **inconclusive** diagnoses at the time of their making:



Witches' broom on *Rhododendron* 'White Bourke' – occasional shoots are affected which usually die. This type of symptom is often caused by sucking insects or mites feeding on the growing point just when new growth is taking place. A diagnostic service could not find any evidence of pests and suggested it could be varietal degeneration. **Inconclusive diagnosis**.



Hoya leaves – damage to older leaves on the lowest part of the plant – no pests or diseases visible – possibly virus infection or heat or sun damage. **Inconclusive diagnosis**.

OVER-RELIANCE ON TESTS

While meters, probes, tests and other procedures can be very helpful, you have to able to **interpret** their results. This may require **expert assistance**. Diagnostic services should report test results in a manner that can be understood by the client. Don't dazzle the client with technology and its language! Explain all scientific, legal or computer terms.

- ***Phytophthora* diseases**. No one piece of information is enough to conclusively diagnose a *Phytophthora* disease, eg the presence of the fungus may only be part of a broader problem. Evidence from the field, sick plants and laboratory tests (baiting, culture, microscopy) must all indicate the same problem. Then you can be more confident of a diagnosis.

FAILURE TO EVALUATE THE DIAGNOSIS

✓ X

Just because you have gone through the diagnostic process does not mean you have made the correct diagnosis. It is important to evaluate your methods and provide an audit trail. (see page 191).

SUMMARY

Step 7. Report the diagnosis

Each step of the diagnostic process reduces the possibilities, eliminating unlikely causes. Recall the original enquiry (Step 1). Having identified the affected plant (Step 2) you can access a list of potential pests and pest information sheets. You have examined the plant (Step 3) and may have tried to match the pest signs and symptoms with illustrations and descriptions in the pest signature. You may or may not have made a diagnosis (Step 7). A site visit and questions (Step 4) and consulting references (Step 5) may have helped to refine your diagnosis. If a more definite diagnosis was required expert help would have been engaged (Step 6).

PROOF OF DIAGNOSIS



Your report should follow the steps in the **diagnostic road map**.

- **Produce a permanent report** to establish proof of your diagnosis so events can be reconstructed to support your diagnosis.
  - Remember not every enquiry requires every step to be implemented. A diagnosis of a insect or a weed is less likely to involve all steps and the report form may vary accordingly.
  - This report should include details of the enquiry, your diagnosis and the clues you to used to reach your diagnosis, and any advice provided.
  - Test results should be reported in a manner that can be understood by the client.
- **What should be in the diagnostic report?**
  - Proof of diagnosis – follow the diagnostic road map to indicate how you observed and collected the information.
  - Any **legal** requirements.
  - What you **did** diagnose.
  - What you did **not** find.
  - Reports of any tests and their results, their interpretation and implications.
  - **Common/scientific** name of plant, pest, disease or weed.
  - How **definite** the diagnosis was.
  - How **reliable** the diagnosis was.
  - References to **samples, photographs** and **sites maps** where relevant.
  - Balance between **costs** and **benefits**.
  - Recommendation for **control**, if requested.

COMMON ERRORS IN DIAGNOSIS

The **most common errors** include:

- Being too definite about the diagnosis.
- Failure to use a systematic framework or a checklist to keep you on track.
- Failure to keep adequate records, including a site map, as proof of diagnosis.
- Failure to recognise normal plants or beneficial organisms.
- Poor client interaction.
- Not taking enough time.
- Lack of skills.
- Inadequate information or equipment.
- Traps of image-matching.
- Difficulty in diagnosing some plant problems.
- Over-reliance on tests.
- Failure to evaluate your diagnosis.

CASE STUDIES

Step 7. Report the diagnosis

Emphasis here is on the various reasons why it is important to report the diagnosis and provide advice correctly.

1. POOR EXPLANATION

?	**Home gardener** complained that bottlebrush plants recommended for replacing an existing hedge had died.
	Bottlebrush, various species. List of pest and pest information sheets available.
	Examination did not reveal any pests or diseases.
	Questions revealed that 30 plants had been planted out during the previous spring but had died. A second planting of the same species has suffered the same fate. No irrigation had been provided as they were 'drought tolerant'.
	Accessed record of enquiry and advice provided was very brief, no mention of care during establishment.
XPERT	-
	Useful diagnosis. Drought tolerance does not mean no irrigation ever! Most plants require irrigation until established.

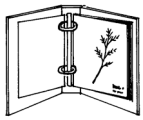
2. LEGISLATION CHANGES

?	**Home gardener** concerned they had been told that control of fruit fly was **not** compulsory any more but a friend had said that this was not correct. No specimen *(see page 148)*.
	Fruit crops, tomatoes
	-
	Questions revealed that the client resided in the ACT but the enquiry related to fruit grown on the south coast of NSW.
	-
XPERT	-
	Information. Control of fruit fly is compulsory in NSW but not in the ACT. Legislation in the ACT was amended so that control is now not compulsory. Provided control advice for NSW & ACT.

3. NO RECORDS

?	**Small orchardist complained** that they had sprayed their peach trees with copper as recommended by their advisor but all the new growth was still curly.
	Peach trees. Leaf curl caused by a **fungus** is commonly controlled by copper sprays. **Aphids** may infest new growth in spring. A sample was requested.
	On examination aphids (cornicles, antennae, ovoid body), nymphs skins and wrinkled rather than curly leaves were observed *(see page 135)*.
	-
	Records of the previous diagnosis & advice were **not** available, so had to presume that previous diagnosis was peach leaf curl & copper sprays were recommended. Record keeping unsatisfactory.
XPERT	-
	Useful diagnosis. Green peach aphid infestation. Control advice was provided.

4. HERBARIUM SAMPLE AS PROOF

?	**Carrot grower** in NSW with samples of carrots covered with orange coloured twine-like stems.
	Carrot crop. List of pests & pest information sheets available.
	Visual examination revealed that it was a species of dodder *(see page 9)*. As some species are declared weeds in some regions, expert advice was sought. 
	Questions revealed that seed was probably introduced to the property in hay from Victoria. The hay was used as mulch.
	Fact Sheets provided clear descriptions and illustrations. **Samples** were dried, correctly labeled and placed in the diagnostic service's herbarium.
XPERT	**Sent to local botanic garden** where specimens were identified as *Cuscuta tasmanica*.
	Definite diagnosis *Cuscuta tasmanica*. Check the status of this species in your region.

5. DISBELIEVING CLIENTS Didn't want to know that they caused the problem

?	**Client** is concerned about some nursery stock with yellow leaves. Client and co-workers convinced it was a nutrient deficiency *(see page 130)*.
	Cherry nursery stock. List of pests & pest information sheets available.
	Bleaching of tissue on leaf margins and between the veins. All leaves on all plants were affected, so probably **not** a parasitic agent and **not** nutrient which usually first appears on older or younger leaves. **Photographs** were taken and catalogued. 
	Accessed records. Fertiliser regime seemed appropriate, but the residual herbicide simazine had been applied uphill from the affected plants several months previously and weather records indicated that it had been applied immediately prior to a rainstorm which had probably washed the herbicide downhill.
	Little information on how much simazine it would take to cause the observed symptoms on the particular type of cherry in question or what the ultimate effect various levels would have on plant health.
XPERT	**Analysis** of the suspect chemical in leaf tissue or in the soil might get answers but this is unlikely as it is probably too late to find significant amounts of the herbicide.
	Preliminary diagnosis based on patterns on leaves, plant and crop, history of application of simazine 6 months previously. Plant may or may not recover.

6. HOW DEFINITE AND HOW RELIABLE

?	**Home gardener** has brought in several azalea plants in spring. Old leaves are stippled and yellowish.
	**Azaleas**, various cultivars. List of pests & pest information sheets available.
	**Black tarry drops** of insect excreta found on leaf undersurfaces. May be produced by both lace bugs and thrips. Spiny nymphs of lace bugs were observed. Some thrips were also seen *(see pages 138, 139).*
	-
	**References** with illustrations and descriptions confirmed observations.
XPERT	-
	**Useful diagnosis** Damage caused by sap sucking lace bugs and thrips on last season's azalea leaves. As treatment is the same for both insect pests on azaleas in a home garden situation, a more definite or reliable diagnosis was not required.

7. SUSCEPTIBLE NEW VARIETIES

?	**Garden advisor** brought in samples of geranium flowers which were damaged, possibly by insects.
	**Geraniums** (*Pelargonium* spp.). List of pests and pest information sheets available.
	**Examination** of flower buds and old flowers with a dissecting microscope revealed tiny caterpillars and moths *(see page 144).* Suggested sending samples to a insect identification service.
	-
	References were obtained from the **internet** and information passed onto the advisor.
XPERT	**Diagnostic service** identified geranium plume moth (*Sphenarches anisodactylus*).
	**Definite diagnosis** Geranium plume moth. Some of the newer varieties being sold as bloomers seemed to be very susceptible, nearly all flowers may be damaged.

REVIEW QUESTIONS & ACTIVITIES

Step 7. Report the diagnosis

1. What is **proof of diagnosis**?

2. Describe **how** should you report a diagnosis.

3. What should be in a **diagnostic report**?
   1.
   2.
   3.
   4.
   5.
   6.
   7.
   8.

4. List **common errors** in diagnosis:
   1.
   2.
   3.
   4.
   5.
   6.
   7.
   8.

5. Once you have **completed your report** of a problem of your choice (see page 112, Question 4) provide the following information:

How **definite** was your diagnosis? Preliminary Useful Accurate Definite positive Definite negative Inconclusive
How **reliable** was your diagnosis? Training Experience Standard tests used Accredited consultant/laboratory
Which **errors** might you have made during any recent diagnosis?
Did you **evaluate** your diagnosis to see how you could improve (see page 191)?
Did you spend time **explaining** your diagnosis to your client?
Was your client **satisfied** with the diagnosis? If not, can you suggest reasons?

6. **Access 2 sample submission forms** from the following list that include a section for reporting the diagnosis.

   Insect identification
   Weed or plant identification
   Potato virus testing
   Botrytis resistance testing
   Soil physical analysis
   Disease & nematode analysis
   Plant disease
   Chemical analysis soil, water & leaf
   Soil analysis
   Landscape ornamentals
   Vegetable crops
   Fruit crops
   Greenhouse crops
   Other

7. Report a diagnosis for an **pest, disease or weed** of your choice.

8. **Practice** diagnosing selected plant problems participating as:
   1. The **client**
   2. The **diagnostician**

A DIAGNOSTIC CHECKLIST

Use it to jog the memory - Steps 1-7 Diagnostic road map

- Keep a **record** of your processes and the discussion with the client for future reference.
- You do **not** need to use every step, you can jump around, you may recognise the problem at any stage.
- This is a general checklist, there are checklists for **specific crops**, eg grapevines, cotton, citrus, turf.
- Try to **build up a picture** of what is happening and the conditions under which it is occurring. This may help you identify the problem, or eliminate certain problems. It will also provide information for diagnostic services.
- It might help to **write in details** or mark **diagnostic clues** with highlighter.
- There is nothing wrong with saying 'I don't know'.

STEP 1. THE CLIENT'S ENQUIRY

THE CLIENT page 30

Date
Name
Business/gardener
Address
Suburb, town, postcode
Tel Fax
Email
Other

THE ENQUIRY page 31, 121

- What is the client **worried** about?
  Identity of plant, weed, insect, fruiting body etc?
  A perceived plant problem?
  Effect on crop, economic, aesthetic?
- What does the client **think** the problem is?
- What does the client **expect**?
  A preliminary/definite diagnosis?
  How reliable a diagnosis?
  Common/scientific name/strains?
  Test, analysis?
  Information?
- **Attach label** to sample (plant, soil, photo) with information on where, when and how it was collected.

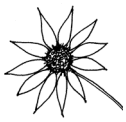


STEP 2. IDENTIFY AFFECTED PLANT

NAME OF PLANT page 36

Common name
Scientific name
Cultivar, variety
Market name
Plant susceptibility, if known

- **Type of plant**, eg fruit, vegetable, ornamental, turf.
- **Growth stage**, eg seedlings, mature, pre or post-flowering, fruiting, senescent, age, post-harvest, age.
- **Plant site**, eg potted/in ground, field crop, hydroponics, courtyard, home garden, public park.



LEGISLATION page 38

- **Status of crop**, eg quarantine, trade, monitoring, use of pesticides.



LIST OF PESTS page 38

- **List** of pests, diseases and weeds available? Caution though as not all may have been listed.

INFORMATION SHEETS page 39

- Are **pest information sheets** for each problem on host available so you can match the pest signature?

STEP 3. EXAMINE PLANT PARTS FOR SIGNS & SYMPTOMS

WHAT IS NORMAL? pages 38, 46

- How do plants differ from normal?
- Does a real problem exist?

SIGNS AND SYMPTOMS

pages 48, 121

- **Carefully describe** any signs and symptoms. There may be a complex of problems. Remember, you will have to match observed signs and symptoms to known pests and diseases of the plant species in question. Do you have adequate references?
- **Do you know what to look for?**
- **Magnification**. Does examination with a hand lens, dissecting microscope reveal any further detail about the signs or symptoms on the plant? Make sure you have good lighting.
- **Signs**. Can you see insects or mites? Look for adults, larvae, and eggs. Are there signs of fungal diseases, rust pustules, powdery mildew? Remember signs may be **away** from damaged plants, eg droppings.
- **Symptoms.** Are they specific (distinctive) or non-specific?



PLANT PARTS

Leaves, shoots page 125

- Check both sides of leaves with a x10 magnifying glass or dissecting microscope for insects or signs of fungal activity. Check sticky cards for pests. Also look under the canopy. Possible signs and symptoms include:

Anthracnose	Distortion
Blights	Fungi, moulds, furry growth
Blisters	Galls, oedema
Blotches, scorch	Insects, mites
Canker	Leafmining,
Chewed, tattered, holes, splitting	Leaf spots
Chlorosis, yellowing	Scabs
Colour changes, **not** yellowing	Silvering
Dead shoot tips	Skeletonisation
Defoliation	Stippling, speckling
Deposits, frass, droppings, structures	Stunted, enlarged leaves
	Wilting

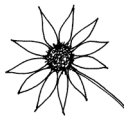
- Does the problem **only affect the leaves** or are other plant parts also affected.
- Are the **stem or roots damaged** and indirectly affecting the leaves?



PLANT PARTS *(contd)*

Flowers & buds page 141

- Blights, burns
- Buds brown/black
- Bud drop
- Buds/flowers, absent, size
- Buds, too many
- Chewed, tattered
- Colour changes
- Distorted flowers
- Fungi, rots
- Galls
- Holes in buds, petals
- Insects, mites
- Spots on petals
- Wilting



Fruit & nuts page 145

- Anthracnose
- Blotches, scorches
- Chewed, tattered
- Colour changes
- Distortion
- Failure to fruit
- Fruit fall
- Gumming, ooze
- Holes, stings, frass
- Insects outside
- Insects inside, cavities
- Ringspots
- Rot, fungi, moulds
- Russet
- Scabs
- Splitting
- Spots
- Tainting



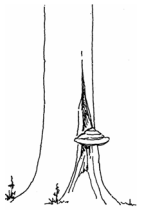
Seeds, seedlings, cuttings page 151

- Allelopathy
- Bolting
- Chewed, tattered
- Colour changes
- Damping off, rot
- Seedlings, insects
- Seedlings, spindly
- Seeds in storage
- Seeds on plants
- Transplant shock
- Weed seeds, pieces

Seedlings may also get the same problems as established plants

Branches, trunks page 155

- Bark chewed
- Bark split, peeling
- Cankers
- Collar rot
- Dieback, decline
- Discoloured bark, frass
- Discoloured internal tissue
- Distortion
- Fungi, wood rot
- Galls
- Gumming, ooze
- Holes **in** trunk
- Holes **on** trunk
- Insects on bark
- Mechanical injury
- Parasitic plants, suckers



Roots, soil, media page 163

Root and soil problems usually result in **non-specific** symptoms such as wilting yellowing or dieback:

- Chewed, mechanical injury
- Debris
- Fungi, bacteria nematodes
- Galls, distortion
- Insects in roots
- Insects on roots in soil
- Invasive roots
- Poor growth
- Replant problems
- Root rots, fungi, odours, discolouration
- Suckering roots
- Weed seed & bud banks



Bulbs, corms, tubers page 169

- Bulbs don't emerge
- Bulbs dried & shrunken, old
- Bulb, diameter, depth, spacing
- Distortion, forked, split
- Fungi, rots, odour, discoloration
- Galls
- Insects **outside**, gouging
- Insects **inside**, tunnels
- Mechanical injury
- Roots hairy, thin
- Scabs
- Weeds



Whole plant page 173

- Allelopathy
- Death of newly planted trees
- Patches of dead plants, sections of hedges
- Reduced yield
- Scorching, silvering, other colour changes
- Slow growth rate



STEP 4. SITE VISIT, HISTORY,QUESTIONS

SITE INSPECTION page 60

What is the extent and pattern of symptoms on the leaves, the whole plant, the crop and the surrounding plants? **Prepare a rough site map**.

Patterns page 63

- As a rule of thumb, **scattered patterns** of signs and symptoms signify parasitic pests and diseases. **Uniform patterns** indicate non-parasitic problems. Look for the junction point of damaged vs. non-damaged tissue.

Species affected

- If a number of different plant species in the area are showing damage it is more likely that an environmental or cultural problem is the cause rather than a pest problem (there are exceptions).
- Is the problem restricted to one species or cultivar or does it attack several?
- Are plants of other species also affected? If so which ones?

Plant parts

- Are symptoms uniform/scattered?
- Are symptoms on **old, new or all** leaves?
- Are symptoms **along** leaf edges along midribs or margins?
- Do leaves show a **browning along** leaf margins or **along** the major leaf veins?
- Do leaves show a **yellowing along** leaf margins, **between** the major leaf veins or **along** the major leaf veins?
- **Other?**

Whole plants

- Is the entire plant affected?
- Is just **one** particular branch or plant section affected? If so it is unlikely to be caused by weather or pesticide.
- Is only the **lower or upper** part of the plant affected? This information is often essential for diagnosis of deficiencies.
- Are the branches still alive or have they died?
- Is there any evidence of plant recovery on new growth which might indicate a non-parasitic problem?

The crop

- Is the **whole** crop affected?
- Are affected plants located in **certain areas** or **scattered** throughout the crop in small or irregular patches?
- **Non-uniform patterns**. The cause may be a soil-borne pest or disease, eg nematodes.
- **Uniform patterns**. Symptoms of pesticide or fertiliser are frequently associated with overlapping application patterns.
- **Is there a slow moving front** in the crop or patterns in populations, which might indicate a parasitic problem?
- Are patterns of symptoms associated with management practices, eg fertilizer or pesticide applications?
- Indications of other 'conditions?

Surrounding plant community

- Are other plants in the surrounding area showing similar problems? What is their general health?
- Other conditions?













SITE INSPECTION *(contd)*

Calendar, time frames page 64



Calendar
- What time of the year did the problem start? Many pests are associated with a crop only at certain times of the year, so that certain problems can be eliminated.
- Is the problem still active or was the damage caused by prior pests?



Time between cause & symptom appearance
- Problems may occur suddenly (acute) after a one time event such as a late frost or spray application, or develop over a period of time (chronic) and are more likely to be associated with an infectious disease, insect or soil problem.
- What is the time between the possible cause of the problem and the appearance of any signs and symptoms?

Signs & symptoms may change with time
- Are the signs and symptoms on the individual plants changing? What stages of any insect pest is currently present? Is the damage on leaves and other plant parts becoming worse?

Patterns may change with time
- Does the problem appear to be spreading to other plants nearby, ie is the area of affected plants increasing.
- Often a problem that appears all at once can be associated with a one time event such as a late season frost or injury from chemical application. Problems that spread gradually over time are more likely to be associated with an infectious disease or soil problem.

Soil type, topography, structures page 65

Have you evaluated the site for suitability for the crop, ie moisture, drainage, aspect.

Soil type
- Clay, sandy, cultivated, light, heavy, compacted, soil pH correct.
- Is there a pattern of symptoms associated with soil type, or the application of fertilizers or chemicals?

Topography & aspect
- Does symptom severity seem to relate to drainage patterns, sun, rain or wind exposure?
- Is the site steeply sloped, if so in which aspect?
- Is the site excessively wet or dry?



Structures & construction work
- What about buildings, fences, pools, large paved areas?
- Who or what uses the area regularly?
- Has there been any recent construction work which might damage roots, eg trenching, work on paths, roads?
- Has the terrain near established trees changed during the last 5-10 years?
- Is there any mechanical damage by machinery?
- Think widely – are plant roots drowning in waterlogged soil? Are the plants being cooked on north-facing brick walls?



On-site tests page 66



- Are the results of any **previous** tests available?
- Have soil, water and soil or media analyses been carried out?
- Have insects been trapped?
- Has plant material been tested for the presence of viruses, or other diseases?
- Has the problem been quantitatively assessed, eg counting insects or affected plants, weeds mapped?

HISTORY

Access records.

Crop/plant history page 67



Review management practices
- Has the plant been maintained properly?
- Previous land use or cropping.
- Land preparation.
- Transplant history; time of planting. Was it normal, early or late?
- Is there competition from other plants, weeds?
- Was it pruned too often or too hard into old wood, or at the wrong time of year? Pruned in wet weather?



Irrigation & temperature
- What is the **water source**? How is the crop watered? Have you checked how much water the plant receives each time it is watered? Is the surrounding soil excessively wet or dry?
- What about **drainage**? Are plants always sitting in water? Are container drainage holes blocked?
- Do the day and night **temperatures** suit the plant? Warm loving plants may be damaged by low temperature during transport.

Fertilizers, mulches, soil, media
- Have there been recent applications of fertilizers either around the plants or close by?
- What fertilizers have been used or have **not** been used? Specific nutritional disorders are often difficult to identify and may need soil, water or leaf analysis.
- What fertiliser **rates** were applied? Were label directions followed?
- Might there be **salinity** problems?
- Nurseries may have **mix problems** even from reputable suppliers.
- Check **soil deliveries** for weed seeds, etc.
- Is soil covered with thick mulch or **impenetrable fabric** which may impede water and oxygen flow? Has the mulch been aged or composted to avoid toxic effects?
- Have ingredients in mixes been appropriately composted or aged?



Pest, disease & weed history page 68



Know what to expect
- List the types of pests, diseases or weeds expected at different times of the year in your region, situation, crop? Has all required testing been done?
- What is their **significance** and **legal status**? Are they quarantine incursions, notifiable pests? Is control compulsory? Do they affect trade?
- Is the problem **complex**? Don't go for the first problem you think of.

Past occurrences
- Recurring or a new problem?
- If a recurring problem, what treatments were carried out?



Past treatments
- Have there been recent applications of herbicides, insecticides or fungicides to the plants, soil or close by? Is there a possibility of drift, or uptake through roots? Were label rates applied?
- Have you check with neighbours?
- Has a 'weed & feed' fertilizer been applied to any adjacent turf?



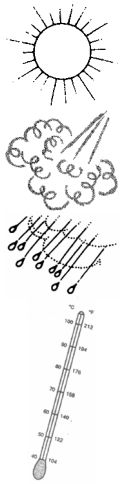
Source of planting material
- Was **certified** planting material used, eg virus-tested stock?
- Where did the **planting material**, eg seeds, cuttings, bare-rooted nursery stock, plants, **soil** come from? Is its hardiness appropriate for your locality?
- Was the planting material **treated** with fungicides or insecticides, if so, what was used at what rates?
- How susceptible are the affected plants?



HISTORY *(contd)*

Environmental history page 69

Check the effect of weather on the **plant** and its **pests, diseases** or **weeds**.



Temperature & moisture

- **Temperature.** Has it been unseasonably hot or cold? Have frosts occurred and if so when?
- **Rainfall**. How heavy and when were the planting and post-planting rains? Is it a normal year or did drought or waterlogged conditions occur?

Light & wind

- **Light** situation (full sun, partial or full shade), compare to the plant's needs. Have any changes been made? Check light levels with a light meter.
- **Wind.** Are plants exposed to excessive wind?

Time frames

- **Recent weather.** Has the weather been unusual, now or 3 months ago, eg drought, rain, hail, hot/cold/frost, windy, heatwave, floods? What was the weather like when the problem began?
- **Weather within 1 year.** Has it been a dry winter/hot summer etc?
- **Weather during the last 1-5 years**. Has there been continuing drought?
- **Microclimate.** Do environmental conditions differ in areas with the affected plants? Are they in low lying areas of the field prone to flooding? Consider conditions in greenhouse, eg ventilation, temperature controls.
- **Are there early warning services** for your area?

ASK THE RIGHT QUESTIONS page 70



- If you were not able to visit the site, questions will need to be **more probing and detailed**, eg about patterns of damage, when it occurred, weather, previous outbreaks, etc. All the things you might observe on a site visit.
- You will need to ask to see crop and other **records**.
- Even if you visit the site, **records** may not be available, so you will still need to ask questions. There may be new clues which need investigation.

STEP 5. CONSULT REFERENCES page 78



- Have you **checked** with books, computers and colleagues, also your and your client's records?
- Did you **access** a list of problems for the affected plant, pest information sheets, pest calendars, keys, expert systems, diagnostic tests or early warning services available for the crop and/or pest or disease?
- Did you **keep records** of the references you used?

STEP 6. SEEK EXPERT HELP pages 86, 179



- **Is it necessary** to seek expert help?
- Did you obtain properly prepared labelled **samples** to send for examination accompanied with their submission form?
- What **tests** were carried out on the sample you sent?
- Did the diagnostic service make a diagnosis? Did they confirm or reject your preliminary diagnosis?

STEP 7. REPORT THE DIAGNOSIS

THE DIAGNOSIS page 104



- What **did** you diagnose?
  Common name of insect, disease or weed?
  Scientific name of pest, disease or weed?
  Cause?
- What did you **not** find?
- Was a **permanent record** of the diagnosis provided as proof of diagnosis?
- **How definite** is the diagnosis? Is it a preliminary, accurate, definite or inconclusive diagnosis? How did the information/visual signs & symptoms of the suspect problem match with the pest signature?
- **How reliable** is the diagnosis? Who carried out the diagnosis? Were standard tests carried out?

PROOF OF DIAGNOSIS page 104

- **Did you use the diagnostic road map to** demonstrate to your client how you made the diagnosis?
- **Did you explain what clues** (diagnostic features) indicated the problem? Was it spores, a diagnostic test, the colour, size of insects, incorrect management, soil/water, environment? Was it a report from a diagnostic service?

OTHER CONSIDERATIONS

Double check the obvious – it never hurts to look again.

APPENDIX 1 – COMMUNICATION GUIDE

Clients are not always right but they are the clients. Listen!

SOME GENERAL TIPS

Have dialogue not debate

- **Only give advice if qualified** to do so.
- **Organize your workplace** so materials are within easy reach, eg recording forms, computers, supplies of paper and pens for site maps.
  - **Be comfortable** sitting. Standing up will give you better vocal quality, but is often not practical.
  - **Reduce distractions**, noise and nearby activity.
- **If the customer offers his/her name**, write it down immediately and use it once or twice at the most.
- **Greet customers** speaking slowly and clearly starting with 'Good morning, how can I help you?' At the end of the visit thank the caller and ask them to let you know the success or otherwise of the advice given.
- **The client is often the only source** of information about the problem. Share knowledge and experience.
- **Listen carefully** before you respond. Do not interrupt customers, unless they become garrulous.
  - **When listening** provide encouragement, sustain eye contact and politely prompt in lulls.
  - **Even if you know what the problem is**, give the client a chance to talk as this often reveals other factors. It also stops the 'shotgun' approach to problem-solving. Pressure of time may limit this.
  - **Seek information** of client's needs. You make ask by open questions, eg 'What plants are you interested in? and closed questions, eg 'Have you been visited a plant clinic before?'
  - **Avoid** getting side-tracked.
- **Speak clearly**, listen to yourself on a tape recorder.
  - **Avoid embarrassing the client** and being condescending.
  - **Smile** – it changes the tone of your voice as well as your attitude. Look at yourself in the mirror.
  - **Use plain language**, share knowledge and talk the customer's language.
  - **Avoid being offhand**, impatient or rushed. Every call is important to the person making it.
  - **Avoid using certain phrases**, eg 'you should have', 'you'll have to'. Instead provide informed choices of solutions.
  - **Phrase statements in positive terms** whenever possible. It is always better to say the glass is half full, rather than half empty.
  - **Look for things to praise** before you look for things to criticise.
  - **Do not eat**, drink or chew gum while on the phone or talking to a customer. Present neatly and cleanly.
- **If the diagnosis is not straightforward**, explain why you may need to consult references or seek expert help. Explain likely costs and time required.
- **If you have completed the diagnosis** but **not** to the satisfaction of the client, you may have overlooked something. You may need to tell them that you would like to check out more information and will contact them. Make sure you have their contact details, and how and when they can be contacted.
- **Nobody** in this world gets along with absolutely everyone else.
- **Apologize** whenever a customer has been inconvenienced regardless of who has caused it.
- **Be reliable** in everything from phoning back when you say you will to replying to letters. Under-promise and over-deliver. Do not promise things you cannot deliver. Act on requests and queries quickly.
- **Evaluate** how you are communicating with clients.

KEEP RECORDS

- Keep a permanent records of all enquiries and advice given as proof of diagnosis.
- Records must include contact details for the client and information about the enquiry. Examples of report forms are available on pages 62, 72, 105 and 121.

MEANS OF COMMUNICATION

All methods of communication have advantages and disadvantages. Some features of the following methods are described.

- **Face-to-face** as in diagnostic services, student plant clinics, garden centers, hopefully accompanied by adequate samples, drawings and photographs.
- **Networking** with other diagnosticians. When you help a colleague you help yourself. There are mutual benefits.
- **Conventional mail** may include a description and information on the problem, drawings and fresh or dried samples and photographs.
- **Faxes** are a bit like conventional mail without the fresh or dried sample. But you can still receive drawings, site maps and photographs, and a sample can be requested if necessary.
- **Emails** with **digital images** can be sent to a diagnostic service via the internet. Images can be enlarged for more detailed scrutiny either on the computer or on a separate screen. Information and data collected from site visits usually accompany the images.
- **On-line pest management and videos** in diagnosis and plant management are increasingly available for specific crops.
- **Computer databases** are an important source of illustrations, images and information on a wide range of pests, diseases and weeds.
- **Training**. Ensure that advisors receives professional training in communication and telephone techniques.
- **Talkback radio, telephone advice**. Only a description of the problem is received. This media is probably the least satisfactory means of communication for diagnosing plant problems. Samples, photographs can always be requested for more detailed examination or the caller can be referred to an appropriate advisory service.

The telephone

- Check that you know how to use the telephone and recording system. Make sure you do not delete recorded messages until they have been acted on.
- Never transfer someone and hang up before the phone is connected to the other person.
- If there is a delay in answering the initial call, apologise for the delay.
- Never keep people holding on without asking if they mind holding for a few minutes (be honest with time estimates) or offering to ring back at a time convenient to them. Make sure you have their telephone number.
- Although the customer can't see you, smile, it changes the tone of your voice as well as your attitude.
- Avoid being technical, people remember very little of details heard on the phone.
- Descriptions of insects and other plant problems may **seem** familiar when described over the phone, however, don't jump to conclusions! Be wary of unseen samples.
- Telephone enquiries often involve asking for the name of the affected plant and asking lots of questions. If requesting a sample provide information on how to collect, pack and send it (see pages 175-178).

THE ENQUIRY

Getting the facts

- **Have the recording sheet in front of you**. Fill it in as you gather the facts, not at a later date.
- **Checklists** are useful for difficult problems.
- **Focus on the main idea** of what the other person is trying to convey, rather than any emotionally-loaded words. Spend time focusing on what plant you are looking at or having described to you.
- **If the enquiry is long** and complicated, summarise the conversation and make sure you both agree on the detail of what has been said.
- **Work through diagnostic steps**. Seek information and background details of customer's needs by open questions.
- **Ask questions** that show you value the other person's input even if it is not positive. Everyone likes to have their opinion valued.

THINKING TIME

If you want an answer I'll give you one,
if you want a better answer give me some time
(old saying)

Reflective or thinking time and consultation with colleagues benefits diagnosis. If possible, take time before giving an opinion.

NO SAMPLE, NO PHOTOGRAPH

Diagnosis without a sample or photograph can be unreliable and clients should be advised of this. In some cases you can gather facts by telephone or letter, email or word of mouth, but a definite diagnosis can be difficult. The caller can be asked to bring in a sample or contact an appropriate diagnostic service. If a sample is not available then the following difficulties may occur:

- A caller may seem to **recognise the pest** and just want advice on control. However, the caller may have misidentified the pest. For example, is the **'fluffy white stuff'** on the plant, powdery mildew, mealybugs, planthoppers or woolly aphid?
- The caller may seem to **identify the plant** being attacked but **does not know what the pest is**. This is a better situation in that you may be familiar with the plant and its common problems, but the caller's description may not match any problems listed for that plant or ones you are familiar with.
- The caller does **not recognize the plant or the pest**. This situation presents the greatest challenge.
- **Avoid jumping to hasty conclusions**, eg you may observe hundreds of soldier beetles feeding on flowers in your backyard. Later when someone calls and says that black beetles are eating 'everything' you may correctly or incorrectly conclude that these clients are being pestered by soldier beetles.
- **Questions** about the colour, size, shape, damage and secretions of a pest may help you narrow down a list to 4-5 possibilities. Based on this information, your experience and reference material, you may be able to identify the pest and give advice.
- **Know what to expect in the area**. Most people enquire about insect pests by phone, making an accurate diagnosis difficult. Diagnosticians and garden advisors should be familiar with local pests and diseases of locally grown plants and crops.

REPORTING THE DIAGNOSIS

- **Do not make your diagnosis too definite** if you do not have the evidence to support it. Many of your diagnoses may be preliminary or useful but not definite. With plant diagnostics it is useful to cultivate humility. Exotic introductions and climate change should make one hesitant.
- **Provide a permanent record** of the enquiry, diagnosis and advice given to the client as proof of diagnosis.
- **The report may be accompanied** by leaflets which have illustrations and advice for control. Pest information sheets usually apply specifically for a particular area. Always check whether the pesticides included in pest information sheets are up-to-date and appropriate for the client's situation, eg home garden or commercial use.

HANDLING COMPLAINTS

- **Recipients** should only attempt to find a solution if they are qualified and have enough information to do so.
- **Record** the name, address and telephone number of the complainant and details of the complaint.
- **Investigate any complaint** quickly and thoroughly.
- **Commercial growers and home gardeners** often **blame themselves** if something doesn't grow or doesn't work. They are unwilling to complain, or show their ignorance of plant and pest identification, and pesticides, which are always changing.
- **Today a client will often go from one advisor** to another and there is nothing wrong with that. It is recognized that plant clinics operate more successfully (diagnose plant problems more accurately) when several advisors can provide pooled knowledge. Commercial growers, home gardeners and other clients are better informed than ever before and more likely to seek different opinions.
- **Complaints are often mishandled**. A typical business hears from only a few of its dissatisfied clients. It takes about 10 positive incidents to make up for 1 negative incident. Many complaining customers will do business with you again if you resolve the problem in their favour on the spot.
- **If the customer is angry or upset**. Indicate that you are concerned and want to help by recording details of the complaint. Ask them to explain the problem carefully. This will calm them and you will have a documented record of the complaint.
- **There are procedures** for dealing with certain types of complaints in most organizations and businesses, eg plant purchases that have died, pesticide didn't work, pesticide misuse.

APPENDIX 2 – RECORDS

Good diagnostics depends on good record keeping!

This Appendix summarises information on record keeping which is scattered throughout the previous text and offers some additional information on submission forms and the National Standards for Pest Records.

WHAT RECORDS TO KEEP

Those required by legislation

There are legal requirements to maintain certain records. Legislation that impacts on diagnosis includes:

- **Guaranteeing** pest or disease freedom for certification schemes.
- **Quarantine regulations**, notifiable pests, phytosanitary treatments.
- **All pesticide** treatments should be recorded, whether mandatory or not.
- **Best Management Practice (BMP)** requires diagnosticians maintain records of the actual diagnosis, how it was arrived at, advice given. Quality Assurance and accreditation schemes require that records be kept.
- **Provision of an audit trail**. Be able to provide a record of how you arrived at your diagnosis and how reliable and definite the diagnosis is. There are National Standards for Plant Pest and Disease Records for pests of national importance which indicate the reliability of a diagnosis.
- **Maintaining an up-to-date** status via training courses and local workshops and plant clinics.

Crop management

Records of crop management are necessary for diagnostic investigations. Many growers are contracted to companies who prescribe how a crop should be grown, pesticides that can be used, etc. Records of these procedures provide proof that they have been complied with. Examples include:

- **Cultural treatments**, eg cultivar selection, source of planting stock, fertilizers, irrigation, soil, media.
- **Pest, disease and weed** occurrences and treatments. In any one crop there are usually **recurring problems**, eg downy mildew, which tend to show up first in the same area at the same time of the year when conditions are favourable. Details of when symptoms first appeared, when a problem was treated, weather conditions and which cultivars appeared to be more resistant or susceptible should also be recorded.
- **Environmental monitoring** of temperature, rainfall, humidity and other parameters predict outbreaks, eg grapevine downy and powdery mildew, and apple scab, *Botrytis*, cereal rusts, onion downy mildew, Western flower thrips, plague locusts.

Previous diagnoses

Keep records of all diagnoses.

- Details of a diagnosis and advice provided must be **permanently recorded** as **proof** of the diagnosis. This information will then be available for future use when similar pest, disease and weed problems occur.
- **Failure to keep adequate records**. If your advice is sound but the client's implementation of it is not, then you have some form of protection in the event of litigation. When the client also has a written copy of your advice then the chances of mistakes are minimised.

Managing records & information

Diagnosis involves detective work, gathering information, taking notes and keeping records. Information and records must be organized in such a way that they can be accessed during future diagnoses.

- **Know what information** you may need to access. Examples include:
  - Records of **previous** diagnoses.
  - **Host indexes** and lists of pests which occur on particular species.
  - **Pest indexes** and keys for identifying pests, diseases and plants.
  - **Pest information sheets**, with diagnostic illustrations, descriptions and tests.
  - **Available expert help**, eg diagnostic services, organizations, quarantine.
  - **Control**. Information on biological control, organics standards, registered pesticides, MSDS, pest control companies.
  - **Herbarium collections**, eg pressed specimens, dried and pickled specimens, living collections.
  - **Books**, photo libraries.
  - **Websites**, digital images.
  - **Which specialist colleagues** have the skills and experience that you may need.
  - Distinguish more **important references** from less important ones.
- **Organize information** in a simple way that everyone understands.
  - **Organise** paper information, images, herbarium material, handout leaflets, records and computer information all in the **same way** to make it more user-friendly and the method easy to remember.
  - **Records of previous diagnoses** can be organised according to host and pest, so that problems associated with a host over the last 10 years can be accessed. Similarly for individual pests and diseases.
  - **Computer records** must be backed up, websites and identification keys easily accessed. Compile records in a form and place where they can be used.
  - **Organization of local information** is often arranged differently from the rest. It should be organised in the same way as other information.
- **Accessing** your records and references.
  - Most people do **not** spend enough time finding their way around the system.
  - **Can I access** the information when I need it?
  - **Is the computer working** so I can access relevant websites?
  - **Are the books available** in the library and in their proper place?
  - **Are colleagues** and specialists available for consultation?
  - **Are the lists** of diagnostic services, contacts for other services up to date, eg local bee keepers, possum-handlers, European wasp identification services.
  - **Has some removed** vital handouts of local information?

RECORDING TOOLS

Recording tools for laboratory and field work include:

- **Good field notebooks** as well as weatherproof pens and markers. Use standard recording sheets. Checklists may be useful.
- **Handheld recorders** are useful if you carry out many diagnoses to either record your observations on a keyboard/pad or speak into a voice recorder.
- **Means of drawing a rough site map** to show **where** samples were collected and **location** of affected plants, their proximity to healthy plants and other factors that may influence the problem, eg percent of site affected, irrigation, shading, proximity to parking areas and buildings, altitude (if known).
- **GPS systems** for feral animals, eg camels, pigs.
- **Aerial photographic techniques** for documenting the distribution of *Phylloxera* in vineyards.
- **A camera** can help record symptoms and site characteristics for others, and can be a valuable validation of the conditions at the time of inspection. This photographic evidence is also useful if post-visit changes are made, such as the removal of affected trees.
- **Digital cameras** can send images via the web to diagnostic services away from the site.
- **Particular crops**, industries and national standards have their own recording systems.

SUBMISSION FORMS, DIAGNOSTIC REPORTS

There are many different types of submission forms, so many in fact that Cornell University Extension in the USA has colour-coded them to help avoid confusion!

- A submission form must accompany any samples or specimens sent to a diagnostic service. Sometimes they are called sample, specimen or identification request forms.
- The submission form is sometimes integrated into the final diagnostic report (see Fig. 18 opposite). Having the submission form as part of the diagnostic report allows both the client and the diagnostic service to be fully informed and links the diagnosis with the samples and information provided.
- Information in a diagnostic report illustrated in Fig. 18 opposite incorporates the 7 steps of the roadmap. The client provides the information for the first 4 steps (which is the information requested in a submission form) and the diagnostician supplies the next 3 steps and makes its recommendations.
- Not every enquiry requires every step to be implemented. Reports for insect or weed identification are less likely to involve all steps and the reporting form will vary accordingly. However, all forms require detailed information about the client, the enquiry and the cost. Some services available from diagnostic services are illustrated in Fig. 17 below.
- Keep a copy of the completed form as a record.

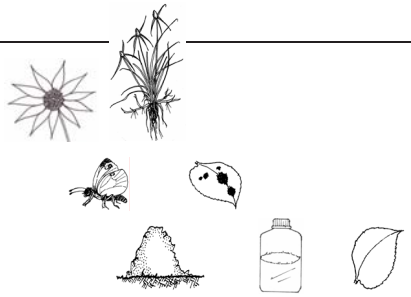
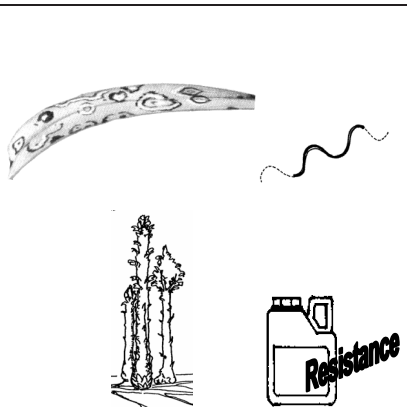
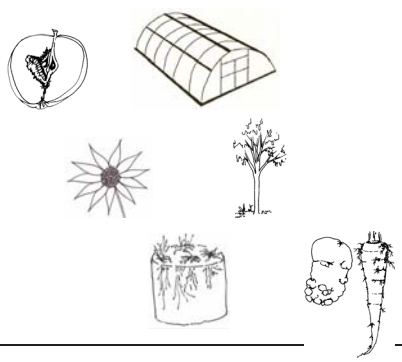
General diagnostics eg Plant/weed identification Insect identification Disease diagnosis Soil, water and plant tissue analysis	
Problem-orientated eg *Botrytis* incidence & resistance (grey mould, petal blight) Potato virus tests Orchid viruses Nematode analysis & counts Broomrape (root parasites) Herbicide resistance testing Pesticide residue testing DNA testing	
Crops-orientated eg Fruit crops, eg grapevine, pome fruits Grain crops Greenhouses, Nursery Ornamentals Trees Turf Vegetables	

Fig. 17. Forms will vary according to the type of diagnostic test requested.

CLIENT ENQUIRY (Step 1)

Client details
- ☐ Date
- ☐ Name
- ☐ Business/home gardener
- ☐ Address
- ☐ Suburb, town, postcode
- ☐ Tel
- ☐ Fax
- ☐ Email
- ☐ Other relevant information

Enquiry details, tests required
- ☐ The enquiry (describe)
- ☐ Does the client know what the problem might be (describe)
- ☐ Significant problem, eg how definite and reliable does the diagnosis have to be (describe), legal implications (describe)
- ☐ Plant, weed or insect identification only
- ☐ Tests required (describe)
- ☐ Request for biological information, eg pest information sheets
- ☐ Information supplied on cost of diagnosis and any tests
- ☐ Sample available, labelled and packaged correctly

CROP/SITUATION LANDSCAPE, NURSERY (Step 2)

Affected plant(s)
- ☐ Common name
- ☐ Scientific name
- ☐ Cultivar, variety
- ☐ Scion/rootstock
- ☐ Source of seed, plants
- ☐ Market names
- ☐ Plant susceptibility
- ☐ Other (describe)

Type of crop
- ☐ Fruit
- ☐ Ornamental
- ☐ Field crop
- ☐ Home garden
- ☐ Vegetable, herb
- ☐ Other (describe)

Growth stage
- ☐ Seedlings
- ☐ Mature plant
- ☐ Pre-flowering
- ☐ Post-flowering
- ☐ Fruiting
- ☐ Post-harvest
- ☐ Senescent
- ☐ Other (describe)

Plant site
- ☐ Potted
- ☐ In ground
- ☐ Hydroponics
- ☐ Courtyard
- ☐ Public park
- ☐ Greenhouse
- ☐ No-till cultivation
- ☐ Other (describe)

Age of planting
- ☐ Age of crop
- ☐ No. plants affected

Status of crop
- ☐ Commercial
- ☐ Home garden
- ☐ Public park
- ☐ Other (describe)

SIGNS & SYMPTOMS (Step 3)

What was collected?
- ☐ Insect, sticky trap
- ☐ Weed
- ☐ Plant part
- ☐ Soil
- ☐ Water
- ☐ Insect, sticky trap
- ☐ Other (describe)

Details of samples
- ☐ Number
- ☐ Where collected
- ☐ Collection date
- ☐ By whom
- ☐ Other (describe)

Effect on crop
- ☐ Economic
- ☐ Aesthetic
- ☐ Other (describe)

Severity of damage
- ☐ High
- ☐ Medium
- ☐ Low
- ☐ Other (describe)

Affected plant parts
- ☐ Leaves
- ☐ Flowers
- ☐ Fruit
- ☐ Seeds
- ☐ Branches, trunks
- ☐ Roots, bulbs
- ☐ Whole plant
- ☐ Other (describe)

Signs
- ☐ None
- ☐ Yes, describe

Symptoms
- ☐ None
- ☐ Yes, describe

SITE OBSERVATIONS, RECORDS (Step 4)

Pattern in crop
- ☐ Scattered
- ☐ In groups
- ☐ Most plants affected
- ☐ Surrounding plants
- ☐ Other (describe)

Pattern on plant
- ☐ Current season's growth
- ☐ Previous season's growth
- ☐ One side
- ☐ Bottom or top
- ☐ Uniform

Time frames
- ☐ When planted
- ☐ When first noticed
- ☐ Other (describe)

Site conditions

Areas affected
- ☐ Lower ☐ Higher
- ☐ Sloping
- ☐ Not associated with terrain
- ☐ Drainage
- ☐ Wet ☐ Dry
- ☐ Sunny ☐ Shaded
- ☐ Driveway, paths
- ☐ Construction activity
- ☐ Cultivated ground
- ☐ **Site map** available

On-site tests
- ☐ Previous tests, results
- ☐ Soil analysis
- ☐ Water analysis
- ☐ Plant tissue
- ☐ Nutrients
- ☐ Pesticide residues
- ☐ Soil moisture
- ☐ Other (describe)

History

Crop culture
- ☐ Fertilizer when, rate
- ☐ Irrigation, rate
- ☐ Other, eg previous crop

Pest, disease & weed history
- ☐ Pests & diseases
- ☐ Pesticide & other treatments

Environmental records
- ☐ Temperature
- ☐ Rainfall, soil moisture
- ☐ Other (describe)

REFERENCES CONSULTED (Step 5)

References
- ☐ Books
- ☐ Websites
- ☐ Colleagues
- ☐ Pest information sheets
- ☐ Other references (describe)

DIAGNOSTIC SERVICES (Step 6)

Laboratory 'tests' required
- ☐ Examination of signs & symptoms
- ☐ Microscopy
- ☐ Taxonomy
- ☐ Culture, baiting
- ☐ Indicator plants
- ☐ Biochemical tests
- ☐ ELISA
- ☐ DNA
- ☐ Soil analysis
- ☐ Water analysis
- ☐ Plant tissue analysis
- ☐ Pesticide residues, herbicide residues
- ☐ Others (describe)

THE DIAGNOSIS (Step 7)

Permanent report
- ☐ Yes
- ☐ Other

The diagnosis
- ☐ Cause
- ☐ Common name
- ☐ Scientific name
- ☐ Strain

Proof of diagnosis
- ☐ Signs & symptoms
- ☐ Diagnostic tests
- ☐ Data collected
- ☐ Pest information sheet matching
- ☐ Other (describe)

How definite
- ☐ Preliminary
- ☐ Useful
- ☐ Accurate
- ☐ Definite
- ☐ Item not found
- ☐ Inconclusive

How reliable
- ☐ Diagnostician (describe)
- ☐ Standard tests
- ☐ Accredited laboratory

Referred to another service
- ☐ No
- ☐ Yes (describe)

CONTROL / RECOMMENDATIONS

Advice provided
- ☐ IPM advice
- ☐ Legislative regulations (describe)
- ☐ Other (describe)
- ☐ References provided (describe)

Action complete
- ☐ Yes
- ☐ Further action required (describe)

Fig. 18. Information which may be in a diagnostic report of a complex disease. The client provides the information for the first 4 steps (which is the information requested in a submission form) and the diagnostician supplies the next 3 steps and makes recommendations.

NATIONAL STANDARDS FOR PEST RECORDS

Diagnostic national standards are being developed for high-risk pest threats to specific plant industries, eg banana, sugar, grains, citrus, viticulture and nursery industries.

- **Disease examples** include citrus canker, fireblight, guava rust, black Sigatoka, Moko and Panama disease of bananas, karnal bunt, Pierce's disease of grapes, potato spindle tuber viroid.
- **Pest examples** include Colorado potato beetle, glassywinged sharpshooter, khapra beetle, sugar borers, thrips.
- **Reference.** Ikin, R. and Small, N. 2000, *Plant Pest and Disease Records: Development and Adoption of National Standards*. Pub. No. 00/32, RIRDC, Barton, ACT.

Permanent records for living organisms

If collecting a permanent record of living organisms, the following information must be collected:

- **Current scientific name** of the organism, eg genus and species and as appropriate sub-specific terms (strain, biotype etc).
- **Life stage** or state.
- **Taxonomic group.**
- **Identification method and identifier.**
- **Date** (year and month) if known, recorded, normally the day will only be required for specific circumstances, eg the first detection of a particular pest for monitoring.
- **Locality**, including important environmental conditions, eg location codes, addresses, geographic coordinates, if under protected cultivation (greenhouse, nursery), should be indicated.
- **Scientific name of host** and/or circumstances of collection, eg trap or soil sample, as appropriate.
- **Host damage** (if applicable).
- **Prevalence** – indication of the level of pest presence or pest numbers.
- **Bibliographical references** if any.
- **Reference collection** data, eg acronyms, accession numbers.

How reliable is the pest record?

The National Standard includes criteria to evaluate the reliability of a pest record:

- **Accredited authority of the collector/identifier** indicates his/her scientific credibility – the accreditation and level of training of the diagnostician.
- **Accredited laboratories** can be relied on to carry out the tests properly, eg from looking at symptoms on the host to advanced microscopic examination and diagnostic testing.
- **Standard peer-reviewed test(s)** are used to identify the pest or disease organism.
- **Standard methods of collection** include location, date and type of the record/pest collection/observation.
- **Standard report, documentation** requirements indicate the way in which the identification has been **recorded**. Records must be published.

Pest status

Pest status is a vital component of international trade and phytosanitary measures for quarantine. Importing, exporting and all other countries may use pest status information for various purposes – pest risk analyses, establishing treatments, establishing national pest lists, establishing and maintaining pest-free areas.

- **Pest status in an area** may be either:
  - **Present**. In all parts of the area, only in specified areas or are seasonal pests.
  - **Absent**. No pest records, pest eradicated, etc.
  - **Transient**. Non-actionable incursion, actionable incursion and outbreak under eradication.
- **Determination of pest status in an area** requires expert judgment on the current distribution of a pest in an area based on a synthesis of both current and historical pest records and information from other sources. These might include:
  - Individual pest records.
  - Pest records from surveys.
  - Evaluation of pest records based on their reliability and consistency.
  - Records or other indications of pest presence.
  - Results of general surveillance.
  - Information from scientific publications and databases.
  - Phytosanitary measures used to prevent introduction or spread.
  - Other information relevant to assessing pest absence or presence.

