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FOREWORD

Australia is largely self-sufficient in fruit and vegetables. The industry is intensive, typically seasonal in operation, and dominated by small-scale farms. With fruit, nut and vegetable cropping worth $5.5 billion, and other horticulture an additional $1.7 billion in 2005–06, horticulture is Australia's third-largest agricultural industry, and a major employer in rural areas.

Most Australian production is for domestic markets, but the horticulture industries also contribute significantly to exports. In 2004–05, fresh fruit, vegetable and nut exports were worth $800 million, wine exports were worth $2.7 billion, and other processed horticultural produce was worth $400 million. At the same time, fruit, nut and vegetable imports provided additional diversity and met gaps in domestic production.

Effective, integrated disease-management and quarantine strategies have been essential for minimising losses and facilitating market access for Australia's development as a major producer and exporter of high-quality fruit, nuts and vegetables. In recent years, the threats of global warming to the sustainability of cropping, the limitations in water and land availability, and the rising costs of fuel and other inputs, have reinforced the need for making production and marketing as efficient as possible through better disease control. Also, in line with community expectations for high-quality produce with minimal chemical residues, it has become critical for the rural community to manage pests and diseases responsibly, as well as effectively.

Accurate identification of the plant diseases attacking horticultural crops is a key step in choosing safe and effective control options and in maintaining biosecurity preparedness. This need was met by publishing the *Handbook of Plant Diseases in Colour – Fruit and Vegetables* by the Queensland Department of Primary Industries in 1978, and in subsequent separate volumes covering fruit and vegetables respectively in 1993 and 1994. This current, complete revision, *Diseases of Vegetable Crops in Australia,* incorporates overviews of the causes and the main disease types attacking vegetable crops, and 21 separate chapters covering particular vegetable groups. The book illustrates the major diseases of vegetables currently present in Australia, with concise information on their cause, symptoms, disease cycle and management. In addition, some key exotic diseases that represent biosecurity threats to Australian horticulture are covered.

Assembling the illustrations and preparing the text has been a national effort. Although most of the authors are from Queensland Primary Industries and Fisheries, plant pathologists in all States have contributed either as authors or by providing images and information. The Australasian Plant Pathology Society, which represents the discipline of plant pathology in Australia and New Zealand, is very pleased to provide sponsorship and support for this important publication.

Previous editions in this series have proved popular and I am sure that this book will prove an essential resource for anyone involved in vegetable production and quality management.

Dr. Greg I Johnson
President
Australasian Plant Pathology Society
Plant Health is Earth's Wealth

PREFACE

Diseases of Vegetable Crops in Australia is the third in a series of plant disease handbooks produced by plant pathologists from Queensland Primary Industries and Fisheries. The purpose of each has been to provide a diagnostic guide and a key reference for diseases affecting vegetable crops in Australia. The first, *Handbook of Plant Diseases in Colour – Fruit and Vegetables,* was published by the Queensland Department of Primary Industries in 1978 with a second edition published in 1982. It was fully revised in the mid 1990s and published as two separate volumes, *Diseases of Fruit Crops* and *Diseases of Vegetable Crops*.

This current edition, written some 15 years later, is extensively revised and expanded.

With the collaboration of colleagues throughout Australia, the editors and authors provide essential information about the important diseases affecting most vegetable crops grown across Australia's diverse production areas. The disease descriptions are supported by many diagnostic images.

Diseases of Vegetable Crops in Australia is a valuable guide for growers, their consultants and managers, horticulturists, plant pathologists, plant protection diagnosticians, integrated pest-management specialists, educators, students and agribusiness representatives, as well as the enthusiastic home gardener and hobby farmer.

The first chapter is an introduction to the causes, nature and principles underlying the control of plant diseases and includes other sources of information about pathogen groups and plant diseases. The second chapter is an overview of several diseases affecting many vegetable crops and links to subsequent chapters on specific crop diseases.

The remaining chapters discuss the diseases of specific crops. The diseases are organised first by pathogen type then by an alphabetical listing of diseases under each type of pathogen.

Each disease description includes information about symptoms, means of spread, disease development and survival, importance and management. The latter emphasises the need to adopt an integrated approach to disease management, applying all the appropriate cultural, crop-management and chemical methods to achieve a cost-effective and sustainable result.

Sources of further information are given at the end of each chapter.

The colour images help with disease identification, and include early symptoms or distinguishing features.

Early detection of exotic diseases that are a biosecurity threat to Australian horticultural industries is vital if they are to be contained or appropriately managed. To assist industry awareness, the major biosecurity threats for most crops have been included.