APPENDIX 3 – SIGNS & SYMPTOMS

Leaves, shoots, herbaceous stems *125*
Flowers, buds *141*
Fruit, nuts *145*
Seeds, seedlings, cuttings *151*
Branches, trunks, crowns *155*
Roots, soil, media *163*
Bulbs, corms, rhizomes, tubers *169*
Whole plants *173*

This appendix provides examples of signs and symptoms to help you know what to look for in Step 3 of the diagnostic road map. **Don't forget to consider the other steps!**

- **Identifying the affected plant** allows you to access **lists** of common problems affecting it, reducing the suspect problems to a manageable number. Access a **pest information sheet** for each suspect problem.
- **Record** all visible external and internal signs and symptoms, insect measurements and microscope examinations.
- **Different** plant species often **react differently** to the same pest or disease, but for **some** pests and diseases, signs and symptoms tend to occur on the **same part(s)** of the plant no matter what the species.
- **Secondary** pests and diseases, eg fungi and insects, can invade weakened or dead tissue and mask the **primary** cause of the problem, eg prolonged drought or poor fertilizer choices.
- **There may be complex** problems and/or **delayed** signs and symptoms.
- **Consult the index** at the end of this book for cross-references of particular symptoms, eg **galls** on leaves, flowers, fruit, seeds, branches and roots.

WHAT IS NORMAL FOR THE PLANT?

see also page 46

Describe the signs and symptoms present that make you believe there is a problem in the first place, eg galls on the roots.

- **An apparent problem on one plant** may be part of the normal plant structure of another, eg tiny galls on roots of tomato are probably caused by root knot nematodes, on peas probably by nitrogen-fixing bacteria.
- **Be aware of variation** in plants, eg variegated leaves, provenances, seedlings.

LOCATION PLANT PARTS

see also page 47

Pests and diseases rarely attack the whole plant. Determine which **part(s)** are affected:

- **Plant parts**, eg leaves and fruit. Signs and symptoms can be located on one part only, several parts or spread over the whole plant.
- **Above or below ground**. Is it the stem or roots that are damaged and indirectly affecting the leaves? Are both the stem and roots affected?
- **On the surface and/or inside a plant part**, eg fruit fly maggots feeding internally. If possible always cut open fruit, stems, tease out flowers to look for insects and diseases.
- **Walk around the whole plant**, then inspect the interior, crowns and roots; there may be multiple problems.
- **Check locations away** from the plant showing symptoms, eg droppings, slimy snail trails, codling moth cocoons on packing cases, soil may test positive for *Phytophthora.*

SIGNS

see also page 48

Signs are the presence of the pest or disease or weed. You can actually see the insect, fungus or weed causing the damage, or you may see some of their products, eg honeydew, frass. **If signs are present**, the immediate problem can usually be readily identified.

- **Signs** rarely tell you about the entire problem, eg insect larvae feeding in tree trunks. If you stop here, you may miss the underlying **primary** factors which stressed the tree, creating an environment favourable for a borer, which is often a **secondary** pest.
- **Colour, size and shape** of insects, fungal fruiting bodies and spore masses may change with time.
- **Measure** insects and use a **hand lens** or **dissecting microscope** to look for small insects, mites and some fungal mycelium and spores.
- Often **no signs** are present, eg
  - Most **non-parasitic causes** only produce symptoms, eg nutrient deficiencies.
  - The **cause may be absent or hidden**, eg leafhoppers may have flown away, it may be winter, or the damage took place last season. Many pests and diseases are **microscopic**, so you may only see symptoms, eg wilting. Some insects bore into stems or trunks or live in the soil where they cause damage without being seen.



Signs may be microscopic



Callistemon sawfly larvae – bottlebrush



Powdery mildew – euonymus

SYMPTOMS

see also page 48



Colour



Size



Shape



Orientation



Damage

Symptoms are the visible responses of the affected plant to a pest or disease.

- **They describe the problem**, they do **not** directly identify the cause, eg **similar symptoms** may be caused by several **different** agents, eg **wilting** may be caused by:
  - **Parasitic** problems, eg *Phytophthora* root rot, root-feeding insects.
  - **Non-parasitic** problems, eg drought, waterlogging, heat.
- **Symptom development often involves changes** in:
  - **Colour**. Colour changes should be noted not only as greens, yellows or reds, but also in shades or tones, eg a pale-yellow colour may be caused by one disorder while another produces a deep yellow colour. Dead tissue may be present and its colour should be recorded. Leaf colour is usually obvious to the client and is often the symptom that generates the greatest concern.
  - **Size**. Plants can be stunted, normal or spindly in appearance. Very small or very large leaves can be produced. There may be excessive growth of some tissues resulting in outgrowths or galls.
  - **Shape**. Shape and size are somewhat related. However, the relationship of length, width and height can alter without changing volume. Thus shape can alter but size remains constant. Some disorders distort leaves, flowers, stems, branches and roots.
  - **Orientation**. The general growth of some plants is vertical, others sprawl horizontally. Disorders can alter the orientation not only of stems but also leaves, eg plants can have a wilted appearance. Some disorders cause normally slightly bent leaves and stems to be held stiffly upright.
  - **Damage**. Symptoms may also show as **damage**, eg holes, chewed areas.
- **Symptoms may be specific** and enable a pest or disease to be diagnosed with certainty, eg the yellowing of new leaves of azaleas due to iron deficiency, but this is not always the case.
- **While symptoms indicate something is wrong** they do **not** necessarily indicate **where** the cause of the problem is located. This is especially so when symptoms are caused by root damage or poor soil conditions.
- **In some cases the plant damage can be difficult to identify**, eg aphid injury to young peach shoots after the aphids have left. Observed damage may be where an insect has been, not where it is feeding at the time.
- **Perennial plants such as trees and shrubs** may be affected by advanced root problems before any foliage symptoms are visible, eg leaf yellowing, leaf drop, nutrient deficiency symptoms, followed by dieback as a response the root loss.
- **Symptoms may be delayed**. Trees may take years to die from drought, salinity, *Phytophthora, Armillaria*, foliage-feeding insects. Conifers frequently suffer from moisture stress during the summer months, but needles do not brown until several months later.
- **Some symptoms can be measured**, eg, the size of a leaf spot, length of dieback from the tip of a shoot.



Colour – iron deficiency on new leaves of azalea (D. Olsen)



Size – fungal rust galls on wattle



Shape – grapeleaf fanleaf virus alters the shape of leaves



Shape – roots of a pot bound plant many years after planting



Orientation – stiff upright shoots caused by tomato big bud



Damage – geranium leaf chewed by snails or caterpillars

COMPLEX SIGNS & SYMPTOM

Many plant problems are caused by a combination of parasitic and non-parasitic problems. Complex signs and symptoms are described in more detail on page 49, and complex causes of plant problems on page 5.

- If **lace bugs** are a possible problem check not only for stippling and yellowing of leaves caused by their sap sucking, but also for tar-like drops of excreta, adults and spiny nymphs on the undersurfaces of leaves (see Table 9, page 139).
- If **wood rot fruiting bodies** develop on the north side of the trunks of flowering cherry trees, look for previous sunburn injury. Check for the **primary** cause of a problem.

Leaves, shoots, herbaceous stems

Some signs & symptoms – Clues!

Anthracnose Blights, oedema Blisters Blotches, burns, scorches Cankers Chewed, tattered, holes, splitting **Chlorosis (yellowing)**, yellowing on most of the foliage, yellowing starting on younger or older leaves, yellow veins, marginal yellowing, line patterns, mosaics, mottles, ringspots, watersoaked, greasy look, haloes	Colour changes (other than yellowing) Dead shoot tips, tip dieback Defoliation, leaf drop Deposits, frass, droppings, structures Distortion, leaf curling, leaf rolling, leaf cupping, leaves tied together, witches broom Fungi, moulds, furry growths Galls	Insects, mites, irritations, odours, stains Leafmining Leaf spots Scabs Silvering Skeletonization Stippling, speckling Stunted, enlarged leaves Wilting

- These examples help you know what to look for; remember to identify the affected plant so you can access a **list** of common problems affecting it, which reduces the number of suspect problems to a manageable number.
- **Record** all visible external and internal signs and symptoms, measurements and microscopic examinations.
- **Leaves** often have the most noticeable symptoms and are often wrongly blamed for problems on twigs, branches, trunks, roots, or in the soil or water, or any combination of these, eg stem cankers may girdle and kill branches and twigs. It is important to try and decide whether the leaves are **directly** affected by a pest or disease, or **indirectly** affected by pests on stems, roots or both. It may be a soil, water or herbicide problem. If possible, always check stems and roots.
- **Perennial plants such as trees and shrubs** may be affected by advanced root problems before any foliage symptoms are visible, eg leaf yellowing.
- **Widespread occurrence of non-specific (indistinct)** symptoms such as leaf yellowing, leaf fall, browning of the tips and edges of leaves, may be serious, but may not in themselves relate to a **specific** cause. Often the only way to arrive at a correct determination of the causes of such plant problems is to gather data from a site visit, access records about the crop, weather, fertilisers, irrigation and soils.
- Some **easily identified problems** which have specific or distinctive signs or symptoms, may on some plants, at some times of the year and under some conditions, be difficult to recognise. For example, powdery mildew on last season's *Photinia* leaves looks silvery.

Carefully examine upper and lower surfaces of leaves

- **Age**. Leaves can be divided into 3 groups:
  Young expanding leaves
  Young maturing leaves
  Old matured leaves
- **Leaf parts**. Each leaf can be divided into:
  Petiole and blade
  Tip and leaf base
  Veins and interveinal areas
  Upper and lower surfaces
- **Do not wet or wipe leaves**.
- **Examine both sides of leaves** with a hand lens or dissecting microscope for **signs** and **symptoms**. It is critical to **observe and record** on which leaves signs and symptoms occur (older, younger or all leaves) and where they occur on individual leaves (upper, lower or both surfaces, margins, tips, etc).
- **Insects, mites and some fungal fruiting structures** may be visible; if they are the cause of the problem you may be able to find them. Remember damage may have taken place last season, or earlier in the season; insects may be inactive or have moved away.
- **Examine leaves internally as well as externally** if considered necessary.
- **In the field** walk around the plant, part foliage and look at what's going on under the canopy.

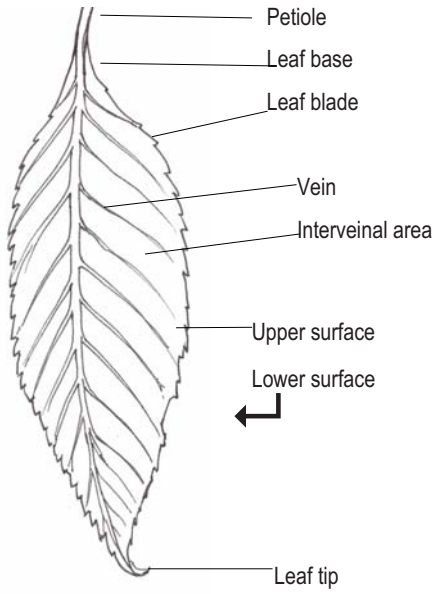


Fig. 19. How to examine leaves.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
ANTHRACNOSE **Plane trees** • **Anthracnose**: Blotched areas are red-brown and concentrated **along** the leaf veins. • **Environment**: Blotches are tannish brown and mostly towards the **outer margins** of the leaves, a marginal leaf scorch.	A brown and sunken spot with a sharply defined margin, sometimes on **leaves**, flowers and stems, is mainly a disease of ripening fruit (see page 145). Causes include: • **Fungal diseases**, eg *Colletotrichum, Glomerella, Gloeosporium, Sphaceloma,* which infect many plants, eg rose, plane tree, protea, peony seedlings, poplar.  Anthracnose – rose   Anthracnose – plane tree. Dead areas develop along veins, into petioles, shoots die. Favoured by wet spring weather. May be mistaken for frost injury in cold areas.
BLIGHTS see also Botches page127 Scorches page 174	A general, soft, rapid collapse and browning of **leaves**, flowers, stems, branches or twigs resulting in their death. May be accompanied by general leaf yellowing, red-to-purple leaf blotches, leaf distortion and desiccation. Rotting may be a secondary problem after tissue is killed. Causes include: • **Bacterial diseases**, eg bacterial blights of mulberry and walnut; bacterial canker of stone fruit; bacterial blight of pea (*Pseudomonas syringae* pv. *pisi*); bacterial blight of geranium (*Xanthomonas campestris* pv. *pelargoniii*); fireblight (not in Australia). • **Fungal diseases**, eg early blight (*Alternaria solani*) and late blight or Irish blight (*Phytophthora infestans*) of potato, tomato and Solanaceae weeds; downy mildew diseases, *Botrytis* blight on eucalypts and other seedlings in greenhouses during cool conditions. Some foliage blights may be accompanied by wet whiskery fungal growth on infected tissue, eg *Rhizoctonia* aerial blight of azalea and other plants, less commonly *Choanephora* blight. ***Some soil diseases***, eg *Chalara, Pythium*, *Sclerotium* may damage roots, above ground parts die; some *Phytophthora* spp. may cause foliage blights. • **Insects & allied pests**, eg thrip, lerp, pear and cherry slug damage may look blighted. • **Non-parasitic agents**. ***Environment***, eg early unseasonable cold, wet weather or frosts in autumn or late in spring. Damage is visible soon after the event, exposed foliage dies.   Early blight (*Alternaria solani*) – tomato. *Left:* Rapid browning of leaves. *Right:* Oldest leaves die rapidly. Disease progresses up the plant  Brown rot – peach shoots. Twigs brown and tree may look blighted
BLISTERS, OEDEMA see also Galls page 135 Leafmining page 137	Raised areas on **leaves**, stems. Causes include: • **Fungal diseases**, eg leaf blister of poplar (upper surface), white blister rust (*Albugo*) of brassicas (upper and lower surfaces), white rust of chrysanthemum (lower surface). • **Insects & mite pests**, eg grapeleaf, pearleaf and walnut blister mites; many leafmining insects, eg leafblister sawfly, lomatia leafminer; pimple psyllid on callistemon. • **Non-parasitic agents**. ***Environment***, eg frost may blister the epidermis of peas. Oedema may develop on the lower surface of some leaves.  Leaf blister (*Taphrina aurea*) – poplar  Grapeleaf blister mite damage  Oedema – *Peperomia*. Small blisters on leaf undersurface

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
BLOTCHES, BURNS, SCORCHES see also Blights page 126	**Brown/black dead areas on leaves** may be regular or irregular in shape and size, or form patterns other than spots. Dead areas may be randomly or evenly distributed on leaves; all leaves may be affected. May occur following yellowing/greying/browning but may occur suddenly on its own. Other plant parts may also be affected. Causes include: • **Bacterial & fungal diseases**. ***Leaf diseases***, eg later stages of downy mildews, blotch of begonia, anthracnose of plane tree; rust of *Prunus* and poplar, may cause leaves to brown and fall. ***Stem or root diseases*** interrupt the water supply, the effects of which may not be obvious until water stress occurs. • **Nematode diseases**, eg foliar nematode of chrysanthemum. • **Insects & allied pests**. ***Leafminers***, eg azalea leafminer, leafblister sawfly; ***sap-sucking insects***, eg lerp insects, lace bugs, scales; ***skeletonizing insects***, eg autumn gum moth, pear and cherry slug. The whole may appear scorched. ***Root-feeding insects***, eg black vine weevil, mealybugs, may cause death of above ground parts. • **Non-parasitic agents**. ***Environment***. **Leaf tips/margins** of soft-foliaged plants such as palms, ferns and Japanese maples, may brown, shrivel and die, during hot dry windy weather. Too rapid transfer of plants from a protected to a more exposed environment. Very occasionally due to overwet soil when leaves may feel soft rather than brittle. Portions of leaves shaded by other leaves or leaves on the shady side of the plant may be undamaged. Heat damage may occur uniformly over all plants in an affected area. **Other conditions** include sunburn, especially after water stress, frost, chilling injury, too much water, poor soil drainage, soil compaction or root injury from construction activity or vehicle traffic. ***Nutrient deficiencies & excesses***. **Excess fertilizer and salinity** may damage roots causing marginal leaf scorch and/or wilting and death of the entire plant. Marginal leaf scorch may also be caused by ammonium or phosphorus excesses or by potassium deficiency on older leaves. Foliar fertilizers may scorch plants. ***Chemical injury***. **Some pesticides** may bleach or scorch foliage of susceptible plants at excessive rates or during very low or very high temperatures, eg sulphur sprays may burn foliage at temperatures above 28°C. **Soil, water & atmospheric pollutants** eg gases associated with traffic, heaters, acid rain or smog, may all damage sensitive plants. Chlorine in hydroponic systems or swimming pools may affect adjacent plants. ***Natural characteristics***, eg end of season, senescence.

Patterns on plants
Pines
- **Needlecast fungi**: Dying needles occur on **new** growth. Check for tiny fruiting bodies.
- **Environment**: Dying needles may occur on **new** growth
- **Normal senescence**: Dying needles occurs on **old** growth.

Patterns on leaves
- **Brittle brown tips or margins** – too little water
- **Soft brown tips or margins** – too much water
- **Brown areas within leaf margin** - sunscorch



Acacia-spotting bug damage – each rectangle is a feeding site

Acacia-spotting bug symptoms. *Left:* Rectangular areas. *Right:* – Severe damage, plants scorched



Left: **Drought** – rhododendron leaf (tips brittle). *Right:* **Sunscorch** – star jasmine (within leaf margin)



Salt injury – hydroponically grown *Dracaena* (leaf tips brown, soft)

CANKERS, STEM ROTS see also Cankers page156	Dead, dark and often sunken areas on herbaceous and woody **stems**; stems may be ringbarked and areas above die. Stems may shoot from below the canker. Causes include: • **Bacterial diseases**, eg bacterial blight of pea (*Pseudomonas syringae* pv. *pisi*). • **Fungal diseases**. Root and stem rots (*Aphanomyces, Ascochyta, Macrophomina, Fusarium, Mycosphaerella, Pythium*) of pea; *Pythium* on geranium; *Rhizoctonia* collar rot on stock. *Botrytis* may attack stems or gerbera and other plants at ground level.



Stem cankers – green stems. Caused by one of several bacteria or fungi which attack stems of pelargonium



Rhizoctonia collar rot – stock (NSW Agric)

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
CHEWED, TATTERED, HOLES, SPLITS see also Skeletonizing page 139	Damage is **clearly visible to the naked eye**. Causes are many and include: • **Virus & virus-like diseases**, eg *Prunus* necrotic ringspot ('tatter leaf'), tomato big bud may cause stem cracking in tomato. • **Bacterial diseases**, eg bacterial canker of stone fruit. • **Fungal diseases**. ***Shothole*** is a symptom in which small fragments of leaves fall out leaving holes in their place, eg shot-hole of stone fruit, antirrhinum. ***Fungal leaf spots and scabs*** may break down, giving leaves a tattered appearance. • **Insects & allied pests**. ***Chewing insects***. Many **caterpillars**, eg common armyworm, cutworms, beet webworm, leafroller moths, potato moth, white cedar moth, palm dart butterflies; **beetles**, eg leafeating beetles and leafeating ladybirds and their larvae, Christmas beetles, garden and vegetable weevils, metallic flea beetles chew tiny irregular holes in leaves, which enlarge to give a 'shotholed' appearance; **sawfly larvae**, eg steelblue sawfly (spitfires); **also** grasshoppers and locusts, stick insects, earwigs. ***Egg laying-activities*** of cicadas and tree hoppers cause splits in leaves or stems, twigs may eventually die. ***Feeding sites*** of sap-sucking insects may break down. ***Leafmined or skeletonized areas*** may disintegrate giving leaves a tattered appearance. ***Emerging foliage*** may be damaged by chewing insects and is often difficult to diagnose. • **Snails and slugs** may make regular or irregular holes usually accompanied by slime trails and curly excreta. Do not confuse with damage caused by ***chewing insects*** especially on plants which may also be attacked by both or by birds, eg brassicas. • **Vertebrate pests**, eg birds, rabbits, sheep, horses, parrots, cockatoos and rats. Possums eat buds of grapes, pistachio and many other plants. • **Non-parasitic agents**. ***Environment***, eg hail, wind, rain and water may tear leaves. ***Mechanical injury***, eg during landscaping, children, dogs. ***Leafcutting bees*** do not feed on leaves but use the cut out pieces to line their nests. ***Normal characteristics***, eg overmature cabbages may split overnight.



Leafcutting bee damage



Bacterial canker – holes in leaves



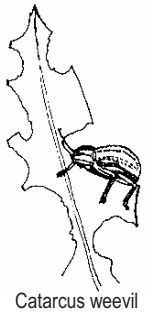
Shothole – cherry



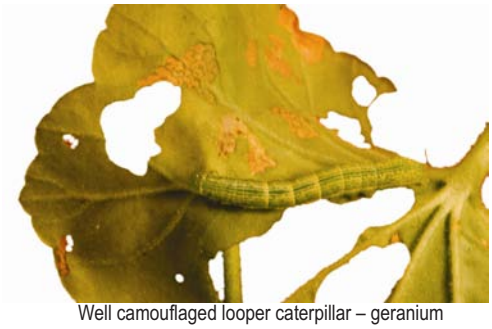
Anthracnose – rose. Spots break down



Weevil damage – euonymus



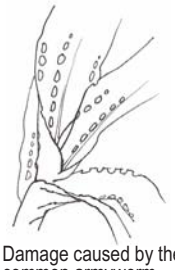
Catarcus weevil



Well camouflaged looper caterpillar – geranium



Willow sawfly – larvae and damage to leaves



Damage caused by the common armyworm feeding on unopened leaves in the throat of maize. Damage is only visible after leaves have emerged (after NSW Agric)



Snail damage – *Agapanthus*. Surface grazing may create a windowpane effect, leaf edges are notched



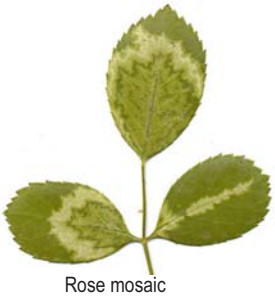
Cabbages may 'split' overnight due to overmaturity – a home garden problem

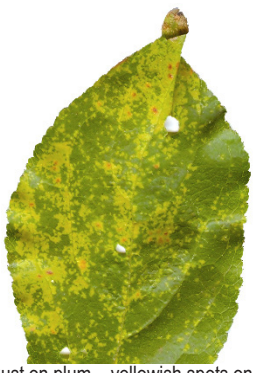
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
CHLOROSIS, YELLOWING see pages 130-132 **Nutrient deficiencies & excesses** • Know symptoms for your **crop** • The most typical and easiest to recognize symptoms show up during the early stages of nutritional problems • The deficiencies which commonly cause leaf yellowing are nitrogen, iron and magnesium or total lack of one to many nutrients • Deficiency & toxicity symptoms can look alike and can be complex to diagnose • At very high or very low pHs, symptoms of a deficiency can override other symptoms • Secondary symptoms may develop that make possible a further separation, eg in tomatoes, black spots appear near the veins in manganese but **not** in iron deficiency • Some groups of plants may suffer from certain deficiencies/toxicities, eg Proteaceae commonly suffer from phosphorus toxicity which is often mistaken for iron or other deficiencies or excesses.	Yellowing of leaves is one of the **most common and noticeable symptoms** of plant problems. Normal green tissue yellows due to partial failure of chlorophyll to develop. It may be localized on part of the leaf and may precede death of the tissue, or all leaves may be affected. Causes include: • **Virus & virus–like diseases**, eg line patterns, mosaics, mottles. Viruses usually have uneven patterns on leaves, on the plant and in the crop. Do not confuse with nutritional problems, herbicide injury or genetic abnormalities (see Table 3 below) or damage by sucking insects and mites (see page 139). • **Fungal and bacterial diseases** are often associated with yellowing, eg leaf spots, black spot of rose, rusts, downy mildews. ***Root diseases***, eg kikuyu yellow (*Verrucalvus* sp.); *Pythium*, *Rhizoctonia* will cause some plants to yellow from lack of nutrients. • **Nematode diseases**, eg root knot nematode attack of roots may cause leaf yellowing. • **Insect and mite damage**. ***Sap-sucking insects***, eg aphids, lace bugs, white flies, leafhoppers (see Table 9, page 139); ***chewing insects***, eg wood and stem borers tunnel in branches, trunks and roots causing leaves to yellow (and die), cutworms and twig girdlers girdle stems, root-feeding insects may reduce water/nutrients available to leaves. • **Non-parasitic**, ***Environment***. **Temperature**. Too hot/too cold, low day temperatures and greenhouses heated at night, tropical plants often do not tolerate cold. **Too little/too much water,** overwatering can be a common cause of yellowing of new growth of seedlings. **Very low or excess light**, lower interior leaves may yellow due to shading. Sudden changes from low to high light intensity or vice versa can cause leaf yellowing, reduced growth and leaf drop or death; shaded plants exposed suddenly to full sun may yellow, brown and vice versa, give plants time to acclimatize. **Wind** may damage soft leaves. ***Nutrient deficiencies & excesses.*** Deficiencies can make plants look quite sick but are **seldom** the primary cause of plant death. **If** it is a nutrient problem then it is often **too much** of something. Reasons for yellowing in nursery plants include over-fertilizing (early in the growing period); under-fertilizing (late in the growing season); low light or high temperatures combined with high fertilizer. Visual symptoms of a given disorder are more distinct on some plants than on others; learn to recognize the visual symptoms of likely nutrient problems which might occur on your crop. **Check pH** of water and soil which affects availability of nutrients, and patterns of symptoms on leaves, plant and crop (see Table 3 below). Time frames, site conditions, crop history and weather should also be investigated. Get soil, water and plant analyses if necessary. ***Mechanical damage*** to stems, trunks or roots. ***Chemicals***, excessive rates of growth regulators; fungicides, eg too frequent applications of copper may cause leaf yellowing in roses; insecticides, eg petroleum oils, or herbicides (glyphosate, simazine). Yellowing is often irregular or mottled, often resembling nutrient problems. Glasshouse heaters may emit ethylene which can affect older leaves. ***Genetic***, eg, albinism in pea seedlings, chimeras on citrus foliage. ***Normal characteristics***, eg variegation which may mimic virus or deficiencies; senescencing leaves may yellow and/or develop other colours.

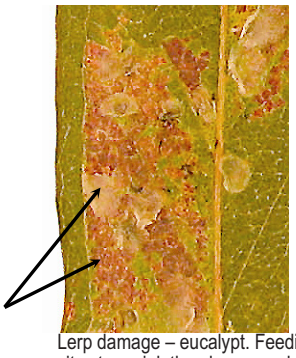
Table 3. Patterns of damage caused by virus and some non-parasitic diseases.

	Parasitic causes	Non-parasitic causes		
Some rules of thumb (always exceptions)	Signs and symptoms generally appear as **uneven patterns** on leaves, individual plants and in the crop.	Symptoms generally appear as an **even pattern** on the leaf, on individual plants and in the crop, eg all leaves of a certain age may be affected. There is usually a **clear border** between the affected portion and the rest of the plant. Nutrient problems may show a pattern associated with soil type. If several different plants in a given area all have deformed leaves on the west side of the plant and the rest of the plant is normal then chemical spray drift may be the cause.		
PATTERNS	**VIRUS DISEASES**	**NUTRIENT DEFICIENCIES & EXCESSES**	**HERBICIDE INJURY**	**GENETIC ABNORMALITIES**
Distribution of symptoms on leaves	Usually uneven pattern on leaf	Usually even, bilateral symmetry, often specific or distinctive pattern	May be even, a specific pattern	Often even over leaf, tendency to bilateral symmetry
Distribution of affected leaves on plant	Usually uneven, patchy, often only a few leaves show symptoms, often seen on new spring growth	Usually all over plant, or beginning either on the youngest or oldest leaves	Often on new growth or on the windward side of the plant or crop	Usually all over plant, or on one branch or shoot (a 'sport')
Distribution of affected plants in the field	Symptoms on a few randomly scattered patches of plants, which may gradually spread	Sudden appearance of symptoms on all plants in a crop, or evenly in an area within the crop	Sudden appearance of symptoms on **all** plants exposed	Uncommon, 1 to 2 plants in a population
Other features	Some plants are susceptible to **specific** viruses	Some plants are susceptible to **specific** deficiencies, eg yellow leaves often occur on citrus, daphne, gardenia	Leaves may be distorted. History of chemical applications	Pattern on leaf or fruit usually 'straight-edged'.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
Yellowing over most of the foliage	Causes include: • **Parasitic pests & diseases**. Occasionally ***sap-sucking insects***, eg severe infestations of twospotted mite, leafhoppers and lace bugs may cause plants to appear yellowish. • **Non-parasitic problems**. ***Environment***. Citrus and passionfruit leaves turn yellow during cool winters when cold soils and wet conditions prevent nutrient uptake (winter yellows); plants recover and leaves green up when weather and soil warms up. Overwatering may contribute to the problem in citrus and daphne. Light intensity, sun and/or excessively high temperatures; too rapid changes from low to high light intensity. ***Nutrient deficiencies & excesses***. General yellowing/light green of the whole plant usually indicates nitrogen deficiency but also could be caused by deficiencies of sulphur or magnesium, severe iron deficiency. ***Chemicals***, eg herbicide injury may resemble nutrient disorders, eg simazine. **Nitrogen drawdown** Some mulches may result in nitrogen deficiencies due to: • Recently chipped pine bark, trees not composted properly. • Microbes in the top layer of soil decompose most of the nitrogen in the mulch leaving little for plants.  Excessive sun – camellia  Simazine injury to *Prunus* – all leaves with **interveinal** yellowing  Glyphosate and simazine injury to honeysuckle – **bleached** leaves
Yellowing starting on younger leaves Upper leaves affected first	Leaves may be yellow (to light green). Causes include: • **Non-parasitic problems**. ***Environment***. Lack of light, moving plants abruptly from a high to low light intensity, transplanting too deeply, occasional waterlogging. Early stages of heat and drought stress may result in **interveinal yellowing** (yellow between green veins). ***Nutrient deficiencies & excesses***. **Deficiencies** of iron, manganese, less commonly zinc of azalea, citrus may result in **interveinal yellowing**. Soil or water pH levels may be too high. Yellowing may also indicate a **toxicity**, eg too much nitrogen, especially urea, ammonium, nitrate forms, or phosphorus. ***Chemical injury***, eg glyphosate. Symptoms of phosphorus toxicity on some Proteaceae, may yellow leaf tips and margins or burn tips and margins of younger leaves. Plants may die  Iron deficiency. *Right:* Citrus. *Left:* Rhododendron (NSW Agric)  Manganese deficiency – itrus (NSW Agric)  Zinc deficiency – citrus (NSW Agric)
Yellowing starting on older leaves	Causes include: • **Parasitic pests & diseases**, eg root diseases, last season's sucking insect or mite damage (lace bugs, leafhoppers, thrips spider mites,). • **Non-parasitic problems**. ***Environment***, eg waterlogging, low light levels, high plant densities, poor soil drainage, soil pH problems. Early stages of heat and drought stress may cause **interveinal yellowing**. ***Nutrient deficiencies & excesses***. Nitrogen, potassium and magnesium **deficiencies** nearly always appear first on the **oldest** leaves – deficiency of magnesium may cause specific patterns (below) or **interveinal yellowing**. High soil salinity. ***Chemicals***. Herbicides, eg simazine and sulphur dioxide may cause **interveinal yellowing**. ***Normal characteristics***. Senescence, eg older leaves may yellow before falling. Symptoms of phosphorus toxicity on some Proteaceae, may discolour or burn leaf tips and margins of older leaves.  Azalea lace bug damage to last season's leaves  Magnesium deficiency – older citrus leaves (NSW Agric)  Senescence – rose leaves in autumn (different stages of senescence)

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
Yellow veins	Veins appear yellow. Occurs on older or younger leaves, interveinal tissue remains green. Causes include: • **Virus & virus-like diseases**, eg rose mosaic (some forms), strawberry veinbanding virus, malva veinclearing virus. • **Non-parasitic problems**, eg pesticide injury, toxins in growing media, normal characteristics, eg net vein patterns on some indoor plants, peas.  Rose mosaic – veins appear lighter than tissue between veins (D. Olsen)  Petroleum oil injury – citrus Veins appear light  White oil damage – *Ficus.* Leaves look greasy yellow
Marginal yellowing	Leaf edges yellow, may later brown. Causes include: • **Virus & virus-like diseases**, eg rose mosaic. • **Non-parasitic problems**. ***Environmental.*** Initial symptom of many environmental problems. ***Nutrient deficiencies & excesses***, eg deficiencies of magnesium and potassium; excessive salt/fertiliser in irrigation water or media. ***Chemicals***, eg pesticides applied as a soil drench. ***Normal characteristics***, eg variegated gazania, senescence.  Rose mosaic, one of many patterns  Sun bleaching – yellow tips on *Ficus pumilis*  Variegated gazania
Line Patterns	Lines of light coloured tissue on normal coloured leaves, **not** delineated by veins. • **Virus & virus-like diseases**, eg rose mosaic, plum line, hydrangea mosaic. • **Non-parasitic problems**, eg cold water patterns on African violet, *Kohleria*.  Rose mosaic  Plum line – Greengage  Hydrangea mosaic – line patterns
Mosaics, mottles	Irregular pale green/yellow and dark areas on leaves, generally caused by virus and virus-like diseases, **not** delineated by veins. • **Virus and virus-like diseases**, eg camellia yellow mottle; apple, daphne, *Kennedia*, rose, turnip and violet mosaics. • **Non-parasitic agents**, eg symptoms of some deficiencies, senescence patterns, and chemical toxicities on some plants can produce mottle-like patterns.  Kennedia mosaic  Camellia yellow mottle  Apple mosaic

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
Ringspots Old one	Yellowish rings with green tissue in the center some of which may become brownish, mostly caused by virus diseases. Causes include: • **Virus & virus-like diseases**, eg peony ringspot, pelargonium mosaic, odontoglossum ringspot, tomato spotted wilt. • **Non-parasitic problems**. ***Environmental***, eg cold water and/or bright light on the leaves of African violet and Kohleria may cause creamy rings; oedema on leaves of umbrella plants may develop under humid conditions.  Rose mosaic  Tomato spotted wilt – capsicum  Odontoglossum ringspot – cymbidium (NSW Agric)  Peony ringspot  Possible virus symptoms on hoya (unconfirmed)  Oedema – umbrella (*Schefflera actinophylla*)
Watersoaked, greasy spots, yellow patches, haloes see also Stippling page 139	They are many yellow symptoms on leaves not as well defined as those shown on pages 129-132. Examples include: • **Virus & virus-like diseases**. Indistinct viral symptoms, eg apple chlorotic leaf spot. • **Bacterial diseases**, eg bacterial canker of stone fruit. • **Fungal diseases**. Downy mildew of grape, eg greasy yellow areas on leaf **upper-surfaces**, greyish spores develop on leaf **undersurfaces** in humid conditions. Rust diseases, eg yellow areas on leaf **uppersurfaces** and red, brown or black spores on leaf **undersurfaces**. • **Insects & allied pests**, eg stippling and other damage by sap-sucking insects may be confusing (see page 139). • **Non-parasitic agents**. ***Environment***, eg chilling injury, rapidly fluctuating greenhouse temperatures and humidities, drought. Condensate drip and cold water injury. ***Chemicals***, eg often the first signs of pesticide injury (see pages 107 and 130).  Downy mildew of grape – greasy yellow areas on leaves. In humid conditions fine grey fungal growth develops on leaf undersurface  Rust on plum – yellowish spots on eaf upper-surface, brown, red or black spores on leaf undersurfaces

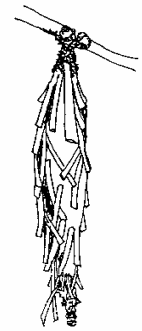
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
COLOUR CHANGES ***Other than yellowing***	Development of colours **other than yellowing** in leaves. Causes include: • **Virus & virus-like diseases**, eg tomato spotted wilt (bronze wilt), broad bean wilt (dark longitudinal streaks may develop on stems). • **Fungal diseases**, eg some powdery mildews (pink tinges); downy mildew infection may cause general leaf yellowing, red-to-purple leaf blotches, leaf distortion and desiccation. Root and vascular wilt diseases may affect foliage colour. Grey mould (*Botrytis* spp.) may look like a grey film over foliage. • **Nematode diseases**, eg root knot may cause deficiency-like symptoms on leaves. • **Insects & allied pests**, eg twospotted mite on apple leaves (bronzing), camellia rust mite, feeding sites of lerp insects turn pinkish then brown. Pimple psyllids on *Callistemon* appear pinkish. • **Non-parasitic agents**. Abnormal or out-of-season colours may develop in leaves. ***Environment***. Low temperatures may cause **leaf purpling** on some plants; cold weather and water stress may cause purpling of bluegrass after it has started growing. **Light green** leaves may be the result of slow plant growth (too cool, too hot), imbalance of day and night temperatures, excess water, waterlogging, dry soil, light intensity (too low, too high) for long periods. ***Nutrient deficiencies & excesses***, eg some varieties of maize and sorghum develop purplish pigments when phosphorus is deficient. ***Chemicals*** Herbicide injury, eg amitrole (bleached, pinkish leaves), siduron and dichlobenil contamination (purpling). ***Genetic*** eg chimeras, reversion to unvariegated forms. ***Normal characteristics***, eg coloured leaves of many plants, new spring growth and senescing leaves.  Lerp damage – eucalypt. Feeding sites turn pink then brown and die  Grapeleaf blister mite damage – pinkish tinges on affected leaves  Pink new growth – *Photinia*
DEAD SHOOT TIPS	Causes include: • **Virus & virus-like diseases**, eg broad bean wilt virus. • **Bacterial diseases**, eg bacterial blight of walnut. • **Fungal diseases**, eg brown rot, peach leaf curl and shothole of stone fruits. Root rots, wilt diseases, stem rots and wood rots may cause dieback of shoot tips. • **Insects & allied pests**. ***Chewing insects***. Tip borers, eg oriental fruit moth, callistemon tip borer, pine shoot weevil. ***Sap-sucking insects & mites***, eg black peach aphid, bronze, crusader and eucalyptus tip bugs, passionvine bug, spider and false spider mites. • **Non-parasitic agents**. ***Environment***, eg too little/too much water, fluctuating water levels, low/high temperatures, frost or heat damage, wind burn, water stress. ***Nutrient deficiencies & excesses***, eg salinity and uncommonly, deficiencies of calcium, copper, manganese, potassium, iron, boron and zinc. ***Chemicals***, eg herbicides, toxic substances in the soil or in the air. ***Normal characteristics***, eg plants have a certain lifespan.  Oriental fruit moth damage to peach – caterpillars bore into tips of shoots  Black peach aphids suck sap from tips of peach causing shoots to die  Nymph of a crusader bug sucking sap from new shoots of wattle which wilt, curl over and die

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DEFOLIATION, LEAF DROP	The premature fall of leaves, which may drop while still green or beginning to turn yellow. Causes include: • **Bacterial diseases**, eg bacterial canker of stone fruit may cause leaf fall in spring. • **Fungal diseases**. ***Leaf diseases***, eg black spot of rose, peach leaf curl, shothole, rusts, needlecasts (*Lophodermium* spp.) of pines. ***Root rots***, eg *Phytophthora*. • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg lerp, twospotted mite. ***Chewing insects***, eg cypress sawfly larvae. ***Root or trunk feeding insects*** may also cause premature defoliation. • **Vertebrate pests**, eg cockatoos may sever twig bases. • **Non-parasitic agents**. ***Environment***. Rapid changes in temperature (low to high and vice versa), low humidity, water stress (too much, too little), wind. Root decline or graft incompatibility. Leaf drop on indoor plants may be due to sudden temperature drop, natural chill in winter in cool areas, poor light, drought stress, waterlogging (even of a short duration). ***Nutrient deficiencies & excesses***, eg rapid increase in soil salinity, low nutrition, planting too deeply. ***Chemicals***, eg ethylene, herbicides, some insecticides. ***Normal characteristics***, eg deciduous plants drop leaves in autumn, evergreen plants intermittently and often after flowering.
DEPOSITS, FRASS, STRUCTURES see also Insects page 139 Don't confuse dust and sand particles with insect eggs	Many pests and diseases leave a variety of deposits on **leaves**, shoots and areas on and around plants which help with diagnosis. Examples include: • **Bacterial & fungal diseases**, eg bacterial ooze, gumming, jelly. • **Insects & allied pests**. ***Frass***, eg nymph skins, eggs, droppings both solid and liquid, cases of case moths; **chewing insects**, eg caterpillars leave solid droppings of various shapes and sizes which can be used to identify insects feeding high in trees and measure their numbers; **sap sucking insects**, eg thrips, lace bugs and shore flies leave tiny dark spots of excreta on leaves (fly specks). ***Exudates***, eg honeydew (some sap-sucking insects), silk (caterpillars), spittle (spittle bugs), wax (mealybugs), fine webbing (spider mites). • **Snails & slugs** leave trails of slime and excreta. • **Non-parasitic agents**. ***Living agents***, eg saprophytic fungal spore capsules may be found on azalea leaves, also on media and pots; sooty mould. Spider webs may irritate fruit pickers. ***Nutrient deficiencies & excesses***, eg fertiliser granules; black, brown or rust-red deposits of calcium, magnesium, sodium and iron compounds found in some water supplies. ***Chemicals***, eg residues from sprays and dusts, granules, snail pellets; copper sprays leave blue residues. ***Others***, eg dust, sand particles and growing media particles.


Infestation of lerp – complete defoliation of a eucalypt


Bacterial canker of stonefruit – defoliation of leaves in spring


Leaf drop after flowering – camellia


Saunder's case moth


Large citrus butterfly – excreta


Webbing caterpillars shelter in 'nests' of plant parts, excreta and webbing


Silk produced by a caterpillar


Aphid nymph skins – sweetcorn


Spider mite webbing on peas – mites lay their eggs and move around on the webbing

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)

DISTORTION

see also
Blisters page 126
Galls page 136
Parasitic plants page 162

Distortion includes:
Leaf crinkling
Leaf cupping
Leaf curls
Leaf rolling
Leaves tied together
Enlarged veins
Enlarged leaves
Small leaves
Vein thickening
Witches brooms

Curling, rolling and distortion of **new leaves and young shoots** which may persist for some time. Anything that interferes with the growing point can result in distorted leaves and shoots. Causes include:

- **Virus & virus-like diseases**, eg some virus diseases of stone fruits, grapevine fanleaf, grapevine leaf roll, potato leaf roll. Lettuce big vein causes vein thickening. Tomato big bud **reduces** leaf size, while tomato spotted wilt **increases** leaf size in nasturtium. Tomato leaf curl viruses are emerging diseases in northern Australia.
- **Fungal diseases**, eg apple and pear scab, powdery mildew of apple, roses (leaf bubbling), peach leaf curl. A witches' broom (proliferation of shoots) may be produced when apricot shoots are infected with peach leaf curl.
- **Nematode diseases**, eg leaves attacked by foliar nematodes may become cupped.
- **Insects & allied pests**. Emerging or immature foliage may be damaged by ***sap-sucking insects and mites*** causing leaf rolling, curling, cupping, eg aphids, bugs, mealybugs, leafhoppers, mites, leaf rolling thrips (callistemon), whitefly; **eriophyid mites** feeding on acacia, casuarina, eucalypt and fuchsia, may cause witches' broom (see page 162); **broad mite, cyclamen mite** and **false spider mites** can cup, curl, pucker and stunt leaves (which is easier to observe than the mites themselves); **twospotted mite** may cause apple leaves to roll. ***Chewing insects*** may damage emerging foliage; leafroller moth larvae roll or tie leaves together and feed within these nests; tip borers, eg callistemon tip borer, oriental fruit moth, have a pruning effect.
- **Non-parasitic agents**. ***Environment***. **Leaf rolling** may be caused by cold weather (dwarf beans, citrus), moisture stress (apple, rhododendron), high soil moisture (tomato), wind (leaf crinkle of citrus) or a combination of factors, eg too little water, too much sunlight (house plants), high temperatures and light intensity. Leaf blades may be thick or excessively succulent due to high temperature and light intensity, low humidity. ***Nutritional deficiencies & excesses***. Deficiency of **molybdenum** on cauliflower (whiptail); deficiencies of **boron, copper and calcium** on some hosts, may cup, blacken or kill leaves. High salt levels in media. ***Chemicals***, eg hormone herbicides (2,4-D, MCPA, dicamba) distort new growth and may cause vein-thickening. Overuse of plant growth regulators. Glyphosate may cause leaf distortions on some plants; delayed symptoms may appear in spring after an autumn application and may persist for some time, plants may die. Sulphur may cause leaf cupping. ***Normal characteristics***, eg juvenile leaves of blue gum, wattles and tortured willow may appear abnormal.

Leaf crinkling – callistemon, leaves emerging during cold weather



Macadamia twig-girdler – caterpillars web leaves together



Peach leaf curl (NSW Agric)



Green peach aphid injury – leaf wrinkling due to aphids sucking plant sap



Leafrolling thrips injury – *Callistemon*



Leaf rolling. – moisture stress on apple



Leaf rolling. – moisture stress on rhododendron



Leaf cupping – geranium, possibly environmental



Hormone herbicide injury to grape leaf



Thick parallel veins – hormone herbicide injury – plane tree



Hormone herbicide injury – tomato

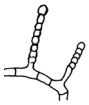


Glyphosate injury – roses. Feathery growth in spring after drift during dormancy. See also page 107

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
FUNGI MOULDS, FURRY GROWTHS	Causes include: • **Fungal diseases**. Surface fungal growth of various colours grow on leaves and **shoots**, eg powdery and downy mildews, rusts, smuts, grey mould (*Botrytis*). ***White/grey powdery*** fuzz on both leaf **upper and lower** surfaces (powdery mildew) or on leaf **under** surfaces (downy mildew). ***Red or black spore masses*** mostly on leaf undersurfaces (rust), ***black sooty spore masses*** on leaves (smuts). Masses of ***grey spores*** and mycelium (grey mould, *Botrytis*). • **Insects & allied pests**. ***Insects which produce wax*** are often confused with fungal mycelium, eg psyllids on many Australian plants, mealybugs, mealybug predators, woolly aphids. ***Some plants react to mites feeding*** by producing erinose (hairy leaves), eg grapeleaf, pearleaf and walnut blister mites. • **Non-parasitic problems**. ***Living agents***, eg lichens; slime moulds; sooty mould growing on honeydew; black non-parasitic fungi may grow on the undersides of low lying leaves where humidity is high. ***Normal characteristics***, eg hairs which cover all leaves on some grape and rhododendron varieties; spores on fern leaves which are sometimes mistaken for rust.  Grey mould *(Botrytis cinerea)* – callistemon (B. A Fuhrer)  Powdery mildew – rose  Downy mildew of grape – downy growth on leaf undersurfaces. Yellow greasy spots on upper surface  Rust (orange, brown spores) – antirrhinum  Sooty mould – daphne  Walnut blister mite erinose (hairiness) on leaf undersurface  Slime moulds (non-parasitic) on geranium – do not confuse with smuts, which are parasitic
GALLS see also Galls pages 143, 160	A swelling, roughly spherical, of unorganized plant cells occurring on **leaves**, stems, roots, flowers, seeds. They vary in colour, and may result in leaf yellowing and leaf fall, plants may die. Causes include: • **Bacterial diseases**, eg bacterial gall of oleander, olive knot. • **Fungal diseases**, eg azalea leaf gall, camellia leaf gall, rust galls on wattle. • **Nematode diseases**, eg stem and bulb nematode. • **Insects & allied pests**. Galls tend to be different for each species of gall insect and are the result of the insect secreting toxic chemicals into the plant during feeding, eg chrysanthemum gall midge, woolly aphid (apple), *Apiomorpha* spp. (eucalypts), *Cylindrococcus* spp. (casuarinas), *Cecidomyia* spp. (tea-tree) and several species of gall-making thrips (wattles). • **Non-parasitic agents**. ***Chemicals***. Herbicides, such as dicamba may cause tumours to form at the base of branches (pines).  Camellia leaf gall  Galls (*Apiomorpha* sp.) – eucalypt. Female on left, male on right  Poplar gall aphid (*Pemphigus bursarius*) creates a hollow gall within the leaf petiole

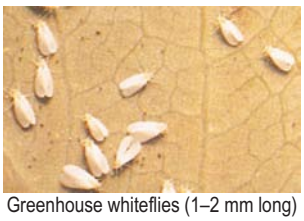
Do not confuse downy with powdery mildew. Not that many species of plants are susceptible to both.

Powdery mildews: White mould may develop on both upper & lower leaf surfaces. Chains of spores may be seen under a microscope.



Down mildews: Greyish mould develops on leaf under surfaces in humid weather. Spore-bearing structures may be seen under a microscope.



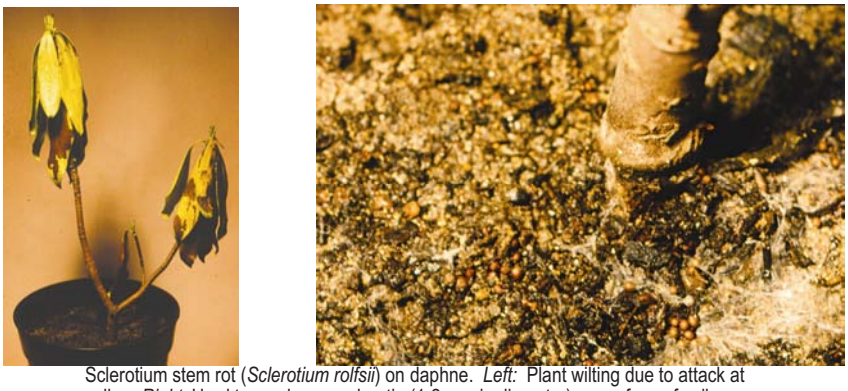
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
INSECTS, MITES, IRRITATIONS, ODOURS, STAINS see also Skeletonization page 139	Insects found amongst foliage may be pests or beneficials. Examples include: • **Insects & allied organisms** ***Chewing insects*** are usually obvious, eg butterfly and moth caterpillars, beetle adults and larvae, sawfly larvae, grasshoppers, locusts. ***Sap-sucking insects and mites***, eg aphids, bugs, leafhoppers, lerp, mealybugs, scales, whiteflies, thrips, broad mite, spider mites. ***Other insects***, eg ants attracted to honeydew. ***Irritations, odours, stains***. Some may have irritation hairs, eg white tailed mistletoe moth, others produce unpleasant odours, eg orange and green stink bugs, or eject evil smelling liquids if disturbed, eg spitfires and spined citrus bug. ***Beneficial insects & allied organisms***, eg lacewings, ladybird beetles, predatory mites, spiders. Always check backs of leaves for aphids, lace bugs, white flies, thrips, other insects and mites  Doubleheaded hawk moth caterpillar (**12 cm long**) feeding on hakea  Black bean aphids parasitized by wasps – note wasp exit holes  Black scale on stems, leaves – daphne  Longtailed mealybug (3-5 mm long)  Greenhouse whiteflies (1–2 mm long)  Diseased and healthy grapevine moth caterpillars (up to 50 mm long)  Larvae of beneficial ladybird (5-7 mm long)
LEAFMINING	Larvae of some chewing insects feed internally between the lower and upper leaf surfaces resulting in characteristic trails, scribble-like markings or 'mines' on leaves. Larvae can be seen with probing or holding leaves up to light; the exit holes of the adult may be seen. Most are host specific. Leafmining insects include: • **Insects & allied pests**. ***Fly maggots***, eg bean fly, lantana leafmining fly, pittosporum leafminer, cineraria leafminer; ***moth larvae*** mine in leaves of azalea, callistemon, citrus, hakea, oak, potato, wattle and many other plants; ***sawfly larvae***, eg leafblister sawfly.  Leafblister sawfly larvae in leaf  Callistemon leafminer damage  Citrus leafminer damage (Ampol Rural)  Cineraria leafminer damage to Marguerite chrysanthemums  Azalea leafminer caterpillars mine in leave tips which roll under and brown  Hakea leafminer damage to tips  Lomatia leaf miner damage (blisters)

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
LEAF SPOTS see also Chewed, tattered page 127	Small self-limiting round spots with distinct margins on **leaves**, stems and fruit. Spot colour may change with age and spots may join together. Mostly host specific. Causes include: • **Virus & virus-like diseases**, eg tomato spotted wilt. • **Bacterial diseases**. Leaf spots tend to be **angular**, limited by veins, may be surrounded by watersoaked areas, eg cucurbits, mango, mulberry and walnut. • **Fungal diseases**. Leaf spots **not** usually limited by veins, may be feathery, have concentric rings of different colours, may have a light yellow edge of infection, centres often tan (old dead tissue), then brown (newly dead tissue), often more prevalent on older leaves. Leaf spots commonly on apple, pear, citrus, rose, eucalypt, pea, banana, hakea, black currant, hebe, chrysanthemum, dahlia, gerbera, strawberry, iris, rhubarb, poplar. Fruiting structures (some microscopic) may form on the leaf spots. • **Insects & allied pests**. Feeding sites of sap-sucking insects, eg acacia-spotting bug. • **Non-parasitic agents**. ***Environment***, eg humidity. ***Chemicals***, eg contact herbicide injury. ***Genetic***, eg privet rootstock/lilac scion incompatibility. ***Normal characteristics***, eg leaf spots on *Gueris,* senescing leaves.  Fungal leaf spots – strawberry ('round' spots)  Bacterial spot – mulberry ('angular' spots)  Contact herbicide injury – tulip  Graft incompatibility – lilac (spots develop on leaves)
SCABS see also Blisters page 126	A rough crust-like area on the surface of **leaves**, fruit, corms. Causes include: • **Bacterial diseases**, eg citrus canker, oleander gall. • **Fungal diseases**, eg apple scab (black spot), lemon scab. • **Non-parasitic agent**, eg oedema, mechanical injury to leaves may callus.  Lemon scab (NSW Agric)  Bacterial gall of oleander. Galls look like scabs. Leaves infected when young will become distorted as they grow
SILVERING see also Stippling page 139	Causes include: • **Fungal diseases**, eg silver leaf of plum, last season's powdery mildew infections on some hosts, eg hebe, photinia. • **Insects & allied pests**. ***Thrips***, eg gladiolus, greenhouse and western flower thrips rasp and suck leaves causing flecking/streaking and silvering with black tarry spots of excreta. ***Mites***, eg peach leaf silver mite, red legged and blue oat mites, tomato russet mite. May be confused with stippling/speckling caused by lace bugs, whiteflies, leaf hoppers and spider mites (see Table 2, page 139). • **Snails and slugs**, eg slime trails look silvery. • **Non-parasitic agents**. ***Poor environmental conditions***, eg cold or wind damage. ***Chemicals***, eg leaf gloss. ***Normal characteristics***, eg senescing leaves on roses and other plants may appear silvery.  Greenhouse thrips injury – silvering of viburnum leaves  Greenhouse thrips injury – viburnum. Tarry excreta mostly on leaf undersurfaces  Variegated pumpkin leaf, even pattern  Senescing rose leaves may look silvery

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
SKELETONIZATION	Insects which feed on the surface of leaves, only the veins are left. Examples include: • **Insects & allied pests**. ***Chewing insects***. **Moth larvae**, eg autumn gum moth, gumleaf skeletonizer, painted apple moth; **beetle larvae**, eg elm leaf beetle, leafeating ladybirds and pumpkin beetles on cucurbits; **sawfly larvae**, eg pear and cherry slug, callistemon sawfly. • **Snails & slugs**, eg young snails may skeletonize leaves of gazania and other plants, damaged leaves shrivel and it is often difficult to recognize this as snail damage. • **Non-parasitic agents**, eg wind may break down leaf surfaces.   Leafeating ladybird and its spiny larva  Pear and cherry slug and damage  Callistemon sawfly damage
STIPPLING, SPECKLING see also Silvering page 138	Leaves randomly stippled with tiny whitish specks (feeding sites), may yellow and occasionally brown and die (see Table 4 below). Do not confuse with symptoms of virus diseases, nutrient problems, herbicides injury or genetic variegation (see Table 8, page 129,). Causes include: • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg leafhoppers, whiteflies, lace bugs, spider mites. Stippling is caused when these pests feed on plant fluids, inject toxins into the plant and the plant cells surrounding the injection site die. Mites cause smaller stipples than many larger bugs. Rarely do sap-sucking insects feeding on leaves kill a plant, but if also stressed by other factors, plants may decline or even die. ***Chewing insects***, eg **leafminer adults** puncture the upper sides of leaves for feeding and egg laying. • **Non-parasitic agents**, eg air pollution (ozone), deficiencies, herbicide damage.  Black parasitized whitefly nymphs on undersurface of leaf – cucurbits  Leafhopper stippling – mulberry  Leafhopper stippling – marigold  Nymph and adult whiteflies on leaf under surface – *Melianthus*  Azalea lace bug symptoms – azalea  Spider mite symptoms – frangipani. Note stippling along the main vein

Table 4. Signs and symptoms of some insects and mites that cause leaf stippling.

LEAVES	TWOSPOTTED MITE	VARIOUS LEAFHOPPERS	GREENHOUSE WHITEFLY	LACE BUGS	GREENHOUSE THRIPS
UPPER SURFACE	Sandy stippling. Sandblasted appearance	Stippled feeding patterns	Sandy stippling	Sandy stippling	Silvering
UNDER SURFACE	Mites, eggs, webbing near growing points, sand particles (**debris**)	Insects fly if disturbed, leaving a few cast skins, but the surface may be 'clean'	Whiteflies, white stationary nymphs, honeydew, sooty mould, nymphs may be parasitized (**black**)	Lace bugs, spiny nymphs, **black** tarry drops of excreta	Adults and nymphs often dark coloured, **black** tarry drops of excreta
Host range	Wide	Wide	Wide	Host specific (olive, azalea & rhododendron)	Wide

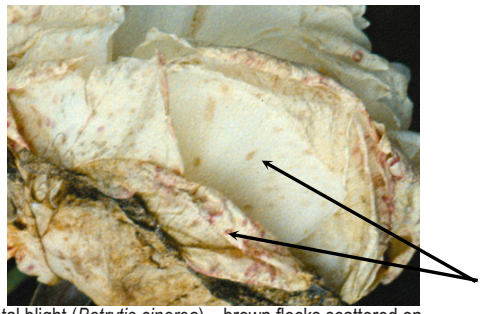
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
STUNTED OR ENLARGED LEAVES see also Slow growth page 174	Leaves smaller or larger than normal. **Larger leaves** that are also thin in cross section are mostly caused by non-parasitic problems, eg growing plants under too low light intensity, humidity too high, too much fertilizer (particularly nitrogen) especially if moisture is excessive. **Smaller leaves** are more common and causes are more wide ranging, anything that damages roots of a plant has the potential to affect leaf size. **Causes of smaller leaves** include: • **Parasitic diseases**, eg some foliage diseases (powdery mildews) and some root diseases. • **Insects & allied pests**. Broad mite and eriophyid mites feeding on leaves; insects feeding on roots. • **Non-parasitic problems**. ***Environmental***, eg high light intensity, high pot temperatures, chronic low humidity and moisture, high soil conductivity. ***Nutrient deficiencies & excesses***, eg lack of major nutrient or trace elements such as copper, zinc or boron. ***Mechanical***, eg root binding. ***Chemicals***, eg excessive growth retardant, some pesticides. ***Normal characteristics***, eg some species or cultivars have small leaves.
WILTING  Vascular wilt – discoloured xylem due to invasion by bacteria or fungi interrupting the water supply to the leaves Many causes of wilting may be eliminated by noting recent weather, determining the soluble salt level in the soil and noting the appearance of roots and internal tissues of the stem.	Wilting is a **non-specific** symptom which includes loss of rigidity and drooping of leaves and shoots, often from insufficient water in the plant. Affected leaves and shoots may yellow, then brown, starting along leaf margins, shoots may die back, leaves may fall early. Causes include: • **Virus & virus-like diseases**, eg broad bean wilt virus. • **Bacterial & fungal diseases**. ***Vascular wilt diseases*** are caused by bacteria or fungi which invade and block the xylem vessels of the host plant, eg bacterial wilt of tomato; *Fusarium* wilts (*Fusarium oxysporum* f.spp.) initially cause leaves on one side of the plant to yellow, wilt and die. If an infected tomato stem is cut lengthwise a brown disoloration of the vascular tissue is seen. ***Crown, stem and root*** **rots** prevent the plant taking up water resulting in wilting, eg bacterial canker of tomato, *Fusarium* crown and stem rot (*Fusarium avenaceum*), *Phytophthora* root rot or *Rhizoctonia* stem canker, *Sclerotium* stem rot, damping off, soft rot of iris rhizomes. • **Nematode disease**, eg root knot nematodes attack plant roots causing wilting, and deficiency-like symptoms on herbaceous plants like tomato. • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg aphids, bugs, mealybugs and leafhoppers cause shoots to wilt during dry weather, tips may die. ***Chewing insects***, eg caterpillars, cutworms, black vine weevil larvae feed on roots and stems; leafmining larvae tunnel in leaves; tip borers may also cause leaves to wilt. • **Non-parasitic agents**. ***Environment*** Insufficient water accompanied by high temperatures, fluctuating water supplies and low humidity; waterlogged soil; high wind speeds; low temperatures under certain conditions. If soft tissue wilts, browning and death usually results. **Some plants may wilt and recover** without showing signs of browning, eg shallow rooted azalea, large leafed pumpkin and rhubarb. **Transplant shock**, inadequate acclimatisation. ***Nutrient excesses***, eg high levels of soluble salts in the soil or media. ***Chemicals***, eg presence of toxic substances in the soil, growing medium or water (saline bore water). ***Mechanical injury*** to roots of newly planted annuals occurs if hoed to remove weeds during warm weather. ***Normal characteristics***, eg weeping cultivars.  Sclerotium stem rot (*Sclerotium rolfsii*) on daphne. *Left:* Plant wilting due to attack at collar. *Right:* Hard to see brown sclerotia (1-2 mm in diameter) on surface of soil.  Wilting of large leaved plants – pumpkin

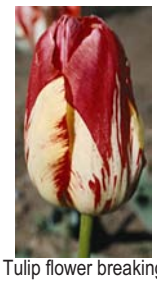
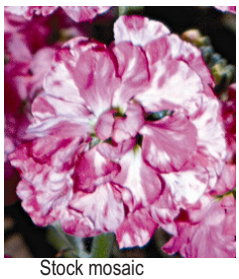
Flowers, flower buds

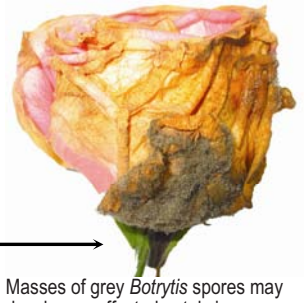
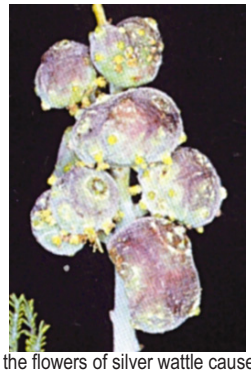
Some common signs & symptoms – Clues!

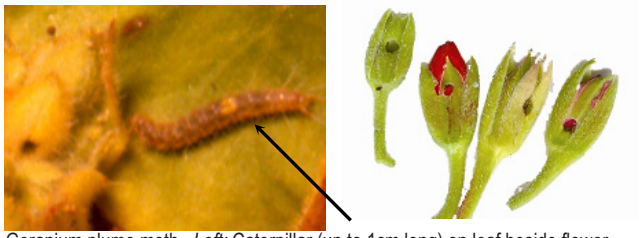
Blights, burns, scorches Buds brown, blacken, fail to open Bud drop Buds, flowers lacking, spot flowering, size Buds, too many	Chewed, tattered, buds, petals Colour changes Distorted buds, flowers, calyx splitting Fungi, moulds, rots Galls	Holes in buds, petals Insects, mites Spots, flecks on petals Wilting, ageing flowers

- **Identify the affected plant** so you can access a **list** of common problems affecting it, reducing the number of suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** all visible external and internal signs and symptoms, measurements and microscopic examinations.
- **Tease buds and flowers apart** to look for pests under a dissecting microscope, eg thrips start in the flower buds, monitor their occurrence so that control can be carried out if necessary.
- Pests and diseases affecting **other plant parts**, eg leaves, shoots, trunks and roots, may affect flowering.
- Symptoms may be **delayed**, eg those caused by water stress, root rotting fungal diseases.
- There are **quality standards** for flowers.
- See also **Leaves**, page 125.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
BLIGHTS, BURNS, SCORCHES see also Fungi page 143 Flowers are often more frost sensitive than leaves	A general and extremely rapid browning of **flowers, buds,** leaves, twigs, branches. Often accompanied by general dying of flowers and stems; rots may follow blights. Causes include: • **Bacterial diseases**, eg anthracnose (*Colletotrichum* sp.) of mango, bacterial canker of stone fruit, fire blight of pome fruits in New Zealand. • **Fungal diseases**, eg blossom blight, petal blight, grey mould (*Botrytis cinerea*) of roses and other plants; azalea petal blight (*Ovulinia azallella*); brown rot of stone fruit; *Rhizopus* soft rot; downy and powdery mildew on grape flowers. • **Insects & allied pests**. ***Sap-sucking insects***, eg aphids and thrips may cause edges of petals to shrivel and brown. ***Chewing insects***, eg budworms (*Helicoverpa* spp.). • **Non-parasitic agents**. ***Environment***, eg sun or early frosts may scorch petals, hot dry winds, wet weather, drought, low humidity, wind. ***Pesticide injury***, eg herbicides, sulphur.  Bacterial canker – plum. Flowers on branch on right have browned  Petal blight (*Botrytis cinerea*) – brown flecks scattered on white petals including edges (see also pages 143, 144)  Sunscorch – pale camellia flowers
BUDS BROWN, BLACKEN, FAIL TO OPEN	Common in some plants. Causes include: • **Fungal diseases**, eg bud rot (*Botrytis cinerea),* azalea petal blight (*Ovulinia* sp). • **Insects & allied pests**. ***Sap-sucking insects & mites*** may kill buds before opening, eg thrips, camellia bud mite, broad mite, tomato mite. • **Non-parasitic agents**. ***Environment***, eg cold wet weather. ***Nutrient deficiencies & excesses***, eg calcium deficiency. ***Genetic***, eg late flowering gardenias when growth buds start to move; camellia buds of some varieties slowly colour, 'ball' or fail to open.
BUD, FLOWER DROP	A mass dropping of buds before they open. Root problems may cause bud drop. Causes include: • **Virus & virus-like diseases**, eg tomato spotted wilt. • **Fungal diseases**, eg powdery mildew may affect buds of roses and other plants. • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg twospotted mite on apple, thrips in buds, camellia bud mites. ***Chewing insects***, eg various caterpillars, weevils. • **Non-parasitic agents**. ***Environment***, eg poor cultural care, sudden changes in temperature, sudden cold nights, too high soil temperatures, under and overwatering, poor drainage, low humidity, poor light. ***Chemical toxicity***, eg pesticides, herbicide and ethylene injury. ***Normal characteristics***, eg some species always drop some buds.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
BUDS/FLOWERS LACKING, SPOT FLOWERING, SIZE	Mainly caused by **non-parasitic problems**. Causes include: • **Insects & allied pests**. Insect invasions may kill buds before opening (see page 141). • **Non-parasitic agents.** ***Culture*** eg plants too crowded, bulbs, tubers may need dividing, incorrect pruning of plants (some only flower on the previous season's wood). ***Environment***, eg shade, light intensity too low or of poor quality, inappropriate day lengths, chilling requirements not met, under or overwatering. There may also be delayed or spot flowering due to unseasonal weather. ***Nutrient deficiencies & excesses***, eg excessive nitrogen encourages vegetative growth, lack of potassium. ***Normal characteristics***. Plants still juvenile and non-reproductive; lilac may take a few years to establish before flowering; male and female plants; some plants have cyclical flowering, eg some eucalypts only flower every 2-4 years; some fruit crops are biennial; inappropriate rootstock.
BUDS, TOO MANY	Overbudding resulting in plants heavily encrusted with flower buds. Causes include: • **Non-parasitic agents**. ***Environment***, eg very good seasons, cyclical or biennial flowering (see above), very dry early summer weather, root damage due to excessively deep cultivation, moving a large plant the previous season without pruning it back.
CHEWED, TATTERED. BUDS, PETALS	Causes include: • **Insects & allied pests**. ***Many chewing insects***, eg budworms (*Helicoverpa* spp.) may completely consume flowers; earwigs, weevils, grasshoppers, locusts. • **Snails and slugs** may seriously damage flowers of many plants. • **Vertebrate pests**, eg parrots may break flower stalks. • **Non-parasitic agents**, eg hail, wind, rain, irrigation sprinklers.  Macadamia flower caterpillars  Budworms (*Helicoverpa* sp.) – snapdragon  Earwig damage – dahlia flowers  Snail damage? – daffodil flowers
COLOUR CHANGES	Development of colours **other than** normal in **flowers**, leaves and fruit. Causes include: • **Virus & virus-like diseases**. ***Greening*** (tomato big bud) of floral parts of many herbaceous species. ***Breaking*** (loss of flower colour) resulting in a variegated flower, eg tulip flower breaking, stock mosaic. • **Fungal diseases**, eg powdery mildew (see page 53). • **Insects & allied pests**, eg thrips rasp and suck flower parts causing whitish flecked areas on dark blooms, which later brown (see page 144). Dark spots of excreta on light coloured blooms adds to the disfigurement. Check for thrips by shaking flowers over white paper. • **Non-parasitic agents**. ***Environment***, eg cold or hot weather, sun bleaching, too little or too much light. ***Soil pH***, eg hydrangeas have blue flowers in acidic soil and pink blooms in alkaline soil. ***Chemicals***, eg herbicide injury. ***Genetic***, eg chimera, sports. ***Normal characteristics***. Irish Bells and the green rose (*Rosa chinensis viridiflora*) have green flowers; many flowers are variegated; senescing hydrangea flowers turn green.  Tulip flower breaking  Stock mosaic  Greening – chrysanthemum  Sun bleaching – rose  Chimera – tulip  Natural variegation – Fiesta double impatiens

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DISTORTED FLOWERS, BUDS, CALYX SPLITTING	Misshapen **flower buds, flowers**, other plant parts. Causes include: • **Virus & virus-like diseases**, eg tomato big bud (greening), iris severe mosaic. • **Fungal diseases**, eg powdery mildew of rose, flowers do not open or are often distorted. • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg aphids, thrips, camellia bud mite, cyclamen mite (on fuchsia), twospotted mite. • **Non-parasitic agents**. ***Environment***, eg extreme temperature fluctuations, frost, hail. Calyx splitting is common and a serious problem in carnations and is due to sudden and/or large fluctuations in temperature. Some flowers bend towards light (positive phototropism), others bend away from gravity (geotropism). ***Herbicide injury***, eg hormone herbicides (dicamba, MCPA). ***Genetic***, eg fasciation. ***Normal characteristics***. Some flowers have an unusual appearance, eg calendula 'Hen and Chickens'.  Hens & chickens marigold (*Calendula officinalis* 'prolifera')  Greening – *Helichrysum* sp.  Cupped sepals – hydrangea. May be caused by greening but some cultivars have cupped sepals  Spikes of gladiolus bend upright if stored horizontally – bending away from gravity (geotropism)
FUNGI, MOULDS, ROTS	Causes include: • **Fungal diseases**, eg powdery mildew on flowers and buds of grape, rose and other plants, petal blight (*Botrytis, Ovulinia*), *Fusarium* bud rot of carnations, brown rot of stone fruits. • **Non-parasitic problems**, eg sooty mould growing on honeydew secreted by some species of sap-sucking aphids, mealybugs, scales or whiteflies which may be feeding on the same or overhanging trees and shrubs.  Grey mould (*Botrytis cinerea*) – pale brown or white spots on pink cultivars where spores germinate. Spots enlarge in size, coalesce until the petal completely browns and rots  Masses of grey *Botrytis* spores may develop on affected petals in prolonged cool humid conditions
GALLS	A swelling, roughly spherical, of unorganized plant cells occurring on any part of the plant including **flowers**, leaves, stems, roots, seeds. Causes include: • **Bacterial diseases**, eg bacterial gall of oleander. • **Fungal diseases**, eg rust galls (*Uromycladium* spp.) on wattles. • **Insects & allied pests**, eg Geraldton wax gall wasp, wattle gall wasp. • **Non-parasitic problems**. The seed capsules of some plants look like galls, eg camellia.  Galls on the flowers of silver wattle caused by a small wasp (*Trichilogaster trilineata*) (H. J. Elliott)  Galls on flower stem of Geraldton wax caused by a small wasp (Eulophidae) (W. Woods & M. Grimm)

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
HOLES IN BUDS, PETALS	Causes include: • **Insects & allied pests**. ***Chewing insects***, eg budworms (*Helicoverpa* spp.) and geranium plume moth; hibiscus flower beetles and earwigs may chew holes in petals.  Geranium plume moth. *Left:* Caterpillar (up to 1cm long) on leaf beside flower buds. *Right:* Holes in buds, caterpillars eat contents – flowers don't develop
INSECTS, MITES  Nectar scarab (6-10 mm long) damage petals with spiny legs	Insects found in flowers include: • **Insects & allied organisms**. ***Chewing insects***, eg budworms (*Helicoverpa* spp.); earwigs, locusts, grasshoppers, metallic flea beetles. ***Sap-sucking insects & mites***, eg aphids, thrips, mites. ***Beneficial insects***. Pollinators, eg bees, flower wasps. Soldier beetles weigh down flowers and feed on nectar-feeding insects. Do not confuse beneficial insects with pest species.  Plague thrips – apple flowers (NSW Agric)  Two spotted mite webbing – gypsophila  Flower wasp – do not confuse with European wasps
SPOTS. FLECKS ON PETALS See also Blights page 141  Petal blight (*Ovulinia azallela*), early symptoms showing white spotting of petals (NSW Agric)	Discrete spots, generally white on dark coloured varieties or brownish or pinkish on lighter coloured varieties, may precede browning of petals. Causes include: • **Fungal diseases**, eg petal blight (*Botrytis*), azalea petal blight (*Ovulinia azallella*). • **Insects & allied pests**, eg plague thrips, gladiolus thrips (silvery specks). • **Non-parasitic problems**, eg sun may bleach petals though water droplets early in morning.  Petal blight (*Botrytis cinerea*) on white petals – initially pinkish spots which later turn brown  Gladiolus thrips damage to flowers – silvery or whitish specks  Sun bleaching of pelargonium petals – early morning sun on tiny drops of water
WILTING, PREMATURE AGEING see also Wilting page 140	Flowers limp and shriveling, flowers senesce more quickly than expected. Mainly due to non-parasitic problems. Causes include: • **Insects & allied pests**, eg various thrips may cause wilting in growing crops. • **Non-parasitic problems**. ***Culture***, eg forcing of cut flowers. ***Environment***, eg too little moisture especially during hot windy weather, domestic heating in winter, low humidities, temperature extremes. Some cut flowers are wired to prevent wilting. Roses may carry a warranty that they will not wilt for 2 days. ***Chemicals***, eg ethylene damage, some pesticides. ***Normal characteristics***, eg after pollination, ageing.

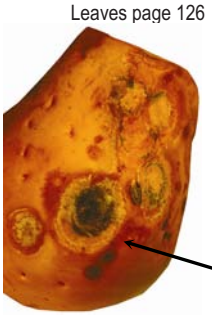
Fruits, nuts

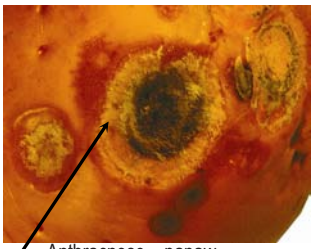
Some signs & symptoms – Clues!

Anthracnose Blotches, scorches Chewed, tattered, missing fruit Colour changes, haloes Distortion, mummies, thick skin, woodiness, shriveled	Failure to fruit, failure to fruit adequately, too many small fruit Fruit fall Gumming, ooze Holes, stings, frass Insects on the outside	Insects inside fruit, cavities, tunnels Ringspots Rots, fungi, moulds Russet Scabs	Splitting, cracking Spots Tainting, bitterness

- **Identify the affected plant**, so you can access a **list** of common problems affecting it, reducing suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** all visible external and internal signs and symptoms, measurements and microscopic examinations.
- Examine fruit **externally** as well as **internally**, slice fruit in half.
- **Secondary** pests and diseases may invade fruit damaged by weather (sun, frost, rain, hail) or handling.
- Many insects and diseases may **commence attack** either at the stem end (where it is connected to the plant) or at the blossom end (where the petals have fallen off).
- **Delayed effects**, eg some anthracnose diseases are dormant in the fruit and only become active after harvest when fruit ripens or is injured, even though infection took place in the field.
- There are **quality standards** for commercial fruit.
- See also **Leaves** page 125, **Flowers** page 141 and **Seeds** page 151.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
ANTHRACNOSE see also Leaves page 126	Principally a disease of **ripening fruit** causing brown and sunken spots with sharply defined margins, caused by a group of fungi (*Colletotrichum* spp.). • **Fungal diseases**, eg anthracnose (*Colletotrichum* spp.) of avocado, cucurbits, mango, macadamia, legumes, French beans.
BLOTCHES, SCORCHES	Dead areas on **fruit** and leaves, which may cover part or most of the plant and may be irregular in shape and size, or form patterns (other than spots). Causes include: • **Virus & virus-like diseases**, eg tomato spotted wilt. • **Fungal diseases**, eg some anthracnose diseases can develop into blotches. • **Non-parasitic agents**. ***Environment***, eg sunburn (golden zucchinis are very susceptible), too little/too much water, frost. ***Nutrient deficiencies & excesses***, eg fertilizer injury, salt toxicity. ***Pesticides*** may damage fruit under certain conditions.
CHEWED, TATTERED, MISSING FRUIT	Causes include: • **Insects & allied pests**, eg various caterpillars, scarab grubs may feed on strawberries. • **Snails and slugs** may gouge strawberries, tomato. • **Vertebrate pests**, eg birds, possums, fruit bats, goannas, rabbits, rats. • **Non-parasitic problems**, eg mechanical injury (hail, wind).





Anthracnose – papaw



Anthracnose – banana



Tomato spotted wilt – ringspots may look blotchy (see page 148)



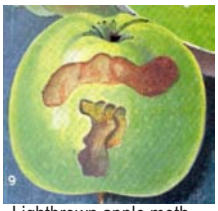
Sunscorch on shoulder– tomato



Sunscorch – capsicum







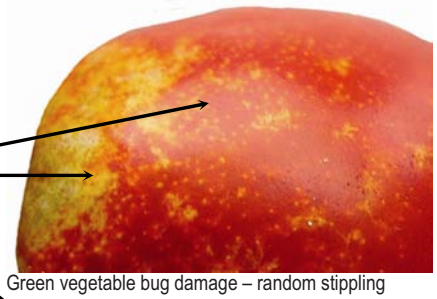
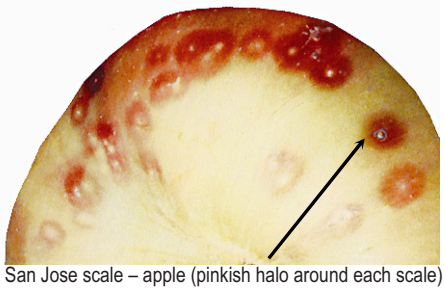
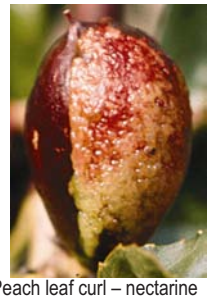
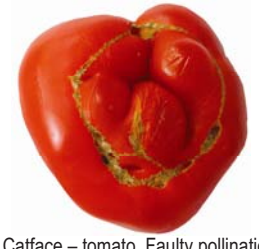
Lightbrown apple moth damage (NSW Agric)

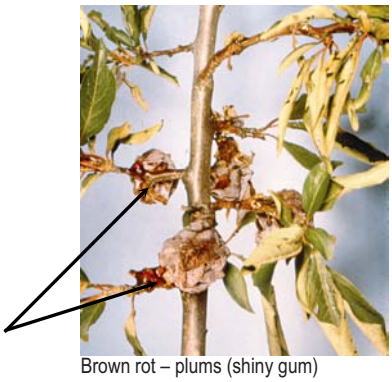
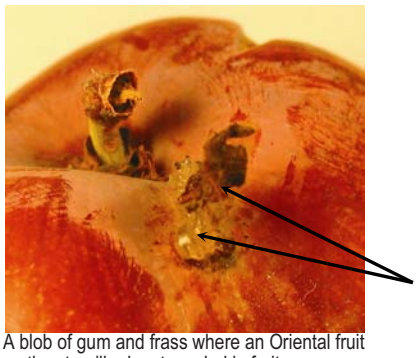
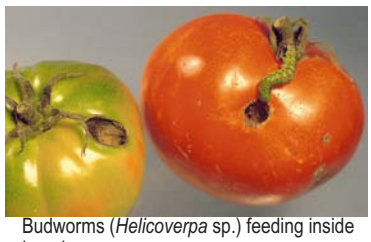


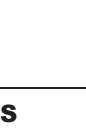
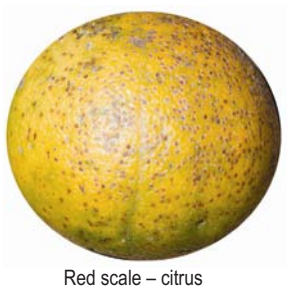
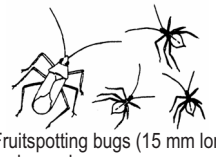
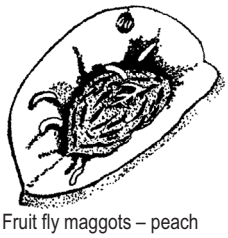
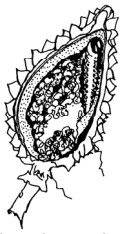
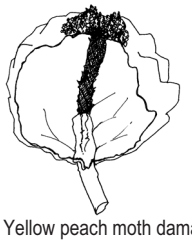
Bird damage – apple



Possum damage – lemon

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
COLOUR CHANGES, HALOES see also Blotches page 145 Rots page 149 Russet page 149	Development of colours other than normal **on or in fruit**. Causes include: • **Virus & virus-like diseases**, eg tomato spotted wilt on tomato fruit (see pages 145, 148). • **Fungal diseases**, eg peach fruit infected with peach leaf curl develop roughened areas which may develop a reddish coloration long before healthy fruits show any colour change. • **Insects & allied pests**, eg sap-sucking insects such as spined citrus bug (premature colouring of citrus fruit), green vegetable bug (stippling), San Jose scale and twospotted mite (apple), rust mite (tomato), broad mite. Also egg laying activities of fruit flies. • **Non-parasitic agents**. ***Environment***, eg lack of light, cool night temperatures. ***Nutrient deficiencies & excesses***, eg boron deficiency in pome fruit (internal staining). ***Chemicals***, eg herbicide injury, ethylene ripening of fruit. ***Genetic***, eg chimeras. ***Normal characteristics***, eg shaded fruit in the middle of the tree, the blush on mango, senescence, uneven ripening.
Sap-sucking insects and the egg laying activities of fruit flies will cause internal discoloration beneath the skin	
 Green vegetable bugs sucking sap from tomato, see also page 148	 Green vegetable bug damage – random stippling  Green vegetable bug damage under skin  San Jose scale – apple (pinkish halo around each scale)  Green shoulders – tomato (low night temperatures)  Chimera – apple
DISTORTION, MUMMIES, THICK SKIN, WOODINESS, SHRIVELLED	Causes of misshapen fruit include: • **Virus & virus-like diseases**, eg tomato big bud (tomato), stony pit virus (pear), woodiness virus (passionfruit), bean twist. • **Fungal diseases**, eg peach leaf curl, brown rot, apple and pear scab (see page 150), lemon scab, bladder plum, downy or powdery mildew (grapes), mango scab (*Elsinoe mangiferae*). • **Insects & allied pests**, eg apple dimpling bug, citrus bud mite, pearleaf blister mite, bean blossom thrips; plague thrips may prevent seed set of strawberry. • **Non-parasitic agents**. ***Environment***, eg wrinkled passionfruit (too little water, frost, hail); grapes may shrivel (water stress due to hot, dry, windy weather). ***Nutrient deficiencies & excesses***, eg boron deficiency in pome fruit. ***Genetic***, eg fasciated strawberry fruit, twin apples. ***Faulty pollination***, eg catface (tomato), poor fruit set in grapes (hen and chickens – large and small grapes). ***Overmaturity***, eg woody zucchini.
 Brown rot 'mummies' hang on the tree	 Tomato big bud – tomato  Peach leaf curl – nectarine  Apple dimpling bug symptoms can be confused with boron deficiency. Check internal symptoms
Thick skin in citrus May be due to cold weather. Thickened rind in citrus is common in young trees and will lesson as tree ages, old trees with thick rind usually due to heavy applications of nitrogen applied later than midsummer.	 Citrus bud mite symptom or a variety  Twin apples  Catface – tomato. Faulty pollination due to low spring temperatures or excess heat in summer

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
FAILURE TO FRUIT, FAILURE TO FRUIT ADEQUATELY, TOO MANY SMALL FRUIT see also Fruit fall below	Failure to produce fruit satisfactorily may involve abnormally small or few fruit. Causes include: • **Virus & virus-like diseases**, eg apple mosaic. • **Bacterial diseases**, eg bacterial blight of walnut. • **Fungal diseases**, eg powdery and downy mildews may rot and wither young fruit on grapevines. Root diseases may affect fruiting. • **Insects & allied pests**. Larvae of various weevils tunnel in trunks causing wilting, eg fruit tree, vine and elephant weevils. Larvae of the currant borer tunnel in the canes. • **Non-parasitic problems**. Incorrect pruning, thinning and care, root bound, soil too compacted, planted too deeply. ***Environmental***, eg inappropriate temperature and moisture, late frosts which may kill very young fruit, waterlogging, excessive dryness. ***Nutrient deficiencies & excesses***, eg excess nitrogen and low phosphorus (too much vegetative growth), excessive fertilizer at planting. ***Faulty pollination***, eg no pollinators due to weather being too wet or too hot during flowering, pollen dried out in heat, blossoms rotted in humid weather (passionfruit). ***Pesticides***, eg the insecticide carbaryl may thin fruit if applied too soon after flowering. ***Normal characteristics***, eg some species are prone to fruiting problems; seedling trees may be variable; trees too young; biennial fruit bearing in apples, pears, Valencia orange, Wheeny grapefruit, mandarins. ***Misidentification***, eg ornamental species, not for fruiting.
FRUIT FALL	A mass dropping of small fruits. Causes of abnormal fruit drop include: • **Fungal diseases**, eg anthracnose and other fungal diseases may cause fruit to drop. • **Insects & allied pests**, eg budworms, thrips. Disease organisms may be introduced by fruitpiercing moths during feeding causing rotting and premature fruit fall. • **Vertebrate pests**. Fruit pecked, eg silver eyes; stalk length of fallen passionfruit can identify whether possums or rodents are the culprits. • **Non-parasitic agents**. ***Environment***, eg frost, drought, uneven watering, rain, wind, hot dry windy weather during fruit development. Fallen passionfruit with stalks of **even** length may be due to lack of water. ***Nutrient deficiencies & excesses***, eg acute lack of nutrients or over feeding can cause premature fruit drop. ***Normal characteristics***, eg some dropping of very small fruit is natural particularly where there is a heavy crop; some fruit, eg feijoa drop when ripe; overmature fruit.
GUMMING, OOZE	An obvious secretion of gum. Causes include: • **Bacterial diseases** eg bacterial canker of stone fruit. • **Fungal diseases**, eg brown rot, shothole. • **Insects & allied pests**, eg oriental fruit moth, Rutherglen bugs.  Brown rot – plums (shiny gum)  A blob of gum and frass where an Oriental fruit moth caterpillar has tunneled in fruit
HOLES, STINGS, FRASS see also Insects page 148	Holes and stings vary in size depending on their causes which include: • **Insects & allied pests**. ***Chewing insects***, eg many caterpillars tunnel in and out of fruit, eg budworms (*Helicoverpa* spp.), codling moth, oriental fruit moth, yellow peach moth; ***fruit flies*** 'sting' fruit to deposit eggs beneath the skin of the fruit. ***Sap-sucking insects***, eg fruitspotting bugs, fruitpiercing moths, green vegetable and other bugs suck juice from fruit.  Codling moth – external symptoms of attack by caterpillars (NSW Agric). Frass may be pushed out  Oriental fruit moth – leaf attached to fruit by caterpillar silk - a characteristic symptom  Budworms (*Helicoverpa* sp.) feeding inside tomatoes

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
INSECTS ON THE OUTSIDE see also Blotches page 145 Colour changes page146	Insects found on the outside of fruit include: • **Insects & allied organisms**. ***Chewing insects***, eg caterpillars of lightbrown apple moth, other moths, dried fruit beetles. ***Flies***, eg various species of fruit flies depending on the region; ferment flies are attracted to over-ripe fruit. ***Sap-sucking insects***, eg bugs (bronze orange, fruitspotting, green vegetable, spined citrus and Rutherglen bugs), woolly aphid, mealybugs, thrips, scales (black, red and San Jose scales) and fruitpiercing moths. ***Beneficial insects***, eg pollinators, wasps, bees.  Rutherglen bug (3 mm long)  Red scale – citrus  Green vegetable bugs – tomato (see also page146)  Spined citrus bug (20 mm long)  Bronze orange bug (25 mm long)  Fruitspotting bugs (15 mm long) and nymphs
INSECTS INSIDE FRUIT, CAVITIES, TUNNELS see also Holes page 147	Insects and other causes of internal breakdown include: • **Insects & allied pests**. ***Maggots***, eg fruit and fermentation flies. ***Caterpillars***, eg budworms (*Helicoverpa* spp.), codling moth, macadamia nutborer, oriental fruit moth, yellow peach moth. ***Beetles***, eg tiny driedfruit beetles (3 mm long). • **Non-parasitic agents**. ***Overmaturity***, eg fruit left on tree too long or kept too long in storage may result in internal cavities with brownish fluids (citrus), flouriness (apples). ***Defects in development***, eg hollowness in tomatoes due to incorrect conditions for growing and harvesting.  Fruit fly maggots – peach  Codling moth caterpillar (NSW Agric)  Macadamia nut borer – macadamia  Macadamia nutborer – lychee  Yellow peach moth damage
RINGSPOTS	Yellowish rings with green or variably coloured tissue in the centre, mostly caused by virus diseases. On some hosts, rings may blacken with age. Causes include: • **Virus & virus-like diseases**, eg cucumber mosaic, papaya ringspot, tomato spotted wilt.  Viral symptoms – watermelon  Tomato spotted wilt – ringspots and blotches (see also page 145)  Tomato spotted wilt – capsicum

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
ROTS, FUNGI, MOULDS	Fruit rots are usually soft and squashy due to the breakdown of tissue and are almost infinite in number. Some occur all over the surface, others may start around the **blossom** or **stem ends** of the fruit, others around **wounds** caused by insects or bruising during picking and subsequent handling. Causes include: • **Virus & virus-like diseases**, eg avocado sunblotch viroid (yellow-red streaks on fruit). • **Bacterial diseases**, eg bacterial soft rot of avocado, banana, many other fruit. • **Fungal diseases**, eg powdery and downy mildew on grape**,** blue and green moulds **(***Penicillium* spp.) on citrus; grey mould (*Botrytis*) and *Rhizopus* soft rot on strawberries. *Botrytis*-infected grapes are used for making natural sweet wines (*Botrytis* Noble Late Harvest). Also brown rot of citrus and stonefruits, *Aspergillus* on peanuts (aflatoxin), early blight (*Alternaria*) of tomato. Other rots include yeast rots of citrus, cucurbits and pineapple. *Phytophthora* may attack fruits of citrus and pineapple. Many fungi attack the stem ends of mango and other fruits. Rust may occur on peach fruit. • **Insects & allied pests**. Feeding sites are entry points for bacterial and fungal rots, eg caterpillars of the oriental fruit moth, driedfruit beetles, thrips, mealybugs. • **Non-parasitic agents**. ***Environment***, eg fruit damaged by sunburn, frost or water stress may also be invaded by disease organisms. ***Nutrient deficiencies & excesses***, eg calcium in tomato (blossom-end rot). ***Normal characteristics***, eg overmature citrus and other species may 'rot' on the tree. Sooty mould may grow on honeydew produced from aphids, scales and other sap-sucking insects infesting foliage and stems.
RUSSET see also Scabs page 150	Brown, roughened areas on the skin of **fruit** due to the formation of corky tissue. Causes include: • **Virus & virus-like diseases**, eg apple russet ring, apple ringspot. • **Fungal diseases**, eg powdery mildew on apples may cause fruit to russet and crack. • **Insect & allied pests**, eg tomato russet mite, fruit damaged by melon thrips may develop scar tissue. • **Non-parasitic agents**, eg frost (apple, plum); some pesticides may russet fruit.

Botrytis Noble Late Harvest

Vintage 2002


Bacterial blight – walnut

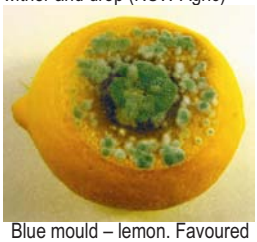

Grey mould (*Botrytis*) – strawberry


Brown rot around entry or exit hole of oriental fruit moth caterpillar – peach


Downy mildew – grapes. Bunches wither and drop (NSW Agric)


Powdery mildew – peas


Stem end rot – mango


Blue mould – lemon. Favoured by injury


Frost damage to exposed side of lemon left on tree too long


Blossom-end rot – Roma tomatoes


Apple russet ring – Granny Smith apple


Frost injury after fruit set – Santa Rose plum


Cold injury – butternut pumpkin

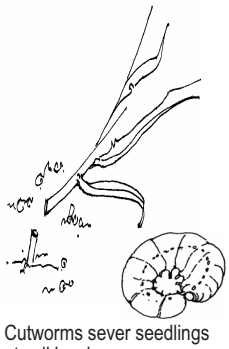
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
SCABS see also Colour changes page 146, Russet page 149	Slightly raised localized lesions on **fruit**, leaves and corms, giving a scabby appearance. Causes include: • **Bacterial diseases**, eg bacterial spot of mango, citrus canker. • **Fungal diseases**, eg apple and pear scab, lemon scab, shothole of apricot, brown spot of mandarin. • **Insects & allied pests**, eg some hard scales on fruit may look like scabs. • **Non-parasitic agents**. ***Environment***. Mechanical injuries, wind rub on citrus and passionfruit may callus and look scabby.  Lemon scab (NSW Agric)  Pear scab  Shothole – apricot
SPLITTING, CRACKING	The skin of fruit may split before harvest. Causes include: • **Fungal diseases**, eg apple and pear scab, blueberry split (downy mildew). • **Non-parasitic causes**. ***Environment***, eg cherries, citrus, grapes, plums, tomato may split after rainfall, uneven irrigation, too rapid growth; lychee fruit split due to dry air. ***Nutrient deficiencies & excesses***, eg severe boron deficiency may cause pears to crack.  Splitting – apple scab  Splitting – tomato  Splitting – plum
SPOTS	Roughly circular black spots on **fruit**, leaves and stems. Causes include: • **Bacterial diseases**, eg bacterial spot of walnut. • **Fungal diseases**, eg black spot of apple, pear and grape; black, brown and *Septoria* spots and other fungal diseases of citrus; freckle (stonefruit) and fleck (pomefruit). • **Insects & allied pests**. ***Sucking insects***. Many bugs suck juice from fruit causing them to become pitted and disfigured with gum, eg fruitspotting bug, Rutherglen bug, spined citrus bug (see page 148). • **Non-parasitic problems**. ***Environment***, eg hail damage, rubbing against other fruit or bark, wind rub, sunburn. ***Nutrient deficiencies & excesses***, eg bitter pit due to low levels of calcium in the fruit of pome fruit especially apples. ***Chemical damage***, eg spray damage. ***Genetic***, eg oleocellosis (oil cell damage) in citrus.  Black spot – grape (NSW Agric)  Freckle – stonefruit (NSW Agric)  Fleck – quince (NSW Agric)
TAINTING, BITTERNESS	Fruit may possess undesirable features, eg smell, taste, stains, toxins. Causes include: • **Fungal diseases**, eg citrus fruit affected by brown rot have an unpleasant odour. Peanuts infected with *Aspergillus* contain aflatoxin which is toxic to humans. • **Insects & allied pests**, eg bronze orange bugs produce an unpleasant odour if disturbed. • **Non-parasitic agents**. ***Checks in growth***, eg cool weather, nutrient problems or ***overmaturity*** (delayed harvest) can cause fruit such as cucumbers to be bitter; overmaturity and delayed cutting of broccoli results in loose flavourless heads.

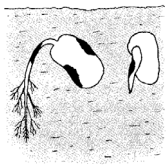
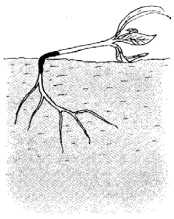
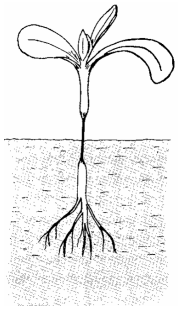
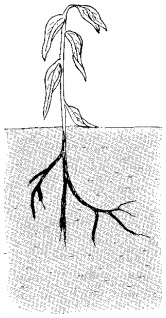
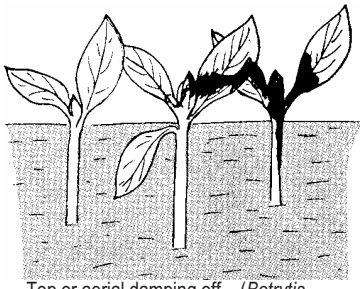
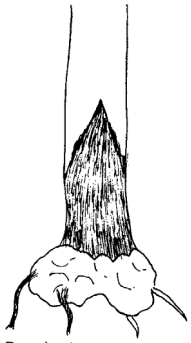
Seeds, seedlings, cuttings

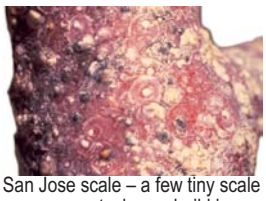
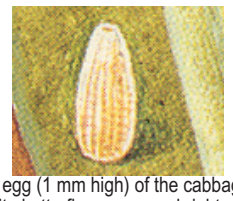
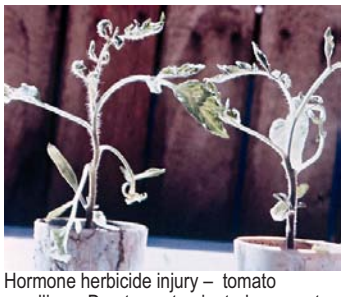
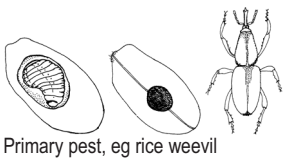
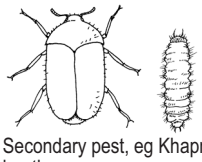
Some signs & symptoms – Clues!

Allelopathy Bolting Chewed seedlings, cuttings, mechanical injury Colour changes, seedlings, cuttings Damping off, poor seed emergence, rot Seedlings, cuttings, insects	Seedlings, spindly, distorted Seeds in storage Seeds on plants Transplant shock Weed seeds, weed pieces

- **Identify affected plants** so you can access a **list** of common problems affecting them, reducing the number of suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** all external and internal signs and symptoms, measurements and microscopic examinations.
- Many pests, diseases and weeds are **carried on, in or in association with** seeds, seedlings and cuttings. Many are not visible to the naked eye. Conventional seed detection tests include visual examination, selective media, serological and seedling grow-out assays. **DNA-based** seed detection methods will be increasingly used to detect disease organisms in seeds.
- **Seed certification schemes** produce seeds of a prescribed quality, eg true-to-type, free from specified weeds, other seeds and specified pests and diseases.
- **Delayed signs and symptoms** due to pests and diseases carried in association with seed.
- Although seedlings and cuttings may get the same problems as **established plants**, there are some problems **peculiar to seedlings**.
- Examine seeds and cuttings **internally** as well as externally, cut or prise open seeds.
- See also **Leaves** page 125, **Flowers** page 141 and **Roots** page 163.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
ALLELOPATHY see also Allelopathy page 173	Allelopathy is the detrimental effect that one plant exerts on another by the release of a chemical substance. **Parent plant allelopathy** occurs when the parent plant produces chemicals that inhibit germination of their own seedlings beneath them. This prevents competition from seedlings with the parent plant. Typically, the zone of inhibition extends to the width of the crown of the plant. Examples include *Allocasuarina*, some eucalypts. Seedlings of *Grevillea robusta* blacken and die in plantations of the same species.
BOLTING	Running to seed prematurely is usually a home garden problem. Vegetables such as cabbage and lettuce run to seed without hearting properly. Causes include wrong variety for the planting time, weather too warm at maturity, growth checks due to temporary dryness, transplant shock.
CHEWED SEEDLINGS, CUTTINGS, MECHANICAL INJURY	Chewed and tattered seedlings are usually a home garden problem. Causes include: • **Insects & allied pests**. ***Chewing insects*** may shred or strip leaves, eg various caterpillars including armyworms and cutworms, budworms (*Helicoverpa* spp.), cabbage white butterfly, leafeating ladybirds, pumpkin beetles, also grasshoppers and locusts which are sporadic pests. • **Snails & slugs** commonly devour seedlings and buds of grapevine and other cuttings. • **Vertebrate pests**, eg birds, mice, rats, rabbits and wallabies may eat tender seedlings to ground level, damage can be difficult to identify because these pests often only feed at night or briefly during the day. • **Non-parasitic agents**. Wind may blow over large-leafed seedlings such as pumpkins, and small trees. Mowers and whipper-snippers may damage tube stock. French bean seed damaged during harvesting and handling produce seedlings with no growing tips, just a bare stump (nail head).  Cutworms sever seedlings at soil level  Caterpillar or snail damage to cabbage seedlings? What signs and symptoms would indicate one or the other?  Nailhead, baldhead – French bean

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
COLOUR CHANGES, SEEDLINGS, CUTTINGS see also Leaves pages 129-133	Colour changes are very noticeable, yellowing being the most common. Symptoms caused by **parasitic** pests and diseases may be indistinguishable from those caused by **non-parasitic** problems. Causes include: • **Virus diseases**, eg cucumber mosaic, tomato spotted wilt. • **Parasitic plants**, eg broomrape (*Orobanche* spp.), dodder (*Cuscuta* spp.). • **Non-parasitic diseases**. ***Environment***, eg cold weather may cause maize seedlings to develop purplish pigments, insufficient light may cause pale green leaves. ***Nutrient deficiencies & excesses*** are not uncommon in seedling mixes. ***Chemicals***, eg residual herbicides in media ingredients. ***Genetic***, eg normal seed variation, home gardeners repeatedly saving pea seed for re-sowing may produce increasing numbers of albino (cream) seedlings which lack chlorophyll.
DAMPING OFF, POOR EMERGENCE, ROT Low temperatures may slow seedling growth, making them more susceptible to damping off fungi	Damping off diseases **rot** seeds and seedlings before or after emergence from the soil or media. Causes include: • **Fungal & bacterial diseases**. *Pythium, Phytophthora, Rhizoctonia* are common causes. Seedlings collapse, rot with discoloration near soil level. *Aspergillus niger, Alternaria alternata, Pestalotiopsis*, and other fungi may also be associated with damping off. • **Insects & allied pests**. Insects may damage seeds ***before*** harvest, eg lucerne seed wasp, or ***after*** planting, eg seedharvesting ants remove seeds from turf areas; bean fly maggots burrow into seedling stems of beans; seedling bean midge and onion maggots burrow into a wide range of vegetable seeds and seedlings. ***Root-feeding insects***, eg scarab grubs, wireworms, cutworms and armyworms. • **Vertebrate pests**, eg birds eat seed before emergence and seedlings after emergence. • **Non-parasitic agents**. ***Environment***, eg poor seed germination due to sowing when ground is too cold or too wet, or planting too deeply; planting at wrong time; incorrect variety for that time of year; seeds may be washed away due to overwatering or rainstorms; transplants may wilt due to root damage, drying out or shock due to temperature extremes; inappropriate growing media. ***Seed quality***, eg poor seed source, seed may be contaminated with weed or other seeds, or too old, eg parsnip seed only retains viability for about 6 months. ***Mechanical injury***, eg seeds may be damaged in storage, roots of seedlings damaged during hoeing to control weeds in warm dry weather. ***Competition*** with surrounding vegetation, eg weeds, other plants. ***Chemicals***, eg pre-emergent herbicides; planting too soon after the application of glyphosate or other herbicides. ***Normal characteristics***. Seeds may be very small and difficult to plant at the correct rate, eg carrot. Some seeds require pre-treatment before germination will commence, eg the hard-coat of *Acacia* seeds must be physically broken to allow moisture required for germination to enter the seed; seeds that exhibit chemical dormancy are more difficult to treat, eg *Leucopogon*.  Damping off – seedling tray  Pre-emergence damping off (bacteria & fungi)  Stem rot (*Pythium*, *Phytophthora*, *Rhizoctonia*, *Chalara*)  Wirestem – seedlings with woody stems remain standing – cabbage (*Rhizoctonia*)  Root and stem rots (*Cylindrocladium*, *Phytophthora*, *Pythium*)  Top or aerial damping off – (*Botrytis*, *Phytophthora* and *Rhizoctonia*) may attack leaves and stems  Basal rot – common on cuttings of many plants

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
SEEDLINGS, CUTTINGS, INSECTS Look for insect eggs and tiny caterpillars on seedling leaves – control can be started early	**Insects & allied organisms** found **in association** with seedlings and cuttings include both pest and beneficial species. ***Chewing insects***, eg various caterpillars, pumpkin beetles, vegetable weevil; black vine weevil and larvae in nursery stock. ***Sap-sucking insects***, eg aphids, seedling thrips, whiteflies, scale (on cuttings); woolly aphids on apple rootstock. ***Beneficial insects***, eg ladybirds which feed on aphids and powdery mildew, caterpillars parasitized by parasitic wasps (you can see wasp cocoons beside the dead caterpillar).  Caterpillar of the cabbage white butterfly – cabbage seedlings  Vegetable weevil larvae – carrots (NSW Agric)  Aphids – pumpkin. Pale swollen parasitized aphid with cornicles  Greenhouse whiteflies (1-2 mm long) on leaf undersurface (see page 139)  San Jose scale – a few tiny scale on nursery stock may build in numbers after planting  An egg (1 mm high) of the cabbage white butterfly – eggs are bright yellow and easily seen
SEEDLINGS SPINDLY, DISTORTED	Yellowing of tissue and elongation of stems. Causes include: • **Insects & allied pests**. ***Sap-sucking insects*** such as aphids cause leaves to grow unevenly so that they curl around their colonies. • **Non-parasitic agents**. ***Environment***, eg insufficient light, darkness, very low temperatures. ***Chemicals***, eg hormone herbicide injury (dicamba, MCPA).  Cabbage aphids – curled leaves  Etiolated seedling  Hormone herbicide injury – tomato seedlings. Due to contaminated compost in the media
SEEDS IN STORAGE	Seed may be damaged in storage. Causes include: • **Fungal diseases**. Rots of various kinds may develop under humid conditions, eg *Alternaria, Aspergillus*. • **Insects & allied pests**. ***Primary pests*** attack and destroy sound unbroken seed, eg grain moths, rice weevils. ***Secondary pests*** are mostly surface feeders eating damaged, moist grain, seed, stored food products, eg driedfruit beetles, flour moths, warehouse beetles. The bean weevil (*Acanthoscelides obtectus*) is a pest of beans and peas. • **Vertebrate pests**, eg mice and rats may eat seed, not only damaging the seed but also contaminating it with their faeces. • **Non-parasitic agents**, eg incorrect storage temperatures and humidity may reduce seed viability and encourage insect reproduction and the growth of fungi.  Primary pest, eg rice weevil  Secondary pest, eg Khapra beetle  Bean weevil damage to bean seed. Weevils are tiny (3-4 mm long)

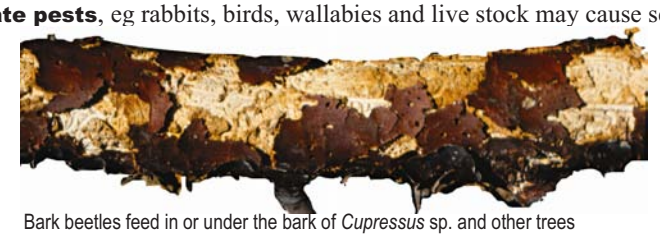
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
SEEDS ON PLANTS	Seed can become infested while still on the plant. Some insect pests, eg bean and cowpea weevils infest seed in the field and become serious storage pests. Causes include: • **Bacteria/nematode complexes**, eg annual ryegrass toxicity (ARGT) occurs when a nematode carries bacteria into developing seedheads of some annual grasses which are then toxic to stock feeding on them. Hay contaminated with infected seedheads is also toxic. • **Fungal diseases**. Seed may be replaced by smuts or ergots. ***Smuts*** cause a disease characterized by the presence of black sooty spore masses in seeds and on leaves, eg loose smut of oats. ***Ergots*** cause a disease which replaces the seeds on plants with sclerotia which are poisonous to grazing animals, eg paspalum ergot. • **Insects & allied pests**. ***Beetles & weevils,*** eg bean weevil, palm seedborer, palm weevil borer, pea weevils, prickly acacia seed beetle. ***Caterpillars***, eg budworms (*Helicoverpa* spp.), dryandra moth, macadamia nutborer. ***Wasp larvae***, eg lucerne seed wasp, parsnip seed wasp, wattle apple-gall wasp. ***Fly larvae***, eg sorghum midge. • **Vertebrate pests**, eg birds, mice and rats. Rats in under-developed countries consume about 15% of seed in crops. • **Non-parasitic agents**. ***Environment***, eg reduced quality and quantity of seed may occur due to seasonal conditions. ***Genetic***, eg some sweetcorn varieties may not tassel properly at low temperatures.  Loose smut – oats (NSW Agric)  Damage to hakea seed – unidentified wasp  Budworms *(Helicoverpa* spp.) – sweetcorn  Pea weevil and damage to seed, note exit holes  Mice and birds damage – sunflowers (NSW Agric)  Faulty tasselling – sweetcorn
TRANSPLANT SHOCK	Impaired growth or seedling mortality soon after planting out, ie when nursery-raised stock is planted into a new environment. This is a serious, under-recognized problem both in home gardens and commercial situations, eg in nurseries, landscapes and re-vegetation of bush areas. Transplant shock is the result of poor acclimatization between nursery and the new site. Causes include ***environmental factors***, eg cold or very high temperatures, frost, drought (the most common cause of transplant shock in tree seedlings); ***soil conditions***, eg compacted clay; ***nutrient deficiencies & excesses***, eg poor nutritional status of seedlings being planted out. Transplant shock may cause bolting in vegetable seedlings.
WEED SEEDS, WEED PIECES	Weed seeds, weed pieces, cuttings and root pieces may **persist in soil** (see page 168).