A glossary and index complete the book.

Specific chemical recommendations are not included in the disease-management sections because they change regularly, and can vary between regions and States. Current chemical recommendations can be found in specific crop management guides, and by government and private extension and consultancy services.

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1 PLANT DISEASES – AN INTRODUCTION

Humankind has struggled with plant diseases since the dawn of agriculture. There are references in the Old Testament to the ravages of rust and blight on cereals and grapevines in the Ancient world. The potato famine in Ireland in the 1840s led to the mass migration of Irish refugees to Australia, Britain and North America so that today, almost one in 10 Australians can trace their ancestry back to Ireland. The cause of the famine was the potato blight pathogen *Phytophthora infestans*, which destroyed plants and tubers under prolonged wet and cold weather.

Plant diseases are closely connected with current issues facing agriculture and the environment. Global warming and rainfall reliability will have a considerable influence on disease distribution and severity in crops. Plant diseases are a major factor in world food security, and biosecurity issues are a key component in international trade agreements. The absence of many damaging pathogens in Australia provides competitive advantage in trade and access to new markets. Furthermore, savings in costs associated with managing or eradicating these pathogens means that, in some cases, production is more efficient and sustainable than in overseas countries.

CAUSES OF DISEASE IN PLANTS

A simple definition of a plant disease is any disturbance that interferes with the plant's normal structure, function or economic value. Plant diseases divide conveniently into (a) those caused by parasitic microorganisms or pathogens, and (b) non-parasitic diseases or disorders. These latter include mineral excesses and imbalances, incorrect storage conditions after harvest, environmental influences (such as atmospheric pollutants) and herbicide damage. Table 1.1 lists some physiological disorders of vegetable crops.

This handbook concerns diseases caused by pathogens. The major groups of plant pathogens are fungi, bacteria, viruses

Fig 1.1 Healthy produce is a team effort between growers, horticulturalists and plant pathologists.

Table 1.1 Some physiological disorders of vegetable crops

CROP	DISORDER	CAUSE
Lettuce	Tipburn	Associated with a low concentration of calcium in the tissues Promoted by conditions favouring rapid plant growth: warm temperatures, excess fertilisation and high light intensity
Cucurbits	Measles	Guttation droplets on the fruit surfaces Extended periods of high humidity, or wide temperature fluctuations between night and day
Cucurbits	Premature fruit abortion	Poor pollination
Capsicum	Yolo spot	Varietal susceptibility Calcium deficiency
Tomato	Blossom end rot	Localised calcium deficiency in the distal end of the fruit
Carrots	Black ring	A combination of varietal, physiological and fungal factors

Fig 1.2 Disease is a constant threat to profitable vegetable production. Left to right: downy mildew in cucurbits, *Tomato spotted wilt virus* and Sclerotinia drop in lettuce.

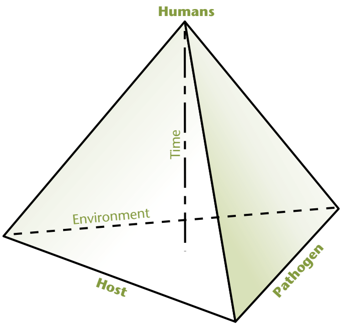

Fig 1.3 Interrelationships in plant disease epidemics.

Fig 1.5 Modern herbaria maintain state-of-the art electronic databases for original specimens and use facelift packaging.

Fig 1.4 The aim of the Australian Vegetable Industry Biosecurity Plan is to reduce the risk of exotic disease introductions to our local crops. Threats include: bacterial ring rot (left) and whitefly-transmitted Geminiviruses, which are common throughout Asia (right).

Fig 1.6 Cooperative research is important for Australia's farming future. It allows us to develop a better understanding of possible threats to our vegetable industries.

Fig 1.7 Conventional research and modern molecular techniques enable today's plant pathologists to develop management recommendations for plant pathogen outbreaks.

and nematodes. All diseases caused by pathogens are the result of an interaction between a susceptible plant, a pathogen capable of causing disease and a favourable environment (Fig 1.3).

The following sections outline key characteristics of plant pathogens.

FUNGI

Fungi are mostly filamentous organisms that lack the green pigment chlorophyll and must obtain energy from the material on which they grow. Most fungi are saprophytes, living entirely on dead or decaying organic matter. Fungi are the most important and common cause of plant disease, with about 23 000 species known to infect plants, although it has been estimated that the actual number may be as high as 270 000 species. Some fungal pathogens can survive only by growing in their living host plants; these are termed obligate parasites or biotrophs. Examples include the rusts, smuts and powdery mildews.