Branches, trunks, crowns

Some signs & symptoms – Clues!

Bark chewed Bark split, peeling, shedding Cankers Collar rots Dieback, decline	Discoloured bark, frass Discoloured internal tissue, wood Distortion, fasciation Fungi, wood rot fruiting bodies Galls Gumming, ooze, weeping	Holes, tunnels inside trunk Holes on surface of trunk Insects on bark Mechanical injury Parasitic plants, suckers, etc

- **Identify affected plants**, so you can access a **list** of common problems affecting them, reducing the number of suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** your observations.
- **Delayed symptoms** are common on trees and shrubs, which may take years to die during a prolonged drought.
- **Examine** trunk and branches **internally** and externally (possible only for small trees and shrubs, scraping bark, etc). Arborists can be called in to assist with diagnosis of internal decay, termites, etc.
- **Symptoms** on branches, trunks and crowns are usually **non-specific**, eg leaf yellowing, crown dieback, both of which tend to develop slowly over time, making diagnosis difficult. Often dieback is not identified in time to halt the condition. Be proactive rather than reactive, eg ensure tree and shrub requirements are met.
- See also **Leaves** page 125, **Flowers** page 141, **Roots and soil/media** page 163.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
BARK CHEWED	The bark has a chewed appearance initially but may callus over, plants may be ringbarked. Causes include: • **Insects & allied pests**, eg bark beetles; weevils chew rose canes, pittosporum and tamarisk stems. • **Snails and slugs** feed on young bark of box, citrus and other plants. • **Vertebrate pests**, eg rabbits, birds, wallabies and live stock may cause serious damage.  Bark beetles feed in or under the bark of *Cupressus* sp. and other trees  Weevil feeding and ringbarking a tamarisk stem
BARK SPLIT, PEELING, SHEDDING	Cracks in bark are common in many trees and shrubs, especially thin-barked species. Plants may die back. Causes include: • **Virus & virus-like disease**, eg scaly butt on citrus (see page 156). • **Bacterial and fungal diseases**, eg some wood rotting fungi. • **Insects & allied pests**. ***Borers*** commonly cause bark to crack. ***Egg-laying*** by cicadas and tree hoppers may cause splits in young twigs. ***Scales***, eg white louse scale (citrus). • **Non-parasitic agents**. ***Environment***. Most bark splitting is due to drought stress. Also by severe heat, sunburn, frost, waterlogging, lightning, hail, wind. ***Normal characteristics***, eg many trees naturally shed bark, eg eucalypts, crabapple (*Malus oensis*).  Splitting and peeling of bark following sunburn and wood rot – fruit tree  Splitting of bark on *Acer palmatum* – excessive irrigation and/or fertilizer?  Splitting on *Eucalyptus maculosa* – drought stress

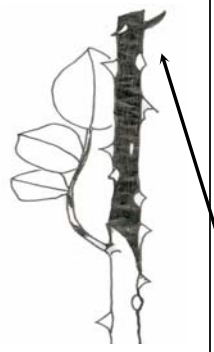
SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)

CANKERS

see also Cankers page 127

A dead, often sunken area on a trunk, branch or twig, may ringbark stems. Cankers may callus around the edges. Causes include:

- **Bacterial diseases**, eg bacterial canker of stonefruit.
- **Fungal diseases**, eg shot hole and brown rot of stone fruit, cypress canker, stem canker of rose (*Phomopsis*), *Botryosphaeria* and *Cryptonectria* on eucalypts.
- **Insects & allied pests**, eg pest feeding injury.
- **Non-parasitic agents**. ***Environment***, eg heat, cold, sunburn (usually on the most exposed side), chilling injury. ***Mechanical injury***, eg hail may damage green stems. ***Chemicals***, eg spray burn.





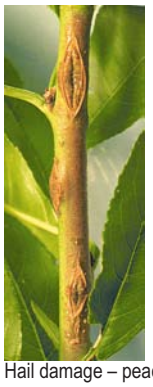
Stem canker of rose (*Coniothyrium* sp.) – commonly enters through pruning cuts



Cypress canker – *Chamaecyparis* sp.



Eucalypt twig canker (*Cytospora eucalypticola*) (D. G. Parberry)



Hail damage – peach

COLLAR ROTS

See also Dieback below Mechanical injury page 162

The collar of a trunk is vulnerable to rot. It is often moist, easily damaged by equipment and often where the graft is. Causes include:

- **Bacterial diseases**, eg bacterial canker of stone fruit.
- **Fungal diseases**. Collar rots, eg *Phytophthora, Sclerotium*. Root rots may progress into the collar or lower trunk, eg *Armillaria*, *Phytophthora*.
- **Non-parasitic agents**, eg bark may deteriorate at the soil line due to waterlogging, moisture stress, extreme soil temperatures, planting too deeply, mulch piled up against trunks, salinity, mechanical injury, chemical injury during spraying operations.

Collar rots caused by bacterial or fungal diseases need to be identified by a diagnostic laboratory



Scalybutt (exocortis virus) – citrus



Weeping base of rowan tree (*Sorbus* sp.) after suckers pruned off, tree died. Suggest possible causes?



Ivy growing on grass clippings piled around the base of *Cedrus atlantica*

DIEBACK, DECLINE

see also Blights page 126 Dead shoot tips page 133 Poor root growth page 166 Whole plants pages 173-174

There is **no clear distinction** between the symptoms of dieback and decline. **Dieback** involves the progressive death of shoots and branches beginning at the **top** of the plant. There is a slowing of growth indicated by reduced canopy, decreasing internodes (space between where leaves are attached and buds located) over seasons. There may also be small leaves, poor foliage colour, scorch, reduced branch numbers, parts may die. New shoot growth or several seasons of stem growth on a branch may be affected. Dieback continues for years or perhaps decades until the tree finally dies. In many cases, the question is not what is **the** cause of the dieback but **how many** causes and interactions are involved. These may include:

Dieback may be the result of problems affecting the:
- Foliage
- Trunks, branches or crowns
- Roots, soil, media or water
- Whole plant

- **Bacterial diseases**, eg bacterial canker of stone fruit causes sunken stem cankers, which ooze gum and have a sour smell; the cankers grow along branches and trunks rather than around them, but eventually girdle and kill them.
- **Fungal diseases**. ***Root rot fungi***, eg *Phytophthora cinnamomi* causes dieback of many trees, eg avocado, jarrah in WA, *Armillaria root rot* may cause dieback in Victoria and Tasmania. ***Trunk & branch fungi,*** eg cypress canker, wood rots, rust galls on wattle. ***Vascular wilt diseases***, eg myrtle wilt in Tasmania, Dutch elm disease (overseas). ***New growth only may dieback***, eg brown rot and powdery mildew of apple; shothole of stonefruit (cankers are only found on wood up to 2-3 years of age).
- **Parasitic plants**, eg mistletoe may cause eucalypts and other species to die back.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DECLINE, DIEBACK ***(contd)***	• **Nematode diseases**, eg citrus nematode (*Tylenchulus semipenetrans*). • **Insects & allied pests**. ***Foliage-feeding insects***, eg Christmas beetles, sawfly larvae (spitfires), leaf beetles and lerp insects repeatedly defoliate eucalypts; trees cannot photosynthesize enough food (see page 2, Fig. 1). ***Trunk insects***, eg bark beetles, borers, ringbarking weevils, twig girdlers, termites, some scales (San Jose and white louse scales). ***Root-feeding insects***, eg borers, termites. • **Vertebrate pests**. Interaction between ***bell miners***, ***lerp insects*** and possibly other factors, causes dieback of eucalypts in SE Australia. • **Non-parasitic agents** are often the 'hidden' causes of dieback and are the most difficult to diagnose. ***Improper planting*** results in dieback of many recently transplanted trees (see page 173). ***Soil compaction*** causes poor growth and even death of mature, well established woody plants. ***Excess mulch*** (8 cm plus) can reduce available oxygen to roots, causing them to die. ***Environmental causes***, both short and long term are many. **Temperature**, eg high and low air or soil temperatures, heat stress, sunburn or frost injury to bark. Temperature extremes in temperate climates cause major bark cracking and splitting, root damage, growing tip damage and dieback in the following spring. Long term temperature increases, eg climate change. Unnatural fire regimes in forest areas. **Water**, eg drought stress, excessive rain, over or under-watering, frequent light waterings, waterlogging, flooding, poor soil drainage, or any combination of these. High root-zone or soil moisture predisposes plants to attack by root diseases. Gradient changes can impede water flow which may damage roots of older trees, which may dieback in dry weather. **Light**, eg excessive shade when the species prefers a higher light intensity. ***Nutrient deficiencies & excesses*** and very high or very low pHs may be a factor in commercial crops but not so much in undisturbed soil; there are exceptions. Excess fertilizer may favour diseases such as *Pestalotiopsos* and *Phoma*. Salinity is a major cause of dieback in the Australian landscape. Lack of calcium, boron or iron and excess phosphorus may cause dieback in twigs and branches on some species. ***Mechanical damage*** to trunks may be caused by improper staking, mowers, weed trimmers, recent installations of driveways, hail, wind and vandalism in shopping areas. Machinery may damage feeder roots within the upper 10-12 cm of the soil surface. ***Mycorrhiza*** may be lacking in media or in soils severely disturbed during construction activities. ***Chemicals*** Residual herbicides in the soil, eg simazine. Green bark of young trees and shrubs may absorb some herbicides, eg glyphosate, with effects in a few days/weeks or not until spring following an autumn application (see pages 107, 135). Young plants may die, older ones may not recover for 1-2 years or die. Spray applications or drift of hormone herbicides (2,4-D, 2,4-DP, MCPA, MCPP) commonly used to control broad-leafed weeds in turf areas, may damage trees and cause dieback. ***Genetic***, eg the source of the species may be the problem; eucalypts of the same species from different regions may perform differently. ***Normal characteristics***. What is the projected life span for that particular species on that site? Many healthy trees exhibit 'normal dieback' within the canopy due to shading by the outer canopy and age.

Inspect trees for borer activity when foliage is sparse, eg deciduous trees in winter

Check whether small branches are dead or alive



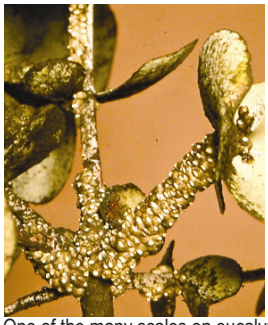
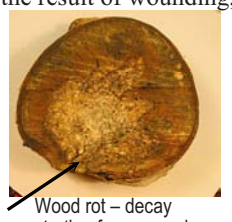
Bacterial canker – stone fruit. Die back of a main branch

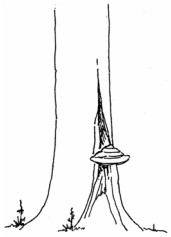


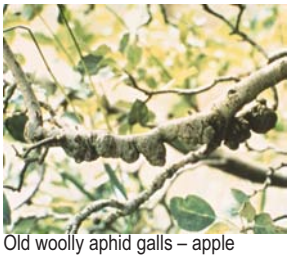
Dieback of *Acer palmatum* – extreme bark splitting possibly due to due to excessive irrigation and/or fertilizer (see page 155)

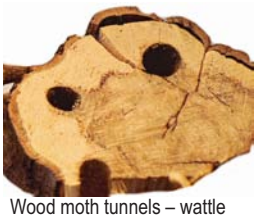
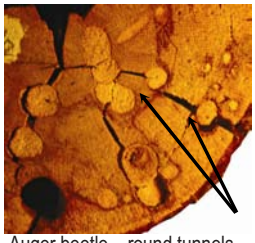
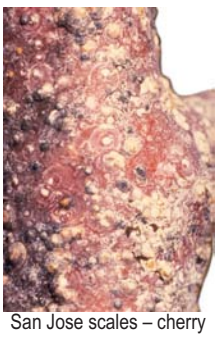


Dieback of ash and suckering from base – prolonged drought

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DISCOLOURED BARK, FRASS see also Gumming page 150	Causes include: • **Bacterial canker**, eg bacterial wet wood on elms. • **Fungal diseases**, eg flat fruiting bodies of some wood rots, eg pink limb blight. • **Insects & allied pests**. ***Mites***, eg bryobia and European mite infestations appear as granular tiny reddish patches. ***Encrusted scales***, eg gumtree, rose, San Jose, tick and white louse scales. ***Wood moth and fruit-tree borers*** may leave piles of frass at the entrance to their galleries. ***Termites*** may make mud galleries on the surface of the trunk. ***Webbing moth caterpillars*** feeding on leaves of tea-trees and other plants make 'nests' of frass amongst branches (see page 134). • **Non-parasitic agents**. ***Ants*** may build nests at the base of trees. Spiders and many insects 'live' on bark. ***Normal characteristics***. Bark colours and patterns, eg spotted gum (*Corymbia maculata*). Lenticels may be confused with hard scales, eg *Prunus* sp.  Pink limb blight *(Corticium salmonicolor)*. NSW Agric.  Frass at entrance to tunnels of the fruit-tree borer – *Albizzia* sp.  One of the many scales on eucalypts, stems look whitish  Rose scale encrusted on canes  Iron-bark (*Eucalyptus sideroxylon*) with deeply furrowed bark – spider egg-sacs  Yellow coloured lichens (non-parasitic) – *Pistacia chinensis*
DISCOLOURED INTERNAL TISSUE, WOOD see also Wilting page 140	Defects in trunks of growing trees continues to be a major research area for arborists and foresters. Causes include: • **Bacterial diseases**, eg bacterial canker of stone fruit. • **Fungal diseases**. ***Vascular wilt diseases***, eg myrtle wilt of beech in Tasmania, Dutch elm disease (overseas). ***Wood rots***, eg brown and white rots. ***Blue stain fungi***. • **Insects & allied pests**, eg stains associated with borers, eg ambrosia beetles. • **Non-parasitic agents**. Pruning cuts, tree injection sites and other mechanical injuries may allow entry of fungal diseases especially in wet conditions. Kino veins or pockets, common in eucalypt, often the result of wounding, insects, fire.  Vascular wilt  Bacterial canker – stonefruit. Bark scraped away to show dead tissue underneath  Wood rot – decay starting from wound on surface of bark  Wood rot – sapwood completely rotted away  Kino veins – *Eucalyptus seiberi*

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DISTORTIONS, FASCIATION see also Galls page 160	Misshapen **branches and trunks**. Causes include: • **Virus & virus-like diseases**, eg flat limb (apple), scaly butt (citrus). • **Insects & allied pests**, eg citrus gall wasp, egg laying activities of some insects. • **Non-parasitic agents**. ***Environmental***, eg extreme temperature fluctuations, frost, hail, drought, insufficient light, prevailing winds and planting too closely may cause trees to become leggy and lean abnormally. Trees planted adjacent to buildings often lean away. ***Mechanical injury*** to trunks may cause abnormal growth. ***Genetic***, eg fasciation, sports. ***Normal characteristics***, eg swollen trunk (baobab tree), corky ridge on branches (liquid amber), natural branch grafts.  Flat limb – apple  Split stems – *Callistemon*. Cause inconclusive, possibly due to insect activity, eg egg laying when stems were young  Fasciation – *Euonymus*  Swollen base (like a plate) – elm
FUNGI, WOOD ROT FRUITING BODIES see also Dieback page 156 Discoloration page158	Fruiting bodies are often found on trunks and branches. Examples include: • **Insects & allied organisms** may appear like fungal growth, eg woolly aphids, mealybugs, predatory mealybug ladybirds and their larvae, spider webbing. • **Fungal diseases**. ***Wood rots*** produce various types of fruiting bodies externally on the trunk and butts of trees. Some are annual, others perennial. ***Many other fungi*** may attack stems killing them and producing tiny fruiting bodies (many can only be seen with a dissecting microscope).  Fruiting body on old fire scar  Red fan-shaped fruiting body(*Coriolus cinnabrinus*) – apricot  White unidentified fruiting body – apricot  Armillaria fruiting bodies, may be found at the base of affected trees, on roots and stumps  Tiny fungi fruiting bodies on dead twigs and branches – *Sophora japonica*  Woody perennial fruiting body – spores produced at intervals on lower surface. The layers can be counted – how old might this one be?

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
GALLS see also Galls pages136, 164	Galls are roughly spherical swellings of unorganized plant cells which occur on **branches, trunks** and other plant parts. Causes include: • **Bacterial diseases**, eg crown gall, olive knot, bacterial gall of oleander. • **Fungal diseases**, eg rust galls on wattle, pine rust (overseas). • **Insects & allied pests**. ***Sap-sucking insects & mites***, eg woolly aphids, European red mite. ***Gall wasps***, eg citrus gall wasp, eucalypt gall wasps. ***Gall-making thrips*** on acacia, tea-tree (*Leptospermum*). ***Arboreal termite nests*** may look like large footballs. • **Non-parasitic agents**. ***Environment***, eg protea stems (frost). ***Chemicals***, eg dicamba at near lethal rates may cause galls on pines. ***Genetic***, eg provenances of poplar. ***Normal characteristics***, eg burr knots (root initials) on *Prunus* spp. (see page 46), lignotubers on eucalypt, epicormic buds (shoot initials), woody galls on old quince and stone fruit trees.  Bacterial gall – oleander  Rust galls – wattle  Old woolly aphid galls – apple  Quince –woody galls develop as trees age. Note regular pattern  Banksia mite gall  Poplar galls – provenance (see case study page 101)  Epicormic buds – *Acer negundo*  Large woody gall – old plum tree
GUMMING, OOZE, WEEPING	A secretion of gum or liquid discharge. Causes include: • **Bacterial diseases**, eg bacterial canker of stone fruit, bacterial wet wood (weeping) on elms may attract moths. • **Fungal diseases**, eg brown rot and shothole of stone fruits, cypress canker, *Eutypa* dieback on grapes, wood rot, *Phytophthora* collar and lower trunk rots. • **Insects & allied pests**, eg various borers, tip borers such as oriental fruit moth. • **Non-parasitic agents**. ***Environment***, eg lack or excess of soil moisture, heat. ***Mechanical injury***, eg heavy pruning; pruning late in winter or early spring may promote copious sap flow in grapes and walnuts; any injury to apricots will cause gumming. ***Copper sprays*** after pruning may cause cherries to gum. ***Genetic***, eg graft incompatibility. ***Natural gumming***, eg apricot, pittosporum.  Bacterial canker – plum  Natural gumming – pittosporum  Gumming – *Cedrus atlantica.* Due to stress or injury  Natural gumming – nectarine

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
HOLES, TUNNELS, INSIDE TRUNK	The term 'borers' is used to describe the larvae of insects which feed internally in trunks, limbs, branches and roots of trees and shrubs. The shape and size of the holes, whether they are filled with frass and their location in the trunk help identify the pest. Causes include: • **Insects & allied pests**. ***Beetle borers***, eg auger, longicorn and jewel beetles. ***Moth borers***, eg currant borer moth, fruit-tree borer, wood moths. ***Wasps***, eg sirex wasp in pines. ***Termite*** injury.  Wood moth tunnels – wattle  Auger beetle – round tunnels packed with frass  Longicorn beetle damage – eucalypt. Bark has been removed – oval tunnels packed with coarse frass  Termite damage – eucalypt  Termite damage – eucalypt
HOLES ON SURFACE OF TRUNK	The larvae of insects which feed internally in trunks pupate just under the surface of the bark so that the adult can emerge through **'exit holes'**. These holes may be round, oval and of varying sizes; some are packed with frass, some have accumulations of frass surrounding the exit hole, or cause bark to lift or gum. Causes include: • **Insects & allied pests**, eg longicorn and jewel beetles, wood moths, fruit-tree borer, sirex wasp on conifers. • **Non-parasitic agents**, eg holes left after injections of micro-nutrients and pesticides.  Auger beetle – tamarisk. Note tunnels inside trunk and exit holes on trunk  Sirex wasp – circular exit holes through the bark of *P. radiata* (NSW For.)  Fruit-tree borer damage – *Albizzia*. Frass removed to reveal tunnel entrance
INSECTS ON BARK	Many insects are associated with trunks and branches. **1000 species have been found on on 1 eucalypt!** Most of these insects would not have been pests. • **Insects & allied organisms**. Many scales, resting moths, froghoppers, adults of various borers (longicorn and jewel beetles, wood moths), larvae of sawflies and moths, cicada eggs. Ants stream up and down trunks seeking honeydew from scales and other sap-sucking insects. ***Many beneficial insects*** inhabit bark, eg spiders looking for prey.  San Jose scales – cherry  Woolly aphids – apple  Steelblue sawfly larvae (spitfires) – eucalypt  Tick scales – wattle

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
MECHANICAL INJURY see also Bark splitting page 155	Mechanical injury may be the **primary** cause of damage which attracts secondary borers or wood rots or it can be a **secondary** cause after prior weakening of trunks and branches due to insect, eg borers and wood rot fungi. Causes include: • **Vertebrate pests**, eg livestock, cockatoos excavate wood boring larvae from wattle stems. • **Non-parasitic agents**. ***Environment***, eg hail, lightning, rain, snow, wind, soil movement, soil temperature extremes, poor drainage. ***Mechanical injury***, eg lawn mowers, string trimmers, tiers or stakes, sprinklers, vehicles, machinery, vandalism, inappropriate pruning, vase-shaped fruit trees may split with heavy fruit loads.  Lawn mower damage  Tiers and stakes
PARASITIC PLANTS, SUCKERS, ETC see also Suckering roots page 168	Causes include: • **Fungal or bacterial diseases**, eg peach leaf curl on apricot shoots (witches' broom). • **Parasitic plants**. Stem parasites, eg devil's twine (*Cassytha* spp.), mistletoe. Do not confuse these with plants which twist around trunks of other plants, eg figs, *Sollya* sp. • **Insects & allied pests**, eg eriophyid mites on many native plants (witches' broom). • **Non-parasitic problems**. Plants may regrow from adventitious shoots, burr knots, epicormic buds, lignotubers, rootstock under a range of adverse conditions, eg after temperature extremes or prolonged drought has caused crown dieback, incorrect or heavy pruning, ringbarking, failure to remove ties and grafting tape, fire. Some plants are prone to sucker. ***Mechanical injury to roots*** during cultivation may cause roots of many species to sucker, eg, *Prunus*, *Pyrus, Sorbus*. ***Nutrient deficiencies & excesses***, eg excess nitrogen may cause olives to sucker. ***Non-parasitic 'plants' found on trunks***, eg epiphytic orchids and ferns, lichens, moss.  Mistletoe  Rust galls – wattle. A tangled mass of galls and foliage  Casuarina - *Left:* Eriophyid mite damage (witches' broom). *Right:* Healthy branch  *Sollya* 'strangling' a shrub  Suckering from hawthorn rootstock – rowan (*Sorbus* sp.)  Lichen (not parasitic) – cherry

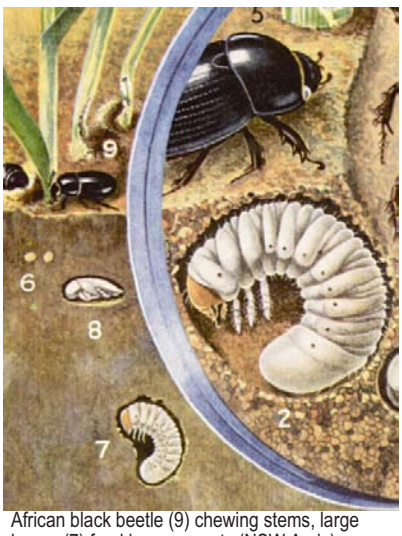
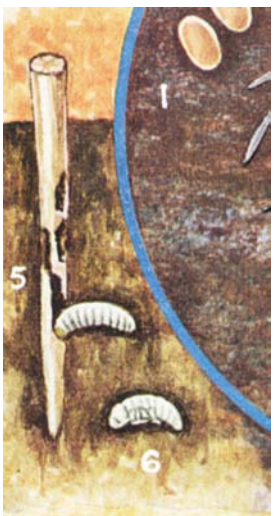
Roots, soil, media

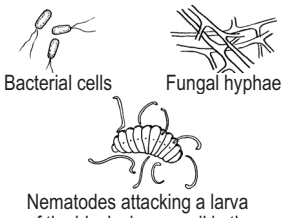
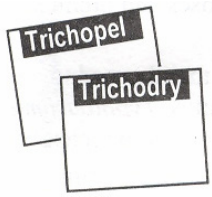
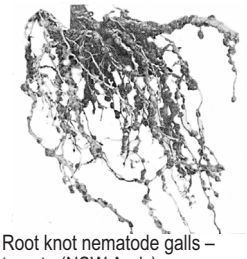
Some signs & symptoms – Clues!

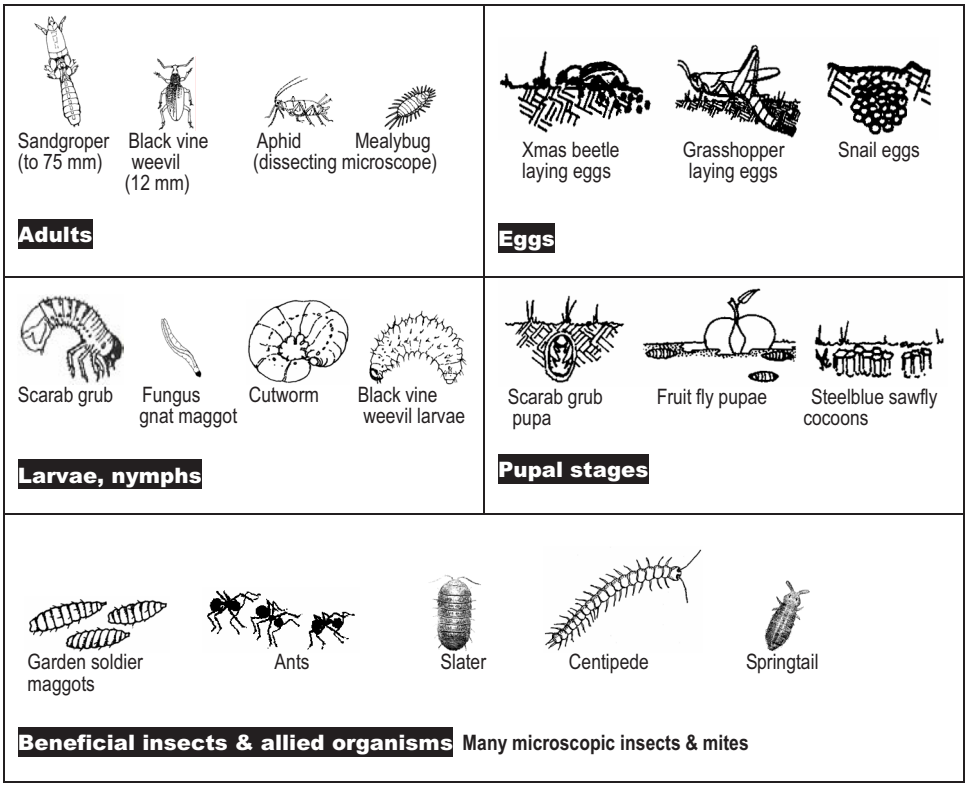
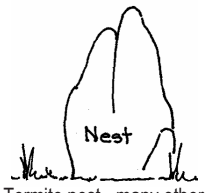
Chewed, mechanical injury 'Debris' Fungi, bacteria, nematodes Galls, distortion	Insects **in** roots Insects **on** roots & in soil, other pests Invasive roots Poor root growth	Replant problems Root rots, fungi, odours, discoloration Suckering roots Weed seed & bud banks

The below ground component of the plant is the most important. Because of the difficulty of seeing roots and soil below ground level, diagnosis from signs and symptoms is difficult, so that soil, water and plant analyses are often required. By way of illustration, only 6 of the 52 pages in this Appendix deal with signs and symptoms you can 'see' on roots and soil. There are many good books on soils and growing media, buy one!

- **Identify the affected plant**, so you can access a **list** of common problems affecting it, reducing the number of suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** all visible external and internal signs and symptoms, measurements and microscopic examinations. Feel and smell soil/growing media, check weight.
- **Soil depth and moisture** will influence tree stability.
- Many plant problems begin **below-ground**, eg soil compaction, over or under-irrigation and fertilizing, poor drainage, poor planting techniques, chemical injury or site-related stress such as restricted rooting area and transplant shock. Problems may be caused by root diseases, insects feeding. **Above the soil surface**, weather, poor site location, air pollution, herbicide injury and other agents may also indirectly affect the roots.
- Examine roots **internally** and externally. If possible dig up plants and tip out potted specimens to inspect roots and media, gently shake off soil and examine again with a hand lens or with a dissecting microscope.
- **Root and soil/media problems** result in **non-specific aboveground symptoms**, eg stunting, ready wilting, leaf yellowing, shedding of older leaves, nutrient deficiency symptoms, lack of new growth, dieback. However, these same non-specific symptoms may also be caused by trunk and foliage problems, making diagnosis difficult.
- **Beware of secondary pests and diseases**. Plants with poor root health are vulnerable to pests and diseases.
- **Delayed effects**, eg **perennial plants** such as trees and shrubs may be affected by advanced root problems before **any** foliage symptoms are visible. Trees and shrubs may take years to die.
- Sometimes root/soil problems can only be **determined by on-site or laboratory tests**. Remember, although nutrient problems may make plants look quite sick they are seldom the primary cause of plant death.
- See also **Flowers** page 141, **Bulbs** page 169, **Branches** page 155, **Seeds** page 151, **Leaves** page 125.

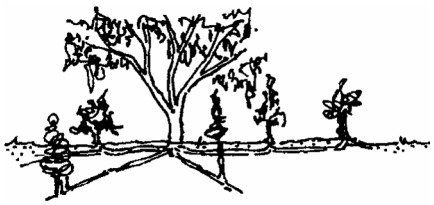
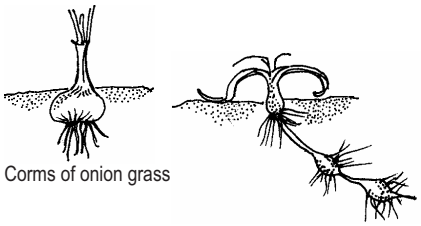
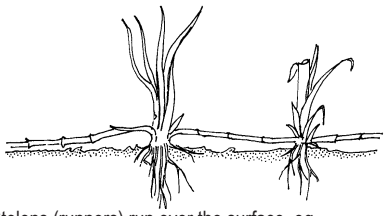
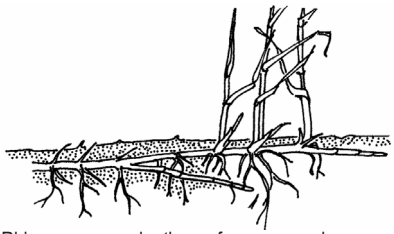
SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
CHEWED, MECHANICAL INJURY see also Insects in roots page 165	Causes include: • **Insects & allied pests**. ***Fly maggots***, eg bean fly, onion maggot, bean seedling midge. ***Beetle larvae***, eg scarab grubs, vegetable and whitefringed weevils, wireworms gouge underground stems of sweetcorn. ***Caterpillars***, eg cutworms. • **Vertebrate pests**. ***Feral pigs*** dig in nature parks to feed on roots. • **Non-parasitic agents**. ***Mechanical injury***, eg landscaping and construction work may damage or expose roots. Hoeing weeds may injure root of seedlings, annual transplants and other plants with shallow roots. ***Birds*** eg blackbirds, magpies, chickens dig amongst roots damaging shallowed rooted plants eg azalea. ***Hoofed animals***, eg livestock, may compact and damage fragile layers of soil.  African black beetle (9) chewing stems, large larvae (7) feed in grass roots (NSW Agric)  Whitefringed weevil larva (5) chew tap or fleshy roots, note pupa (6) in soil (NSW Agric)

SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
'DEBRIS'	**Soil depth** varies from a few centimetres to a metre or more, its main components are rock and mineral matter, organic matter, water and air. Depending on the soil, region and conditions, the soil and areas around plant roots (rhizosphere) may or may not be a seething mass of microorganisms. Stones, rocks, organic matter and larger insects, slaters and millipedes etc, **can** be seen but most micro-organisms **cannot**. • **Decaying plant material** which is the main component of organic matter is broken down by saprophytic bacteria, fungi, nematodes, insects, mites etc, which are mostly **microscopic**. Saprophytic fungi growing on dead roots in the soil can sometimes be seen when digging in soil and are often thought to parasitic when they are not. • **Decaying animal material**, eg insect parts, bones are similarly broken down into organic matter (see page 167). • **Items added by humans**, eg granules of fertiliser, waterwise products, media filler, pesticides. Some of these are often mistaken for 'eggs' of snails or other pests. Excess fertilizer may result in encrusted salts on soil and pots.
FUNGI, BACTERIA, NEMATODES see also Root rots page 167	Most nematode, many fungal and some bacterial diseases are soil-borne. Rarely are virus diseases soil-borne but living roots of plants may be infected with virus. Most pest and beneficial micro-organisms in soil are **microscopic** and can only be **identified** and **differentiated** by a specialist diagnostician. For example, you might see plenty of nematodes under a dissecting microscope but you would not be able to tell whether they were pests or beneficials. If pests, then they would need to be counted in a laboratory to see if their numbers warranted treatment. Many beneficial soil micro-organisms have been developed as biological control agents. Mycorrhizal fungi and growth-promoting bacteria are often added to media. Algae, lichens, mushrooms and slime moulds of various colours may grow on the soil surface or low lying plants.  One of the many fungal fruiting bodies growing on organic matter in the soil (about 2 cm across)  Bacterial cells Fungal hyphae Nematodes attacking a larva of the black vine weevil in the soil; marketed as Weevilnem®  A soil fungus (*Trichoderma*) is marketed as Trichopel® to control soil diseases
GALLS, DISTORTIONS see also Galls page 160 Poor root growth page 166	A swelling, roughly spherical, of unorganized plant cells occurring on **roots,** leaves, stems, flowers and seeds. Causes include: • **Bacterial diseases**, eg crown gall on roses, peaches, and other plants. • **Fungal diseases**, eg club root (*Plasmodiophora brassicae*) of brassicas. • **Nematode diseases**, eg root knot nematode of many plants. • **Insects & allied pests**, eg woolly aphid, fungus gnat larvae in pots in greenhouses. • **Non-parasitic agents**. ***Plants in pots*** may develop girdled roots. This is a common cause of trees and shrubs dying a few years after planting. ***Normal structures***, eg lignotubers (eucalypts), proteoid roots (waratah), actinorrhizal galls (alder); nitrogen-fixing bacteria (*Rhizobia*) on legumes, eg peas, beans, wattles.  Crown gall – rhubarb  Crown gall – cane fruit (*Rubus* sp.)  Root knot nematode galls – tomato (NSW Agric)  Proteoid root – waratah (Proteaceae)  Actinorrhizal root – alder  Root girdling, pot bound.  Nitrogen-fixing nodules (*Rhizobia*) – pea roots  Lignotubers – eucalypt

SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
INSECTS IN ROOTS	Larvae of many chewing insects tunnel in roots Examples include: • **Insects & allied pests**. ***Chewing insects***. ***Moth and beetle larvae of borers*** may tunnel down from stems into woody roots, eg ghost moths (swift moths), wood moths (goat moths), longicorn beetles, elephant weevil. ***Termites*** may nest in woody roots, chew tunnels in them and the workers may later use them to access other food sources. ***Beetle larvae*** of the African black beetle and whitefringed weevils may feed either on or in roots of herbaceous plants. ***Fly maggots***, eg maggots of the bean fly, seedling bean midge and onion maggot tunnel into stalks and stems of some vegetable seedlings.  Larva of the wattle goat moth (*Xyleutes encalyptii*) grow up to 15 mm long (H. J. Elliott) – large larvae of ghost and wood moths may feed in trunks and roots
INSECTS ON ROOTS, AND IN SOIL, OTHER PESTS	Most insects, both **pest and beneficial**, spend part of their life cycle in the soil, so you may find eggs, larvae or nymphs, adult insects and nests in soil. Examples include: • **Snails & slugs**, eg eggs, empty shells, slime trails, trails of excreta. • **Vertebrate pests**, eg rabbit burrows. • **Insects & allied pests**. ***Chewing insects***. **Beetles and their larvae**, eg scarab beetles, wireworms/false wireworms, African black beetle; also black vine, vegetable, whitefringed and sweetpotato weevils. **Moth larvae**, eg armyworms, cutworms, larvae of various borers. **Ants and termites** and their nests are common. **Cricket** nymphs. ***Maggots*** of the bean fly, seedling bean midge, onion maggot, fungus gnats. ***Sap-sucking insects***, eg root aphids, root mealybugs, woolly aphids, thrips. • **Beneficial insects & allied organisms**, eg springtails, centipedes and slaters breakdown organic matter; predatory snails and slugs. ***Flies***, eg garden maggots breakdown compost, moth flies feed on sewage, shore flies. ***Bush cockroaches*** live in leaf litter in bush areas. Examples of stages of insects & allied organisms found in soil   Termite nest - many other insects & allied organisms nest in soil, eg ants, wasps and spiders

SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
INVASIVE ROOTS	Some trees, shrubs and climbers have invasive roots. Causes are: • **Non-parasitic**. ***Poor siting*** of trees, eg eucalypts near drains and house foundations, foot paths, turf areas, etc can result in the need for expensive repairs and maintenance. Public safety issues may be involved. ***Cutting down some trees***, and some climbers, eg elms, wisteria without applying herbicide treatments will result in extensive root suckering. ***Large roots*** which are not removed will decay and may produce fungal fruiting bodies that are capable of lifting pavers and breaking up road surfaces.  Birch roots growing over a foot path  A large root of Chinese elm has invaded turf and has been repeatedly damaged by mowers
POOR ROOT GROWTH see also Dieback page 157 Galls page 164 Replant problems page 167 Transplant shock page 154 Whole plants page 174 Where the root/stem junction is more than 8 cm below the soil surface the roots may receive inadequate aeration	Often associated with roots that are too shallow or too few. Causes include: • **Fungal & bacterial diseases**, eg many such diseases result in brown, obviously discoloured roots, poor root development at the base of pots, a lack of fine roots and roots which are easily broken when handled. • **Insects & allied pests**, eg root-feeding scarab grubs and weevils feed on the roots of turfgrasses, sugar cane and other crops. **Non-parasitic agents**. ***Poor cultural practices*** ***Overcrowded plants*** compete for space, nutrient and water; all plants but especially perennial trees and shrubs should be planted at recommended spacings. ***Stem girdling roots*** can slowly weaken and kill trees and shrubs in a few years or over the longer term. Girdling restricts the movement of water and nutrients and may be the result of being held in a container for too long, planting into a restricted root space or both. Planting too deeply makes the plant more susceptible to root girdling. Planting in poorly drained, compacted clay soil, and digging a hole that is too small with an auger that will compact and glaze the sides, confines the root system and provides poor drainage. High nutrient levels in the hole further confines root development to the hole exacerbating the problem. ***Exposed roots***, eg some species push upward in the container due to inadequate soil added at time of potting, soil splashed out by irrigation, excessive shrinkage of media components and earthworms. Plants that are loose in holes are an indication that roots are not well established. ***Environment***. Root development may be one-sided in pots, possibly indicating excessively high root zone temperatures on the exposed side of pot, poor uniformity of wetting after irrigation, or excessive fertiliser applied to one side of the plant. **Frequent light waterings** encourage a weak shallow root system that is prone to moisture stress. Irrigation (both too much and too little) with inadequate drainage, soil temperature extremes and compaction all contribute to poor root growth. ***Nutrient deficiencies & excesses***, eg poor nutrition, excess fertilizer, salinity. ***Chemicals***, eg pesticide drenches, toxic components in soil mixture (certain types of bark). ***Normal characteristics***. Root systems vary widely. Some may be shallow, others produce massive tap roots as deep as the tree is high. Some roots grow slowly during dormancy. Roots may senescence and new roots form.  Azaleas planted too deeply  Stem girdling roots, pot bound

SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
REPLANT PROBLEMS	When some trees and shrubs, especially members of the rose family, are planted into soil in which the same species were previously growing, they may fail to thrive and even die. The stunting and poor growth are the result of poor root development. Plants will recover if moved to fresh soil. The **general opinion** is that during the life of the first planting, there is significant build-up of pests and diseases on roots, eg nematodes, fungi, also possibly toxic saprophytic micro-organisms. These increase gradually and do not reach high levels until plants are well established by which time the root systems are large and robust enough to withstand any adverse effects. The pathogens therefore have no effect on the vigour of the initial planting, however, when the original plants are removed, high populations of these harmful organisms still remain in the soil. When new young replants with only small root systems are planted in this contaminated soil they struggle to survive.
ROOT ROTS, FUNGI, ODOURS, DICOLORATION see also Damping off page 152 Fungi rots page 170	Actively growing roots are normally firm and white with abundant root hairs. The colour of the outer epidermis can vary depending on the species, but the xylem/cortex of healthy roots should be white. If roots or root tips are discoloured, watery and break off easily, leaving only a thin white core when they are teased from the rooting medium, or if there are signs of root darkening or blackening progressing to the crown or lower stem, then root rot should be suspected. Dark slightly sunken rot may develop at the base of stems, a dark discoloration is seen when the stem is cut. Rotting of newest roots allows a plant to be easily pulled from soil. • **Bacterial diseases**, eg bacterial soft rot of potatoes, stem rot of geranium. • **Fungal diseases**. Most sampling and testing of roots is done to determine the **presence** or **absence** of *Phytophthora*. ***Other important soil fungi*** include *Rhizoctonia and Pythium, Cylindrocladium* in spathiphyllums and many native plants, *Bipolaris* in cacti and *Fusarium* in carnations, *Sclerotinia* rot, *Rhizopus* soft rot, *Rhizoctonia* stem and root rots. *Sclerotium* stem rot, wood rotting fungi and *Armillaria* root rot may affect woody roots. ***Root rot complexes occur on some plants***, eg *Aphanomyces, Fusarium, Pythium* on beans which become stunted, older leaves yellow and wilt, tap root and lower stem develop a red-brown rot. ***In nurseries, root and collar rots***, *Phytophthora, Rhizoctonia, Chalara, Fusarium* and *Pythium* cause major problems, often coupled with lack of general nursery hygiene and overwatering. *Fusarium* and *Pythium* are found on plants suffering stress from other causes. *Chalara* seems to be more prevalent in either hot or cold conditions which can stress plants and reduce their resistance. • **Nematode diseases**, eg root knot, stem and bulb nematode and other nematode infections may be followed by secondary rotting. • **Insects & allied pests**, eg root mealybugs and root aphids produce white wax making roots and growing media appear whitish or greyish, which may be mistaken for fungal disease. Woolly aphids have a limited host range, so are unlikely to be misidentified. • **Non-parasitic agents**. ***Environment***, eg waterlogging, poor drainage, blocked drainage holes in containers. Overwet conditions favour parasitic soilborne diseases. Roots of container plants are susceptible to excessive heat or cold, causing black or spongy roots with a lack of new growth or root hairs usually near the container edge. ***Nutritional deficiencies & excesses***, eg excess soluble salts, bore or washing machine water. ***Chemicals***, some herbicides favour certain root rotting fungi. ***Offensive odours*** occur when anaerobic bacteria grow on rotting roots and soil organic matter in wet conditions. Many root rots produce similar symptoms. Few root rotting fungi produce distinctive signs and symptoms and even these are difficult to divide into species and strains. It is necessary to send samples to a diagnostic service to have them identified.  *Phytophthora* root rot. *Left:* Root system of 2-year-old citrus tree on rough lemon showing absence of fibrous roots. Roots are discolored, easily broken when handled. *Right:* Root regeneration – healthy root and root hairs – (NSW Agric)  Daphne roots from below the crown to those deeper in the soil – outer tissue has gradually rotted  Smaller roots of daphne – outer tissue has rotted and easily sloughs off

SIGNS/ & SYMPTOMS	SOME CAUSES (not exhaustive)
SUCKERING ROOTS, ROOT PARASITES see also Parasitic plants page 162	Suckers are adventitious shoots produced from the base of trunks, roots, rhizomes or stolons of a woody plant that gives rise to a new plant. Suckering can be a problem in both landscaped and bush areas. The degree to which a plant may sucker should be considered when selecting plants. • **Parasitic plants** can be confused with suckers, eg native cherry is parasitic on roots of eucalypts, young Western Australia Christmas trees are parasitic on roots of grasses. • **Activities which favour suckering in plants.** ***Mechanical injury to roots***, eg digging, mowing. ***Heavy pruning*** of trees. ***Fire, drought***. ***Cutting down some trees and shrubs,*** eg elm trees, eucalypts, wisteria, without using herbicide treatments. ***Grafted plants***. Suckers from plants grafted onto rootstock must be analyzed carefully to determine if the growth is coming from above or below the graft. Suckers originating from below the graft should be removed (see page 162). ***Normal characteristics***. Some species sucker naturally (without any interference), eg white poplar, bamboo.  White poplar naturally suckers  Young native cherry trees are parasitic on eucalypts
WEED SEED & BUD BANKS	Weeds are one of Australia's most serious environmental problems, competing with desired plants for moisture, nutrients and light; they occupy potentially useful space (see page 12). Weeds use seed and bud banks to regenerate in following years. • **'Seed banks'**. Persistence of dormant seeds in the soil as a 'seed bank' is a common weed attribute. Some weed seeds are short-lived, other not so. Buried seed loses viability over time and seed 'turnover' can be rapid. **Crop seed** may be contaminated with weed seeds and seeds from previous crops. • **'Bud banks'**. Some perennial weeds have 'bud banks'. These are the buds on perennial structures, like rhizomes, stolons and some stem or root pieces, which persist for some time and which perform a similar function to seeds. Buds are often less resistant to elimination measures than seeds. Exceptions include bulbous weeds such as oxalis which have robust small bulbs as well as seeds. **Forecasting perennial weeds** is often easier than for annual weeds. Perennials persist from year to year, often in 'refuges' safe from attack, eg amongst buildings, paving, permanent plantings of perennial borders, trees and shrubs, bushland or deep in the soil.  Tap roots of plants, eg dandelion may be broken during weeding and cultivation, pieces may regrow  Seeds Broken stems strike roots eg willows  Corms of onion grass Tubers of nut grass  Stolons (runners) run over the surface, eg couchgrass (*Cynodon dactylon*), buffalo grass (*Stenotaphrum secundatum*), kikuyu (*Pennisetum clandestinum*), red-flowered mallow (*Modiola caroliniana*), creeping buttercup (*Ranunculus repens*)  Rhizomes run under the surface, eg couchgrass (*Cynodon dactylon*), buffalo grass (*Stenotaphrum secundatum*), kikuyu (*Pennisetum clandestinum*), Johnson grass (*Sorghum halpense*), rhizomatous bamboo species

Bulbs, corms, rhizomes, tubers

Some signs & symptoms – Clues!

Bulbs don't emerge Bulbs dried, shrunken Bulb diameter, depth, spacing Distortion, forking, splitting Fungi, rots, odours, discoloration	Galls Insects & other pests on **outside** of bulbs, gouging Insects **inside** bulbs, holes, tunnels Mechanical injury	Roots, thin or hairy Scabs Weeds invading bulbs

- **Identify the affected plant**, so you can access a **list** of common problems affecting it, reducing suspect problems to a manageable number; access a **pest information sheet** for each problem.
- **Record** all visible external and internal signs and symptoms, measurements and microscopic examinations.
- Many pests and diseases are **carried on, in or in association with** bulbs, corms, rhizomes and tubers. Many are not visible to the naked eye. Signs and symptoms will, therefore, often be **delayed**.
- **Examine** bulbs **internally** and externally. Cut bulbs longitudinally and transversely, tease scales apart.
- See also **Leaves** page 125, **Flowers** page 141, **Roots** page 163.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
BULBS DON'T EMERGE	It is disappointing when planted bulbs do not emerge. Causes include: • **Fungal & bacterial diseases**, eg bulbs rotted in soil (see page 170). • **Non-parasitic problems**, eg buried too deeply, too dry, too wet, too much organic matter, all of which favour fungal and bacterial diseases; herbicide injury may occur due to absorption through dying leaves. Lack of chilling for some bulbs, eg tulips.
BULBS DRIED, SHRUNKEN	Bulbs are probably about 90% water, loss of which can occur for a variety of reasons, including: • **Fungal diseases**, eg bulbs may rot in storage (too humid) or in the soil after planting out (too wet). Under subsequent dry conditions they dry out, shrink and become papery. • **Non-parasitic agents**, eg healthy bulbs can become papery in very dry conditions, both in the ground and in storage. Bulbs may be just too old.
BULB DIAMETER, DEPTH, SPACING	For optimum flowering there is an **minimum** bulb diameter for each species. • There are **recommended planting depths** and distances apart (see Figure 20 below). • **Potato tubers** in the ground must be kept covered as exposure to light causes them to develop green pigments which are toxic to humans, and attack by the potato moth.