The majority of fungal pathogens are non-obligate or facultative parasites requiring a living host plant for only part of their life cycle. Fungi consist of individual living filaments called hyphae, which collectively form mycelium. As in other organisms, reproduction is an essential part of the life cycle of a fungus. Most fungi have the ability to reproduce both sexually or asexually. Usually, the asexual (imperfect, anamorphic) stage is the active pathogen and the sexual (perfect, teleomorphic) stage may occur only rarely. The sexual stage helps the fungus survive adverse, often seasonal conditions, and provides genetic diversity for the organism. The basic reproductive unit of fungi is

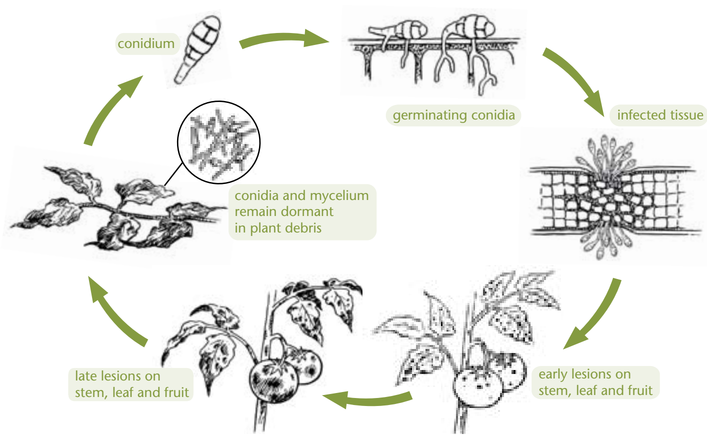

Fig 1.8 Disease cycle of *Alternaria* species.

Fig 1.9 Symptoms of Alternaria on tomato leaf and fruit and a magnified view of the spores.

Fig 1.10 Rust on asparagus fern. Inset: Rust uredinospores.

the spore, which germinates to produce hyphae. Spores may result from both asexual and sexual reproduction and often a single fungal species may produce several different types of spores. The sexual stage of some fungi is unknown, or may not even exist, and so only the asexual stage is known. Formerly called *Fungi Imperfecti,* most are actually ascomycetes or basidiomycetes.

Spores develop in special structures called fruiting bodies, which provide some protection against desiccation and ultraviolet radiation. Often produced in enormous numbers, spores disperse by wind currents, rain, running water or insects. Thick-walled spores resistant to adverse conditions allow fungi to survive for long periods in the soil and on both living and dead plants.

Fungal mycelium may also form small, hard structures called sclerotia, which are important survival structures for many fungi.

The true fungi belong in their own kingdom, the Fungi. Now we know that the true fungi are more closely related

Fig 1.11 Powdery mildew on a pumpkin leaf. Inset: Spore-bearing structures.

to animals than to plants. The four major groups (phyla) of true fungi are the Ascomycota, Basidiomycota, Chytridimycota and Glomeromycota (includes traditional Zygomycota). The first two groups contain most of the plant pathogenic fungi.

Some important and widespread plant pathogens known as oomycetes were once considered part of the fungal kingdom. Their name derives from the round oospores produced by sexual reproduction and serving as thick-walled survival spores. Oomycetes are adapted to living in moist environments and produce asexual zoospores with flagella that allow them to swim. The best-known oomycetes are the plant pathogens *Phytophthora*, *Pythium* and the downy mildews. Structural, molecular and biochemical studies show that oomycetes are more closely related to diatoms, kelps and golden-brown algae. These organisms are now placed into the Kingdom Stramenopila.

The main characteristics of the plant pathogenic fungi and oomycetes are listed in Table 1.2.

Fig 1.12 Fungi and bacteria are major causes of disease in vegetable crops. Most will grow in culture.