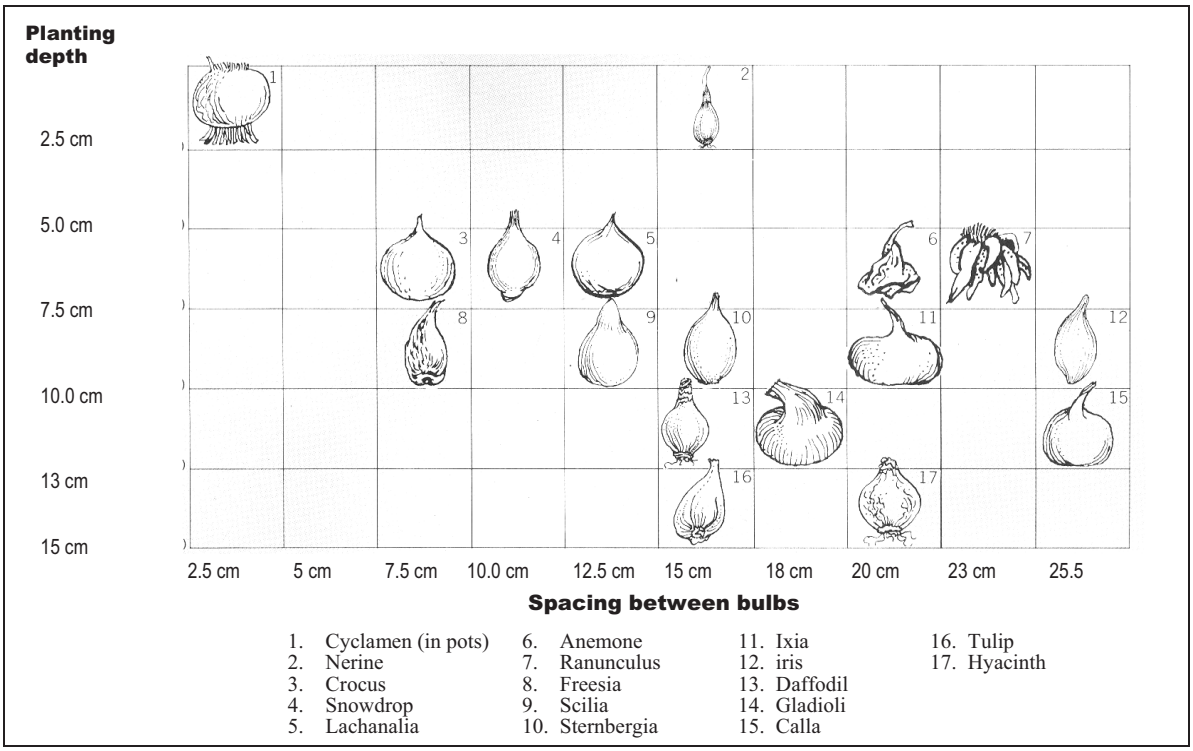
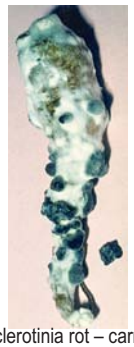


Fig. 20. Optimum bulb diameter, depth and spacing of some bulbs (Yates).

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
DISTORTION, FORKING, SPLITTING	Common in home gardens. Causes include: • **Fungal diseases**, eg *Pythium* root rots (stunting ands forking of tap roots of carrots). • **Nematode diseases**, eg root knot, other soil species. The proportion of galled, distorted and split carrots, together with their weight, can be correlated with populations of root knot and other nematodes in the soil. • **Non-parasitic problems**. In carrots and parsnips forking and splitting may be due to overmaturity, poor soil structure, excess fertilizer, too much rain, irregular watering and dryness. Surface cracks on potato are due to uneven growing conditions (both soil moisture and temperature), poor growing conditions followed by good conditions, some varieties are more susceptible.  Forking and galls. *Left:* Parsnip with root knot nematode. *Right.* Carrot with forking due to excess fertiliser  Distorted and split carrots  Surface growth cracks – potato
FUNGI, ROTS ODOURS DISCOLORATION See also Discoloured internal wood page 158 Wilting page 140	Some rots produce spore masses and are easily recognizable. Some infect bulbs in the field and become a problem in storage. Some are host specific. Causes include: • **Bacterial diseases**, eg bacterial soft rot (*Erwinia* spp.) of storage roots, eg potatoes, bulbs. There is often a foul smell. Potato pieces, when planted may rot in wet conditions. • **Fungal diseases**, eg *Fusarium* wilt (*Fusarium oxysporum* f. spp.) may affect bulbs in the field and in storage. Also black root rot (*Thielavioipsis*), *Phytophthora* root rot, *Rhizopus* soft rot, *Sclerotinia* and *Sclerotium* rots; *Sclerotium cepivorum* specifically attacks garlic, leeks, onions. ***Storage rots*** include those mentioned above and Irish blight (*Phytophthora infestans*) of potato. Various moulds develop on the outside and between scales on bulbs and are commonly called after the colour of the spores produced, eg blue mould (*Penicillium*), grey mould (*Botrytis)*, black mould (*Aspergillus*). • **Nematode diseases**, eg stem and bulb nematode. • **Insects & allied pests**. Rots may follow attack by bulb mites, gladiolus thrips, etc. • **Non-parasitic agents**. Slime moulds may grow on bulbs in wet weather outdoors. Internal tissue may be discoloured by poor drainage, waterlogging, moisture stress, excess organic matter, mulch, fresh manure. ***Nutrient deficiencies & excesses***, eg boron deficiency in beetroot (corkiness). ***Overmaturity of root vegetables*** in the ***field*** and ***storage conditions*** may cause internal discolouration or corkiness (especially potatoes).  Grey mould (*Botrytis*) – onion  Sclerotinia rot – carrot  Fusarium wilt – decay advances from base upwards  Stem & bulb nematode – scales brown and rot  Slime moulds – bulbs  Green potato – exposure to light

Some rots on cyclamen

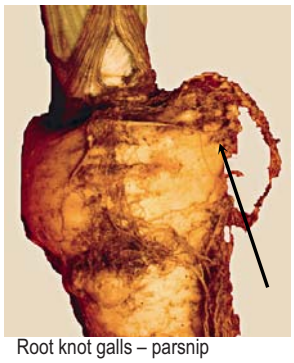
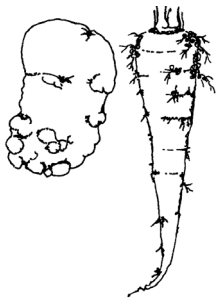
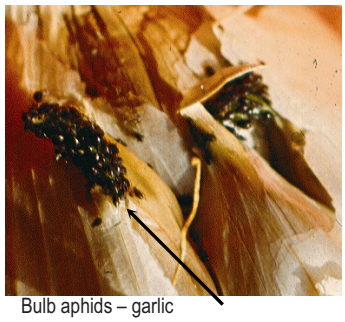
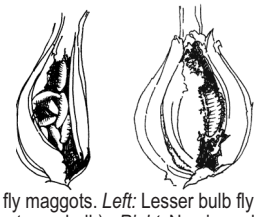
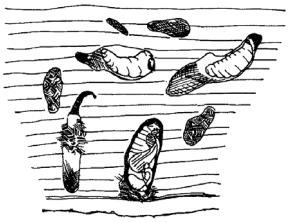
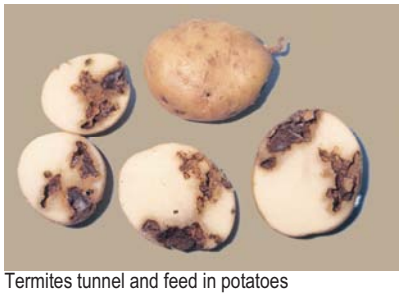
Typically leaves develop mottles, dull-green to yellow areas that can wilt or turn brown. Within days the whole leaf wilts, shrivels and the plant dies.

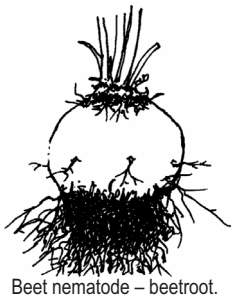
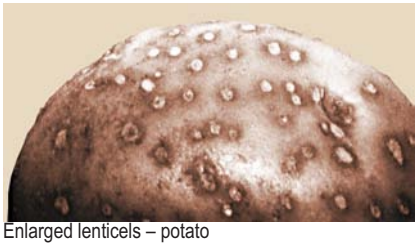
Cut through corm with a knife

Healthy cyclamen corms are white inside.

Fusarium wilt (*F. oxysporum* f. spp. *cyclaminis*). Diagnostic features are reddish-brown discoloration in the water-conducting tissues. Diagnostic tests are required to confirm a diagnosis.

Bacterial soft rot (*Erwinia* sp.). Tissue inside corms is discoloured and becomes soft and mushy – tissue affected by *Fusarium* wilt is dry and hard.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
GALLS see also Galls page 164	A swelling, roughly spherical, of unorganized plant cells occurring on **tubers**, leaves, stems, roots, flowers, seeds. Causes include: • **Fungal diseases**, eg clubroot may infect some brassicas, especially cabbage, cauliflower. • **Nematode diseases**, eg root knot nematode on carrot, parsnip, potato.  Clubroot – swede turnip  Root knot galls – parsnip  Root knot galls – potato, carrot
INSECTS & OTHER PESTS ON OUTSIDE OF BULBS, GOUGING  Black vine weevil damage, cyclamen	Usually obvious, but some are **secondary pests**, invading damaged tissue. Causes include: • **Insects & allied pests**. ***Chewing insects*** gouge holes, eg black vine and other weevils and their larvae, cutworms, scarab grubs. ***Sap-sucking insects & mites***, eg bulb aphids, bulb mites, gladiolus thrips, mealybugs. ***Secondary pests***, eg slaters, millipedes. • **Snails & slugs** may damage bulbs, tubers close to the soil surface. • **Vertebrate pests**, eg rats and mice eat bulbs in storage, droppings may be present.  Vegetable weevil and larva – carrot (NSW Agric)  Bulb aphids – garlic  Wax from mealybugs – daffodil bulbs. Hand lens or dissecting microscope required – could be mistaken for fungal mycelium
INSECTS INSIDE BULBS, HOLES, TUNNELS	Damage may or may not be obvious, sometimes a **'softness'** may be felt. Causes include: • **Insects & allied pests**. ***Chewing insects***, eg bulb fly maggots, potato moth larvae, scarab grubs, larvae of various weevils such as black vine, cyclamen, banana and sweetpotato weevils, wireworms, termites and carrot fly maggots (don't strictly chew). ***Some insects feed in the throats of bulbs***, eg mealybugs in throat of agapanthus are often not seen until large numbers are present. • **Non-parasitic agents**, eg potatoes may split **internally** due to uneven growing conditions.  Bulb fly maggots. *Left:* Lesser bulb fly (several maggots per bulb). *Right*: Narcissus bulb fly (one maggot per bulb)  Banana weevil larvae tunnel in banana corms  Termites tunnel and feed in potatoes  Sweet potato weevil larvae tunnel in tubers creating a honeycomb effect

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
MECHANICAL INJURY	It is easy to mechanically damage bulbs, potato tubers and similar plant parts, during weeding, hilling or lifting.
ROOTS THIN OR HAIRY	Uncommon. Causes include: • **Virus & virus-like diseases**, eg potato tubers infected with potato leaf roll virus produce spindly shoots when planted out. • **Nematode diseases**, eg the beet nematode may cause excessive root branching.  Potato tubers. *Left:* Healthy tuber with normal sprouts. *Right:* Spindly sprouts due to infection by potato leaf roll.  Beet nematode – beetroot. Causes excessive branching of roots
SCABS	Slightly raised localized lesions on **bulbs**, fruit and leaves giving them a scabby appearance. Causes include: • **Bacterial diseases**, eg bacterial scab of gladiolus. • **Fungal diseases**, eg common and powdery scab of potato tubers, potato black wart causes wart-like growths on tubers making them unmarketable (NZ, other countries). • **Non-parasitic agents**, eg enlarged lenticels develop on potato tubers when grown in wet soil or hydroponically.  Common scab – potato  Enlarged lenticels – potato
TAINTING	***Kerosene*** applied for weed control may taint carrots. ***Turnips*** may taint the milk of cows fed on them.
WEEDS INVADING BULBS	Weed seeds, rhizomes and other weeds parts may invade or be associated with bulbs, eg perennials species such as couchgrass, can be a major problem.  Couchgrass growing through a daffodil bulb

Whole plants

Some signs & symptoms – Clues!

Allelopathy Death of newly planted trees Patches of dead plants	Reduced yield Scorching, silvering, colour changes Slow growth rate

- **Identify the affected plant**, so you can access a **list** of common problems affecting it, reducing the number of suspect problems to a manageable number; access a **pest information sheet** for each suspect problem.
- **Record** all visible signs and symptoms.
- Look at the plant as a **whole**. What is its overall health? Compare it with a healthy plant of the same age growing under similar conditions and to other plants nearby.
- **Natural variability is normal** and not necessarily indicative of parasitic pests and diseases or stress. Plants sourced from different genetic lines, eucalypts from different provenances, have different habits.
- **Natural life span**. Estimate the plant's age and time in its present location. Plants have a limited natural life, growth will slow over time and the plant may become more prone to some problems. Whatever the life-span of the species, some plants will not live as long as others. Normal annual growth can allay fears that something major is wrong with the plant.
- **Symptoms may be delayed**, especially on trees.
- There can be **over-riding problems**, eg drought on unirrigated playing ovals.
- See also **Leaves**, page 125, **Flowers**, page 141 and **Roots** page 163,

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
ALLELOPATHY	This a natural idiosyncrasy of plant life. Allelopathy is the detrimental effect that one plant exerts on another plant by the release of a chemical substance. Tomatoes, rhododendron, apple, pear and some other plants are unable to grow successfully in the vicinity of black walnut trees. Leachates from eucalypt bark on trees, bark already shed and leaf litter, may inhibit surrounding plants. **Parent plant allelopathy** is described on page 151.
DEATH OF NEWLY PLANTED TREES, SHRUBS see also Dieback page 156 Galls, distortions164 Poor root growth page 166 Replant problems page 167 Transplant history page 154	Small amounts of damage can be tolerated but repeated injury may be fatal. Causes include: • **Bacterial & fungal diseases** may invade lower stems, crowns and roots under wet conditions, poor planting procedures and excessive pruning. • **Insects and allied pests** may feed on foliage of some species. • **Vertebrate pests**, eg rabbits, wallabies and livestock may nibble plants. • **Non-parasitic agents**. Poor planting techniques and care during the establishment period. ***Environment***, eg sunburn, frost cracking, inadequate irrigation, prolonged drought. The most common cause of failure is lack of moisture – even drought tolerant species require care during establishment in the Australian environment. ***Check transplant history***. During winter or summer months, some plants are slow to get away after planting out. ***Mechanical injury***, eg staking too tightly, mowers, weed trimmers. ***Herbicides***, eg plantings less than 2 years of age are particularly sensitive to certain herbicides, check labels. ***Replant problems*** may affect plants of the rose and other families. • **Weeds** compete with transplants for moisture and nutrients. Special effort must be made to control weeds during the first year after planting.
PATCHES OF DEAD PLANTS, SECTIONS OF HEDGES see also Dieback page 156 Poor root growth page 166	Patches of dead plants or one or two plants in a planting **may** indicate a parasitic soil problem (see page 63). Remember to check likely problems which are known to affect your hedge or planting. Causes include: • **Parasitic diseases & pests**. Range of soil-borne fungi or nematode diseases and root-feeding insects depending on the species. Examine roots **and** stems **and** foliage. • **Non-parasitic agents.** An even wider range of possibilities.  English daisy – gradual dying of plants in patches. Roots appeared rotted. A soil-borne parasitic agent is suggested as a possible cause – there is a random distribution of affected plants in the planting and of dead areas on the plants themselves. Remember this would have to be confirmed by diagnostic tests.

SIGNS, SYMPTOMS	SOME CAUSES (not exhaustive)
REDUCED YIELD	It is possible that up to 15% of invisible crop losses can occur with many plant diseases without induction of obvious plant disease (Brown & Ogle 1997). Check the known pests and diseases that may affect the plants in your area.
SCORCHING, SILVERING, OTHER COLOUR CHANGES see also Leaves page 125 Blights page 126 Blotches page 127	Leaves are often affected to an extent that the whole tree or shrub appears discoloured. Causes include: • **Fungal diseases**, eg silver leaf (*Stereum* spp,) on stone fruit, rust on some plants in some seasons may cause leaves to quickly wither and brown. • **Parasitic plants**, eg mistletoe growths on eucalypts. • **Insects & allied pests**, eg severe infestations of pear and cherry slug, autumn gum moth and lerp insects on eucalypts, make plants look scorched; greenhouse thrips and peach silver mite make leaves look silvery. • **Non-parasitic causes**. ***Natural characteristics***, eg autumn colours, spring growth, juvenile growth of some eucalypts.  Papyrus 'dripping' mealybugs  Callistemon scorched by frost  Autumn colours on deciduous trees
SLOW GROWTH RATE, STUNTING see also Allelopathy page 151 Dieback page 157 Poor root growth page 166 Replant problems page 167	A generally unhealthy appearance with poor plant development and slow growth. Bud internodes may be shorter than normal. Can be caused by a foliage or root problem. Causes include: • **Virus & virus-like diseases**. 'Stunt' diseases, eg chrysanthemum stunt, subterranean clover stunt, tomato big bud, dahlia mosaic and stem pitting of grapefruit cause plants to fail to reach normal size. The whole plant is stunted and there may be no other obvious symptoms, plants are unusually small for their age. There diseases are mostly host specific, some exceptions. • **Bacterial & fungal diseases**, eg low levels of root and stem diseases can greatly affect plant growth, eg *Phytophthora*, *Armillaria*, wide range of wood rots on trees and shrubs. • **Parasitic plants** can seriously inhibit the growth of their host, eg dodder (*Cuscuta* spp.) broomrape (*Orobanche* spp.), mistletoes. • **Nematode diseases**, eg various species. Mainly a problem where there is continuous cropping of the same species. • **Insects & allied pests**, eg foliage-feeding insects may greatly reduce plant growth and production, borers and other insects may have invaded trunks and roots. • **Non-parasitic causes**. The most important cause of slow growth is poor establishment of plants in unsuitable sites. ***Salinity*** affects many trees, shrubs, grasses and crops across Australia. ***pH extremes*** affects the availability of nutrients. ***'Burnt out'*** soils which have been cropped for many years may result in depleted nutrition and be responsible for the long term slow decline in some crops. ***Mycorrhizal fungi*** may be lacking in soil or media. ***Non-lethal rates*** of some herbicides.

APPENDIX 4 – MONITOR & SAMPLE

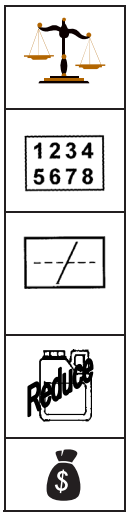
The best fertilizer is the footsteps of the gardener
(an old gardener's saying which encouraged spotting potential problems early)

WHAT IS MONITORING?

- Monitoring does **not** necessarily indicate a pest problem.
- **Monitoring is a program** of inspecting, sampling, and recording which aims to:
  - **Detect, locate, identify and quantify** potential pests and their natural enemies at an early stage of infestation by looking for signs and symptoms or testing for diseases that do not show symptoms.
  - **Record** any changes in levels of pest infestation and spread which may indicate the need for, or effectiveness of, treatment. Continuous monitoring shows regular seasonal patterns of pest occurrence.
- **A scout** is someone who monitors crops and compiles reports for control recommendations. They collect **information**.
- **Monitoring must be planned** taking into account the value of the crop, possible financial risk, resources available and the data required. This could include pests and beneficials, where and when, area, varieties, soil types, analysis and reporting.

WHY MONITOR & SAMPLE?

- **To collect samples** for your own examination or to send to a diagnostic laboratory for testing.
- **Diagnostic samples** assist with obtaining an accurate diagnosis, eg determining the possibility of nematodes being the cause of poor growth and yield.
- **Monitoring programs** are available for specific pests and diseases on some crops, eg citrus (Scaleman, Sprayman), downy and powdery mildew on grapes.
- **Effective pest control**. Monitoring detects problems early as they are then easily controlled. Don't wait until the problem is widespread to scout and collect samples. Monitoring is applicable to all types of controls:
  - **Legislation**. To safeguard plant health and minimise quarantine risks, regional, national and international regulations, certification schemes, IPM programs.
  - **Determine need for treatment**. Regular monitoring of crops is an important IPM strategy. Pests can be detected, identified and **quantified** if necessary.
  - **Determine the threshold levels** at which treatment should be applied. Thresholds may be economic, aesthetic or environmental. Pest or symptom levels can be kept below the threshold at which epidemics are initiated.
  - **May assist in reducing chemical use** in some situations. When the problem is found and identified early it is generally much easier to control with chemicals.
  - **May reduce treatment** costs.



WHO CAN MONITOR?

- **Many growers** should, with training, be able to scout their crops. **Time and expertise are required** to do the job accurately.
- **Professional plant health scouts** have the required knowledge to detect and diagnose most common problems on-site and know where to seek information.
- **In-between**. Growers can forward sticky traps to monitoring services and receive counts of thrips, white fly, aphids, sciarid flies and shore flies. They receive a report showing any changes in counts.
- **Aerial photography** can detect disease outbreaks, irrigation and soil problems, eg the distribution of grape phylloxera in vineyards can be monitored.
- **In Australia**, dogs are used in quarantine searches, even pigs can locate truffles for harvest in the field.

WHEN TO MONITOR

- **Before** purchasing a property.
- **Pre-plant** soil, water and nematode analysis, prior to planting recommended varieties of plants may prevent many problems.
- **Diagnostic services** can tell you when to monitor.
- **Some crops**, eg citrus, and some **problems**, eg some fruit flies, require regular monitoring.
- **Prior to** and at pre-determined times after pesticide applications or releasing biological control agents.
- **After transplants** are in the ground or seedlings begin to emerge to avoid pests establishing.
- **Time of day**. Green vegetable bugs feed during hot sunny times of the day when they are readily seen and collected. Fungal hyphae are more readily observed early in the morning before the dew dries off. In the heat of the day spores dry up and are not easily seen.
- **Frequent, regular crop inspections** leads to the early observation of possible problems, determines pest and predator numbers, symptoms and seasonal patterns of pests. The need for, or effectiveness of, treatment can be evaluated.
  - **Regular short term monitoring** lets growers control decision-making and at the same time graph pest trends and their response to treatments. Some areas may need to be monitored twice a week.
  - **Regular long term monitoring** lets a grower build up a picture of when pest cycles occur so that problems can be anticipated and prevented. Progression of symptoms can be observed over time.
  - **Increased pest count** may indicate a need for treatment, poor results through incorrect timing of sprays, choice of chemical, spray rotation or poor spraying techniques. **Decreased pest count** may indicate effectiveness of both chemical and non-chemical treatments.

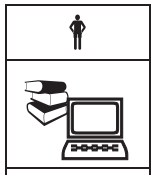
WHERE TO MONITOR & SAMPLE

You need to know where to look for the pest or where it is likely to occur.

- **Pests and diseases.** Look at upper and lower leaf surfaces, open flowers and bark crevices for signs or symptoms using a hand lens, if possible. Dig up plants and examine the roots if necessary.
- **Weeds**. Scout and map areas where weeds tend to grow, eg bare or disturbed soil, cultivated areas (shrubs, flower beds), trampled or close mown lawn, playing areas, fence lines, areas with low nutrient levels, or where the same herbicide is used repeatedly.
- **Monitoring patterns** requires some **pre-knowledge** of pests present and their behaviour, eg spread, plants affected, appropriate sample points.
  - **Random patterns** generally yield good results, but as many plant pests have a clustered distribution, systematic methods give more precise coverage in most situations. True randomisation is not always easy to do in the field.
  - **For systematic sampling**, a simple diagonal is acceptable for very low or very high disease incidences but **specific zig-zag shaped** sampling paths may give better coverage in some cases. Both are easier to do than randomised or complex systematic approaches but they can be biased. Provide precise instructions for sampling to eliminate personal selection of the units to be sampled, eg specify number of paces between samples.
  - **Specific places for some problems**, eg if testing for presence of *Phytophthora* concentrate on the lower lying sections of an area where water may collect. Include samples from under unhealthy plants if they are present.

SOME TOOLS

What is in your diagnostic tool kit will depend on what you are sampling. Diagnostic services can provide information on sampling, packaging and dispatch and suppliers of equipment. Some have websites, eg Australian Entomological Supplies. You must have good light for examining samples. Basic equipment for horticulturists includes:

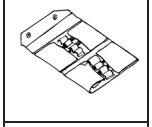


- **Someone** with the skills, interest and time to do the work.

- **References**. Acquire as many books as you can get, including some good soils and media books. Access computing programs.



- **A good hand lens** (preferably x 10) or a dissecting microscope to detect mites and small insects on affected foliage or sticky traps, or for the start of fungal growth and fruiting bodies. If further examination is needed under a high powered microscope samples may need to be sent to a diagnostic service.

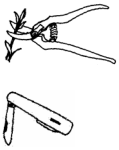


- **A dissecting kit** with forceps, scalpels, razor blades, dissecting needles and scissors for examining specimens.





- **Traps** of various kinds. **Yellow sticky cards** catch flying insects such as thrips, leafminers, whiteflies, fungus gnats, shore flies and winged aphids. **Indicators plants** which are susceptible to particular pests and diseases are useful, especially in greenhouses.



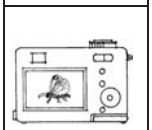
- **Sharp secateurs** to cut off small twigs for close examination. A penknife is useful for scraping away bark or cutting into stems to check for discolouration of the vascular stem (typical of wilt diseases) or for the presence of insect borers. For larger stems, a tree pruner or a small foldable pruning saw is easy to carry.



- **Digging tools**, eg trowel and narrow digging spade to check for girdling roots, bud unions and trunk flare, or to collect a root or soil sample. Sampling tubes or augers are useful if large numbers of samples are required.



- **Sample containers** include paper bags or envelopes which can easily be written on using a **pencil or waterproof pen**. Plastic bags are useful for **short** term storage from field to laboratory only, as they encourage condensation and fungal growth. Plastic specimen tubes, jars and petri dishes are ideal for small or delicate specimens, eg most insects, small fruiting bodies. Labels, tiers and rubber bands. Pyrethrum aerosol to kill insects.

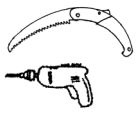


- A **digital camera** is a great tool for distance diagnosis. It can convey symptoms, and site conditions at the time of inspection. It is also useful if post-visit changes are made. The grower or sender must have some knowledge of what to photograph. A good pictorial reference collection of signs and symptoms can be built up.



- **There are on-site tests** for pH, nutrient levels, salinity, soil moisture, texture and compaction at various depths, also maximum/minimum and wet/dry thermometers, light meters. 'Feel' the soil for soil moisture. Always follow instructions on test kits for selecting samples for testing. **Pocket weather meters** can measure wind speed, temperature, wind chill, relative humidity, other weather features. **Global Position Systems** (GPS) can indicate where tests were done or where they are required. **Laboratory tests** are usually more detailed and more accurate.





- **Specialist situations**, eg
  - **If chlorine** is used to disinfect irrigation water, swimming pool chlorine test kits can used (Bodman et al 1996).
  - **Trees**, eg mallet for sounding, various measuring tapes, portable drill and range of drill bits, resistograph, calculator. Knife, shovel and hand lens are useful for woody plant diagnosis.





- **Records**
  - **Monitoring and sampling** Have a field notebook and weather-proof pens and markers. If you do many diagnoses a handheld digital recorder is essential, eg palm pilot. It can accurately relay relevant information to others and indicate pest populations over time. Correlate this with crop and spray records and you can soon see when to expect pest build up indicating what control measures were effective (see page 119).
  - **Sample labels** Make sure samples are properly labeled. Note that the collector may not be the person sending the samples to the diagnostic service.

    Name of Collector
    Date
    Sample number
    Location (on site)
    How it was collected



  - **A sample submission form** is needed if sending samples to a diagnostic service. Submission forms can be obtained either from the diagnostic service or their website (see page 121). The more you tell the laboratory about the situation the better the diagnosis will be. They can also provide information on how to collect the samples and means of dispatch.

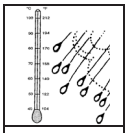


What you send is what gets used in diagnosis!

WHAT CAN BE MONITORED & SAMPLED?

Environment, water, soil/media

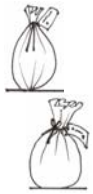
Nearly every plant parameter can be monitored. Seek advice from your diagnostic service on how to monitor and sample.



- **Environmental sensors** measure temperature, relative humidity, etc. Early warning services are available from many crops and their pests. Some devices measure leaf temperature, sap flow and stem diameter, soil moisture.



- **Water testing kits** are available, otherwise collect samples in clean containers. *Phytothphora* and *Pythium* are the most frequently found micro-organisms of concern in surface water supplies. Other soil disease organisms can contaminate surface water after rain.



- **Soil testing kits** are available, otherwise take soil samples from a depth of 0-10 cm and 10-20 cm of soil, excluding grass and litter. Each sample should be about 400-500 g and consist of at least 4 sub-samples taken from various sites around the diseased or dying plants (not dead plants). Soil samples for baiting should **not** be taken when soil is dry or be allowed to dry out. Place each sample in a separate, labelled, clean robust plastic bag and close the opening securely. Store at 10-15°C until dispatch.



- **Growing media** (post delivery and during storage). Standards apply to potting mixes and test compliance is stamped on bags so there should be no need to test them prior to use. When testing large piles of growing media take samples from several locations around and through the pile. Test adjacent drains, bushland or gardens which drain into storage areas.

Insects

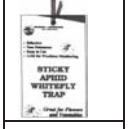
Insects may be collected directly from plants, by tapping plants over white paper and from traps. Check the websites of diagnostic services for information on how to collect and kill particular insects.



- **Small insects** such as thrips, scales and aphids can be sent attached to the affected part and treated as a plant sample. Live or dead butterflies and moths can be placed in a crush-proof container. Submit live **caterpillars** with plenty of its food plant in a crush-proof box. Most **larger** insects can be killed by freezing or placing in a vial containing alcohol. Soil insects can be sent in moist (not wet) soil.



- **Pheromone and lures** are available for many insects in commercial crops, eg codling moth, corn earworm.

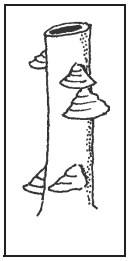


- **Sticky traps** capture and keep a check on insects that fly, eg **yellow** for aphids, whitefly and thrips, **blue** mainly for thrips. Sticky traps can be used as an early warning tool to detect changes in flying pest populations in crops. **Shelter traps**, eg sacks or baits are useful for monitoring slugs, weevils, earwigs.



- **Sift through plant debris** at the base of affected plants, under pots, trays or on the media surfaces around where damage is observed, for black vine weevils which hide during the day. Check for larvae feeding on roots.

Bracket fungi



- **Bracket fungi, mushrooms**. If the specimen is tough wrap loosely in dry newspaper, if soft, moist or fragile, dry them in a cool oven (about 40°C) before dispatch. Record and include details of the colour of the **fresh** fungus, eg cap, gills or pores, stems and any colour changes resulting from handling or bruising of the specimen. Send at least 3 fruiting bodies of small specimens. For those causing wood decay remove by cutting them about 10 cm beyond each side of the affected area.

Plant material

For plant/weed identification collect leaves, flowers and seeds, and roots if plants are small. Leave parasitic plants attached to their host, if possible, to aid identification. **Wrap in clean dry newspaper**. Paper breathes and discourages secondary infections, eg moulds and rotting. Soft-foliaged specimens can be placed in thin paper and **then** in a plastic bag.



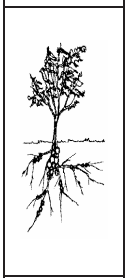
- **Small plants**, **bedding plants, field crops, seedlings, cuttings, grasses**. Submit whole plant (leaves, flowers, seeds, roots, soil) when possible. Carefully dig 4-5 affected plants, which show a range of decline from early stages to near death. Wrap foliage in thin paper to prevent soil contamination, then wrap each plant separately in a plastic bag.



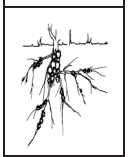
- **Turf**. Collect core samples (10 cm diameter x 7 cm deep or 15 cm by 10 cm) from the margin of affected areas making sure roots are intact. Include one core sample from a healthy area. Wrap each plug in several layers of newspaper to hold soil in place then in a plastic bag.



- **Foliage, shoot and flower** samples can be placed between sheets of paper in a plastic bag and place in a padded envelope or box as appropriate. Individual leaves or shoots may be pressed between layers of dry newspaper and put between pieces of stiff cardboard. Leaves may need to be spread out so that they are flat and do not overlap. A good sample consists of several handfuls of foliage, from both healthy and damaged parts of the plant. The paper may need changing prior to despatch. Collect enough leaves to show a range of symptoms from early to older damage.



- **Whole plants**. Whether **potted, tubed or in-ground** (up to 1 m tall), the root ball, tube or container must be placed in a plastic bag and tied or taped at the base of the stem to prevent soil falling out and contaminating foliage (see Fig. 21, page 178). Wrap the foliage in plastic. Select 3-6 tree samples showing initial and advanced symptoms. Carefully dig around the root ball keeping root and soil ball intact (larger root balls may be cut in half). Pulling out the roots will tear weakened roots. Dig carefully.



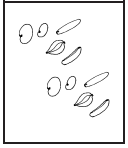
- **Root samples** from trees and shrubs too big to dig out must include enough soil to keep the roots moist during transport. Small fibrous roots are needed for checking for some root rots. If nematodes or other diseases are suspected, seal in plastic bag, store and despatch in an esky.



- **Stem and branch** samples. Collect several branches with a range of symptoms. To prevent drying out place in plastic bags, one for each specimen. **For cankers** include healthy tissue from above and below diseased areas. If dieback is observed send digital photographs or arrange to visit the site. **For suspected vascular diseases** sample a part of the tree or shrub showing wilting, yellowing or dieback but which still has live wood. Collect 6-12 branch sections 1 cm in diameter and 15-20 cm long. Wrap each sample in slightly damp paper then in layers of dry newspaper and finally in a plastic bag.



- **Fruit, bulbs and succulents**. Place between paper towels before packing. Samples packed in airtight plastic often decay before arriving in a laboratory.



- **Seeds**. Seed growers or licensees must submit seed for analysis to prescribed laboratories. Samples must be representative of the seed lot in question and of the proper weight and meet minimum International Seed Testing Association (ISTA) standards.

SIZE, NUMBER & QUALITY OF SAMPLES

What you send is what gets tested!

Accurate diagnosis of plant problems is dependent on the type and quality of samples submitted. Make sure your sample is what the diagnostic service wants, is in good condition and is **representative** of the problem. **Always check** with the diagnostic service or their website prior to sampling, packaging and dispatching samples.

- **Each type** of pest, weed or soil requires special techniques to get samples to a diagnostic laboratory.
- **Often it is necessary to send samples** of both the plant damage that is of concern and of the possible causes, eg insects, fungi.
- **Label** each sample clearly with a waterproof marker.
- **On-site test kits** provide clear instructions for collecting samples and test procedures. **Follow them!**

- **Sample size & number**
  - **Sub-samples.** A sample is usually made up of several sub-samples. The larger the area the greater the number of sub-samples required.
  - **The larger the number and size** of sub-samples to examine, the better the chance of recovering pests and getting an accurate diagnosis, eg one leaf or flower is not as useful as a 20-30 cm section of stem with several affected leaves or flowers attached.
  - **Tests**. Determining the cause of leaf spots and other problems requires enough sample material to run several tests. Diagnosticians may need at least 10 typical leaf spots to work with.
  - **Take soil samples** from different levels, eg 0-10 cm and 10-20 cm. If tests are on-site then take at least 4-5 samples. Take soil samples to compare areas with different soil properties, and at the top and bottom of slopes.



- **Quality samples** are often the difference between a good and bad diagnosis.
  - **Samples should be freshly** collected and taken from recently affected plants. Keep samples fresh.
  - **Submit the whole plant** if possible.
  - **Collect with minimum disturbance** to avoid pests dropping or flying off before packaging.
  - **Choose affected plants** with a minimum of varietal variation, and different **growth stages** of the host and of the pest, disease or weed.
  - **Choose representative samples**.
    - ❑ **Collect** samples showing the transition zone from diseased to healthy tissue to show a progression of signs and/or symptoms, ie **early** and **late** stages of damage. The diagnostic service will take cultures from actively rotting margins. Include samples of **normal growth**.
    - ❑ **Diseased samples** can be placed in a sealed plastic bag and left in an air-conditioned room overnight to see what develops. Fungal hyphae and spores will often develop which can then be examined microscopically, so that it may be possible to verify a preliminary diagnosis.

  - **Do not .....**
    - ❑ **Do not collect** samples from dead, dry or rotten plants or from those recently treated with pesticides. The presence of secondary pests or diseases that live on dead plant material can obscure the primary pest or disease.
    - ❑ **Do not place** insect, mite, and other samples in sealed plastic bags, or wet them, as they will break down in high humidity.
    - ❑ **Do not collect** leaves when wet. If unavoidable remove excess moisture by blotting.
    - ❑ **Do not wash or wipe** leaves or stems as this can remove insects, mites. **Do not wet** the sample or paper wrapping.

  - **Do not .....** ***contd***
    - ❑ **Do not expose samples to heat**, eg sun. If collecting soil samples for nematode or fungal analysis, a small esky is helpful. If despatch is delayed on hot days, store samples in a refrigerator or cooler until you can deliver them.
    - ❑ **Do not mix** several host species in a single bag.
    - ❑ **Do not pack** loose soil. Place each sample in an appropriately labelled plastic bag.
    - ❑ **Do not pull up** plants from soil.
    - ❑ **Do not** post glass or other breakable containers.

STURDY CONTAINER, 'PAPER WORK'

In **very hot conditions** an esky or aluminium foil-lined carried bag is ideal.

- **Do not forget** to include the diagnostic service's submission form with your name, address and information about the samples.
- **Check that each sample** is clearly labelled.
- **Protect** specimens from being **crushed** in transit. Place bagged specimens in a sturdy rigid container such as a cardboard box. Fill spaces in the box with wadded paper. Label fragile, handle with care. **Padded mailing envelopes** can be used for older plants that are not fragile.
- **Keep the different parts of the plants separate**. To prevent cross – contamination, each part of the plant, eg root/soil and stems/twigs, must be packed and secured separately within the container.

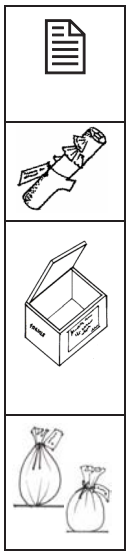




Fig. 21. Examples of how whole plants can be wrapped in plastic

SHIP THE SAMPLE QUICKLY

Plant or materials containing fungal, insect or other living micro-organisms are fragile and may be destroyed or killed by extremes of temperature, drying out and excessive time in transit.

- **Do not expose package to heat** from sun during transit.
- **Dispatch samples on the same** day they are collected and protect from drying out and temperature extremes.
- **If personal delivery is not possible**, use a 24-hour delivery service (express post for small specimens or courier for larger ones). The sooner the samples reach the laboratory the more accurate the diagnosis will be.
- **Ship samples early in the week** to arrive on Monday-Wednesday, **not** a public holiday or Friday at 4pm or during the weekend.
- **Once the laboratory receives your sample** diagnosticians may take a few minutes or a few days to process your sample.

APPENDIX 5 – DIAGNOSTIC TESTS FOR SPECIFIC CAUSES

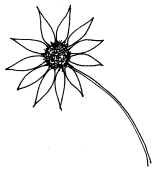
Identifying plants & weeds
Parasitic pests & diseases
- Insects & allied organisms
- Snails & slugs
- Vertebrate pests
- Nematode diseases
- Virus & virus-like diseases
- Bacterial diseases
- Fungal diseases

Non-parasitic problems

Not all detection and identification techniques are suited for all plant problems on all plants or crops.

Identifying plants & weeds

IDENTIFYING PLANTS



Some plant specimens brought in for identification are easy to identify while others, eg specimens without flowers or seeds and weed seedlings, are difficult, if not impossible.

- **To identify a plant** one needs to understand:
  - **Botanical terms** used in descriptions, eg petals, sepals, stamens, pistils. If one is unfamiliar with these terms, then it is not really possible to identify a plant using a key.
  - The **structure of a flower**. If flowers are not available leaves and other structures can be useful. A hand lens or dissecting microscope may be required, eg for grasses.
  - **The naming and classification of plants**, their relationship with each other and where they originated in the world.
  - **How to access and use references**, eg books, colleagues, CD-ROMs, the internet, named plants in botanic gardens and collections of dried, pressed and named specimens in herbaria. There is an excellent list of Floras in Clarke, I and Lee, H. 2003. *Name that Flower : The Identification of Flowering Plants.* Melbourne University Press, Carlton, Vic.
    - **Floras may relate to specific groups of plants**, eg bulbs, eucalypts, wattles, weeds, crop weeds, grasses, or to **specific regions**, eg floras of the ACT, Central Australia, New South Wales, South Australia, Tasmania and Victoria,
    - **Botanical keys** match the specimen's structural features to each of a series of paired statements. Keys with descriptions and illustrations are often included in floras, eg eucalypts, wattles, grasses, weeds. Multi-access and interactive keys are easier to use than older either/or keys (see pages 81).
- **Provide, confirm or reject** a preliminary identification.
  - **Because of difficulties in keying out plants**, students in plant clinics and similar situations mostly use illustrations, images and descriptions in references to confirm or reject what the plant might be.
  - **Expert assistance**. If you are unable to identify the plant or weed, and it is necessary to do so, consult a diagnostic service or your local botanic garden with staff more able to use keys.
  - **DNA techniques**. Botanists use computer analysis of **DNA** information, often in combination with plant features such as leaf length, to establish species and genera and even families (Spencer, 2003).
  - **Even the most detailed taxonomic analysis** is open to interpretation and a diversity of opinions may arise in the assignment of names to the natural groups which are found among many plants, eg chrysanthemums, eucalypts (see page 95).
  - **Identification of invasive roots** is often required by householders and is based on the cellular structure of woody tissue of the root.
  - The **experienced diagnostician** may be able to make a preliminary identification of the host from the pest or disease which has affected it because there is a known host/pest relationship, eg rose scale will only infest roses, blackberry, loganberry and raspberry (*Rubus* spp.), *Photinia serrulata* is susceptible to powdery mildew while other species are not.



CLASSIFICATION OF FLOWERING PLANTS

Angiosperms

Flowering plants can be divided into two classes, the monocotyledons and dicotyledons. An abbreviated classification of one plant in each class is presented.

Class Monoctyledons	**Class Dicotyledons**
1 seed leaf	2 seed leaves
Floral parts mostly in **3s**	Floral parts mostly in **5s**, sometimes **4s**
Almost all species herbaceous	Plants woody or herbaceous
Leaf veins mostly parallel (**narrow-leafed**)	Leaf veins mostly reticulate (**broad-leafed**)
Roots usually **fibrous**	Often **tap** root, well developed lateral roots
For example: Family Liliaceae (lily family)	**For example: Family** Rosaceae (rose family)
Genus *Tulipa* (tulip)	**Genus** *Rosa* (rose)
Species *gesneriana*	**Species** *hybrida*
Cultivar 'Apeldoorne'	**Cultivar** 'Peace'

Table 5. Some diagnostic tests and techniques used to detect and identify pests, diseases and weeds.

PESTS DISEASES WEEDS	Taxonomy Keys	Reference collections	Hand lens Microscopy	Electron microscopy	Isolation Culture Baiting	Patho-genicity * tests	Stain re-actions	Indicator plants	ELISA	DNA-tests	Grow-on tests	Plant analysis	Soil, water, air analysis
Insects	■	■	■	■						■			
Snails	■	■	■	■						■			
Vertebrate	■	■	■	■						■			
Nematodes	■	■	■	■		■		■		■			
Viruses		■		■		■		■	■	■			
Bacteria	■	■	■	■	■	■	■		■	■			
Fungi	■	■	■	■	■	■			■	■			
Parasitic plants	■	■	■			■				■			
Environment Temperature Water Etc		■									■		
Deficiencies, excesses pH Salinity Sodicity		■						■			■	■	■
Chemicals Pesticides Pollution		■									■	■	■
Weeds, plants	■	■	■							■			

* Previously undescribed organisms

Parasitic pests & diseases

INSECTS & ALLIED ORGANISMS









Classification of insects (Class Insecta) to orders and families is based on a wide range of features, including:

- Wing features, eg winged or wingless, number of pairs of wings, size, texture, scales, thickenings, venation, vein patterns, internal or external wing development.
- Type of life cycle, mouthparts, antennae, numbers of body segments, pairs of legs.
- Clubbed or feathery antennae.
- Abdomen, eg egg-laying apparatus, abdominal appendages, hairs, constrictions.
- Body shape, eg flattened, small size, wedge-shaped.

- **Signs and symptoms**
  - **Most horticulturists** can recognise common insects, mites and diseases but may confuse more unusual pest damage with environmental or cultural problems.
  - **When insect pests are the problem** they may or may not be obvious. Though mites themselves are so small that you cannot easily see them, stippled mite damage to leaves is fairly easy to detect once you have seen it a few times.
  - **Some insect problems** may be easy to identify, because you can actually see the insect doing the damage or the material they leave behind, eg honeydew, excreta, silk, wax, spittle, webbing. It is trickier when the insect has eaten its fill and flown away, is inactive during winter or summer, or when the insect is too small to see without a hand lens. Some insects bore into stems, trunks or roots where they can cause damage without being seen, look for small holes on stems or trunks. Examine leaf undersurfaces and buds with a hand lens.

- **Confirm or reject** a preliminary identification.
  - **Many keys** for pests of specific crops, eg turf, ornamentals are based on **morphological** features. They usually include illustrations for comparison of the more common pests and the more common symptoms. Many other pests will not progress easily through a key.
    - **Insect keys** may identify:
      - Adults, nymphs and larvae of insects to orders and families.
      - Pests of specific crops, eg turf.
      - Groups of insects on specific crops, eg moth and butterfly larvae on brassica crops.
    - Traditional **either/or keys**, where you start at the beginning and are presented at each step with 2 choices, fail as soon as you make a wrong choice or can't make a choice for any reason, **Interactive keys** are more user-friendly (see pages 81). Many insect keys may be difficult for the non-expert to use, due to:
      - The **small size** of some insects.
      - Some insect parts may be **missing**; structure may be difficult to recognize.
      - It is not always easy to tell if a **wingless insect is adult or immature**. An insect with wings, mating, laying eggs or giving birth to young is an **adult** insect. Generally adult insects (especially winged insects) are easier to key out and identify than immature stages, eg eggs, nymphs. As some insecticides are applied at different stages of the pest, growers must be able to recognize different stages.
      - Some allied forms **resemble insects** at some stages, eg springtails, so that a specimen may not even belong to the group covered by the key, eg trying to key out a mite in a key to insect orders.
      - The large **number** and **diversity** of insect species; there are over 86,000 species in Australia.
      - **Some insects such as scarab grubs** are readily recognized but it can be difficult to identify the precise species, which is needed for implementing effective control measures in commercial turf.
    - **There are simple keys** of the **more common symptoms** caused by pests of some crops, eg canola, field peas, lucerne and lupins in WA. These keys may include illustrations or photographs.
  - If identity has not been established **but is required**, send specimens to a diagnostic service.



Thrips (< 3 mm)



DNA fingerprinting can be carried out in a laboratory for insects of special interest

SNAILS & SLUGS



Snail identification is based on features of the **shell** and size, shape, colour and culture of the snail itself, **slug identification** on size, shape, colour and culture.

- **Signs and symptoms** Common species are easy to recognize from illustrations. Look for or trap them at night or during rainy weather. Damage by adult snails and slugs is usually easy to recognize from their **silvery trails** and **excrement casts**, which are long and curly and adhere to feeding sites.
  - **Do not confuse snail or slug damage** with that caused by **chewing** insects, eg caterpillars, beetles, cutworms, or **birds** on certain plants, eg lettuce.
  - **Some species are predatory on other species,** most native species cause little harm.
- **To confirm or reject** a preliminary diagnosis, send specimens to a diagnostic service.

VERTEBRATE PESTS

Most of us can recognize flying foxes, mice, rats, etc.

- **Confirm or reject** a preliminary diagnosis. Pest control operators identify the exact genus/species of a pest from trapping, droppings and other features, prior to treatment. **DNA** is used by scientific laboratories to identify races of various pests, eg dingoes.

NEMATODE DISEASES













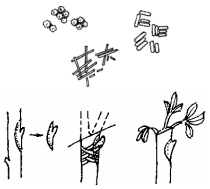
Classification. All plant parasitic nematodes belong to the Phylum Nematoda. There are several orders, sub-orders and families into which nematodes are classified mainly according to their morphology, eg tail shape. Methods used to detect and identify nematodes include:

- **Symptoms exhibited by the host plant**.
  - **Below ground symptoms** can be **specific** (distinctive), eg the galls of root knot nematodes, but they do not indicate **which species** of root knot. Root knot galls could be confused with nitrogen-fixing nodules on some hosts.
  - **Above ground symptoms** on foliage can also be **distinctive**, eg those caused by foliar nematodes, or **non-specific**, eg yellowing or stunting, caused by root knot nematodes feeding on the roots, or by other soil diseases, moisture stress and nutritional problems.
- **Microscopy**.
  - **Simple nematodes** can be seen with a dissecting microscope but not all nematodes seen under microscope are pests, eg saprophytic nematodes may feed on rotting bulbs caused by other problems.
- **Confirmation/rejection** of a preliminary diagnosis by specialists may involve:
  - **Microscopy**. **Keys** based on morphology have been developed to help identify plant parasitic nematodes to species in a diagnostic laboratory. If the nematode can be identified as belonging to a species or genus known to cause such a disease, then the diagnosis can be made with a degree of certainty. Sometimes nematodes **cannot** be identified using morphological features alone and other methods are needed.
  - **Variations in host range** can occur within a species and these can be detected by testing the nematode against a range of plant species.
  - **Indicator plants**. Low populations of root knot nematodes can be detected by growing, susceptible plants, eg tomato seedlings, in soil samples for about 1 month then the root system is removed and examined for galls.
  - **Soil and plant samples** can be sent to a laboratory for extraction, identification and counting of nematodes present **before** and **after** planting. This will indicate whether nematodes are the cause of the problem, the kinds and numbers present and the need for any treatments. Property surveys can be carried out.
    - ❑ **Nematode populations in soil** can be isolated by either a Baermann funnel method or by sieving (Brown & Ogle 1997, O'Brien & Stirling 1991).
    - ❑ **Isolation of nematodes from plant material** involves cutting tissue into very small pieces by hand or by blending for a few seconds. The tissue is then placed in a special funnel where the nematodes leave the tissue and move into the water in the tubing from which they are collected in a shallow dish.
  - **DNA-based diagnostic tests** are being researched for some species, eg root lesion nematodes.

VIRUS & VIRUS-LIKE DISEASES



Hydrangea mosaic



ELISA Testing Service



Classification and nomenclature. All viruses belong to the kingdom Viruses. Within the kingdom, viruses are distinguished as **RNA** and **DNA** viruses (Agrios 1997). Viruses are further classified into families and genera. Most of the names of virus groups are derived either from the common name of their type member or from their main characteristics. Acronyms of these viruses have been standardized and each is unique, eg tomato spotted wilt virus (**TSWV**). Methods used to detect and identify viruses include:

- **Symptoms exhibited by the host plant**.
  - **Some viruses** cause distinctive symptoms in their hosts and so the disease and the virus can be quickly identified from symptoms. However, frequently this is not possible.
  - **Some virus symptoms can be confused** with unfavourable growing conditions, nutrient deficiencies or excesses, herbicide or insect injury.
  - **Map the distribution** of infected plants in the crop. Vector-borne viruses frequently show patterns depending on how far the vector has traveled or how much plant to plant spread has occurred within the crop. Rarely are all plants infected in a crop.
- **Confirmation or rejection** of a suspected virus by a diagnostic laboratory may be needed. For example, tests for the presence of virus in parent stock for certification schemes, eg strawberry, cut flowers, potato, grape. Tests include:
  - **Electron microscopy.** Virus particles can only be seen under an electron microscope. Sometimes identification is as simple as preparing a sap sample and checking it for the presence of virus particles, rods, bullets or sphericals. For some viruses, though, the shape of particles is not a reliable means of identification.
  - **Indicator plants (herbaceous indexing)**. This involves the inoculation of indicator host plants with material from the diseased plant and noting the symptoms produced. The development of characteristic symptoms by an indicator identifies the virus with which the indicator was inoculated.
  - **ELISA** tests release a colored compound if a suspect virus is present. They are quick, sensitive and can be used to test large numbers of plant samples. **ELISA** test kits are available for a range of virus diseases but their use is generally restricted to laboratories. More sensitive tests are being developed for viruses that accumulate in low amounts in their natural hosts, eg carnation, and so escape detection.
  - **DNA and RNA technology** can be used to detect unknown viruses for which there is no antiserum or information available.