Table 1.2 Fungal and fungal-like pathogens

GROUP		DISTINGUISHING FEATURES	REPRESENTATIVE MEMBERS
True fungi	Chytridiomycota (Chytridiomycetes)	Motile oospores; survive as resting sporangia; most species saprobic	*Physoderma, Synchytrium, Olpidium*
	Glomeromycota (includes traditional Zygomycota)	Sexual spores: zygospores; asexual spores; sporangiospores from sporangia	*Rhizopus, Mucor*
	Ascomycota (Ascomycetes)	Sexual spores; (ascospores) form in an ascus; asexual spores are conidia; septate hyphae	Powdery mildews, *Cercospora, Guignardia, Meliola, Taphrina, Septoria, Venturia*
	Basidiomycota (Basidiomycetes)	Sexual spores (basidiospores) produced in a basidium; clamp connections develop at hyphal septa	Rusts, smuts, mushrooms, *Armillaria*
Fungal-like organisms	Stramenopila (Stramenopiles) Oomycota (Oomycetes)	Non-septate hyphae cell wall contains cellulose and glucans instead of chitin as in true fungi; sexual spores are oospores; asexual spores are zoospores (two flagellae) produced in a sporangium	*Phytophthora, Pythium, Albugo,* downy mildews
	Protozoa Plasmodiophoromycota	Intracellular in algal, fungal or plant hosts; develops a multinucleate, unwalled plasmodium in host cell; flagellate zoospores; common in soil and aquatic habitats	*Plasmodiophora brassicae* — club root of brassicas

BACTERIA AND PHYTOPLASMAS

Bacteria are tiny, single-celled organisms that lack chlorophyll. Cells reproduce rapidly by dividing into two (fission). Many bacteria produce extracellular polysaccharides that form a slime layer or capsule around the cell, which assists in plant infection. Members of the genera *Agrobacterium, Clavibacter, Erwinia, Pseudomonas, Xanthomonas, Ralstonia* and *Xylella* account for most species that cause diseases in plants.

Most bacterial plant pathogens are facultative parasites that adapt readily to different environments and can usually be cultured easily in the laboratory. Some bacteria that infect plants have never been cultured, or only with great difficulty, using specialised media. These are known as fastidious bacteria. They include the xylem-limited *Xylella fastidiosa*, the cause of Pierce's disease of grapevine, and the phloem-limited *Spiroplasma citri*, the cause of citrus stubborn disease.

Bacteria can survive for some time on plant surfaces as epiphytes, becoming active when conditions favour their development. The organisms can also survive in soil and crop debris, and in seeds and other plant parts. With the exception of *Streptomyces,* plant bacterial pathogens do not form spores.

Bacteria spread in infected seed and propagating material, water splash and wind-driven rain. Overhead irrigation is often an important means of spreading bacteria within a crop. Bacteria also spread with insects and with workers and machinery moving through a crop that is wet from rain or dew. Some species such as *Xylella* have specific insect vectors.

Bacteria infect plants through wounds or natural openings such as stomata and hydathodes. Warm, wet weather favours their development, whereas growth is often arrested by hot, dry conditions.

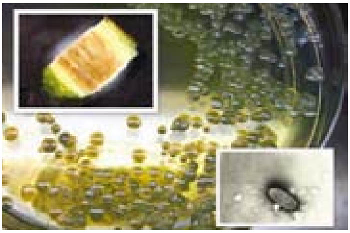

Fig 1.13 Bacteria growing in culture showing bacterial ooze from plant tissues (left) and a cell viewed through the microscope (right).

Fig 1.14 A tomato plant infected with tomato big bud disease showing distorted, new growth and the phytoplasma pathogen in an infected cell.

Phytoplasmas, previously called mycoplasma-like organisms, are similar to the true bacteria. They are of various shapes, including spherical, ovoid and filamentous, and lack a rigid cell wall. Phytoplasmas are spread by sap-sucking leafhoppers and planthoppers and infect only the phloem tissue of plants.

Typical diseases caused by phytoplasmas are the 'big bud' and 'little leaf' diseases of many crop and weed plants.

VIRUSES AND VIROIDS

Viruses are minute, non-cellular, obligate parasites consisting of a nucleic acid core, which contains the genetic information necessary for replication, surrounded by a protective protein or lipoprotein coat. Viruses cannot reproduce outside a host cell and they use the plants cell structures and components to produce more virus particles, to the detriment of the plant.

Many plant viruses are spread by sap-sucking insects, in particular, aphids, leafhoppers, thrips and whiteflies. All have piercing-sucking mouthparts including needle-like stylets which allow the insects to feed on the contents of plant cells. Transmission is an intricate biological process, often requiring the virus to form a close relationship with insect tissues before transmission is possible. Particular viruses are, almost always, spread by only one insect type. For example, aphids can transmit *Papaya ringspot virus* but not *Tomato yellow leaf curl virus*, which, in turn, is transmitted only by the silverleaf whitefly.

Three broad categories of insect transmission of plant viruses are recognised: non-persistent, semi-persistent and

Fig 1.15 Plant viruses viewed through an electron microscope showing isometric, flexuous and bullet-shaped particles.