BACTERIAL DISEASES



Bacterial gall of oleander



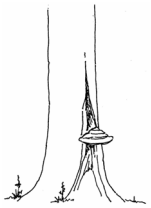
ELISA Testing Service



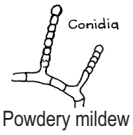
Classification of bacteria is largely based on what they can **do** rather than what they look like. Bacteria are best identified by considering several characters together, rather than one by one as in a key, or comparing one bacteria with another (Brown and Ogle 1997). For some bacteria there are specific tests, eg citrus greening.

- **Symptoms**. **Preliminary diagnosis** may be based on comparing symptoms, eg galls, with illustrations and descriptions. Often though, similar symptoms may be caused by non-parasitic agents, eg environmental extremes and chemical toxicities; bacterial leaf spots may be confused with fungal leaf spots and bacterial wilts with fungal wilts.
- **Microscopic** morphology is of little value in identifying bacteria, they can be **seen** with a compound microscope but they all resemble tiny rods with no distinguishing features. When tomato plants infected with bacterial wilt are kept in a moist chamber, creamy bacterial ooze may seep from the vascular system. Alternatively, if suspect stems or leaf lesions are cut transversely with a razor blade and placed on a microscope slide in water under a compound microscope the ooze can be easily seen. Association of bacteria with symptoms does not prove that they are the **primary** cause, they may be **secondary** invaders of tissue damaged by other agents.
- **Confirm/reject**. A more positive identification by diagnostic services may be needed by commercial growers and quarantine to detect and identify bacteria associated with parent stock and certification schemes, eg strawberry, cut flowers, potato, grape. Tests include:
  - **Pure cultures and pathogenicity tests** can prove that the bacteria observed are the cause of the problem. **Continuous culture-indexing** of plant material for bacterial infection may be carried out over a 2-year period.
  - **Various keys** have been developed for genera and species identification.
  - **Gram stains** for separating **Gram-negative** from **Gram-positive** bacteria are probably the oldest test and are still used today.
  - **ELISA** tests are relatively low cost. A color change indicates a positive test result. **ELISA** tests are not as sensitive as some other methods.
  - **Biochemical tests**, eg **BIOLOG** Identification System (BIS) tests are based on substances utilized by bacteria for food. Enzyme actions and many other tests have been developed.
  - **The fatty acid** composition of cells can be used to identify some bacteria.
  - **DNA** techniques can distinguish one bacterium from another by comparing segments of **DNA**. This is used to detect and identify strains of some bacterial diseases.

FUNGAL DISEASES



Fruiting body of a wood rot fungus, a conk



Powdery mildew



ALERT Testing Kit



Classification is mainly according to types of hyphae and sexual spores produced. The shape, size, colour and manner of arrangement of spores are used to identify the fungus, ie its class, order, family and genus. The features of the fungus can then be compared with published descriptions. **Distance diagnosis** works with fungal diseases, especially when the fungus is visible on some part of the infected plant, eg powdery mildew, grey mold (*Botrytis*) and rust. **The method** used for detecting soil fungi will depend on the fungus. **The detection and identification** of fungi, especially *Phytophthora*, in plants, soils, potting mix, sand and other materials is a major part of the work done by laboratories diagnosing plant diseases. However, no one piece of information is enough to conclusively diagnose a *Phytophthora* disease. Evidence from the field, sick plants and identification in a laboratory must all indicate the same problem. Then you can be reasonably sure of your diagnosis. Even isolating the fungus is not enough to diagnose the problem, the presence of the fungus may only be part of a broader or deeper problem or not related at all.

- **Signs & symptoms** may be sufficient for a preliminary diagnosis of some fungal diseases, eg **signs** of grey powdery coating on leaves (powdery mildew) or **symptoms**, eg leaf spots. This preliminary diagnosis is often based on experience in recognizing certain diseases, their similarity to published descriptions and illustrations. Association of a fungus with symptoms does not prove that it is the **primary** cause of the symptoms, it may be a **secondary** invader of tissue damaged by a primary disease organism or other agents.
- **Confirm or reject** of a preliminary diagnosis.
  - **Microscopy** detects and identifies some diseases which cannot be cultured, eg powdery mildew, or when fungicides have been previously applied. Examine affected tissue directly, under a low powered (dissecting) or high powered (compound) microscope for mycelium, fruiting structures and spores which may be sufficient for an useful diagnosis. If spores are lacking, diseased tissue can be kept in a high humidity chamber for a few days or cultured to promote spore development. Spores of some species of *Phytophthora*, *Pythium* and *Cylindrocladium,* or the characteristic hyphae of *Rhizoctonia*, can be identified this way.
  - **Isolation and culture** from infected material obtains pure cultures of fungi which can be identified from the spores produced. Suspect plant tissue or seeds are placed on agar media and the organisms that grow from it identified. Others need to be incubated under certain temperature, aeration or light conditions to produce spores. **Baiting** for disease organisms, eg *Phytophthora, Pythium*, *Rhizoctonia,* involves floating plant material (carrot, lupin baits) on the surface of a representative sample of soil, media or water and observing the baits for signs of fungal invasion and rotting.
  - **Biochemical tests** are used for accreditation schemes. Commercial growers use Alert Fungal Disease Kits to detect some soil fungi, eg *Phytophthora, Pythium* and *Rhizoctonia*.
  - **ELISA** tests are quick and efficient and mostly laboratory-based, some can be used on-site. The fungus specifically reacts with chemical reagents to cause a detectable color change.
  - **DNA** techniques are used to identify a few fungi, eg *Phytophthora*, black sigatoka smut of banana. The *Phytophthora* – IDENTIKIT™ has been marketed.

Non-parasitic problems

AN INFINITE NUMBER



Etiolation

Non-parasitic problems are a real challenge. Remember this group of plant problems is almost infinite and can be very difficult to diagnose because they include site conditions, weather variations and cultural practices. Nutritional problems can often be confused with parasitic pest and diseases. The **absence** of a clear parasitic primary cause (as determined by a diagnostic service) reinforces a non-parasitic diagnosis especially if samples are acquired promptly after the damaging event when symptoms are usually very obvious.

- **Symptoms**
  - **Symptoms could be caused by any of the following:**
    - ❑ **Environmental agents**. **Temperature**, eg unseasonable cold/frost or hot weather, sunscorch, low soil temperatures. **Moisture**, eg waterlogging, drought stress, uneven or inefficient irrigation, poor drainage. **Oxygen**, eg lawn compaction (insufficient oxygen). **Light**, eg insufficient light may cause seedlings to become long and thin (etiolated), flowering may not occur or be delayed. **Soil structure**, compacted clay soil. **Wind injury**.
    - ❑ **Nutritional deficiencies & excesses**, eg nitrogen, iron, magnesium deficiencies, unfavourable soil pH, pH extremes, fertilizer excess, salinity. They are often complex.
    - ❑ **Chemicals**, eg poor pesticide selection and application, herbicide injury, drift, air, soil and water pollutants.
    - ❑ **Mechanical injuries**, eg equipment damage to roots, stems, vandalism, lightning, wind.
    - ❑ **Genetic abnormalities**, eg fasciation.
    - ❑ **Natural characteristics**, eg variegated zucchini leaves.
  - **Keys**, are available and can be used as a guide to symptoms of nutrient deficiencies and excesses on higher plants (see page 81). In practice a key should be **subsequently backed** by analyses of the soil, water or plant tissue where possible.
  - **From a site visit or asking question** check suspect causes with symptom patterns, time frames, site conditions and the results of any onsite tests (see pages 60-66). Access records of crop management, pests, diseases and weeds and of the environment (see pages 67-69).
- **Confirm or reject** a preliminary diagnosis.
  - A **preliminary** diagnosis of some non-parasitic diseases **can be made** from symptoms and gathered information alone, but if a definite and reliable diagnosis is required, evidence of the diagnosis must be provided. **On-site tests** may have been carried out by the grower, eg testing pH of soil and water, salinity, nutrient levels. Results of tests and additional samples can be passed on to diagnostic services for more detailed examination.







    - ❑ **Soil/media analysis**.
      - o **Chemical analysis**, eg pH, salinity, nutrient levels, pesticide residues. There are maximum residue limits (MRLs) for pesticides in fruit and vegetables, spot checks at Sydney fruit market. Modified techniques can detect minute level of pesticides residues.
      - o **Physical analysis**, eg soil type, hydraulic activity, dryness, benefits of mulching.
    - ❑ **Water analysis**.
      - o **Chemical analysis**, eg pH, nutrient levels, nutrient run-off, fertigation, salinity, pesticide residues.
    - ❑ **Plant or leaf tissue analysis**.
      - o **Chemical analysis**, eg nutrient levels, pesticide levels, resistance of weeds to herbicides.
    - ❑ **Air analysis**, environmental monitoring, eg temperature, rain, humidity, pollution, pesticide residues, dust levels. Information relayed from field sites to a laboratory for analysis is used in early warning services.
    - ❑ **Controlled environment experiments**, where temperature and other parameters are controlled.
    - ❑ **Grow-on tests** are useful to confirm certain **non-parasitic** disorders such as herbicide injury where plants may recover after initial exposure, whereas **parasitic** diseases will often persist into new growth.
    - ❑ **Seed-testing** for viability, presence of specified diseases, purity, contamination with other seeds and compliance with seed specifications.
  - **Remember**:
    - ❑ **Experts are better able to interpret** symptoms and the information collected by the grower.
    - ❑ **It may not be possible** to confirm or reject some problems, eg herbicides applied 12 months ago, insects which have long since gone, sporadic insect pests (locusts).

APPENDIX 6 – TRAINING & PRACTICE

WHY TRAIN?

Developments in the horticultural industry such as increased scale of operations, high financial risks and the high quality required by consumers all point to a need for effective pest management.

- There may be **legal responsibilities** to detect, report and treat some pests, eg
  - **Trade**. Phytosanitary certificates are issued for various export and import markets.
  - **Plant quarantine**. Quarantine detection, threats within Australia, eg citrus canker, fire ants, fruit flies, grape phylloxera, and entering Australia, eg Asian gypsy moth, fireblight.
  - **Use of pesticides**, Label directions indicate on which **plant** or **crop** and on which **pest** a pesticide must only be used to prevent illegal pesticide residues and other environmental problems.
  - As a **duty of care** you should only give advice if you are qualified to do so.
  - **Best Management Practice (BMP)** requires diagnosticians to undergo training. Keep records of your training.
- **All horticulturists** involved in growing or handling plants should be able to use a diagnostic process and its components. There is also a need to recognise the **less common threats** including:
  - **New** (detected within the last 5 years), eg fire ants.
  - **Emerging** (incidence has increased in the last 20 years), eg European wasp.
  - **Chronic or spreading** (known for longer than 20 years), eg St John's wort.
  - **Re-emerging diseases**, eg *Botrytis* in greenhouse crops previously controlled, but now a problem because of resistance or changes in management.
- **Introduction of new plants and cultivars**.
- **Changes in management practices**, eg minimum tillage.
- **New technologies** are continually improving pest, disease and weed identification and control, eg DNA fingerprinting, genetically modified crops.
- **If you can diagnose** the more common pests yourself it can significantly reduce the cost of diagnosis and treatment. You will be able to compare cost of treatment with likely benefits; some problems will not require treatment.

TYPES OF TRAINING

Choose training to suit your circumstances, it can include formal and informal 'short courses'.

- **Professional diagnosticians and advisors** are university trained in a number of specialized fields, eg plant identification, entomology, plant pathology, soil science, etc.
- **Most horticultural and agricultural courses** at TAFES and universities include some training in diagnosing plant problems. Flexible delivery packages are available in some areas, using on-line self-paced learning materials, workplace mentoring and face-to-face classes.
- **Accreditation schemes** provide some training in diagnosis, eg
  - **NIASA** (Nursery Industry Accreditation Scheme Australia) for nurseries & growing media suppliers, **NGI** (Nursery & Garden Industry Accreditation Programs), **NGIP** scheme (Nursery & Garden Industry Professional) and **AGCAS** (Australian Garden Centre Accreditation Scheme).
  - **Professional accreditation** of advisers & consultants in specialist competencies. Diagnostics are performed under a Quality Management System Requirements 2000 (Toohey 2000).
  - **Diagnostic services** such as Crop Health Services offer training courses in pest and disease identification and management, tissue culture and certification schemes.
  - **Diagnosis for Crop Problems**, a teaching aid for crop protection students produced by the University of Qld (www.cbit.uq.edu.au).
- **Other learning opportunities** are often more target-orientated and include:
  - **Master classes** in Agriculture BioSecurity (AQIS), import risk analysis and quarantine. These include learning how to recognize and identify exotic diseases.
  - **Workshops** run by professional diagnosticians for students, growers and home gardeners. They offer diagnostic reliability and many function within educational institutions. Others are concerned with specific industry sectors, eg fruit, mushrooms, nursery industry.
  - **Diagnostic visits** either locally, interstate or overseas conducted by trained diagnosticians are useful in training students and trainers in diagnosis.
  - **In-house training** emphases the pests, diseases and weeds affecting the particular business. Ideally it should be used in combination with external training.
  - **Plant clinics** conducted by advisory services, garden centers, horticultural courses.
  - **Websites** open up vast resources for those willing to learn. Some websites provide for audience participation, eg diagnosing pests of grapes (Cropwatch online).
  - **Information services.** Subscribe to on-line to trade sites, quarantine and other information services.
  - **Public education/campaigns**, eg National Science Week (Sydney 2003), Australian Science Festival, Top End Science Fair, Weedbuster weeks.
  - **Participate** in radio, television, talkback gardening shows, Gardening Australia, State/Territory Garden advisory services.

WHAT DO I NEED TO TRAIN IN?

There are many layers of diagnostic services with different levels of expertise.

- What is your **current** diagnostic ability? What do you **want or need** to be able to do? Do you want to develop some basic skills and do the initial diagnosis yourself? If so, **choose a course** that suits your situation, eg landscaper, grower, nursery manager, industry consultant, quarantine officer.
- **Legislation** may require a certain level of training, eg quarantine, pesticides.
- **You may just need some training** in how to keep up-to-date in new pests and diseases, record keeping, scouting, using traps and lures, thresholds, evaluation of your diagnostic efforts, or help with interpreting information collected.
- You might be a **trainer** wanting to update your diagnostic skills.

BACKGROUND KNOWLEDGE

Good diagnosticians start with lots of background knowledge (see Figure 22, opposite). Diagnosing plant problems is not difficult, but is an ongoing learning process. Diagnosis requires some observational skills and the ability to investigate and consolidate information so that causal events can be reconstructed. A holistic approach will allow elimination of many apparent alternatives.

- **Training** should involve a **common-sense** approach to diagnosis.
- **Identifying pests and diseases** (and their controls) change so you need to have some basic knowledge of how the process works. The level at which a pest becomes apparent depends to a large extent on the ability of the observer to recognize the pest.
- **Both theoretical** and **practical training** is required. **Theoretical training** is best presented in a systematic way while **practical skills** can be obtained by diagnosing seasonal problems and participation in plant clinics or similar exercises.
- A **systematic approach** to acquiring the knowledge is helpful.
- A **general framework** incorporating the following stages is suggested.

General horticulture

All diagnosticians benefit from being able to recognize and name the plants they handle or grow. How many depends on whether you work in a nursery, in a botanic gardens, or grow only a couple of crops.

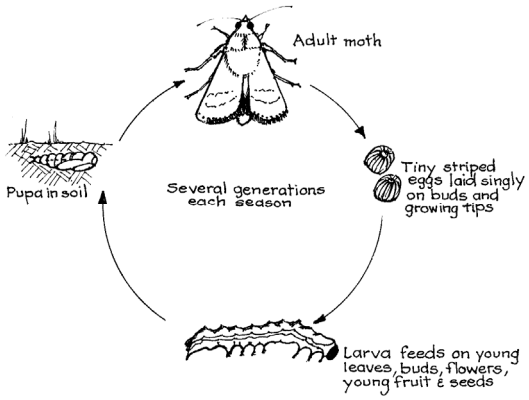
- The **relationship between species** is important when considering plants likely to be affected by a pest, eg some pests only attack certain members of the Rose family. Knowing even the family may help eliminate some pests and can help locate information. There are usually weed species in the same families as crop species. Try to recognize the 10 most important plant families in your region and identify desired and weed species, eg
  - **Asteraceae** (daisies), eg sunflower, cape weed.
  - **Brassicaceae** (brassicas), eg cabbage, turnip weed.
  - **Cucurbitaceae** (cucurbits), eg pumpkin, zucchini, paddy melon.
  - **Fabaceae** (peas), eg bean, pea.
  - **Mimosaceae** (wattles), eg leucaena, wattle, prickly acacia.
  - **Myrtaceae** (eucalypts), eg bottlebrush, eucalypt.
  - **Poaceae** (grasses), eg sweetcorn, winter grass.
  - **Proteaceae** (waratahs), eg grevillea, protea.
  - **Rosaceae** (roses), eg pome and stone fruits, rose, blackberry.
  - **Rutaceae** (citrus), eg lemon, eriostemon.
  - **Solanaceae** (nightshades), eg potato, tomato, silverleaf nightshade.
- The **relationships between species** is important when considering **quarantine and trade**, eg the potential host ranges of exotic pathogens, safety of proposed biological control agents, alternate and carryover hosts, etc. A knowledge of where exotic and Australian floras occur in the world is important for assessing exotic disease risks.
- **Knowledge of crop culture**. One of the greatest aids to a diagnostician is having a basic knowledge of how plants respond to different **environmental** and **cultural conditions –** what the plant may look like under changed conditions.
- To interpret plant symptoms and relate them to possible causes, the diagnostician must understand some basic plant anatomy, physiology and nutrition and what the plant looks like normally.

'Causes' of plant problems

Pests, diseases & weeds

To diagnose plant problems, you need to have a general understanding of pests, why they occur and their likely impact on production.

- Students should learn to recognise key **local pest** and **beneficial species**.
- You need to be able to **recognise** and interpret the **signs and symptoms** that these pests produce on plants.
- You need to be able to access **pest information sheets** (pest signatures) for each pest which will indicate other plants likely to be affected (host range), and may include illustrations of its signs and symptoms. It will also provide information on the significance of the problem and its occurrence in the field, eg its life cycle, spread, where it overwinters and conditions which favour it. Knowledge of the life cycle/pest cycle will help include or eliminate an organism as a cause. The following is a simple illustration the life cycle of the corn earworm (*Helicoverpa* sp.):



Control methods

Diagnosticians need to know how control methods work, how they might affect plants, when they are obligatory or when to do nothing, eg end of season, low level of damage or location in the enterprise.

- **How control methods may affect plants**. Plants may be affected directly, eg by herbicide injury, excess fertiliser. By **not using** disease-tested seed or other planting material or by **not selecting** resistant cultivars, certain diseases may develop. Lack of sanitation or poor pasteurisation may favour certain nursery diseases. The use of biological control agents may result in slightly more pest damage than if pesticides had been used.
- Having identified a pest, **legislation** may require that you notify some authority, or carry out some treatments. You may need to improve sanitation practices, use certified seed or other disease-tested planting material, apply a pesticide treatment. Management practices may need to be reviewed.

DIAGNOSING PLANT PROBLEMS

In making a diagnosis consider the following steps. Experienced diagnosticians will do this instinctively, following the steps to varying degrees depending on the level of importance of the problem.

Step 1. The client's enquiry.
Step 2. Identify the affected plant.
Step 3. Examine plant parts for signs & symptoms.
Step 4. Visit site, history, questions.
Step 5. Consult references.
Step 6. Seek expert help, if needed.
Step 7. Report the diagnosis.

GENERAL HORTICULTURE

Plant identification
Botany
Morphology
Propagation
Culture
Soils
Irrigation
Machinery
Equipment
Landscaping

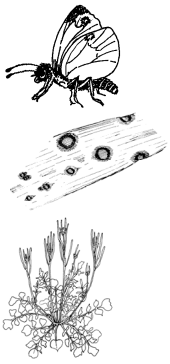
CAUSES

PESTS & DISEASES

Parasitic problems eg
- Insects & allied pests
- Snails & slugs
- Vertebrate pests
- Nematode diseases
- Virus diseases
- Bacterial diseases
- Fungal diseases
- Parasitic flowering plants

Non-parasitic problems, eg
- Living agents, eg fairy rings
- Non-living agents, eg heat

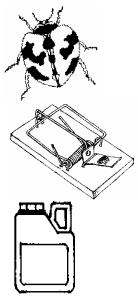
WEEDS



CONTROL METHODS

IPM & BMP, Organic Standards

Cultural methods
Sanitation
Biological control
Resistant varieties
Plant quarantine
Disease-tested planting material
Physical & mechanical methods
Pesticides



DIAGNOSING PLANT PROBLEMS	
?	**STEP 1. The client's enquiry**
	STEP 2. Identify affected plant
	STEP 3. Examine plant parts for signs & symptoms
	STEP 4. Visit site, history, questions
	STEP 5. Consult references
XPERT	**STEP 6. Seek expert help**
	STEP 7. Report the diagnosis

Fig. 22. A training pathway for diagnosticians that can be modified as required.

RESOURCES NEEDED FOR TRAINING

These will depend on the level of expertise the students need to acquire. Basic resources include:

- **Trained staff**.
- **Collecting and dissecting tools**, insect nets, bags, tubes, bottles, jars, secateurs, scissors, tweezers, razor blades, scalpels for cutting up and teasing needles for probing rotted tissue.
- **Hand lens, microscopes**.
  - **Hand lens** with a magnification of x10 for observing insects and mites.
  - **Dissecting microscopes** with a magnification of x40 to x60 are adequate for observing mites, insects, nematodes and some microscopic fungal fruiting bodies but not for most diseases.
  - **Binocular compound microscopes** with a magnification of x100, x200 to x400 are needed for basic fungal identification. Bacteria can be seen but not identified. Magnified views of insect and mite pests, fungi and nematodes can be observed. Many growers will decide **not** to attempt this level of diagnosis preferring to send samples to a diagnostic laboratory. **Microscope** slides, cover slips, lens paper, stains, eg cotton blue.
- **Record keeping facilities** are essential and include field and laboratory notebooks, waterproof pens/ pencils to record observations and counts and make drawings.
- **References** include books, colleagues, websites, and a range of educational programs that assist crop producers and industry consultants. Caution with overseas publications and websites. You may have access to references collections systematically organized, with material identified by experts. Living collections of plants are available in botanic gardens.
- **Adequate and reliable computing facilities** with access to the internet.

Computers & cameras

Computer facilities must be capable of running teaching aids and the wide range of keys available for identifying insects, weeds and other pests and distance imaging.

- **Access** Commonwealth/state/specific crop organization/business websites to access information relating to particular crops and pests.
- **Diagnosis for Crop Problems** is a teaching aid for crop protection students produced by the University of Qld. The software enables the building and running of problem solving activities so that students can **practice** diagnosing plant problems (Biological Information Technology (CBIT), University of Qld. www.cbit.uq.edu.au)
- **CD keys** for identifying particular groups of weeds, seeds, thrips, canegrubs, nematodes, urban pests. Extension tools are available for specific crops, eg citrus, cotton, grapes, rice, for teaching taxonomy, biocontrol of weeds, and for managing mice, foxes and rabbits (see page 81). www.cbit.uq.edu.au
- **Cameras/photographs** provide 'permanent' records of signs and symptoms, field observations of damage in the field over time and site conditions. Digital cameras are especially helpful. Clients should still be encouraged to bring in specimens.
- **Distance diagnosis.** A wide range of still or video images can be sent via computer or mobile phone to a diagnostic laboratory which accepts such images. A diagnosis may be made or a sample requested.
  - **Photographs** of plants, signs and symptoms can be scanned and forwarded.
  - **Cameras on a microscope** attached to a computer can send digital images of **microscopic** insects and mites, fungal mycelium and spores, etc.
  - **Speed**. Digital photos of an insect/diseased plants can be sent to a diagnostic service within minutes. The diagnostician at the other end can look at the photo, determine the problem and respond on the same day.
  - **Obtain multiple opinions** of an unusual problem which does not require fresh samples, for diagnosis.
  - **Limitations**. When remote diagnosis works, it works very well but it is hard to diagnose some diseases by symptoms alone. Some can only be diagnosed if samples are sent to a laboratory for microscopic examination and/or diagnostic tests, eg many virus, fungal and bacterial diseases.
- **Overseas web sites** can be a valuable source of information about a pest when the **diagnosis is correct**. Remember not everything is applicable to Australia.
  - **South Carolina's** home and garden information center web site allows users to download fact sheets for insects and diseases of landscape, garden and indoor plants. http://hgic.clemson.edu
  - **Maryland Cooperative Extension** has a web based diagnostic clinic allowing viewers to scan through a series of pictures designed to enable identification for common problems. www.agnr.umd.edu
  - **Digital imaging online training**. Overseas many fungal genera can be identified by this means (Nameth 2001).
  - **Interactive keys and expert systems** are better suited to diagnosing disease complexes they are usually more flexible than either/or keys.

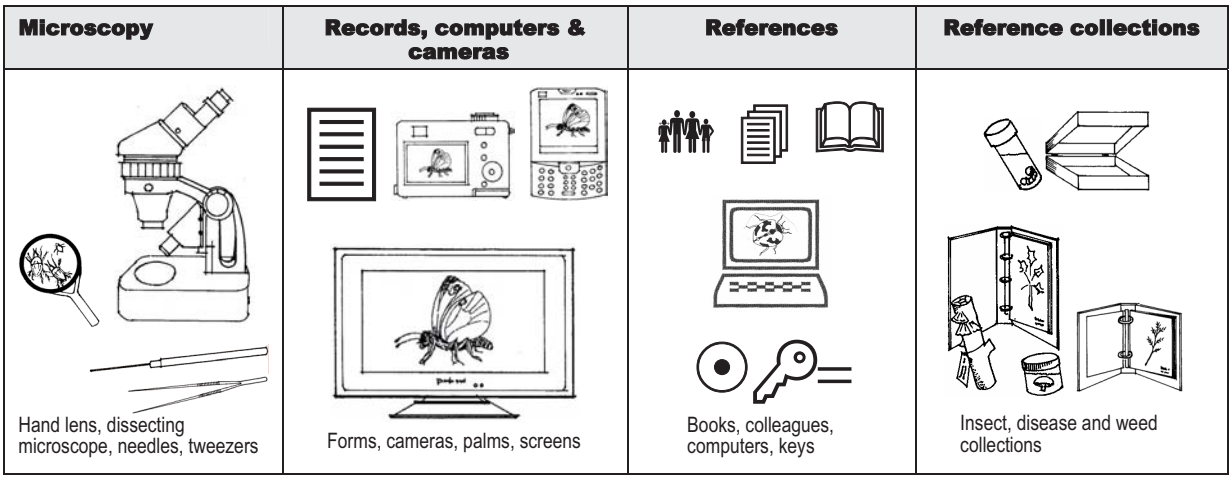


Fig. 23. Recommended resources for training and practice.

PRACTISE MAKES PERFECT

Practice may not actually make you perfect but it will enhance your skills. By way of encouragement – everyone, including the most highly skilled in any field of endeavour, starts off knowing nothing – time and practice makes the difference.

- **Learn to use references** quickly and effectively, eg books, colleagues, computers. In other words, access and use host lists, pest lists and pest information sheets effectively.
- **Learn to recognize the common** pests and diseases which affect the plants in your region. Sweet potato vines are particularly susceptible to mites, be on the lookout for them.
- **Consult with colleagues** or a diagnostic service when in doubt or inform your client that you are not sure.
- **Participate in real-life** problem-solving.
  - **Make field trips** on a seasonal basis. Every opportunity should be taken to examine problems in the field.
  - **Participate in case studies**. Examine real plant problems with colleagues or trained diagnosticians at work in a range of field conditions.
  - **Regular** weekly or fortnightly testing your diagnostic skills will give you some idea of how you are progressing.
  - **Collect** specimens for study and diagnosis.
- **Plant clinics**, advisory and diagnostic services provide valuable experience. Both commercial and garden advice services may offer educational plant clinics, workshops and demonstrations either as a once-off or on a regular basis.
- **Checklists** help you to look for the relevant signs, symptoms, patterns of problems in the field and ask the right questions.
- **Keep an up-to-date status** to ensure that you are familiar with pests that are currently in your area, or likely to occur in the future. **Be prepared!** Attend local workshops on pest, disease and weed identification and management.
- **Students could assist** in setting up and participate in an internet blog site where information and their opinions on currently occurring pests, diseases and weeds can be discussed.
- Access **Diagnosis for Crop Problems**, a teaching aid for crop protection students produced by the University of Qld. This will give **practice** in diagnosing plant problems, samples are not present.

Plant clinics – Training & practice

Plant clinics use the public as a resource for students practicing their diagnostic skills under the supervision of trained staff. They provide realism to their training and have proved to be very effective and popular. Plant clinics aim to disseminate accurate unbiased information, educate the public and growers to adopt practices that are sustainable with emphasis on selecting the correct plants, and reducing unnecessary pesticide and fertilizer use.

- **Plant clinics are effective teaching aids**. Although some participants are better at advisory work than others, all benefit from the experience. If it is not possible to hold plant clinics, mock clinics can be held. Participants benefit from working with experienced diagnosticians and often make their own contributions to the clinic.
- **Participants get experience** in diagnosing plant problems with and without samples, and with samples of varying quality. They learn to handle digital images, email and telephone enquiries.



An image of red-coloured slime moulds on eucalypt leaves downloaded from a client's digital camera



Landscape students, under supervision, advising a client



Student using a dissecting microscope to examine tomato leaves for mites

Fig. 24. Plant clinic activities at the Canberra Institute of Technology, 2006.

Plant clinics – Training & practice

contd

- **Advantages of plant clinics.** The old saying '**2 heads are better than 1'** is especially true at plant clinics. Pooling knowledge with others, improves expertise and diagnostic skills. Networking skills are enhanced. From the **client's point of view** the multidisciplinary plant clinic is ideal.
- **Records** are kept of all diagnosis carried out by participants. Diagnostic errors can be easily checked.
- **Legal aspects** of holding plant clinics should be explored. Plant clinics may not serve the public well if incorrect diagnoses are allowed to slip through. Procedures should be in place to reduce this as much as possible. The quality of the advice provided must also be evaluated but is more difficult to do and can be time consuming. Diagnosing plant problems is similar to diagnosing medical problems in this respect, **every diagnosis is not going to be correct**.
- **It is important to differentiate between** commercial clients and home gardeners.

Plant clinics – Organization & resources

Using the public as a teaching resource opens up a wealth of opportunities also present some problems. Planning is essential.

- **Decide what services the clinic is to offer**, eg a preliminary diagnosis accompanied with information sheets and sending difficult problems to a diagnostic service; or offering an extended range of services.
  - **Plant identification.** The plant species and problems received by plant clinics are diverse. Probably about a third are about plant identification and the rest for pests, diseases and weeds. A small number will result in an inconclusive diagnosis.
  - **Identification of common pests**, diseases and weeds.
  - **Simple tests.** It is relatively easy to offer basic soil pH tests.
  - **Telephone advice.** Gathering information by telephone is less satisfactory because you cannot see the pest or plant but it is a technique students need to master. They must practise the skill of getting information by asking relevant questions, recording the information received and, if necessary, arranging for a sample or at least photographs to be sent (see page 117).
  - **Mailed samples.** Both samples and photographs may be sent by mail, however, in most cases it is a sample that is forwarded.
  - **Email enquiries with digital image attachments.** This is ideal for some types of enquiries but samples may still be needed for diagnosing some problems, soil tests, etc.
  - **Provision of pest information sheets** so clients can understand the bigger picture.
- **Provide supervising staff** to help students. The role of the supervisor is to guide the student through the diagnosis, but avoid taking it over to the extent that the student is sidelined. They should:
  - **Have an interest** in the topic and have some experience. They may have a wide range of skills, or specialize in pests, diseases, weeds or plant identification and culture or Australian plants.
  - **Guide students** discreetly through the seven steps of diagnosis, even if the student recognizes the problem immediately. This stops the 'shotgun' approach and gives the customer time to talk.
  - **Prepare student instructions** and **rosters** (if required).
- **Venue and advertising.** Most clinics function within educational institutions with varying levels of training and expertise. Venues may include horticulture laboratories and facilities, special horticultural events such as a open days, horticultural shows. **Advertise** well in advance in appropriate venues, gardening columns of local newspapers, on radio and television community news programs. The public and other clients should be encouraged to bring in appropriate specimens.
- **Organize work areas** to provide adequate space for staff and students behind the counter and allow members of the public to be seated during a consultation.
  - **Items required**. Hand lens, binocular dissecting microscope for close observations of pests, references, internet access, additional items as required.
  - **Expert diagnostic services**. Know how to access them and what they offer. Most are user pays.
- **Standard diagnostic procedures** involve communicating effectively and keeping records. Follow the diagnostic road map.
- **De-briefing** is essential for all participants. Plant clinics must be evaluated (see page 191).
- **Organize dry runs** for students to practise. Mock clinics can be held during the week before clinics start so that students can understand and follow prescribed steps in diagnosis, record keeping and obtain practice in giving verbal and written advice as simply and precisely as possible.

APPENDIX 7 – EVALUATION

Evaluation is a vital step in Best Management Practice (**BMP**). The following questionnaires can be used to check your progress. Circle your answer. Note that if the answer is **NO**, it might be the appropriate answer, that activity may not have been required.

THE DIAGNOSTIC PROCESS

Step 1. The client's enquiry page 29		
• Were client's details recorded?	Yes	No
• Was the client's enquiry recorded?	Yes	No
• Did the grower indicate what they thought the problem was?	Yes	No
• Did you find out what the client **expected** from you?	Yes	No
• Did you find out how **definite** and **reliable** the diagnosis had to be??	Yes	No
Step 2. Identify affected plant page 35		
• Did you identify the affected plant?	Yes	No
• Did you access a list of possible problems for that plant?	Yes	No
• Did you access pest information sheets to compare the suspect problem with its pest signature?	Yes	No
Step 3. Signs and symptoms page 45		
• Did you know what the plant looked like normally?	Yes	No
• Did you observe any **signs**?	Yes	No
• Did you observe any **symptoms**?	Yes	No
• Were the signs and symptom clear?	Yes	No
Step 4. Visit site, history, questions page 59		
• Did you visit the site, access records?	Yes	No
• Did you carry out any on-site tests, assessment?	Yes	No
• Did you draw or get the client to draw a site map?	Yes	No
• If you did not visit the site, did you ask relevant questions?	Yes	No
• Did you collect samples for sending to a diagnostic service?	Yes	No
Step 5. Consult references page 77		
• Have you consulted with colleagues or specialists?	Yes	No
• Did you use any **books** or **websites** during your diagnosis?	Yes	No
• Are your references up-to-date?	Yes	No
Step 6. Seek expert help page 87		
• Did you access a diagnostic service? If so, did you:	Yes	No
• Were the samples forwarded of the required number and quality?	Yes	No
• Did you complete a submission form and send it with the sample?	Yes	No
• Were standardized tests carried out?	Yes	No
• Did you receive a **written** report?	Yes	No
• Was the diagnosis **reliable**?	Yes	No
• Was the diagnosis **definite**?	Yes	No

Step 7. Report the diagnosis page 103		
• Did you follow a systematic process (Steps 1-7)?	Yes	No
• Have you checked for errors in your diagnosis?	Yes	No
• Were you able to provide **written proof** of your diagnosis?	Yes	No
• Did you discuss the diagnostic road map?	Yes	No
• Were there any **legal requirements** that had to be satisfied, eg notification?	Yes	No
• Did you **compare** the observed signs, symptoms, tests and information gathered with the pest signature to confirm **or** reject its identity?	Yes	No
• Was the diagnosis as **definite** as required, eg		
Preliminary?	Yes	No
Useful?	Yes	No
Accurate?	Yes	No
Definite positive (what was found)?	Yes	No
Definite negative (what was **not** found)?	Yes	No
Inconclusive?	Yes	No
• Was the diagnosis as **reliable** as required?	Yes	No
• Was the client **satisfied** with your findings?	Yes	No
• Did you follow up your advice to the client see if it was successful?	Yes	No
Comments		

THE CHECKLIST

page 113

• Did you use an extended checklist? If so:	Yes	No
• Did the checklist fit your problem?	Yes	No
Suggested improvements		

COMMUNICATION

page 117

• Did you evaluate communication between client and **yourself** ?	Yes	No
• Did you evaluate communication between the client and any **diagnostic service** contacted?	Yes	No

RECORD KEEPING

page 119

• Did you **access client records** dealing with the history of the crop, pests, environmental conditions and on-site tests?	Yes	No
• Did you **fill in** and **keep a copy** of the submission form supplied by the diagnostic service to accompany any sample sent to them?	Yes	No
• Did you access and update your own records by including a **record of the diagnosis**?	Yes	No

SAMPLING

page 175

• Were samples collected, packaged and sent as **recommended** by the diagnostic service?	Yes	No
• Were the correct **number** of samples taken?	Yes	No

TRAINING

page 185

Trainers		
• Were the trainers **competent** and **up-to-date**?	Yes	No
• Was the knowledge delivered **relevant** to the level of training required?	Yes	No
Student assessment		
• Are you doing a course **appropriate** for your needs?	Yes	No
• Did you think the assessment was **appropriate**?	Yes	No
• Did you participate in a **review** of the training, activities and assessment?	Yes	No
Training & practice		
• Have you participated in a diagnostic service, plant clinic or worked in a garden center or retail nursery?	Yes	No

Plant clinics

page 189

On arrival, were you:		
• Dressed appropriately?	Yes	No
• Wearing name tags?	Yes	No
• Organized to work in **pairs**?	Yes	No
• Instructed in how to **use** the available space, telephone, answering service, computers?	Yes	No
Telephone, email, mail, enquiries:		
• Were the messages on the answering machine read and dealt with **prior** to being deleted?	Yes	No
• Did you deal with all outstanding enquiries including emails, samples?	Yes	No
• Did you post out leaflets to clients?	Yes	No
• Did you answer the telephone, greet clients and deal with their enquiries appropriately?	Yes	No
Records of enquiries:		
• Were enquiries recorded on forms?	Yes	No
• Were **unsolved** plant problems/ queries labeled with the client's name, address and telephone number and appropriately packaged?	Yes	No
• Was the client **contacted** as soon as possible?	Yes	No
• Was **interesting** material kept for further study?	Yes	No
• Was all the remaining material appropriately disposed of?	Yes	No
Material given to client:		
• Did you give each client a written record of your diagnosis along with a legal liability notice?	Yes	No
• Did you check all advisory leaflets for outdated information, especially pesticide information?	Yes	No
• Did you provide information on when the plant clinic is open for business, current phone and fax numbers, postal address, email address.	Yes	No
Diagnostic steps followed:		
• Client's enquiry	Yes	No
• Identified affected plant	Yes	No
• Examined the plant	Yes	No
• Asked appropriate questions	Yes	No
• Consulted references to provide proof of diagnosis, ie confirm diagnosis, information on life cycles and control	Yes	No
• Got expert advice if you still could not identify the problem	Yes	No
• Reported the diagnosis	Yes	No
Did you consider non-chemical control options before pesticides:		
• Cultural methods?	Yes	No
• Sanitation?	Yes	No
• Biological control?	Yes	No
• Resistant varieties?	Yes	No
• Plant quarantine?	Yes	No
• Disease-free planting material?	Yes	No
• Physical & mechanical methods?	Yes	No
• Pesticides (home garden/commercial) depending on the situation?	Yes	No
• Organic standards and IPM?	Yes	No
Communication:		
• Did you greet and communicate with each customer appropriately?	Yes	No
Did you check with staff when you had doubts about the:		
• Diagnosis?	Yes	No
• Control measures, recommendations?	Yes	No
Evaluation and debriefing:		
• Were the written records of student diagnoses and recommendations checked by trainers for accuracy?	Yes	No
• Did you participate in a de-briefing?	Yes	No

APPENDIX 8 – CONTROL

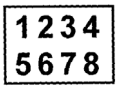
A request for a diagnosis is often accompanied by a request for information on how to control the problem. **IPM** (Integrated Pest Management) and **BMP** (Best Management practice) provide frameworks for controlling pests (see page 18). **BMP** provides an environmental framework for managing most businesses, **IPM** on the other hand, is specifically for managing pests.

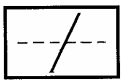
IPM

PLAN









1. Plan strategies to solve the problem or prevent it from recurring. Prepare a plan that fits your situation and according to Commonwealth/State/local legislation. **IPM** and **BMP** are part of the complex system of producing the crop.

2. Crop, region, situation **IPM**/**BMP** programs vary with, and are specific to, each crop, region or site. Check if a program is available for **your** crop, many commercial crops have computer programs and web addresses.

3. Identify the problem accurately Control recommendations assumes the problem has been correctly diagnosed using a succession of steps:

- Step 1. Enquiry
- Step 2. Identify the crop/plant
- Step 3. Examine plant parts for signs & symptoms
- Step 4. Visit site, history, questions
- Step 5. Consult references
- Step 6. Seek expert help
- Step 7. Report the diagnosis

4. Monitor and sample pests and beneficials.

- Monitoring and sampling may be required by **quarantine regulations**.
- Early detection of a pest and its natural enemies is essential for **effective control** in commercial crops. Often it is too late to control a pest once damage is obvious.
- Decide **what** has to be monitored, eg eggs, larvae, adults of pests, beneficial insects, symptoms, nutrient levels. Work out how and when the monitoring is to be done.
- Pest numbers and damage can be **quantitatively assessed** to evaluate the need for treatment. Small amounts of pest and weed invasions may not warrant control, biological or natural controls may exist; exceptions include quarantine incursions, eg citrus canker. Nurseries and landscaped areas are sensitive to the aesthetic effects of pests and weeds which are more difficult to measure.

5. Threshold levels may be economic, aesthetic or environmental, or in the case of quarantine, a **nil** threshold. Thresholds are the 'levels' **above** which control is considered for some pests. For many plant problems the 'level' is not so clear cut. Things to consider include:

- How much damage is acceptable to the client?
- Is it too late to reduce symptoms in this growth cycle? Can the problem be reduced for next year?
- Are control measures, eg pesticides, justified and likely to be successful?

6. Control This has to be considered within the context of **legal** and organic standards and the situation of the client, ie commercial grower, home gardener. Appropriate action should only be taken when an agreed or legal **threshold is reached**. This will mean selecting a control which causes least damage to the environment, which maximizes the use of non-chemical methods, while minimizing the use of pesticides. This is done by considering the following:



- **Cultural control** Each plant should be provided with its cultural and environment requirements. This **prevents stress** which may lead to attack by pests, eg invasion by fungal diseases in an over-wet nursery environment. Cultural controls **enhances** the choices of control methods, eg changing the environment may forego the need for a pesticide application; pre-plant soil analysis can prevent nutrient deficiencies and over-fertilization.



- **Sanitation practices** can reduce fungal root rot diseases such as *Phytophthora* in nurseries. Removal of infected material, proper disinfection of propagation areas prevent cross infection and are important control procedures in nursery accreditation schemes. Correct pruning of infected, dead or weak growth may allow a plant to recover.



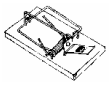
- **Biological control agents** Are bio-control agents available? Do natural controls exist which might provide some control and reduce pesticide use?



- **Are resistant varieties available?** Resistance **does not mean complete immunity**, but some ability to withstand attack. Know what pests are common in your region, what plants or crops are prone to attack, whether there are species, varieties or cultivars which have some resistance to attack.









6. Control ***(contd)***

- **Plant quarantine** regulations ensure protocols are in place to monitor movement of plants and plant materials and to track or contain a potential outbreak. Contingency plans are in place for emergency responses to incursions of major exotic pests.
- **Disease-tested planting material** is certified free of specified pests and diseases. This material allows a grower to avoid infected parent stock and contaminated seed sources. Is it available for your crop?
- **Physical and mechanical methods** have become more prominent due to the development of pesticide resistance. Traps are used to monitor some economic pests and heat treatments to disinfect seeds. Early warning services alert growers to conditions of temperature and moisture which favour infection.
- **Pesticides** Chemical controls may seem to provide a 'quick fix' but better horticultural practices, eg cultural practices, may provide better long term control. So consider whether the problem is really severe enough to warrant the application of a pesticide. If you do use pesticides:
  - ❑ Only recommend pesticides registered for use in your State/Territory, on the **pest** causing the problem on your **particular crop**.
  - ❑ Make sure your advice is **up-to-date** and from a reliable source. Books and pest information sheets often contain **out-of-date** pesticide recommendations. Always check pesticide registrations with the **free APVMA website** www.apvma.gov.au. More detailed information is available from the **user pays Infopest** www2.dpi.qld.gov.au/infopest/
  - ❑ Advise the client to read the label and use the product only according to label directions. Advisors do not have the support of manufacturer when giving off-label advice in many circumstances.
  - ❑ Advise the client that rates, frequency and method of application are on the label attached to the container.
  - ❑ Advise the client to follow safety and environmental instructions on the label.
  - ❑ Select pesticides which are effective and can be used safely according to label directions and play a supportive rather than disruptive role in the environment.
  - ❑ Consider toxicity of pesticides to humans, animals, eg birds, bees, fish, biological control agents, persistence of some pesticides.
  - ❑ For commercial crops, be aware of the risks of pests, diseases and weeds developing strains resistant to regularly used pesticides.



7. Evaluate control methods used Firstly, was the diagnosis correct? If so, was the recommended treatment effective? If not, do you know why? A few hints which may help are outlined below.

Timing 	Timing of any control action, whether sanitation, biological or chemical is critical. They must be carried out at the correct time in relation to the stage of growth of the crop and the pest. Insecticides must be applied at a vulnerable stage of an insect's life cycle. For many fungal diseases it is important to know when spores are produced and when the host plant is susceptible to infection by germinating spores. Treatments may be directed at protecting plant surfaces from attack. Sometime several pesticide applications or releases of bio-control agents are necessary.
Provide informed choice	No one recommendation is correct for every situation. Sometimes nothing is satisfactory. For example, if powdery mildew is a problem on a euonymus hedge in a public planting, choices which could be offered include removal of the hedge, replanting with resistant species, or putting up with the problem. Pruning off affected shoots may encourage new growth which will also become infected. Spraying plants in this situation is impractical and unlikely to be successful over the long term. However, wholesale nurseries will spray susceptible euonymus species, because they have to sell them. If you offer only one solution and it fails, clients are less likely to seek further advice from you.
No control program is perfect	Avoid knee jerk reactions. Some growers have unreal expectations. For example, copper sprays are applied in late dormancy to control the fungal disease peach leaf curl. If a few curly leaves develop on new growth in spring it does not mean that your spray program was incorrectly carried out.

Fig. 25. A few hints.

SELECTED REFERENCES

General references
The diagnostic process
Identifying affected plants
Host indexes
Pest indexes (causes of plant problems)
Pests & diseases
Insects & mites, snails & slugs
Vertebrate pests
Diseases (nematode, virus, bacterial, fungal, parasitic flowering plants, non-parasitic)
Weeds

GENERAL REFERENCES

Pest information sheets for pest, diseases and weeds are available from state/territory departments of agriculture, primary industries, environment, industry organizations, some botanic gardens. Nearly all have websites, some can be purchased as leaflets, CD ROMs. Local councils provide information on vertebrate pests and certain weeds. There are regional orchard pest and disease handbooks.

Books, CD-ROMs

Horticulture Sites on the World Wide Web. cur. edn. Book and CD-ROM. GrowSearch, Cleveland, Qld.

Websites

Commonwealth Government

www.affa.gov.au AFFA (Agric Fish. & For. Australia)
www.apvma.gov.au APVMA (Australian Pesticides & Veterinary Medicines Authority)
www.aqis.gov.au Plant quarantine
www.horticulture.com.au Horticulture Australia
www.planthealthaustralia.com.au Plant Health Surveillance, Plant Health Diagnostic Network
www.rirdc.gov.au RIRDC (Rural Industries & Research Development Corporation)

State/Territory Depts. of Agriculture/Primary Industries

www.agric.nsw.gov.au New South Wales
www.primaryindustry.nt.gov.au Northern Territory
www.dpi.qld.gov.au Queensland
www2.dpi.qld.gov.au/growsearch/ Growsearch
www2.dpi.qld.gov.au/infopest/ Infopest
www.pir.sa.gov.au South Australia
www.dpif.tas.gov.au Tasmania
www.dpi.vic.gov.au Victoria
www.agric.wa.gov.au Western Australia

Others

www.greeningaustralia.org.au Greening Australia
www.usda.gov United States Dept. of Agric.
www.maf.govt.nz NZ Min of Agric & Forests
www.hortnet.co.nz HortNET New Zealand
www.fwprdc.org.au Forest & Wood Products
www.lwa.gov.au CRCs Land & Water
www.npws.nsw.gov.au/wildlife NSW Parks & Wildlife Service
www.ngia.com.au/accreditation/niasa NIASA (Nursery Industry Accreditation Scheme Australia)

THE DIAGNOSTIC PROCESS

Websites

www.cbit.uq.edu.au *Diagnosis for Crop Problem,* CBIT, University of Qld
www.tpp.uq.edu.au/ CRC (Co-operative Research Centre) for TPP (Tropical Plant Protection)
www.lucidcentral.com/ Lucid software for developing and distributing identification and diagnostic keys
www.apsnet.org/online APS (The American Phytopathological Society) Plant Pathology Online
www.ipmnet.org CICP (Consortium for International Crop Protection)
www.plantclinic.cornell.edu Plant Disease Diagnostic Clinic, Cornell University
http://hgic.clemson.edu Clemson University Extension. South Carolina
www.danrcs.ucdavis.edu University of California, click on the link to the ANR catalogue
www.agdia.com/ Agdia Inc. Diagnostic test kits
www.hydros.cc/ Hydros, Inc. Diagnostic test kits
www.neogeneurope.com/ Neogen Europe Ltd. Diagnostic test kits

Books, articles

Agrios, G. N. 1997. *Plant Pathology*. 4th edn. Academic Press, NY.
American Phytopathological Society. 1978-1993. *Common Names for Plant Diseases 1994*. APS Press, St. Paul, Minnesota.
Ascerno, M. E. 1981. *Diagnostic Clinics, More than a Public Place*. Bull. Entomological Society of America, Vol. 27 No 2, June.
Ausher, R., Benzeev, I. S and Black, R. 1996. *The Role of Plant Clinics in Plant Disease Diagnosis and Education in Developing Countries*. Ann. Rev. Phytopathology 34:51-66.
Ball, J. and Lloyd, J. E. 1997. *Plant Health Care and the Diagnostic Process*. Arborist News, Oct.
Bodman, K. et al. 1996. *Ornamental Plants: Pests, Diseases & Disorders.* Q196001. Qld DPI, Brisbane.
Brown, J. F. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pubs., Armidale, NSW.
Chatfield, J. A., Boggs, J. F. and Draper, E. A. 2002. *The 20 Questions of Plant Problem Diagnostics: Part 1.* American Nurseryman, June 1.
Chatfield, J., Boggs, J. and Draper, E. 2002. *The 20 Questions of Plant Problem Diagnostics: Part 11.* American Nurseryman, June 15.
Creswell, T. 2001. *Collecting Plant Samples.* Grounds Maintenance, March.
Davies, R. 1991. *Your Garden Questions Answered.* Hyland House, South Melbourne, Vic.
Flynn, P. H and Gleason, M. L. 1997. *Deciphering Diseases*. American Nurseryman Sept 15.
Gilbert, A. 2003. *Why has my Lemon Tree got Yellow Leaves?* Aust. Hort., Nov.
Goodwin, S. et al. 2000. *Integrated Pest Management in Ornamentals: Information Guide.* Agrilink. QAL0004, NSW Agric. Sydney. Contains fact sheets on important pests, collecting and dispatching samples for laboratory testing. There is a companion field guide with clear pictures.
Hall, B. 2000. *Ornamentals Workshop, USA 2000*. HRDC Travel Report NY00031, SARDI, Adelaide.
Hayes, E. 2002. *Using Diagnostic Equipment to Inspect Trees: Bring a Calculator*. The Australian Arborist Age www.arborage.com.au
Heacox, L. 2000. *Be a Disease Detective*. AVG, March. Ohio.
Howell, J. and Forsberg, L. *How to Collect, Package and Dispatch Samples for Laboratory Diagnosis.* Grow Help Australia, Cleveland, Qld.

Joyner, B. G. 1997. *Diagnosing Disease Problems on Trees.* Arborist News, Feb.
Kerruish, R. M., Unger, P. W. and O'Brien, D. 1986. *Plant Clinics: A Practical Exercise in Teaching Horticulture.* Australian Horticulture, Oct.
Lloyd, J. E. and Ball, J. 1997. *Plant Health Care: Part 1*. Arborist News, Aug.
Marshall, D. W. 2002. *Diagnosing Plant Problems*. Advanced Master Gardener Training, Fact sheet, Plant Clinic, Cornell University.
Marshall. G. 1996. *Diagnostics in Crop Production*. BCPC, Alton, Hampshire, UK.
McKinnon, J. P. 1978. *Minnesota's Information Clinic*. Horticultural Science, Vol. 13 No 6, Dec. 1978, 656-657.
McMaugh, J. 1994. *What Garden Pest or Disease is That?* Lansdowne Pub., Sydney.
McMaugh, J. and Hanks, M, 1990. *Gardening Questions and Answers*. Houghton Miffin Australia, Knoxfield, Vic.
Miller, F. 2000. *Be A Better Diagnostician*. NMPRO (Nursery Management & Production), July.
Nameth, S. T. 2001. *Technology Provides State-of-the-Art Disease Diagnosis*. GMpro, (Greenhouse Management & Production) June.
Narayanasamy, P. 2001. *Pathogen Detection and Disease Diagnosis*. 2nd edn. Marcel Dekker, NY.
Naumann, I. D. (ed.). 1993. *CSIRO Handbook of Australian Insect Names: Common and Scientific Names for Insects and Allied Organisms of Economic and Environmental Importance.* 6th edn. CSIRO, East Melbourne. www.ento.csiro.au
Pasian, C. C. 2001. *Diagnosing Noninfectious Disorders of Floricultural Crops*. Ohio State University Extension Fact Sheet, Columbus OH. www.ohioline.osu.edu/hyg-fact
Rris, W. 1992. *Diagnosing Tree Problems. Arboriculture: Integrated Management of Landscape Trees, Shrubs and Vines.* 2nd ed., Prentice-Hall, NJ, USA. p 512
Shurtleff, M. C. and Averre.111, C. W. 1997. *The Plant Disease Clinic and Field Diagnosis of Abiotic Diseases*. APS, St. Paul, MN, USA.
Shurtleff, M. C. and Averre.111, C. W. 2000. *Diagnosing Plant Diseases Caused by Nematodes*. APS, St. Paul, MN, USA.
Thomson, et al . 1992. *Prototyping an Expert System for Diagnosing Forest Seedling Nursery Problems Using an Expert System Shell*. Agriculture & Environmental Science, Vol. 6, 21-31.
Toohey, D. E. 2002. *Towards Professional Accreditation for Advisors and Consultants in Agriculture, Natural Resource Management and Related Sectors.* RIRDC Pub., No. 02/104, Barton, ACT.
Walker, S. E. and Schubert, T. S. 1997. *Assessing Plant Problems in Cropping Systems: A Systematic Approach.* Plant Pathology Circular No. 381, Jan/Feb 1997. Dept of Agric and Consumer Services, Div. of Plant Industry Florida.
Waller, J. M., Ritchie, B. J. and Holderness, M. 1998. *Plant Clinic Handbook*. CABI International, New York.
Wolf, B. 1996. *Diagnostic Techniques for Improving Crop Production*. The Haworth Press, Binghamton, NY. Accompanied by an *Instructor's Manual.*

IDENTIFYING AFFECTED PLANTS

Websites

www.anbg.gov.au ANBG (Australian National Botanic Garden) *email* email@anbg.gov.au
- Plant Enquiry Service
- Directory of Australian Botanic Gardens and Arboreta
- Census of Plants in Major Australian Botanic Gardens
- Australian Cultivar Registration Authority (ACRA)
- Australian Plant Name Index (APNI)
- Australian Plant Image Index (APII)
- Common Names of Australian plants
- Correct name for an Australian Plant & Recent Name Changes
- Flora of Australia online
- Centre for Plant Biodiversity Research

www.ipni.org/ IPNI (International Plant Names Index)
www.hort.net/gallery HortNET plant gallery
www.rhs.org.uk/rhsplantfinder/plantfinder.asp RHS (Royal Horticultural Society) Plantfinder
www.weedinfo.com.au Catalogue of floras, weeds, fungi, grasses, orchids
www.ishs.org/sci/icra.htm ICRAs (International Cultivar Registration Authorities)
www.flowersqueensland.asn.au FAQ (Flowers Association of Qld)
www.rbg.vic.gov.au/opcaa OPCAA (Ornamental Plants Conservation Association of Australia)

CD-ROMs

AusGrass: Grasses of Australia
EUCLID: Eucalypts of Southern Australia
WATTLE: Acacias of Australia
Flora of the World
ICBN: International Code of Botanical Nomenclature.
Horticultural Flora of S.E. Australia (in preparation)
Greenlife data base (Australian nursery industry plants)
Seed Identification Key
Key to Australasian Liverwort & Hornwort Genera

Books, articles

Floras, eg Floras of the ACT, Central Australia, New South Wales, South Australia, Tasmania and Victoria, Eucalypts of southeastern Australia, Southeast Queensland, Central Australia, The Western Australia Flora, Eucalypts of southeastern Australia. Available in book form or as CD-ROMs.

Adler, M. (ed.). 1994. *The Smart Gardener's Guide to Common Names of Plants*. Adland Horticultural, Melbourne.
Adler, M. *Botanica: Australia's Horticultural Directory.* cur. edn. Botanica Pub. Aust., Cheltenham, Melbourne.
Chittenden, F. J. (ed.) 1955. *Dictionary of Gardening: A Practical & Scientific Encyclopedia of Horticulture.* The Royal Horticultural Soc., Oxford: Clarendon Press, The Royal Horticultural Society.
Clarke, I and Lee, H. 2003. *Name that Flower: The Identification of Flowering Plants.* Melbourne University Press, Carlton, Vic.
Commonwealth of Australia. 1982-94. *Flora of Australia*. AGPS, Canberra.
Costermans, L. 1996. *Native Trees and Shrubs of the South-Eastern Australia*. Lansdowne Pub., Sydney.
Elliot, R. W. and Jones, D. L. 1980. *Encyclopaedia of Australian Plants Suitable for Cultivation.* Vol.1. Lothian Pub., Sydney.
Hibbert, M. 2004. *Aussie Plant Finder*. Florilegium, Glebe, NSW.
Hickey, M. and King, C. 1997. *Common Families of Flowering Plants*. Cambridge Univ. Press, England.
Lazarides, M. and Hince, B. (eds). 1993. *CSIRO Handbook of Economic Plants of Australia*. CSIRO, Melbourne.
Liberty Hyde Bailey Hortorium. 1976. *Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada.* rev. edn., Macmillan, NY.
Lumley, P. F. and Spencer, R D. 1991. *Plant Names.* 2nd edn. RBG, Melbourne (being revised).

McAdams, W. R. 2002. *Nursery Insect and Disease Management*. American Nurseryman, June 1.
Spencer, R. D. 2002. *Making Plant Names Clearer*. Aust. Hort., Nov.
Spencer, R. D. 2003. *Plant Names in the Melting* Pot. Aust Hort., Nov.
Spencer, R. D. 1995-2005. *A Horticultural Flora of South-eastern Australia.* Vol. 1-4. Univ. NSW Press, Sydney.
The Royal Horticultural Society. *The Garden Plant Selector: The Guide to Choosing the Right Plants for Your Garden Conditions*. Joyce, D. 1998. Rylands, Peters & Small, London.
Wrigley, J. W. and Fagg, M. 1998. *Australian Native Plants*. 4th edn. Reed New Holland, Sydney.

HOST INDEXES

BMP & **IPM** programs are available for many commercial crops in Australia either as books, CD-ROM or on the web that describe the common pests and diseases of the host plant.

Websites

www.ausveg.com.au/contact.cfm AusVeg (Australian Vegetable & Potato Growers Federation)
www.cropwatch.com.au/ CropWatch Online is an identification guide to diseases of commercial grapevines in Australia
www.crdc.com.au CRDC (Cotton Research & Development Corporation). A key to cotton pests
www.grdc.com.au GRDC (Grain Research & Development Corporation)
www.gwrdc.com.au GWRDC (Grape & Wine Research & Development Corporation)
www.ngia.com.au/accreditation/niasa NIASA (Nursery Industry Accreditation Scheme Australia)
www.horticulture.com.au Horticulture Australia
www.srdc.gov.au SRDC (Sugar Research & Development Research Corporation)
www.apsnet.org/online APSnet On-line Service
www.treekeeperonline.com TreeKeeper® online (*Air Pollution, People &Forest Decline Concept)*
www.chaseresearchgardens.com Chase Research Gardens
www.globeaustralia.com.au/ Globe Australia
www.agcsa.com.au/ AGCSATech (Australian Golf Course Superintendents Assoc.)
www.weedinfo.com.au Weed information (identification, management, catalogue)
http://hgic.clemson.edu Clemson University Extension, South Carolina has a garden information website which enables viewers to download fact sheets dealing with landscape, garden and indoor plants, insects, diseases and other problems.

CD-ROMs

Canegrub (BMP for the Australian Sugar Industry)
Peanuts (EXNUT)
Rice IPM
Sweetpotato (tool for diagnosing sweetpotato problems)

Books, articles

American Phytopathological Society (APS) Press, St. Paul, Minnesota, produces compendia on diseases and pests of particular plants. Available as books or CD-ROM. APSnet On-line Service www.apsnet.org/online

Alfalfa Diseases
Apple & Pear Diseases
Bean Diseases
Beet Diseases & Insects
Chrysanthemum Diseases
Citrus Diseases
Conifer Diseases
Corn Diseases
Cotton Diseases
Cucurbit Diseases
Diseases of Woody Ornamentals & Trees in Nurseries
Dutch Elm Disease & the American Elm: Risks & Benefits of Monoculture
Elm Diseases
Flowering Potted Plant Diseases
Foliage Plant Diseases
Forest Decline Concepts
Grape Diseases
Lettuce Diseases
Managing Diseases in Greenhouse Crops Nut Crop Diseases in Temperate Zones
Onion & Garlic Diseases Ornamental Foliage Plant Diseases colour atlases
Ornamental Palms
Pea Diseases
Peanut Diseases
Raspberry & Blackberry Diseases & Insects
Potato diseases
Potato Health management
Rhododendron & Azalea Diseases
Rice Diseases
Rose Diseases
Sorghum Diseases
Soybean Diseases
Stone Fruit Diseases
Strawberry Diseases
Sweet Potato Diseases
Tobacco Diseases
Tropical Fruit Diseases
Turfgrass Diseases
Turfgrass Patch Diseases
Umbelliferous Crop Diseases
Vegetables
Wheat Diseases
Wheat Health Management

Bodman, K. et al. 1996. *Ornamental Plants: Pests, Diseases & Disorders.* Q196001. Qld DPI, Brisbane.
Chase Research Gardens. *Chase Flash Cards:*
Flowering Potted Plant Problems
Indoor Plant Problems
Bedding Plants 1&2
Troubleshooting Foliage Plant Diseases
Troubleshooting Diseases of Flowering Plant
Herb Diseases Chart
Chase et al. 1995. *Ball Guide to Diseases of Annuals & Perennials*. Ball Pub., Batavia, IL.
Daughtrey, M. and Chase, A.R. 1992. *Ball Field Guide to Diseases of Greenhouse Ornamentals: Includes Certain Problems Often Misdiagnosed as Contagious Diseases*. Ball Pub., Batavia, IL.
Goodwin, S. et al, 2000. *Integrated Pest Management in Ornamentals: Information Guide.* Agrilink. QAL0004, NSW Agric. Sydney. There is a companion field guide with clear pictures.
Horst, R. K. 2001. *Westcott's Plant Disease Handbook.* 6th ed. Kluwer Academic Pub., Boston, Mass.
Jones, D. L. and Elliot, W. R. 2000. *Pests, Diseases & Ailments of Australian Plants.* Lothian Pub., Sydney.
Keane, P. J. et al. (eds). 2000. *Diseases and Pathogens of Eucalypts*. CSIRO Pub., Collingwood, Vic..
Kerruish, R. M. 1997. *Plant Protection 3: Selected Ornamentals, Fruit & Vegetables.* 2nd edn. RootRot Press, ACT.
Magarey, P. A. et al. 1999. *The Australian and NZ Field Guide to Diseases, Pests and Disorders of Grapes*. Winetitles, Adelaide.
Matheny, N. P. and Clark, J. R. 1994. *A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas.* 2nd edn. Inter. Soc. of Arboriculture, Illinois.
Mathias, P. 1995a. *Handbook of the Major Pests and Diseases of Nursery Plants.* HRDC/NSW Agric., Locked Bag 11, Windsor, NSW 2756.
Persley, D. M. (ed.). 1994. *Diseases of Vegetable Crops.* Qld DPI, Brisbane.
Persley, D. M., Pegg, K. G. and Syme, J. R. (eds). 1989. *Fruit and Nut Crops: A Disease Management Guide*. Qld DPI, Brisbane.
Persley, D. M., O'Brien, R. and Syme, J. R. (eds) 1989. *Vegetable Crops: A Disease Management Guide.* Qld DPI, Brisbane.
Persley, D. M. and Syme, J. M. (eds). 1990. *Field Crops and Pastures: A Disease Management Guide*. Qld DPI, Brisbane.
Pirone, P. P. 1978. *Diseases & Pests of Ornamental Plants*. 5th edn. John Wiley & Sons, NY.
Pyke, B. A. and Brown, E. H. 1996. *The Cotton Pest and Beneficial Guide.* CRDC, Narrabri & CTPM, Brisbane.

Smith, D., Beattie, G. A. C. and Broadley, R. (eds). 1997. *Citrus Pests & Their Natural Enemies: Integrated Pest Management in Australia.* HRDC/Qld DPI, Brisbane. There is an accompanying *Field Guide*.
Wallwork, H. 2000. SARDI/CSIRO, Melbourne. *Cereal Diseases: The Ute Guide* (TOPCROP/GRDC). *Cereal Root and Crown Diseases* (SARDI/CSIRO) *Cereal Leaf and Stem Diseases* (SARDI/CSIRO)
Wood, B. and Grimm, M. *Insect Pests of Wildflowers and Proteas.* Farmnote 90/88 (Agdex 280/620).
Yates. *Yates Garden Guide*. cur. edn. Angus & Robertson, Sydney.

PEST INDEXES

Causes of plant problems

Pests & diseases

Books, articles

Bodman, K. et al. 1996. *Ornamental Plants: Pests, Diseases & Disorders.* Q196001. Qld DPI, Brisbane.
Goodwin, S. et al, 2000. *Integrated Pest Management in Ornamentals: Information Guide.* Agrilink. QAL0004, NSW Agric. Sydney. There is a companion field guide with clear pictures.
Jones, D. L. and Elliot, W. R. 2000. *Pests, Diseases & Ailments of Australian Plants.* Lothian Pub., Sydney. There is a host index at the end which is useful.
Kerruish, R. M. 2003. *Plant Protection 1: Pests, Diseases & Weeds*. 3rd edn. RootRot Press, ACT.
Mathias, P. 1995. *Handbook of the Major Pests and Diseases of Nursery Plants.* HRDC/NSW Agric., Windsor, NSW 2756.
McMaugh, J. 1994. *What Garden Pest or Disease is That?* Lansdowne Pub., Sydney.

Insects & mites, snails & slugs

Websites

www.ento.csiro.au CSIRO Entomology
www.ourgardenpests.com Australian Ants Online
www.ento.csiro.au/Ecowatch Ecowatch
www.entosupplies.com.au Australian Entomological Supplies
www.amonline.net.au Australian Museum Online
www.bugsforbugs.com.au Bugs for Bugs
www.hortnet.co.nz BugKEY (Insects & Mites of Pip & Stone fruits)
www.floraforfauna.com.au Butterflies and moths
www.affa.gov.au/aplc APLC (Australian Plague Locust Com.)
www.cbit.uq.edu.au CBIT (Centre for Biological Information Technology)
www.ces.ncsu.edu *Master Gardener Insect Guide for Ornamental and Turf* (cur. edn) Agric. Extension Service, North Carolina State University AG 433

CD-ROMs

CBIT BugMatch series
Cotton
Citrus
Grapes
Mites in Soil
CBIT Australian Urban Pest Management System
Ozpest
DNRE Insect Pest & Disease Database for Victoria for Forests, Pip Fruit & Stone Fruit
Pest thrips of the world
Victorian Butterflies Database (Crosby, D. and Quirk, N. 1995, Viridans, Brighton, Vic)
CSIRO, Melbourne:
Insects & World of Diversity
Insects: Little Creatures in a Big World.
Beetles of the World
Beetle Larvae of the World
Spiders of Australia

Books, articles

Bodman, K. and Hargreaves, J. 2000. *Whiteflies in Queensland Crops: A Review*. DPI Note, Qld Agdex 290/622.
Braby, M. F. (ed.). 2001. *Butterflies of Australia: Their Identification, Biology and Distribution.* CSIRO, Melbourne.
Broadley, R. and Thomas, M. 1995. *The Good Bug Book. Beneficial Insects and Mites Commercially Available in Australia for Biological Pest Control.* ABC/Qld DPI/RIRDC. Avail. from Bugs for Bugs
Brunet, B. 2000. *Australian Insects: A Natural History.* Reed New Holland, Frenchs Forest, NSW.
Chapman, B., Penman, D. and Hicks, P. 1992. *The Garden Pest Book: An Illustrated Australian Guide.* Viking O'Neil, Ringwood, Vic.
Common, I. F. B. 1990. *Moths of Australia*. Melbourne University Press, Melbourne.
Common, I. F. B. and Waterhouse, D. F. 1981. *Butterflies of Australia*. CSIRO, Melbourne.
Commonwealth of Australia. 2001. *Forests and Timber: A Field Guide to Exotic Pests and Diseases.* AFFA, AQIS, Canberra.
Crefield, J. W. 1996. *Wood Destroying Insects: Wood Borers and Termites*. 2nd edn. CSIRO, Melbourne
CSIRO. (ed). 1991. *Insects of Australia*. 2nd edn. CSIRO, Melbourne.
CSIRO posters CSIRO, *Melbourne. Australian Beetles, Australian Moths & Butterflies, Australian Insects, Australian Spiders, Soil Animals Soil Mites*
Dollin, A. et al. 2000. *Native Bees of the Sydney Region: A Field Guide*. Australian Native Bee Research Centre, North Richmond, NSW.
Fisher, R. 1999. *A Field Guide to Australian Butterflies.* Surrey Beattie, Chipping Norton, England.
Gerozisis, J. and Hadlington, P. W. 2001. *Urban Pest Management in Australia.* 4th edn. UNSW Press, Sydney.
Hadlington, P. W. and Johnston, J. A. 1998. *An Introduction to Australian Insects*. revised edn. UNSW Press, Sydney.
Hadlington, P. W. 2001. *Australian Termites and Other Common Timber Pests*. 2nd edn. UNSW Press, Sydney.
Hadlington, P. and Johnston, J. 1996. *Australian Trees: Their Care and Repair.* UNSW Press, Sydney.
Hangay, G. & German, P. 2000. Insects of Australia. Reed New Holland, Frenchs Forest, NSW.
Harvey, M. and Yen, A. L. 1989. *Worms to Wasps: A Illustrated Guiide to Australias's Terrestial Invertebrates.* Oxford University Press, Melbourne in association with Museum of Australia.
Hely, P. C., Pasfield, G. and Gellatley, J. G. 1982. *Insect Pests of Fruit and Vegetables in NSW*. Inkata Press, Melbourne.
Hopkins, D. and Miles, M. 1996. *Insects*: *The Ute Guide.* TOPCROP. Southern Region, GRDC, Kingston, ACT.
Horne, P & Crawford, D. 2005. *Backyard Insects.* 2nd edn. The Miegunyah Press, Carlton South, Vic.
Kent, D. 1995. *Eucalypt Sawflies*. Forest Protection Series. State Forests of NSW, Sydney.
Kerruish, R. M. 2003. *Plant Protection 1: Pests, Diseases & Weeds*. 3rd edn. RootRot Press, ACT.
Mathias, P. 1995. *Handbook of the Major Pests and Diseases of Nursery Plants.* HRDC/NSW Agric., Windsor, NSW 2756.
Jeppson, L. R., Keifer, H. H. and Baker, E. W. 1994. *Mites Injurious to Economic Plants.* reprint. University of California Press, Berkeley, LA.
Lindsey, T. 1998. *Green Guide: Spiders of Australia.* New Holland, Sydney.
Mathias, P. 1995. *Handbook of the Major Pests and Diseases of Nursery Plants.* HRDC/NSW Agric., Windsor, NSW 2756.
Metcalfe, R. L. and Metcalfe, R. A. 1993. *Destructive and Useful Insects: Their Habits and Control.* 5th edn. McGraw-Hill, New York.

Morgan, F.D. 1984. *Psylloidea of South Australia.* Series: Handbook of the Flora and Fauna of South Australia. SA Government, Adelaide.
Mound, L. A. and Gillespie, P. S. 1997. *Identification Guide to Thrips Associated with Crops in Australia.* NSW Agric./CSIRO, Melbourne.
Naumann, I. D. (ed.). 1993. *CSIRO Handbook of Australian Insect Names: Common and Scientific Names for Insects and Allied Organisms of Economic and Environmental Importance.* 6th edn. CSIRO, East Melbourne. www.ento.csiro.au
New, T. R. 1997. *Name that Insect: A Guide to the Insects of Southeastern Australia*, Oxford University Press, Melbourne.
Moulds, M. 1990. *A Guide to Australian Cicadas*. UNSW Press, Sydney.
Scientific Advisory Services, Bugs for Bugs. www.bugsforbugs.com.au
Fruit Flies of Australia: Major species in Australia - Monitor and Control.
Minor and Non-pest Species in Australia: Eradication and Suppression.
Slater, P. 1997. *Amazing Facts about Australian Insects and Spiders and other Bush and Garden Creatures*. Steve Parish Pub., Brisbane.
Zborowski, P. 2002. *Insects of Australia.* Green Guide series, New Holland, Sydney.
Zborowski, P. 1998. *Field Guide to the Locusts and Related Grasshoppers in Australia*. APLC, GPO Box 858, Canberra, ACT 2601.
Zborowski, P. and Storey, R. 2003. *A Field Guide to Insects in Australia.* 2nd edn. Reed, Chatswood, NSW.
Stanley, J. 2004. *A Three-tiered Approach is Best for Customers*. Aust. Hort., Dec.

Vertebrate pests

Websites

www.ea.gov.au Biodiversity
www.brs.gov.au/ Bureau of Resource Sciences
www.cse.csiro.au/research/rodents CSIRO Rodent Management Research Team
www.nht.gov.au NFACP (National Feral Animal Control Program)

CD-ROMs

Fox/Rabbit Management (resource centre for extension officers)
Mouser (information support on mouse management)

Books, articles

Hall, L. and Richards, G. 2000. *Flying Foxes: Fruit and Blossom Bats of Australia.* UNSW Press, Sydney.
Olsen, P. 1998. *Australia's Pest Animals: New Solutions to Old Problems*. Kangaroo Press, Sydney.

Diseases

Websites

www.apsnet.org/online APSnet On-line Service
www.parasiticplants.siu.edu/ The Parasitic Plant Connection
www.rbg.vic.gov.au/fungimap Fungimap Australia (macrofungi)

CD-ROMs

NemaSYS

Books, articles

ABRS/CSIRO. 1996. *Fungi of Australia*. Melbourne.
Vol.1A. *Introduction – Classification.*
Vol.1B. *Introduction – Fungi in the Environment.*
Vol.2A. *Catalogue & Bibliography of Australian Macrofungi: Basidiomycota.*
Agrios, G. N. 1997. *Plant Pathology*. 4th edn. Academic Press, NY.
American Phytopathological Society. 1978-1993. *Common Names for Plant Diseases 1994*. APS Press, St. Paul, Minnesota.
American Phytopathological Society (APS) Press, St. Paul, Minnesota:
A Plant Disease Video Image Resource
Full Color Disease Note Cards
Identification of Rhizoctonia Species
Air Pollution, People and Plants
Anon. 1996. *New Decay Detection System Uses Ultrasound.* Arborist News, International Soc. of Arbor., Vol.5 (4), Aug.
Anon. *National Collection of Fungi (NCOF).* cur. edn. Database. Agriculture Victoria/NSW Agriculture. Not in the public domain.
Bennett, W. F. (ed.). 1993. *Nutrient Deficiencies & Toxicities in Crop Plants.* APS Press, St. Paul, Minnesota.
Bethge, K., Mattheck, C. and Hunger, E. 1996. *Equipment for Detection and Evaluation of Incipient Decay in Trees.* Arbor. Jrn. Vol.20:13-37.
Boersma, J. G, Cooke, D. E. L. and Sivasithamparam, K. 2000. *A Survey of Wildflower Farms in the south-west of Western Australia for Phytophthora spp. associated with root rots.* Aust. Jrn. of Exper. Agric., 40(7) 1011-1019.
Brown, J. F. and Ogle, H. J. (eds). 1997. *Plant Pathogens and Plant Diseases*. Rockvale Pub., Armidale, NSW.
Brunt, A. A., Crabtree, K., Dallwitz, M. J. and Gibbs, A. J. 1996. *Viruses of Plants*. CABI, UK.
Buchen-Osmond, C., Crabtree, K., Gibbs, A. and McLean, G. (eds). 1988. *Viruses of Plants in Australia*. Research School of Biological Sciences, The Australian National University, Canberra.
Carson, C. 2000. *Testing Your Own Rice Flower Planting Sites for Nematodes.* DPI Note. Qld DPI, Brisbane.
Commonwealth of Australia. *Flora of Australia*. AGPS, Canberra. Vol. 54 & 55. Lichens.
Cooper, J. I. 1994. *Virus Diseases of Trees and Shrubs.* Chapman & Hall, NY.
Cresswell, G. C. and Weir, R. G. 1997. *Plant Nutrient Disorders 5: Ornamental Plants and Shrubs.* Inkata Press, Melbourne.
Cresswell, T. 2001. *Collecting Plant Samples*. Grounds Maintenance, March.
Fahy, P. C. and Persley, G. J. 1983. *Plant Bacterial Diseases: A Diagnostic Guide.* Academic Press, North Ryde, NSW.
Fleer, F. L. and Linder man, R. G. (eds). 1994. *Mycorrhizae and Plant Health.* APS Press, MN.
Grgurinovic, C. A. 1998. *Larger Fungi of South Australia*. Botanic Gardens, South Australia.
Hadlington, P. W. and Johnston, J. A. 1988. *Australian Trees: Their Care and Repair*. NSW University Press, Sydney.
Handreck, K. 2001. *Gardening Down-Under: A Guide to Healthier Soils and Plants.* 2nd edn., CSIRO, Melbourne.

Handreck, K. and Black, N. *Growing Media for Ornamental Plants & Turf.* cur. edn. NSW University Press, NSW.
Harrison, B. D. and Murant, A. F. (eds). 1996. *The Plant Viruses*. Vol. 1-5. Plenum Pub., NY.
Horst, R. K. 2001. *Westcott's Plant Disease Handbook*. 6th ed. Kluwer Academic Pub., Boston, Mass.
Hull, R. 2002. *Matthews' Plant Virology.* Academic Press, NY.
Jones, D. L. and Elliot, W. R. 2000. *Pests, Diseases & Ailments of Australian Plants.* Lothian Pub., Sydney.
Katterman, F. (ed.). 1990. *Environmental Injury to Plants*. Academic Press, CA.
Kerruish, R. M. 2003. *Plant Protection 1: Pests, Diseases & Weeds*. 3rd edn. RootRot Press, ACT.
McMaugh, J. 1994. *What Garden Pest or Disease is That?* Lansdowne Pub., Sydney.
O'Brien, P. C. and Stirling, G. R. 1991. *Plant Nematology for Practical Agriculturalists*. 3rd end. Qld DPI, Brisbane.
Orchard, A. E. (ed.). 1996. *Fungi of Australia Series.* ABRS/CSIRO, Melbourne.
Reuter, D. J. and Robinson, J. B. 1997. *Plant Analysis: An Interpretation Manual.* 2nd ed. CSIRO Publishing, Melbourne.
Shepherd, C. J. and Totterdell, C. J. 1988. *Mushrooms and Toadstools of Australia*. Inkata Press, Melbourne.
Stirling, G. F. 2000. *Nematodes Monitoring Strategies for Vegetable Crops.* No.00/25. RIRDC, Barton, ACT.
Stirling, G., Nicol, J. and Reay, F. 1999. *Advisory Service for Nematode Pests: Operational Guidelines.* Pub.No.99/4. RIRDC, Barton, ACT.
Weir, R. G. and Cresswell, G. C. 1992a. *Plant Nutrient Disorders 1: Temperate and Subtropical Fruit and Nut Crops.* Inkata Press, Melbourne.
Weir, R. G. and Cresswell, G. C. 1992b *Plant Nutrient Disorders 3: Vegetable Crops.* Inkata Press, Melbourne.
Weir, R. G. and Cresswell, G. C. 1994 *Plant Nutrient Disorders 4: Pastures and Field Crops.* Inkata Press, Melbourne.
Weir, R. G. and Cresswell, G. C. 1995. *Plant Nutrient Disorders 2: Tropical Fruit and Nut Crops.* Inkata Press, Melbourne.

Weeds

Websites

www.weeds.org.au Weeds Australia
www.weedinfo.com.au Weed information (identification, management, catalogue)
www.weeds.crc.org.au CRC Weed Management
www.hear.org/gcw Global Compendium of Weeds

CD-ROMs

Blackberry
Crop Weeds of Australia
Declared Plants of Australia
Noxious weeds
Suburban & Environmental Weeds
WeedBiocontrol: the theory and practical application of biological control of weeds

Books, articles

Auld, B. A. and Medd, E. W. 1987. *Weeds: An Illustrated Botanical Guide to the Weeds of Australia.* Inkata Press, Melbourne.
Blood, K. 2001. *Environmental Weeds: A Field Guide for South-eastern Australia*. ANCA/NRE, Melbourne.
Blood, K. 2001. *Environmental Resource Directory For Victoria.* ANCA/NRE, Melbourne.
Blood, K. 1999. *Future and Expanding Weeds.* Plant Protection Quarterly Vol.14(3).
CRC Weed Management Systems, Waite Institute, Adelaide. Publications include:
Weed Watch. External Newsletter of the CRC Workshops
Weed Navigator Resource Guide
Weed Navigator Contact Directory
The National Weeds Strategy
Various weed societies in Australia
Csurhes, S. and Edwards, R. 1998. *Potential Environmental Weeds in Australia: Candidate Species for Preventative Control*. Environment Australia, GPO Box 636, Canberra.
Friend, T. E. 1983. *Queensland Weed Seeds.* Qld DPI, Brisbane.
Harvey, J. 1991, *Weeds of Central Queensland.* Qld DPI, Brisbane.
Hussey, B. M. J. et al. 1997. *Western Weeds: A Guide to the Weeds of Western Australia.* Plant Protection Soc. of WA, Perth.
Kerruish, Ruth M. 2003. *Plant Protection 1: Pests, Diseases & Weeds*. 3rd edn. RootRot Press, ACT.
Lamp, C. A., Forbes, S. J. and Cade, J. W. 1990. *Grasses of Temperate Australia: A Field Guide.* Inkata Press, Melbourne.
Lamp, C. and Collet, F. 1999. *A Field Guide to Weeds in Australia.* Inkata Press, Melbourne.
Lazarides, M., Cowley, K. and Hohnen, P. 1997. *CSIRO Handbook of Australian Weeds*. CSIRO, Melbourne.
Moerkerk, M. and Barret, A. G. 1998. *More Crop Weeds*. R. G & F. J Richardson, Meredith, Vic.
Muyt, A.C. 2001. *Bush Invaders of South-East Australia: A Guide to the Identification and Control of Environmental Weeds Found in South-East Australia.* R. G. and F. J. Richardson, Meredith, Vic.
National & Regional Ute & Field Guides include:
WeedDecks which consist of individual weed cards each with a clear description and colour photos of different stages of growth.
Weeds: The Ute Guide – The Northern Grain Belt. TOPCROP.
Parsons, W. T. and Cuthbertson, E. G. 2001. *Noxious Weeds of Australia*. 2nd edn. CSIRO, Melbourne.
Sainty, G., Hosking, J. and Jacobs, S. (eds). 1998. *Alps Invaders: Weeds of the Australian High Country.* Australian Alps Liaison Committee. Saint & Assoc., Darlinghurst, NSW.
Wilding, J. L., Barnett, A. G. and Amor, R. L. 1986. *Crop Weeds*. Inkata Press, Melbourne.
Wilson, B. J.. Hawton, D. and Duff, A. A. 1995. *Crop Weeds of Northern Australia.* Qld DPI, Brisbane.

GLOSSARY AND ACRONYMS

Abiotic Non-living.

Accreditation Formally authorized.

ACRA Australian Cultivar Registration Authority.

Adventitious Normal buds arising from unusual places in the plant allowing regeneration after damage.

Aerobic A microorganism that lives, or a process that occurs, in the presence of molecular oxygen.

Agar A gelatin-like material obtained from seaweed and used to prepare culture media on which micro-organisms are grown and studied.

AIRA Australian & International Registration Authority.

Algae. Microscopic green plants which occur naturally in soil and water, having a simple plant body, but no roots, stems or leaves.

Allelopathy The release of chemicals by a species of plant into the environment, which interferes with surrounding plants.

Amendment Any substance added to the soil to improve its physical properties.

Anaerobic A microorganism that lives, or a process that occurs in the absence of molecular oxygen.

Analysis The determination of the simple elements of something complex.

ANBG Australian National Botanic Gardens.

Annual A plant that completes its life cycle in one year.

Ant A chewing insect (Order Hymenoptera).

Anthracnose. Brown and sunken ulcer-like lesions on the stem, leaf, flower or fruit caused by fungi; asexual spores are produced in an acervulus.

Aphid A sap-sucking insect (Order Hemiptera).

APVMA Australian Pesticide and Veterinary Medicine Authority.

AQIS Australian Quarantine and Inspection Service.

Armyworms The larvae of moths belonging to the Family Noctuidae (Order Lepidoptera).

Arthropoda A Phylum in the Animal Kingdom, members have a segmented body, hard outer covering with flexible joints for movement, 3 pairs of legs and bilateral symmetry (each side of the body is a mirror image of the other).

Assay To test, to put to the proof.

Audit An official verification of a process.

AUSVEG The national peak industry body representing vegetable and potato growers.

AusVit A set of software applications (modules) that combine to form the AusVit Vineyard Management System (AVMS), a computerized Decision Support System designed as a management tool.

Bacterium (pl. bacteria) A single-celled microscopic organism lacking chlorophyll and which multiplies by simple cell division.

Bag shelter Leaves of plants bound together by silk produced by caterpillars which shelter within.

Baiting Floating plant material, eg lupin baits, on the surface of a representative sample of soil, media or water to observe for fungal invasion and rotting indicating the presence of disease organisms, eg *Phytophthora*.

Bee A beneficial insect (Order Hymenoptera).

Beetle A chewing insect (Order Coleoptera).

Beneficial insect An insect that is useful or helpful to humans, eg pollinators, parasites, predators of pests.

Best Management Practice Environmentally-sound management of pests, diseases and weeds.

Biogeography The study of the distribution of plants and/or animals.

Biennial A plant that completes its life cycle in 2 years. It grows vegetatively for 1 year then flowers, seeds and dies in the 2nd year.

Bioassay The use of a test organism to measure the relative infectivity or toxicity of a substance.

Biochemical test A test pertaining to living cells, tissues or organisms.

BIOLOG An identification system for bacteria, or of the substances utilized by bacteria for food.

Biological control Classical biological control is the deliberate use of a pest, disease or plant's natural enemies to control a particular pest, disease or weed.

Biotic Living.

Bleaching To whiten or become colourless, caused by sun exposure, herbicide injury.

Blight A general and extremely rapid browning of the leaves, flowers, branches or twigs resulting in their death, caused by fungi, insects, frost or other agents.

Blister Raised area on leaves or fruit, may be caused by blister mites, leafmining insects, fungal disease, frost.

Blotch Dead areas on leaves and fruit which may cover most of the plant, be irregular in shape or form patterns other than spots, caused by bacteria, fungi, leafmining insects, sunscorch, or other agents.

BMP Best Management Practice.

Bolting Prematurely running to seed.

Borers The chewing larvae of moths and beetles and occasionally wasps, which feed internally in trunks, limbs, branches, stems and roots of trees and shrubs.

Breaking Loss of flower color resulting in a variegated flower, usually caused by virus diseases.

Broad–leafed plants See Dicotyledons.

Bronze Metallic brown colour.

Brown patch A fungal disease of turf.

Brown rot diseases Fungal diseases of citrus and stone fruit.

Bud bank The buds on perennial weed structures, eg rhizomes, that perform a similar function to seed banks.

Bud drop A mass dropping of buds before they open, not necessarily a symptom of disease.

Bug A sap-sucking insect (Order Hemiptera).

Bugmatch A series of keys to identify various insects.

Butterfly An insect belonging to the Order Lepidoptera.

Callus The mass of cells which usually develop as a result of a wound.

Calyx The outermost whorl of flower parts, the sepals collectively.

Cambium Thin layer of longitudinal cells between the xylem and phloem that gives rise to growth.

Canker Dead, sunken ulcer-like lesion on a branch, stem or twig, eg bacterial canker of stone fruit.

Case study Study of a plant problem as an example.

Caterpillar Larva of a moth or butterfly (Order Lepidoptera).

Cause That which brings about the problem, eg an insect.

CBIT Centre for Biological Information Technology, University of Queensland.

CCFM Conservation Council and Forestry Ministers.

Certification schemes To guarantee something, eg that plant material is free from the diseases for which it has been tested.

Chewing damage Caused by insects or snails, feeding externally or internally on leaves, stems, shoots, fruit, flowers and other plant parts.

Chimera A tissue segment with a different genetic makeup, eg a different colour from adjacent cells.

Chitin A hard substance forming the outer coat of insects, mites, slaters, millipedes, centipedes, spiders.

Chlorosis See Yellowing.

Cicada A sap-sucking insect (Order Hemiptera).

Class A division of a plant or animal Order.

Classification A systematic arrangement of plants and animals into groups based on general characteristics then subdivided according to specific differences.

CLIMEX A computer software package that predicts spread of pests, diseases, weeds, beneficial organisms.

Cockroach A chewing insect (Order Blattodea).

Conditions favoring The specific conditions which favour development of a pest, disease or weed.

Conidia An asexual fungal spore.

Contact herbicide A herbicide active at the point of application (leaves, stems, roots) which does not move into plants.

Crawler The 1st stage nymph of a some insects, eg scales, which can crawl a short distance before settling and becoming stationary.

Cricket A chewing insect (Order Orthoptera).

CRC Co-operative Research Centre.

Critical weed density The minimum number of weeds worth spraying in a crop which will give a return to cover cost of spray and application.

Cultivar A cultivated variety.

Culture **1.** To artificially grow microorganisms or plant tissue on prepared food material. **2.** A colony of microorganisms or plant cells maintained on such food material.

Cutworm The larva of moths belonging to the Family Noctuidae (Order Lepidoptera).

Damage Generally refers to plant damage clearly visible to the naked eye, eg chewing, skeletonizing.

Damping-off A fungal disease that rots seeds and seedlings before or after emergence from the soil. May be caused by fungi, bacteria or other agents.

DED Dutch elm disease.

Defoliation The premature fall of leaves caused by insect, mites, diseases and non-parasitic agents.

DELTA Description Language for Taxonomy.

Desiccant A chemical that promotes drying or loss of moisture from leaves or other plant parts.

Detection To detect the presence of an organism or some other causal agent.

Diagnosis Identification of a disease by investigation of its symptoms (Oxford Concise Dictionary.

Diagnostician One skilled in diagnosis.

Diagnostic road map A diagram illustrating steps that may be followed when diagnosing plant problems.

Diagnostic test See Test.

Dichotomous keys Keys with usually only two choices.

Dicotyledons Flowers that have 2 seed leaves, floral parts mostly in 5s, sometimes 4s, plants woody or herbaceous, leaves mostly reticulate, often tap root.

Dieback Progressive death of shoots and branches beginning at the top of the plant which may be caused by insects, bacteria, fungi or other agents.

Disease Any condition of a plant that interferes with its normal structure, functions, or value.

Disease cycle See Pest cycle.

Disease signature See Pest signature.

Disease-tested planting material Plant material free from specified diseases and pests for which it has been tested.

Distortion Misshapen plant parts including buds, flowers, fruit and trunks.

DNA Deoxyribonucleic acid, a component of the nucleus of all cells.

DNA fingerprint The unique sequence of any organism's DNA.

Dollar spot A fungal disease of turf.

Downy mildew A fungus in which spores appear as white or grey downy growth on leaf undersurfaces, stems and fruit.

DPI Department of Primary Industry.

Dragonfly A beneficial insect (Order Odonata).

Dry patch A disease of turf.

Earwig A chewing insect (Order Dermaptera) which feeds mostly on organic matter, occasionally on petals.

Early warning service The monitoring of temperature, moisture and other parameters which favour pest development, so that growers can apply preventative control measures (pest predictive service).

EC Electrical conductivity, used to measure soil salinity.

ELISA (Enzyme-Linked Immunosorbent Assay) A serological test in which one antibody carries an enzyme that releases a coloured compound indicating a positive result. Used to identify viruses, bacteria and fungi.

Ectoparasite A parasite living on the outside of a host.

Electron microscope A scientific instrument that uses a beam of electrons instead of light to 'image' the specimen and produce information on its structure.

Electrophoresis A technique in which molecules are separated by their rate of movement in an electric field across a porous medium, eg DNA fragments are separated by size.

Endophyte A beneficial fungus or a bacterium growing systemically in grasses, causing few or no symptoms, but protecting them from diseases and pests, while improving growth and drought tolerance.

Environment Conditions such as temperature, moisture, light, wind, which influence the growth of plants and development of pests, diseases and weeds.

Environmental weed A cultivated plant which invades natural ecosystems threatening indigenous biodiversity.

Epicormic buds Small buds close to or just above the surface of bark, capable of sprouting, when the tree is damaged in some way.

Epidemiology. Factors affecting the outbreak and spread of infectious diseases in plants and animals.

ESD Ecologically Sustainable Development.

Etiolation A yellowing of tissue and elongation of stems, usually caused by reduced light or darkness.

EUCLID An interactive identification and information key to the eucalypts of Australia.

Evaluate To work out the value or the worth of something, to find a numerical expression.

Evidence Proof.

Excreta The waste products of insects, animals.

EXNUT An expert management system for irrigated peanut production.

EXSYS A prototype expert system for diagnosis of forestry nursery problems to improve production.

Expert system A system which captures the knowledge of an expert in an IT (Information Technology) system.

Family A group of allied genera which can be a sub-division of an Order.

Fasciation A plant abnormality on any part of the plant characterized by a flattening of the affected part.

Fatty acid profiling An automated analysis of fatty acid profiles of bacteria for taxonomic purposes.

Fertigation Application of nutrients to a crop in irrigation water.

Field diagnosis Diagnosis of a problem from observations and information gained during a site visit when conditions favouring a certain pest are observed.

Fireblight A bacterial disease of pome and stone fruit, some other Rosaceae and other species.

Fleck A fungal disease of apples, pears, Rosaceae.

Flowchart A diagram of the stages of a process of connected activities leading to a result.

Fly An insect belonging to the Order Diptera.

Frass Solid or liquid food and waste particles passed out through the anus of an insect, usually seen on leaves, flowers, and at exit holes on trunks, fruit or other plant parts; may be 'sawdusty' in appearance; often used to describe any insect remains, eg, nymph skins of aphids.

Freckle A fungal disease of stone fruit.

Fruiting body A complex fungal structure containing spores, eg a mushroom. Many are too small to be seen with the naked eye.

Fungus (pl. fungi) A simple plant with a mycelium as a body, possesses no chlorophyll and reproduces by spores; in a separate kingdom of their own.

Gall A swelling, more or less spherical, of unorganized plant cells occurring on any part of the plant, as a result of infection by fungi, other disease organisms or infestation by insects.

Genetic engineering (GE) Transfer of genes from plants, animals, viruses, bacteria and fungi to other plants and organisms where these genes do not normally occur.

Genus A classification group of a number of species possessing certain common characters, distinct from those of any other group, ranking next under family and above species.

GMO Genetically modified organism.

Gram-negative Bacteria which do not retain a violet stain.

Gram-positive Bacteria which retain a violet stain.

Grasshopper A chewing insect (Order Orthoptera).

GRDC Grain Research & Development Corporation.

Greening Floral parts are green, usually caused by a phytoplasma disease (tomato big bud).

Grey mould A fungal disease caused by the fungus *Botrytis cinerea*.

Grow-on test A test used to confirm certain non-parasitic problems where plants recover after initial exposure compared to pathogen-related problems which persist into new growth.

Grubs Thick-bodied larvae of beetles and weevils (Order Coleoptera) and butterflies and moths (Order Lepidoptera).

Gumming, gummosis An obvious secretion of gum which may be caused by bacterial or fungal diseases, insect pests or other agents.

Halo A circle of coloured plant tissue, often yellowish, which occurs around some sap-sucking scale insects, leaf spots and other agents.

Herbarium (pl. herbaria) A reference collection of preserved, pressed and named plants.

HERBASYS A herbicide advisory system.

Honeydew An excretion of some sap-sucking insects (aphids, bugs, leafhoppers, lerp insects, mealybugs, scales, whiteflies), with a high carbohydrate, sugar and nitrogen content attractive to ants. Black sooty mould grows on it.

Hormone herbicide A herbicide belonging to the phenoxy aliphatic acid group, eg 2,4-D, MCPA, and benzoic acids, eg dicamba, which are active against broad-leafed weeds. They act in a similar manner to the natural plant hormone auxin.

Host A plant on, or in which, a pest or parasite lives.

Host index. A reference in which plants are listed alphabetically, by accepted common and/or scientific names.

Host range Plants attacked by a pest or disease.

Humidity The concentration of water vapour in the air.

Hyphae Single branches of a fungal mycelium.

ICBN International Code of Botanical Nomenclature.

Identification and identify To identify a plant, pest, disease or weed or other organism by its scientific name.

Image-matching Comparing illustrations and photographs of a an organism with a fresh, dried sample or photograph of an organism for identification purposes.

Immune Ability of a plant to remain completely free from attack by specified diseases and pests.

INCP International Nomenclature of Cultivated Plants.

Indexing A procedure used to determine whether a given plant is infected with a virus by transferring a bud, scion or sap from an suspect plant to one or more kinds of (indicator) plants that are sensitive to the virus.

Indicator plants A plant that reacts to certain viruses, insect feeding or environmental factors with the production of specific symptoms and is used for detection and identification of these agents.

Infection The establishment of a parasite within a host plant.

Infectious disease Caused by a pathogen which can spread from a diseased plant to a healthy one.

Infestation 1. The arrival and multiplication of pest populations causing plant damage. **2.** Can also refer to established pest populations.

Insect Arthropod with 3 body segments, 3 pairs of legs on thorax, 1 pair antennae, with or without wings.

Insects & allied organisms Insects and related animals, eg springtails, mites, spiders, slaters and millipedes, belonging to the Phylum Arthropoda.

INSV Impatiens necrotic spot virus.

Integrated Pest Management (IPM) The systematic management of pests, diseases and weeds with consideration for the environment.

Internode The section between where a leaf is attached or has been attached.

IPM Integrated pest management.

Invasive A pest or plant which colonizes and persists in an ecosystem in which it did not occur before.

Isolate 1. A single spore or culture and the subcultures derived from it. **2.** Also used to indicate collections of disease organisms made at different times.

Isozyme Different forms of the same enzyme.

Key A key is a device that unlocks something. A key is a tool which can be used to identify plants, weeds, insects, fungi and other micro-organisms. Keys use the process of elimination where the user is presented with a series of observations that describe features of the object.

Kino pocket Small hollow in the wood of eucalypts filled with gum or resin, that may limit its use.

Koch's rules Procedures used to prove that a particular disease organism causes a specific disease; not much used today due to new technology.

Lace bug A sap-sucking insect (Order Hemiptera).

Lacewing. A predatory insect (Order Neuroptera).

Larva (pl. larvae) The growing worm-like stage of insects with a complete metamorphosis, eg butterflies, moths, flies, beetles, sawflies, lace wings.

Latent infection An attack by a disease organism which does not show any symptoms, eg some viruses.

Leaf curl, leaf cupping Distortion and malformation of leaves and shoots caused by insects, diseases, herbicide injury and other agents.

Leafhopper A sap-sucking insect (Order Hemiptera).

Leaf insect A chewing insect (Order Phasmatodea).

Leafmining Damage caused by the larvae of insects feeding internally between lower and upper leaf surfaces, eg moths, sawflies, flies, beetles.

Leaf rolling An obvious rolling of leaves caused by a insects, mites, cold weather, lack of water, other agents.

Leaf scorch Dead areas of various shapes on leaves, which may be caused by heat, lack of water or other agents, eg insects, fungal and bacterial diseases.

Leaf spot A self-limiting lesion on a leaf, commonly caused by fungal diseases but also by other agents.

Lerp A sap-sucking insect (Order Hemiptera).

Lesion A local spot of diseased tissue on a leaf, fruit, trunk or other plant part.

Lichen A combination of a fungus and an algae in which the two components are interwoven to form what appears to be a single individual.

Life cycle The stage, or successive stages, in the growth and development of an organism that occur between the appearance and the re-appearance of the same stage, eg spore, egg.

Lignotubers Gall-like swellings at the base of some eucalypt stems, or at or below ground level, with dormant buds which may sucker after top growth is lost due to fire, etc. May occur in other species.

Line pattern Lines of light coloured tissue on normal coloured leaves caused by some virus diseases.

Locust A chewing insect (Order Orthoptera).

Lodging The bending and falling of plants, especially cereals, at or near the soil surface, on to the ground.

Looper A caterpillar that loops its body as it moves (Order Lepidoptera).

LucID Professional The Lucid family of software used to create identification and diagnostic keys.

Lure A chemical that attracts a pest to a trap, bait or to a lethal deposit of pesticide.

Maggot Legless larva of flies (Order Diptera).

Mantid A predaceous insect (Mantodea), also called mantids, praying mantids.

Masked symptoms Absence of symptoms on virus-infected plants under certain environmental conditions, but which appear when the plant is exposed to certain conditions of light and temperature.

Mealybug A sap sucking insect (Order Hemiptera).

Mechanical injury Physical injury due to insects, wind, vehicles, other agents.

Melanose A fungal disease of citrus.

Metamorphosis The process of change from egg to adult.

Microorganism A small organism that cannot be seen without the aid of a microscope, eg bacteria.

Mildew Fungal diseases with conspicuous mycelium or spore mass, on the host plant surface, eg downy and powdery mildews, grey mould.

Millipede An small animal belonging to the Phylum Arthropoda. (Insects & Allied Organisms).

Mite A tiny sap-sucking animal with 8 legs, a body divided into 2 parts, no antennae, belonging to the Phylum Arthropoda (Insects & Allied Organisms).

Monitoring A program of sampling, inspecting and recording which aims to detect, locate, identify and quantify potential pests, diseases, pests and weeds and their natural enemies at an early stage of infestation and record any changes in levels of pest infestation and spread which may indicate the need for, or effectiveness of, treatment.

Monocotyledons Flowers that have only a single seed leaf. Floral parts mostly in 3s, mostly herbaceous, leaf veins mostly parallel, roots usually fibrous.

Morphology The study of form and its development; structure.

Mosaic Irregular light and dark areas in leaves (mottling) caused by many virus & virus-like diseases.

Moth An insect belonging to the Order Lepidoptera.

Mottle See Mosaic.

Mould See Mildew.

Moult The shedding of skin by insects, mites and other animals as they grow.

Mummified fruit Dried wrinkled fruit resistant to breakdown by other organisms.

Mutation An abrupt appearance of a new characteristic as the result of an accidental change in a gene or chromosome.

Mycelium (pl. mycelia) The hyphae or mass of hyphae that make up the vegetative body of a fungus.

Mycorrhiza A symbiotic association of a fungus with the roots of a plant.

Narrow-leafed plants See Monocotyledons.

Natural enemy A naturally occurring beneficial organism which controls or suppresses a pest.

Necrosis, necrotic Death of plant cells, tissue turns brown, dark colored, and may appear sunken.

Needle cast The copious shedding of needles caused by certain fungal diseases of conifers.

Nematode An unsegmented generally microscopic, round worm (Class Nematoda).

NIASA Nursery Industry Accreditation Scheme, Australia

Node Enlarged region of stems that are generally solid where leaves are attached and buds located.

Non-parasitic Describes plants and animals which damage plants in some way other than by obtaining food from them; includes agents such as environment, nutrient deficiencies and excesses, mechanical injury, chemicals, genetic causes. They are not infectious and do not spread from affected to healthy plants.

Non-target organisms Accidental victims directly or indirectly affected by control measures.

Noxious weed A plant defined by law as being economically troublesome, undesirable and difficult to control. Also called a declared or proclaimed weed.

NRM Natural Resource Management.

NRM Natural Resources and Mining (Queensland).

NSOBP National Standard for Organic and Bio-Dynamic Produce.

Nymph The growing stage of insects with a gradual metamorphosis, eg aphid.

Obligate parasite A parasite that in nature can only grow and multiply on or in living organisms.

Oedema Small masses of tissue which expand and break out on plant parts (mostly on leaf undersurfaces) causing a watery swelling or small galls The exposed surface may become rusty, raised or scabby. Occurs when the plant absorbs more water through the roots than it can transpire through the leaves.

On-site diagnostic tests Tests carried out in the field during a site visit.

Ooze Liquid discharge from diseased or injured tissue. May occur with bacterial or fungal diseases, some insect infestations, pruning or other injury. Some plants ooze naturally.

Order Individuals with some common characteristics, a subdivision of a class.

Overwintering The method by which a pest, disease or weed carries over from one growing season to another.

Ozone A gas within a layer of the upper atmosphere which is spread fairly evenly around the globe absorbing dangerous UV rays from the sun preventing injury to plant, animal and human life.

OZPEST An interactive CD-ROM of insect identification keys for pest control operators.

PALMS An expert database for palms.

Parasitic A plant, animal or micro-organism living in, on or with another living organism for the purpose of obtaining all or part of its food.

Pathogen An organism that causes disease.

Pathogenicity The capability of a disease organism to cause disease.

Pathovar (p.v.) In bacteria, a subspecies or group of strains that can infect only plants within a certain genus or species.

Patterns Certain patterns of pests, diseases and weeds in the field and in the surrounding plants.

PBR Plant Breeders Right.

PCR (polymerase chain reaction) A technique that allows an almost infinite multiplication of a segment of DNA for which a short piece of DNA is available.

Perennial A plant which lives for 3 years or more and may be short-lived or long-lived. Some may be classified as woody species or herbaceous.

Pest A term used to include 'any species, strain or biotype of plant, animal or pathogenic agents injurious to plants or plant products' (International Plant Protection Convention (IPPC).

Pest calendar A reference to the week/month of the year when pests occur.

Pest cycle Describes each stage of the life cycle of the pest and where it occurs (leaves, soil, etc).

Pesticide A chemical or other agent used to kill, control or suppress pests.

Pest index A reference in which pests, diseases or weeds, are listed alphabetically according to their accepted common and/or scientific names.

Pest information sheet Details of the scientific name, host range, significance, diagnostic descriptions, tests, measurements, pest cycle, spread, conditions favouring and recommended control methods of any given pest or other agent.

Pest management See Integrated Pest Management.

Pest predictive service See Early Warning Service.

Pest signature The information in a pest, disease or weed information sheet which is used to provide, confirm or reject a diagnosis.

Pest triangle A depiction of interactions between an affected plant, a pest or disease and the environment.

Petal, flower or blossom blights Fungal diseases which infect flowers.

Petal A member of the inner whorl of flower parts, often brightly coloured.

pH A convenient way to write the concentration of hydrogen ions in a solution, ie pH 1-7 acid; pH 7-14 alkaline.

Phasmatid A chewing insect (Order Phasmatodea).

Pheromone A substance emitted by an animal that influences the behaviour of other animals of the same species, may be synthetically produced for insect traps.

Phloem Tissues which transport nutrients from the leaves which produce them to other plant parts.

Phylum A division of the plant and animal kingdom.

Phytoplasmas Bacteria-like organisms that infect plants, but cannot yet be grown in culture. As they behave rather-like virus diseases, in this book they are included in the group virus & virus-like diseases.

Phytosanitary Any legislation, regulation, or official procedure which prevents the introduction and/or spread of quarantine pests.

Picture-matching See Image matching.

Pigmentation Development of pigments other than chlorophyll in leaves, flowers and fruit as a result of insect infestations, disease, weather or other agents.

Pistil The seed-bearing organ of a flower; consists of the stigma, style and ovary.

Plant growth regulator A substance which accelerates, retards or alters the natural development of any vegetation.

Plant quarantine Legislative control against the introduction and dissemination of weeds and pests and diseases of plants into new areas. May involve isolation, inspections, treatments and destruction of contaminated plants or their parts.

Post-emergent herbicide A herbicide applied after weeds have appeared through the soil.

Powdery mildew A fungus which produces white, powdery spores on upper leaf surfaces, stems, flowers, fruit. May also infect lower leaf surfaces.

Praying mantid A predatory insect (Mantodea), also called mantids, praying mantids.

Predator An animal that attacks, kills and feeds on other animals.

Pre-emergent herbicide A herbicide applied before weeds have appeared through the soil.

Primary pest or disease An agent that initially stresses the plant and starts the decline process, predisposing the plant to secondary agents.

Probe A device used to investigate and obtain information, eg soil testing probes.

Prognosis A forecast of the probable course of a disease.

Proof of diagnosis Written evidence that provides, confirms or rejects a diagnosis.

Protocol A negotiated formal procedure drawn up and recorded.

Provenance(s) Populations of a species from different regions, individual trees within provenances, and even different branches of one tree.

Pupa (pl. pupae) The stage during which an insect with a complete metamorphosis transforms from the larval to the adult stage.

Pustule A small blister-like elevation of epidermis created as spores from underneath push outwards.

QA Quality Assurance.

Qualitative assessment A formal description of the quality of any given factor.

Quality Assurance Having in place standards to consistently and repeatedly produce desired outcomes.

Quantitative assessment A precise numerical measurement, ie pest populations.

Quarantine See Plant Quarantine.

Race **1.** A genetically and often geographically distinct mating group within a species. **2.** A group of pathogens that infect a given set of plant varieties.

Record Permanent evidence in 'writing' of an account of a process and its results.

Red thread A fungal disease of turf.

Registered trade mark A legal symbol of a commodity.

Resistance (host plant) Ability to suppress or retard the activities of one or more specified pest organisms.

Resistance (pest, disease or weed) A population of organisms that are unaffected by a certain dosage of chemical used to control other populations of the same organisms successfully.

Rhizobium A genus of symbiotic bacteria in roots of legumes which fix nitrogen that is used by the plant.

Rhizomorph A root-like strand of fungal hyphae, spreading for long distances through soil, along or under bark of woody plants, eg *Armillaria* spp.

RHS Royal Horticultural Society.

RIRDC Rural Industries Research & Development Corporation.

Ringspot Yellowish rings with green tissue in the centre, on leaves, fruit, caused by some virus & virus-like diseases.

Risk assessment The process of assessing whether a pest, disease or weed is likely to become a major pest.

RNA Ribonucleic acid.

Road map See diagnostic road map.

Root hair An absorptive, unicellular protuberance of an epidermal cell of a root.

Rot A decay or decomposition of plant tissue affecting roots, trunks, fruit, bulbs, seed, caused by bacteria, fungi, water-logging or other agents.

Russet Development of brown, roughened areas on the skin of fruit due to the formation of cork, caused by mites, virus diseases, powdery mildew, frost.

Rust A fungus which causes a disease characterized by orange brown spore masses.

Salinity The amount of soluble salt in a soil. Saline soils are defined as those in which the concentration of soluble salts in the water between the soil particles is sufficient to restrict plant growth.

Sample A relatively small quantity of material or an individual object, from which the quality of the mass, group or species, etc, which it represents, may be inferred.

Saprophyte An organism which lives on dead and decaying organic matter.

'Sawdust' See Frass.

Sawfly An insect belong to the Order Hymenoptera.

Scab Localized lesion on leaves, fruit, corms, usually slightly raised.

Scale A sap-sucking insect (Order Hemiptera).

Scientific name The internationally accepted formal name of animals and plants, ie genus, species.

Sclerotium (pl. sclerotia) A hard compact mass of fungal threads, that are dark brown on the outside when dry and can survive unfavourable conditions.

Scorch Dead, 'burnt' areas on leaves and fruit, which may cover nearly the entire plant, irregular in shape, or form patterns (other than spots). May be caused by insects, disease, environmental conditions.

Scout Someone who monitors crops.

Scouting is the monitoring of crops for pests, diseases, beneficial organisms and weeds.

Scum Black or green algae affecting turf areas where soils stay wet for long periods, not parasitic.

Secondary pests and diseases Pests or diseases which attack plants already stressed by a primary agent, eg drought.

Secretions. Substances produced by special glands, eg wax, webbing.

Seed banks Persistence of existing seeds in the soil, allowing weeds to re-invade.

Sepal Outermost series of floral parts, usually green, leaf-like, collectively form the calyx.

Serology Using the specificity of an antigen-antibody reaction for the detection and identification of antigenic substances and the organisms that carry them. Used to identify viruses, bacteria and fungi.

Shothole Small spots on leaves which fall away to leave small holes. Used to describe types of fungal diseases but may also be caused by other agents.

Sign The presence of an insect, fungus, snail or other agent which may be the cause of a problem.

Silk Produced by caterpillars of butterflies and moths from special glands in the mouth to construct cocoons and bind leaves together and for dispersal. Spider mites also produce silk from mouth glands, they crawl over it and fasten their eggs to it. Spiders produce silk for their webs from spinnerets at the end of their body.

Silvering Leaves become silvery in appearance instead of the normal green colour, most commonly caused by thrips rasping and sucking leaf surfaces, but is also caused by senescence and other agents.

Site An area under investigation, eg field, nursery, greenhouse, landscape area.

Site map A map of a site showing the topography, structures, fences, aspect and distribution of any pests, diseases or weeds, where samples were collected and where on-site tests were carried out.

Skeletonization Chewing insects and snails feeding externally on the surface of leaves, leaving only veins.

Slater An small animal belonging to the Phylum Arthropoda (Insects & Allied Organisms).

Sleeper weeds Weeds that appear benign for many years then suddenly spread rapidly.

Slime mould A very simple fungus.

Smut A parasitic fungus disease characterized by black sooty spore masses in seeds and on leaves.

Snail An animal belonging to the Phylum Mollusca.

Sodicity The amount of sodium in soils.

Sooty mould The dark hyphae of fungi growing on the honeydew secreted by some aphids, lerps, scales, mealybugs, whiteflies (Order Hemiptera).

Species Individual plants or animals with some common characteristics, a subdivision of a genus.

Spider A small 8-legged animal belonging to the Phylum Arthropoda (Insects & Allied Organisms).

Spittle bug A sap-sucking insect (Order Hemiptera), the nymph of which produces protective frothy spittle.

Splitting **1.**The cracking of fruit commonly due to rain/too much water and too rapid growth. **2.** The splitting of trunks due to stress, borers and other agents.

Spore The reproductive unit of a fungus consisting of one or more cells.

Springtail A tiny 6-legged animal belonging to the Phylum Arthropoda (Insects & Allied Organisms).

Stamen Male reproductive structure of a flower, consists of an anther and filament.

Standard An authorized recognized measure of correctness which may be enforceable.

Stick insect A chewing insect (Order Phasmatodea).

Sting Female fruit flies pierce (sting) the maturing fruit and lay clutches of eggs under the skin.

Stippling Fine speckles on leaves or fruit, caused by insects and mites sucking sap.

Stomates Small openings on leaves and stems which regulate the flow of water from the plant into the atmosphere and admit carbon dioxide from the atmosphere for photosynthesis.

Strain Descendants of a single isolate in pure culture, an isolate, a race.

Streaking Dark longitudinal streaks on stems infected with virus diseases, eg tomato spotted wilt virus on stems of broad bean.

Stunting Failure of a plant to reach normal size, caused by virus diseases, insect pests, other agents.

Sucker A secondary shoot produced from the base or roots of a woody plant that gives rise to a new plant.

Surveillance Close monitoring of pests, diseases, beneficial agents or weeds.

Susceptible Being prone to attack by any given pest or disease organism.

Symbiosis Mutually beneficial association of two or more different kinds of organisms.

Symptom The visible response of the host plant to a pest or disease, eg chlorosis, leaf curl, scab.

Synonym A word having the same sense as another.

Systematic Arranged in an organized method.

Systemic A chemical or disease organism spreading internally throughout a plant.

Taint To imbue with some undesirable quality, eg smell, taste, stain, poison.

Target organism The pest, disease or weed to be controlled.

Taxonomy The scientific classification of plants and animals.

Termite A chewing insect (Order Isoptera), also known as 'white ants'.

Test In this book the term diagnostic test or test is used to describe any method or procedure which detects and identifies an organism or causal agent.

Threshold level The level of pest numbers or damage at which treatment is necessary to control a pest problem.

Thrips A rasping and sucking insect (Order Thysanoptera).

Time frames Time between the cause of an event and the appearance of symptoms; time of year that it can be expected to occur.

Tolerance The ability of organisms, including pests, to withstand a certain degree of stress, pest attack, unfavourable weather and other agents.

Topography A detailed description of the features of a site.

Trade name A descriptive or commercial name by which a plant or animal is known to the trade.

Transplant The planting out of seedlings and rooted cuttings.

TSWV Tomato spotted wilt virus.

TURFPLAN An expert planning system for turf managers.

Variety A plant or animal differing from those of the species to which it belongs in some minor but permanent or transmissible feature.

Vascular system Conducts water and minerals to the leaves and the photosynthetic products away from the leaves to the rest of the plant. See also Wilt.

Vector An animal (insect, nematode, mite) or parasitic plant that can carry and transmit a disease organism from one host to another.

Vegetative Asexual reproduction of plants.

Veinbanding Regions along the veins of leaves darker or lighter in colour than the tissue between the veins; caused by some virus diseases.

Veinclearing Veins of leaves become translucent rather than yellow; caused by some virus diseases.

Virescence See Greening.

Virus & virus-like 'organisms' A group of related 'organisms', eg phytoplasmas, viruses, viroids and prions, with roughly similar properties, which mostly only multiply in living cells, spread from one plant to another and can only be seen with aid of an electron microscope.

Warning services See Early warning services.

Wasp An insect belonging to the Order Hymenoptera.

Wax A normal secretion of the epidermal glands in some insects, eg mealybugs.

Webbing See Silk.

Weed A plant growing where it is not wanted.

Weevil A chewing insect (Order Coleoptera).

WFT Western flower thrips.

White ant A chewing insect (Order Isoptera), better known as termites.

Whitefly A sap-sucking insect (Order Hemiptera).

Wilt A drooping of plants due to an inadequate water supply, excessive transpiration, or other causes. Vascular wilt diseases (true 'wilt' diseases) are caused by fungi or bacteria blocking xylem vessels in the host plant.

Winter yellows The yellowing of leaves of citrus and other plants during cool winters when cold soils and wet conditions prevent nutrient uptake.

Wireworm Larvae of click beetles (Order Coleoptera).

Witches' broom Broom-like growth or massed proliferation of shoots, caused by insects or mites, other agents, and occasionally by fungal diseases.

WONS Weeds of National Significance.

Woodiness Fruit are hard, may be caused by viruses, environmental agents, senescence.

'Worm', 'weevil' damage Damage caused internally to fruit, nuts, seeds by caterpillars of moths and the larvae of flies, beetles and wasps.

Xylem Specialized cells through which water and minerals move upwards from the soil through the plant.

Yardstick A measurement; a defined value against which other measurements can be compared.

Yellowing A yellowing of normal green plant tissue due to partial failure of chlorophyll to develop. Occurs on all parts of the plant, but commonly associated with leaf colour. Caused by virus diseases, other parasitic pests and diseases, the environment, nutrient deficiencies and excesses, natural variegation, senescence.

Yellows A plant disease characterized by yellowing and stunting of the host plant.

INDEX

Main references are in bold

20 questions 70, 116

A

Accreditation
diagnostic services 89, 122
identifiers (diagnosticians) 122, 185
laboratories 122
professional accreditation 185
Accurate diagnosis *see* Diagnosis
Actinorrhiza 46, 164
Affected plants 22, 35, 39
Allelopathy 151, 173
Analyses
soil, water, plants **66**, 98, 177, 184
Anthracnose
fruit 145
leaves 126
Ants 165
Aphids 6, 153
aphid skins 134
black bean aphid 137
black peach aphid 133
bulb aphids 171
green peach aphid 135
poplar gall aphid 136
woolly aphid *case study* 43, 160, 161
Aspect 65
Audit *see* Evaluation

B

Bacterial diseases
diagnostic tests 183
distinguishing features 8
examples of bacterial diseases
bacterial blight of mulberry 138
bacterial blight of walnut 8, 149
bacterial canker of stone fruit
leaves 128, 134
branches 157, 158, 160
bacterial gall of oleander 138, 160
bacterial leaf & stem rot of geranium 97, 127
bacterial soft rot 170
common scab 172
crown gall *case study* 74, 164
fireblight *case study* 101, 126
Baiting 95
Bark *see* Branches, trunks, crowns.
Bark beetles *see* Beetles & weevils
Beetles & weevils
African black beetle 163
auger beetle 161
banana weevil borer 171
bark beetles 155
bean weevil 153
black vine weevil 165, 171
Christmas beetle 5, 165
elephant weevil 165
khapra beetle 153
leaf beetles 5
leafeating ladybirds 139
longicorn beetle 161, 165
nectar scarabs *case study* 56, 144
pea weevil 154
predatory beetles 137
rice weevil 153
scarab beetles 163
sweetpotato weevil 171
vegetable weevil 153
weevil damage 128, 155
whitefringed weevil 163
Beneficial agents
actinorrhiza 164
bacteria, fungi, nematodes 164
insects, mites 106, 137, 144, 153, 165
mycorrhiza 46
nitrogen-fixing bacteria 164
proteoid galls 46, 164
Best Management Practise *see* BMP
Biochemical tests 96
BIOLOG 96
Biological control agents *see* Control methods, Beneficial agents
Birds *see* Vertebrate pests
Bitterness, tainting 150
Blights
flowers 141
leaves 126
Blisters
fruit 146
leaves 126
Blossom-end rot 107, 149
Blotches, scorches
flowers 141, 144
fruit 11, 145
leaves 11, 49, **127**
whole plants 174
BMP **18,** 78, 193
Bolting 151
Borers
auger beetles 161
fruit-tree borer 161
longicorn beetles 161
sirex wasp 161
wood moth 161, 165
Botanical names *see* Names & labels
Branches, trunks, crowns 155-162
Broad-leafed plants 62, 179
Bud banks 168
Buds brown, drop, 141
Budworms *see* Caterpillars
BugMatch series 81
Bugs
acacia-spotting bug 127
apple dimpling bug 146
azalea lace bug *case study* 111, 130, 139
beneficial bugs 106
bronze orange bug 148
crusader bug 133
fruitspotting bug 148
green vegetable bug 146, 148
spined citrus bug 148
Bulbs, corms, rhizomes, tubers 169-172
Burns *see* Blotches, scorches
Burr knots 46
Butterflies & moths *see* Caterpillars

C

Calendars 64
Calyx splitting 143
Cameras *see* Digital cameras
Cankers
branches 53, 156
leaves, shoots 127
Case studies
Diagnosis 28
Step 1. The client's enquiry 34
Step 2. Identify affected plant 43
Step 3. Examine plant parts for signs & symptoms 55
Step 4. Visit site, history, questions 74
Step 5. Consult references 85
Step 6. Seek expert help 101
Step 7. Report the diagnosis 110
Caterpillars
budworms (*Helicoverpa* spp.)
flowers *case study* 56, 142
fruit 147
seeds 154
cabbage white butterfly 25, 153
case moth 134
codling moth 147, 148
corn earworm *case study* 56
cutworms 151
doubleheaded hawk moth 137
fruitpiercing moth 147
fruit-tree borer 161
geranium plume moth *case study* 111, 144
large citrus butterfly 134
Caterpillars *(contd)*
lightbrown apple moth 145
macadamia nutborer 148
Oriental fruit moth 133, 147, 149
vine hawk moth 6
wood moths 161, 165
yellow peach moth 148
Catface, tomato 146
Causes of plant problems 4-12
complex causes 5, 49, *case study* 74
complex signs & symptoms 49
diagnostic tests **179-184**
errors in diagnosis 106
primary & secondary causes 5, 49
Cautions
diagnostic tests 93
errors in diagnosis 106
image matching traps 83, 107
keys 83
references 83
signs & symptoms 49, 50
Centipedes 6
Centre for Biological Information Technology (CBIT) 81
Checklist 113-116
Chewing damage
branches, bark 155, 161
flowers, buds, petals 142
fruit, nuts 145, 148
leaves, shoots 124, 128
roots 163
seedlings 151
Chimera 11, 142, 146
Chlorosis *see* Yellowing, Colour changes
Classification of plant problems
bacterial diseases 8
fungal diseases 9
insects & allied pests 6
nematode diseases 7
non-parasitic diseases 10
parasitic flowering plants 9
snails & slugs 7
vertebrate pests 7
virus & virus-like diseases 8
weeds 12
see also Diagnostic tests for specific causes
Client, grower 27, **29-34**, **70,** 107, *case study* 110, 117
Clinics *see* Plant clinics
Cold weather *see* Temperature
Collar rot *see* Fungal diseases
Collections 188
Colour changes 124
branches, trunks 158
bulbs, corms, rhizomes, tubers 170
flowers, buds 142
fruit 146
leaves, shoots *yellowing* **129-132, 133**
roots 167
seedlings, cuttings 152
whole plants 174
Common names *see* Names & labels
Communication guide **117**
Compaction 65, 163, 166
Complaints 118
Complex causes 5, 49, *case study* 74
Complex signs & symptoms 49
Computers, cameras 176, 188
Conditions favouring 40, 61, 69
Confirm/reject a preliminary diagnosis 104, 179-184
Step 1. The client's enquiry 32
Step 2. Identify affected plant 41
Step 3. Examine plant parts for signs & symptoms 51
Step 4. Visit site, history, questions 71
Step 5. Consult references 83
Step 6. Seek expert help 99
Step 7. Report the diagnosis 104

Construction 65
Consult references 77-86
Control methods 17, 40, **193-194**
biological control 106, 164, 193
calendar 64
cultural methods *case study* 74, 193
disease-tested material 68, 194
IPM & BMP 18, 193
legislation 17 *see also* **Legislation**
pesticides 17, 37, 38, 194
physical & mechanical 40, 194
plant quarantine 24, 89, 91, 194
resistant varieties 68, *case study* 111, 193
sanitation 193
training 186, 187
Copper fungicide 11, 52, *case study* 110, 160
Corms 169
Correct names *see* Names & labels
Costs **19,** 30, **90,** 104, 105, 185
Cracking *see* Splitting
Crop history *see* History
Cropwatch Online 81
Crowns 155
Cultivar 36
Cultural control *see* Control methods
Culturing bacteria, fungi 95, 183
Cuttings *see* Seedlings
Cutworms, seedlings 151

D

Damage *see* Signs & symptoms
Damping off *see* Fungal diseases
Dead shoot tips 133
Death of newly planted trees 173
Debris *see* Frass, debris
Decline *see* Dieback
Deficiencies *see* Nutrient deficiencies & excesses
Definite diagnosis *see* Diagnosis
Definitions 22
Defoliation 134
Deposits 134 *see also* Frass, debris
Detection 22
Diagnosis 21-27, *case study* 110, *case study* 111
diagnostic services 89, 91-92
difficulties 108
errors in diagnosis 106
how definite **26**, 89
accurate 26, *case study* 28
definite negative 26
definite positive 26
inconclusive 26, *case study* 74, 108
preliminary 26, 32, 41, 51, 83
useful 26
how reliable **27,** 89, **122**
proof of diagnosis 22, 88, **104**
when to diagnose problems 24
Diagnosis based on
Step 1. The client's enquiry 32
Step 2. Identify affected plant 41
Step 3. Examine plant parts for signs & symptoms 51-53
Step 4. Visit site, history, questions 71, 72
Step 5. Consult references 83
Step 6. Seek expert help 99
Step 7. Report the diagnosis 104
Diagnosis for Crop Problems 185, 188, 189
Diagnostic reports 62, 72, 105, 121
Diagnostic resources 176, 188-190
Diagnostic road map 21
Step 1. The client's enquiry 29
Step 2. Identify affected plant 35
Step 3. Examine plant parts for signs & symptoms 45
Step 4. Visit site, history, questions 59
Step 5. Consult references 77
Step 6. Seek expert help 87
Step 7. Report the diagnosis 103
Diagnostic services 89
accreditation 122, 185
list of diagnostic services 91-92
Diagnostic tests 19, **93-98, 179-184,** 190
analyses, of soil, water, plants 66, 98, *case study* 101
baiting 95
biochemical tests 96
cautions with test 93
culture 95
diagnostic services 89, 91
diagnostic standards 122
diagnostic tools 176
DNA finger prints 97
electron microscopy 94
ELISA 97
grow-on tests 98
indicator plants 96
isolation 95
keys 81, 83, 95, 179
Koch's rules 98
laboratory tests 93
microscopy **94**
on-site test **66,** 93, 98
PCR 97
signs & symptoms **48-50**, 94, **123-174**
serology 97
stains 183
taxonomy 95
Diagnostic tests for specific causes
bacterial diseases 183
flowering plants 36, 37, 179
fungal diseases 183
insects & allied pests 181
nematode diseases 182
non-parasitic diseases 184
plants, weeds 12, 36, 37
snails & slugs 181
vertebrate pests 181
virus & virus-like diseases 182
weeds *case study* 43, *case study* 85, 179
see also Classification of plant problems
Dicotyledons 179
Dieback *case study* 74, **156,** 173
Digital cameras 82, 176, **188**
Discoloration *see* Colour changes
Disease cycle *see* Life cycle
Diseases *see* Bacterial diseases, Fungal diseases, Nematode diseases, Virus & virus-like diseases, Non-parasitic diseases
Disease-tested material *see* Control methods
Distance diagnostics 82, 176, 188
Distinctive features of pests & diseases **6-12**
Distortion
branches, trunks, crowns 159
bulbs, corms, rhizomes, tubers 170
flowers, buds 143
fruit, nuts 146
leaves 135
roots 164
seedlings 153
Distribution 63
DNA 97
Documentation *see* Records
Downy mildews *see* Fungal diseases
Drought stress *see* Moisture

E

Early detection **24**
Early warning services 24
Earwigs 142
ELISA 97
Enlarged lenticels, potato 172
Enquiry 31, 118
Environment 40, **69**, *case study* 75
Epicormic buds 160
Errors in diagnosis 106-108
Etiolation 153
European wasp *case study* 55
Evaluation
diagnostic process 108, **191**
IPM & BMP 18
plant clinics 192
training 192
Examine plant parts 45-58, *case study* 55, 63
branches, trunks, crowns **155**
bulbs, corms, rhizomes, tubers **169**
flowers **141**
fruit **145**
leaves, herbaceous stems **125**
roots, media, soil **163**
seeds, seedlings, cuttings **151**
whole plants **173**
Excess nutrients *see* Nutrient deficiencies & excesses
Experience 122, 185, 189
Expert help 87-98
Expert systems **81,** 83

F

Failure to flower 142
Failure to fruit adequately 147
Fairy rings 10
Fasciation 12, 53, 159
Faulty tasselling, sweetcorn 154
Fertilizer *see* Nutrient deficiencies & excesses
Fireblight *case study* 101, 126
Flies
bulb flies 171
cineraria leafminer 12, 137
fruit flies 25, 66, 148, 165
fungus gnats 165
garden soldier fly 165
Floras **179**
Flowers, buds 141-144
Flower wasps 144
Forked roots 170
Frass, debris
branches 72, 158
fruit 147
leaves 134
roots, soil, media 164
Freckle 150
Frost *see* Temperature
Fruit bats *see* Vertebrate pests
Fruit drop 147
Fruit flies *see* Flies
Fruit, nuts 145-150
Fungal fruit bodies 159
Fungal diseases
collecting and sampling 177
diagnostic tests 183
distinguishing features 9
examples of fungal diseases
azalea petal blight 141
black spot (of grape) 150
black spot (or rose) 53
blue mould (citrus) 9, 149
Botrytis cinerea
flowers 141, 143, 144
fruit 149
leaves, shoots 136
brown rot, stonefruit
fruit *case study* 56, 146, 149
shoots 126
camellia leaf gall 136
citrus canker 138
clubroot 171
collar rots 156
cypress canker 156
damping off 152
downy mildews
fruit 149
leaves 132, 136
early blight 126
freckle 150
Fusarium wilt 140, 170
grey mould *see Botrytis cinerea* above
leaf blister (poplar) 126
leaf spots 138
lemon scab 9, 150
peach leaf curl 135, 146
pear scab 150
petal blight *see Botrytis cinerea* & azalea petal blight above
powdery mildew *case study* 55
flowers 53, 143
fruit 149
leaves 9, 123, 136

Fungal diseases *(contd)*
examples of fungal diseases *(contd)*
root & stem rots
damping off 152
Chalara 167
Fusarium *case study* 102, 167
Fusarium wilt 140, 170
Phytophthora *case study* 74, *case study* 102, **105, 167, 183**
Rhizoctonia solani 9, 167
Sclerotinia rot 170, 167
Sclerotium stem rot 140, 167
rusts 12, 132, 136, 160
shothole 128, 150
stem canker 53, 156
slime moulds 10, 136, 170
sooty mould 136
vascular wilts **140,** 158, 170
wood rot 49, **61, 72,** 158, **159**
Fungi, moulds, rots
branches, trunks, crowns 159
bulbs, corms, tubers 170
flowers 143
fruit, nuts 149
leaves 136
roots, soil, media 167
Fungicides, copper 11, 52, *case study* 110, 160
Fungus gnats 165
Fusarium wilt *see* Fungal diseases

G

Galls
branches, trunks, crowns *case study* 101, 160
bulbs, rhizomes, tubers 171
flowers, buds 143
leaves, shoots 136
normal characteristics 46
roots *case study* 43, *case study* 56, *case study* 74, 164
Garden Advice *see* Plant clinics
Garden maggots *see* Flies
Genetic abnormalities
chimera
flowers 11, 142
fruit 146
seeds 152
fasciation 12, 53, 159
faulty tasselling 154
Genetically modified organisms (GMOs) 25
Genus, species, cultivar 36, 179
Glyphosate *see* Herbicides
Graft incompatibility 138
Gram stains 183
Green potatoes 170
Green shoulders on tomato 146
Greening *see* Virus & virus-like diseases
Grey mould *see* Fungal diseases
Grower *see* Client
Grow-on tests 98
Growth rate (whole plants) 174
Gumming, oozing
branches, trunks, crowns 160
fruit 147

H

Haloes
leaves 132
fruit 146
Hand lens 94, 176, 188
Herbaceous stems 125
Herbicides
amitrole, other herbicides 133, 134
contact herbicides 138
glyphosate 53, *case study* 85, **107, 130, 135**
hormone herbicides 49, **62,** 94, **135**, 153
pre-emergent herbicides *case study* 75
residues *case study* 110, 130
resistance to herbicides *case study* 101
History
crop 67
environmental 69, *case study* 75
pests, diseases & weeds 68
Holes
branches, trunks, crowns 161
flowers, petals, buds 142, 144
fruit 147
leaves 128
Honeydew 10, 136
Host 22, 35, 39, *case study* 43, *case study* 56
Host index *see* Indexes
Host susceptibility 68
How to help 90

I

Identify the affected plant 35-44, **179**
Identify the cause *see* Diagnostic tests
Image-matching 82, 83,107
Inconclusive diagnosis *see* Diagnosis
Indexes
host index **79,** 197, 203
pest index **79**, 198, 204
Indicator plants 96
Information
access 16, **38,** 88
inadequate 107
management **119**
Insecticides 134
carbaryl 147
white oil 131
Insects & allied pests
collecting & monitoring 177
diagnostic tests, identification 181
distinguishing features 6
examples of insects & allied pests *see* Aphids, Beetles & weevils, Borers, Bugs, Caterpillars, Flies, Leafmining, Locusts, Mealybugs, Mites, Sawflies, Scales, Skeletonizing, Thrips, Tip borers, Wasps, Whiteflies
Integrated Pest Management *see* IPM
Internet *see* Websites
Invasive roots 166
IPM 18, **193**
Iron deficiency *see* Nutrient deficiencies & excesses
Irrigation *see* Moisture
Irritation 137

J

K

Keys 81, 83, 179
Kino veins 158
Koch's rules 98

L

Labels *see* Names & labels
Laboratory tests 93, **94-98**, **179-184**
Ladybirds *see* Beetles & weevils
Leaf analysis 184
Leaf blisters 126
Leaf cupping 135
Leaf curling 135
Leaf rolling 135
Leaf spots
anthracnose 53, 126
bacterial leaf spots 8, **138**
black spot of rose 53
eye spot 48
fungal leaf spots 9, **138**
graft incompatibility 138
normal characteristics 46
see also Spots
Leafcutting bee damage 49, 128
Leafhoppers 139
Leafmining 137
azalea leaf miner 137
callistemon leafminer 137
cineraria leaf miner 12, 137
citrus leafminer 137
hakea leafminer 137
lomatia leafminer 137
Leaves, shoots, stems 125-140
Legislation 17, 24
diagnostic services 89, 122, 185
monitoring 175
pesticides 17, 37, 38, 40
plant clinics 190
Step 2. Identify affected plant 38, *case study* 43
Step 5. Consult references 80
Step 6. Seek expert help 88
Step 7. Report the diagnosis 104. 109, *case study* 110
Lenticels 172
Lerp insects 5, 133, 134
Lichens 158, 162
Life cycle 39, 186
Light 69, **129**
etiolation 153
Lignotuber 164
Line patterns 131
List of pests & diseases 38, 52
Liverworts 12
Living agents (non-parasitic) 10
Location (signs & symptoms) 47, 123
Locusts & grasshoppers 128, 165
Lucid software website 195
Lures 66, 177

M

Management *see* Control methods
Manganese deficiency *see* Nutrient deficiencies & excesses
Marketing names *see* Names & labels
Mealybugs *case study* 43, *case study* 56, 137, 171, 174
Media 163
Mechanical damage
branches, trunks, crowns 10, 162
bulbs, corms, rhizomes, tubers 172
roots 163
Microscopes, hand lens 94, 176, 188
Millipedes 6
Mistletoe *see* Parasitic flowering plants
Mites 6
banksias mite gall 160
broad mite 135
bulb mites 171
citrus bud mite 146
eriophyid mites 135, 162
grapeleaf blister mite 49, 126, 133
spider mites 49, *case study* 55, 134, **139, 144**
twospotted mite (red spider) *see* spider mites above
walnut blister mite 136
Moisture 67, 69, *case study* 110
branches, trunks, crowns *case study* 74, 157
bulbs, corms, tubers 170, 172
fruit 147
leaves 11, 49, 126, 127, 132, 134
Monitoring 22, **175-178**
Monocotyledons 179
Mosaics, mottles *see* Virus & virus-like diseases
Mottles *see* Mosaics
Moulds *see* Fungi, moulds, rots
Mouse damage *see* Vertebrate pests
Mouth parts
insects & allied organisms 6
nematodes 7
snails & slugs 7
Mulch 67
Mummies 146
Mundulla yellows *case study* 101
Mushroom 10, 159, 164
Mutations *see* Genetic abnormalities
Mycorrhizae 46, 164

N

Names & labels
pest & disease names 25, 39
common name 25
scientific name 25
strain 25

pesticide labels 17, 37, 38
plant names 36, 179
botanical name 36
common name 36
cultivar, variety 36
family, genus, species, order **179**
market name 36
plant breeders' rights 36
plant label 37
scientific name 36
synonyms 37
trade marks 37
trade names 36
sample labels 176
Narrow-leafed plants 62, **179**
National standards for pest records 122
Nematode diseases
diagnostic tests 182
distinguishing features 7
examples of nematode diseases
beet nematode 172
leaf, foliar nematodes 7, 127
root knot 164, 170, 171
stem & bulb nematode 170
Nemasys 81
Newly planted trees & shrubs 173
Nitrogen-fixing bacteria 46, 164
Non-living agents 10
Non-parasitic pests & diseases
diagnostic tests **184**
examples of non-parasitic pests & diseases **10-11, *63-69***
see also Allelopathy, Bolting, Fungicides, Genetic abnormalities, Graft incompatibility, Herbicides, Insecticides, Lichens, Mechanical damage, Moisture, Nutrient deficiencies & excesses, Overmaturity, Planting depth, Pollination, Pot bound, Replant problems, Salinity, Temperature
Normal plants 38, **46,** 106, 123
green rose 53
lignotubers 164
new growth 133
Nutrient deficiencies & excesses 129
blossom-end rot 107, 149
boron deficiency 146
fertilizers 11, 67
iron deficiency *case study* 101, 124, 130
magnesium deficiency *case study* 55, 130
manganese deficiency 130
molybdenum deficiency 135
nitrogen deficiency 130
on-site tests 66, 176
pH 66, 176
phosphorus deficiency 133
phosphorus toxicity 129
salinity *case study* 101, 127, 174
zinc deficiency 130
Nuts *see* Fruit
Planting depth
bulbs 169
trees, shrubs 156, 166

O

Odours
bulbs 170
fruit 150
roots, soil, media 167
Oedema (leaves) 126, 132
On-site tests, field tests 66, 93, 98, 163
Ooze *see* Gumming, oozing
Organic standards 89
Orientation 124
Overmaturity
bulbs, corms, rhizomes, tubers 170
fruit 147, 149
Ozpest 81

P

Parasitic flowering plants
diagnostic tests 179
distinguishing features 9
examples of parasitic flowering plants
devil's twine 162
dodder 9, *case study* 110, 133
mistletoe 162
native cherry 168
Parasitic pests & diseases
diagnostic tests **179-183**
distinguishing features **6-9**
examples of parasitic pests & diseases **63-69**
see also Bacterial, Fungal, Nematode & Virus & virus-like diseases; Parasitic flowering plants; Insects & allied pests, Snails & slugs, Vertebrate pests
Parasitic wasps 139, 153
Patterns **64**, 129
PCR 97
Peeling bark 155
Pest calendars 64
Pest categorization 19
Pest cycle 39, 186
Pest index see Indexes
Pest information sheets 16, 22, **39,** 41
Pest management *see* Control methods
Pest signature 16, 22, ***39,*** *case study* 85
Pest significance 39
Pest status 122
Pest triangle 31
Pesticide injury *see* Fungicides, Herbicides, Insecticides
Pesticide labels 17, 37, 38
Pesticides *see* Control methods
Pests 22 *see also* Insects & allied pests, Snails & slugs, Vertebrate pests
Petal blight *see* Fungal diseases
pH *see* Nutrient deficiencies & excesses
Pheromones lures 66, 177
Phosphorus toxicity 129
Photographs
aerial photography 175
cameras 176, 188
image-matching 82
no photographs, no samples 118
Physical & mechanical *see* Control methods
Phytophthora *see* Fungal diseases
Planning
BMP 18, 193
monitoring 175
Plant analysis 66
Plant clinics 189, 192
Plant history *see* History
Plant identification 36, 179
Plant labels *see* Names & labels
Plant names *see* Names & labels
Plant parts *see* Examine plant parts
Plant quarantine *see* Control Methods
Poisonous plants, seeds 154
Pollination
catface 146
fruit 147
Pollution, pollutants 10
Poor emergence (seedlings) 152
Poor planting techniques 166
Poor root growth 166
Possum damage *see* Vertebrate pests
Pot bound 166
Powdery mildews *see* Fungal diseases
Predatory insects 106, 137
Predictive services *see* Early warning services
Preliminary diagnosis 104
Step 1. The client's enquiry 32
Step 2. Identify affected plant 41
Step 3. Examine plant parts for signs & symptoms 51
Step 4. Visit site, history, questions 71
Step 5. Consult references 83
Step 6. Seek expert help 99
Step 7. Report the diagnosis 104
see also **Diagnosis**
Primary causes 5, 49
Primary pests of seeds in storage 153
Proof of diagnosis *see* Diagnosis
Proteoid galls **46,** 164
Provenance 36
Pruning 67

Q

Quarantine *see* Control methods, Legislation
Questions to ask 70

R

Recommendations *see* Control methods
Record of the diagnostic process 62, 72, 105, 121
Records 119-122
access records 67
diagnostic reports 62, 72, 105, 121
diagnostic road map 22, 23
evaluation 192
pest records, status 122
Step 1. The client's enquiry 31
Step 2. Identify affected plant 36
Step 3. Examine plant parts for signs & symptoms 47
Step 4. Visit site, history, questions 60, 70
Step 5. Consult references 78, *case study* 85
Step 6. Seek expert help 88
Step 7. Report the diagnosis 104, 105, *case study* 110
Reduced yield 173
Reducing the possibilities 38
References 78, *case study* 85, **195-200**
cautions with references 83
diagnostic process 195
diseases 198
general references 195
host index 197
identify plants 196
insects & mites 198
pest calendars 82
pest index 198
pests & diseases 198
resources 188
snails & slugs 198
vertebrate pests 199
weeds 200
Reject preliminary diagnosis *see* Confirm/reject a preliminary diagnosis
Reliability 27
Replant problems *case study* 74, *case study* 102, **167**
Report forms 105, 121
Report the diagnosis 62, 72, 103-112, *case study* 110, 121
Resistance to herbicides *see* Herbicides
Resistance to pests & diseases 68, *case study* 111
Resistant varieties *see* Control methods
Resources *see* References
Review questions & activities
Causes of plant problems 13
Diagnosis 28
Step 1. The client's enquiry 34
Step 2. Identify affected plant 44
Step 3. Examine plant parts for signs & symptoms 57
Step 4. Visit site, history, questions 75
Step 5. Consult references 86
Step 6. Seek expert help 102
Step 7. Report the diagnosis 111
Why identify the causes of plant problems 20
Rhizobia 164
Rhizomes *see* Bulbs, corms
Rhizoctonia *see* Fungal diseases
Ringspots
leaves 132
fruit 148
Road map *see* Diagnostic road map

Root bound 166
Root rots *see* Fungal diseases
Roots, soil, media *case study* 74**, 163-168**
Rose, pests & diseases 52, 53
Rots
branches, trunks, crowns 156, 159
flowers 141, 143
fruit 149
leaves, shoots, stems 126, 127
roots 167
seeds, seedlings 152
Rules of thumb 63, 129
Russet
fruit 149
Rusts *see* Fungal diseases

S

Salinity *case study* 101, 127, 174
Salt buildup on containers 11, 66
Samples, sampling 175-178
evaluate sampling 192
inadequate sampling 107
no sample 118
submission forms 90, **105**, 120, **121**, 176
what can be sampled 177
Sanitation *see* Control methods
Sawflies
callistemon sawfly 123, 139
cypress pine sawfly 50
leafblister sawfly 137
pear & cherry slug 139
spitfires 161
steelblue sawfly 161, 165
willow sawfly 128
Scabs
bulbs, corms, rhizomes, tubers 172
fruit, nuts 9, 150
leaves, herbaceous shoots 138
Scales
black scale 137
red scale (citrus) 148
rose scale 53, 158
San Jose scale 146, 161
Scarab grubs *see* Beetles & weevils
Scientific names *see* Names & labels
Scorches *see* Blotches, scorches
Scouting *see* Monitoring
Secondary causes 5, 49
Secondary pests of stored seeds 153
Secretions (insect) *see* Frass, debris
Seedlings, cuttings 151-154
bolting 151
damping off 152
etiolation 153
poor emergence 152
spindly distorted seedlings 153
transplant history, shock 67, 154
Seeds 151-154
seed banks 168
seed screening, testing 97, 183
seeds in storage 153
seeds on plants 154
small seed 152
weed seed, weed pieces 168
Seek expert help 87-102
Senescence
fruit 147, 149
leaves *case study* 56, 128, 130, 138
Serology 97
Shape 124
Shoot tip dieback, dead shoots 133
Shoots *see* Leaves, shoots, stems
Shothole *see* Fungal diseases
Significance of pest 39, 122
Signs & symptoms 48-50, 123-174
advantages & disadvantages **50,** 94
examples of signs & symptoms
see Anthracnose, Blights, Blisters, Blotches, Buds brown, Cankers, Caterpillars, Chewing damage, Chlorosis, Colour changes, Damping off, Dead shoots tips, Death of newly planted trees, Defoliation, Dieback, Distortion, Etiolation, Failure to flower, Failure to fruit, Fasciation, Flies,
examples of signs & symptoms *(contd)*
Forked roots, Frass, Fungal diseases, Galls, Genetic abnormalities, Gumming, Holes, Insects & allied pests, Leafmining, Leaf rolling, Leaf spots, Mechanical damage, Mites, Mosaics, Mottles, Nematode diseases, Nutrient deficiencies & excesses, Odours, Oedema, Reduced yield, Ringspots, Root rots, Rots, Russet, Sawdust, Sawflies, Scabs, Scales, Scorch, Silvering, Size, Skeletonization, Snails & slugs, Splitting, Spots, Stippling & speckling, Suckers, Termites, Thrips, Tip borers, Vertebrate pests, Virus & virus-like diseases, Wasps, Webbing, Weeds, Whiteflies, Wilting, Witches' broom, Woodiness, Yellowing
plant parts 47, 123
branches, trunks, crowns **155**
bulbs, corms, rhizomes **169**
flowers **141**
fruit, nuts **145**
leaves, shoots, stems **125**
roots, soil, media **163**
seedlings, seeds **151**
whole plants **173**
checklist 113
colour, orientation, shape, size 124
complex signs & symptoms 49, 124
delayed symptoms 64, 124
location 47, 123
measuring 124
microscopy 94
normal plants 38, 46, 106, 123
green rose 53
lignotubers 164
new growth 133
primary & secondary 5, 49
specific/distinctive, nonspecific 11, 50, 94, 124
Silk 134
Silvering
leaves 138
whole plants 174
Site maps 62, 72
Site visit 59-72
calendar 64
history 67
patterns 63
questions 70
records 60
site maps **62, 72**
soil type, aspect 65, *case study* 74
tests 66
Size
flowers 142
fruit 147
leaves 140
whole plant 174
Skeletonization 139
Skills *see* Training
Slaters 6, 165
Slime moulds *see* Fungal diseases
Slow growth rate 174
Smut (oats) 154
Snails & slugs
distinctive features 7
eggs in soil 165
flowers 142
identification 181
leaves 128, 139, 181
Soil analysis 66, 163, 182, 184
Soil, media, roots 65, 98, **163-168**, 177
Soil type, topography 65
Sooty mould 10, 136
Species affected 39, 63
Speckling, *see* Stippling & speckling
Spider mites *see* Mites
Spiders 6
Spitfires *see* Sawflies
Spittle bugs 134
Splitting
bark 155
bulbs, corms, rhizomes, tubers 170
flowers 143
fruit 150
leaves, stems 11, 128
Spots
flowers, petals 144
fruit, nuts 150
see also Leaf spots
Spread 40
Springtails 165
Stains 183
Standards, diagnostic 122
Status of pest 39, 122
Stem girdling roots 166
Stings (fruit) 147
Stippling & speckling
fruit **146 -148**
leaves *case study* 55**, 139**
Stolons 168
Strains, races *see* Names & labels
Structures 65
Stunt, stunting, slow growth
leaves 140
whole plant 174
Submission forms 90, 105, 120, 121, 176
Suckers 168
Sucking insect damage *see* Mouth parts, Stippling &speckling
Summaries
Step 1. The client's enquiry 33
Step 2. Identify affected plant 42
Step 3. Examine plant parts for signs & symptoms 54
Step 4. Visit site, history, questions 73
Step 5. Consult references 84
Step 6. Seek expert help 100
Step 7. Report the diagnosis 109
Sunscorch *see* Blotches, scorches
Susceptibility of host 68
Symptoms *see* Signs & symptoms
Systematic approach 22, 106

T

Tainting (fruit) 150
Taxonomy (pests) 25, 95
Taxonomy (plants) 95, 179
Telephone enquiries *case study* 55, 117
Temperature 67, **69**
frost
flowers 141
fruit 149
leaves. stems 11, 174
low temperatures
fruit 146
seedlings 152
sunscorch
flowers 141
fruit 11, 145
leaves 127
Termites *case study* 101, 161, 171
Tertiary causes 5, 49
Tests *see* Diagnostic tests
Thick skin 146
Threshold 18, 193
Thrips 6
callistemon leafrolling thrips 135
gladiolus thrips 144, 171
greenhouse thrips **138, 139**
plague thrips 53, 144
western flower thrips *case study* 28
Time frames 64
Tip borers 133
Tomato big bud *see* Virus & virus-like diseases
Topography 65
Toxic plants, plant parts
peanuts 150
seed 154
weeds 12, *case study* 43, *case study* 85
Toxicities (nutrients) *see* Nutrient deficiencies & excesses

Training 19, *case study* 28, 107, **185-190**
background knowledge 186
evaluation 192
plant clinics 189
resources 188
systematic approach 186
Transplant history 67
Transplant shock 154
Traps 66, 177
Treatments (previous) 68
Tree suckers *see* Suckers
Trees *see* Branches, trunks & crowns
Trunks 155
Tubers 169
Tunnels
branches, trunks 161
fruit 148
Twenty (20) questions 70
Twospotted mite *see* Mites

U

Useful diagnosis *see* Diagnosis

V

Vandalism 10
Variegation 46
Varieties 36
Vascular wilts *see* Fungal diseases
Vertebrate pests
distinguishing features 7
examples of vertebrate pests
birds, fruit bats 145
mice, rats, rabbits 154
possums 145
identification 181
Virus & virus-like diseases
diagnostic tests 182
distinguishing features 8
examples of virus diseases & virus-like diseases
apple flat limb 159
apple mosaic 131
apple russet ring 149
camellia yellow mottle 131
cumber mosaic 148
grapevine fanleaf 124
greening *see* tomato bid bud below
hydrangea mosaic 131
impatiens necrotic ringspot 96
Kennedia mosaic 131
odontoglossum ringspot 132
peony ringspot 132
plum line 131
potato leafroll 172
rose mosaic 52, 53, 131, 132
scaly butt (citrus) 156
stock mosaic 142
tomato big bud (greening)
flowers 142, 143
fruit 146
leaves, shoots 124,
tomato spotted wilt, blotches
fruit 145, 148
tulip flower breaking 142
Visit site 59-76

W

Wasps
citrus gall wasp 160
European wasp *case study* 55
flower wasp 147
Geraldton wax gall wasp 143
seed wasps 154
wattle gall wasp 143
Water *see* Moisture
Water analysis 65, 66, 98, 177, 183
Waterlogging, drainage *case study* 74
Watersoaked, greasy leaves 132
Webbing
flowers 144
leaves 134
Webbing caterpillars *case study* 43, 134
Websites 78, 82, **195-200**
Weed Biocontrol 81
Weeds
diagnostic tests. identification 179
distinguishing features 12
examples of weeds
bamboo 168
buffalo grass 168
cardamine 12
couchgrass 168, 172
creeping buttercup 168
dandelion 168
Johnson grass 168
kikuyu 168
liverworts 12
mallow 12
nutgrass 168
onion grass 168
Paterson's curse 12, *case study* 85
poplar 168
prickly pear 12
red-flowered mallow 12, 168
sowthistle 12
suckers 168
weed pieces & seeds 168
weed seed & bud banks 12, **168**
willow 168
winter grass 12
WONS (weeds of national significance) 39
harmful effects 12, *case study* 43, *case study* 85
legislation 39, *case study* 43
Weeping 160
Weevils *see* Beetles & weevils
White ants *see* Termites
Whiteflies
ash whitefly *case study* 55
greenhouse whitefly 137, 139
Whole plants 173-174
poor root growth 166
Wilting
flowers 144
leaves 140
vascular wilt diseases *see* Fungal diseases
Wind 49, 69
Witches' broom 162
Wood rot *see* Fungal diseases
Woodiness 146
Woody branches, trunks 155

X

Y

Yellowing *case study* 55, **129-132**
haloes 132
line patterns 131
marginal yellowing 131
mosaics 131
mottles 131
new leaves, younger leaves 130
normal 46
older leaves 130
ringspots 132
veinbanding 131
veinclearing 131
watersoaked 132
yellow veins 131

Z

Zinc deficiency *see* Nutrient deficiencies & excesses

?	**Step 1. The client's enquiry is the key to diagnosis** Listen to the client – get the facts – be a good communicator. What does the client expect from you? *Under-promise and over-deliver.* *Clients are not always right, but they are the clients!*
	**Step 2. Plant identification is an important part of diagnosis** Common or botanical names? Reducing the possibilities – access lists of pests and pest information sheets. *Is there a 'One stop shop' for your crop?*
	**Step 3. Signs and symptoms are clues!** Do you know what to look for? What is normal? Signs and symptoms may be complex. *Observing symptoms is not the same as identifying the cause.* *'Hath thy rose a canker, Somerset?'*
	**Step 4. A site visit – more clues!** Draw a site map, look for patterns. Access crop records. Ask 20 questions. *'The best fertilizer is the footsteps of the gardener'* *'The early bird catches the worm'*
	**Step 5. Consult books, colleagues and websites** Most diagnoses will include references. Can you match a pest signature? *Image matching – 'One picture is worth a thousand words!'* *Consult a colleague – 'Two heads are better than one'*
XPERT	**Step 6. The trick is knowing when to call in expert help** Diagnostic tests – what you send is what gets tested. *Don't forget the submission form!*
	**Step 7. The diagnosis – who or what done it?** 'If you want an answer I'll give you one, but if you want a better answer give me some time' – don't be rushed into a diagnosis. *Don't be definite unless you can provide proof.* *'Even a doctor may make mistakes and their patients can talk!'*

The Author's Aim in this series of books is to provide users with the systematic understanding of Plant Protection and Plant Management required of modern horticulture. The books are used to teach Plant Protection throughout Australia and as a reference by people working in the horticulture industry.

Ruth Kerruish's interest in diseases and pests of plants commenced with her post-graduate studies at the University of Western Australia. She later worked as a researcher with CSIRO (Forest Products, Melbourne and Plant Industry, Canberra) and taught Plant Protection in the Department of Horticulture in the Canberra Institute of Technology.

Adrienne Walkington trained in architectural drafting in Adelaide and in Horticulture in Canberra where she worked as a technician in the Department of Horticulture in the Canberra Institute of Technology.

Plant Protection Series:

1. Pests, Diseases and Weeds
2. Methods of Control
3. Selected Ornamentals, Fruit and Vegetables
4. How to Diagnose Plant Problems

ISBN 1-875907-03-3

9 781875 907038

Rootrot Press
22 Lynch Street, Hughes, Canberra, ACT, Australia 2605
(02) 6281 3650 Fax (02) 6285 1657
ISBN 1-875907-03-3