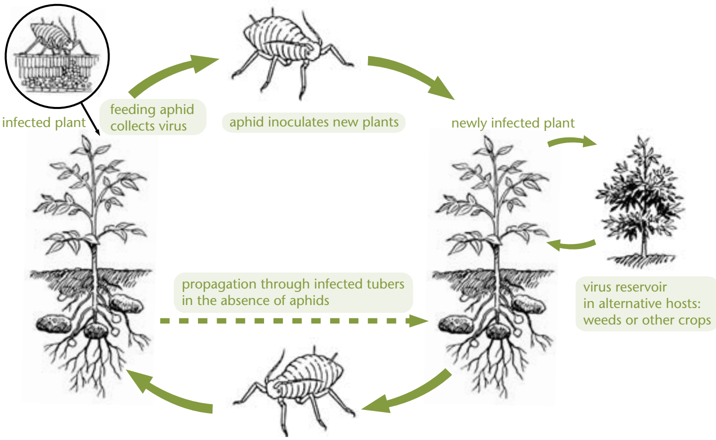

Fig 1.16 Disease cycle of *Potato leafroll virus*.

persistent or circulative transmission. The terms relate to the length of time an insect takes to acquire and transmit a virus, and the length of time the insect remains capable of transmitting the virus.

In non-persistent transmission the virus can be acquired from an infected plant or transmitted to another plant in less than one minute; the virus particles are usually retained on the insect's stylets for only a few hours. After this time, the insect obtains more virus only by feeding again on an infected plant.

In semi-persistent transmission, a virus can be acquired after 15 to 20 minutes of feeding, and the ability to transmit is retained for several days.

In persistent or circulative transmission, the insect needs to feed for up to several hours on an infected plant to acquire the virus, which then must circulate through the insect's body to the salivary glands for transmission to occur. This means there is a latent period, or time during which transmission cannot occur, while the virus particles travel through the insect's body. When the latent period is completed the insect can transmit the virus for many weeks, or the rest of its life, without collecting more virus from an infected plant.

Fig 1.17 Field symptoms of *Potato leafroll virus*.

Table 1.3 Important viruses in Australian vegetable crops

VIRUS/VIRUS GROUP	MEANS OF SPREAD	IMPORTANT HOST PLANTS
Bean common mosaic virus (Potyvirus)	Seed, aphids (non-persistent)	Beans
Bean yellow mosaic virus (Potyvirus)	Aphids (non-persistent)	Legumes, some ornamentals
Beet western yellows virus (Polerovirus)	Aphids (persistent)	Brassicas, lettuce, legumes, brassica weed species
Capsicum chlorosis virus (Tospovirus)	Thrips (three species)	Capsicum, tomato, peanut
Carrot virus Y (Potyvirus)	Aphids (non-persistent)	Carrot
Celery mosaic virus (Potyvirus)	Aphids (non-persistent)	Celery
Cucumber mosaic virus (Cucumovirus)	Seed, vegetative propagation, aphids (non-persistent)	Wide host range including legumes, cucurbits, capsicum, tomato, lettuce, ornamentals, weeds
Iris yellow spot virus (Tospovirus)	Thrips (*Thrips tabaci*)	Onion
Johnson grass mosaic virus (Potyvirus)	Aphids (non-persistent)	Sweet corn, maize, sorghum
Lettuce mosaic virus (Potyvirus)	Lettuce seed, aphids (non-persistent)	Lettuce
Mirafiori lettuce virus (Ophiovirus)	Zoospores of the soil-borne fungus *Olpidium virulentus*	Lettuce
Papaya ringspot virus – Type W (Potyvirus)	Aphids (non-persistent)	Cucurbits
Pea seed-borne mosaic virus (Potyvirus)	Pea seed, aphids (non-persistent)	Pea and several other legumes
Potato leaf roll virus (Polerovirus)	Aphids (persistent), vegetative propagation (tubers)	Potato, tomato
Potato virus Y (Potyvirus)	Aphids (non-persistent)	Potato, tomato, capsicum
Squash mosaic virus (Comovirus)	Seed, several leaf chewing beetles	Cucurbits
Subterranean clover stunt virus (Nanovirus)	Aphids (persistent)	Legumes, including beans, pea, broad beans
Sweet potato feathery mottle virus (Potyvirus)	Vegetative propagation (cuttings, roots); aphids (non-persistent)	Sweetpotato
Tomato mosaic virus (Tobamovirus)	Seed, contact by handling, contaminated implements	Tomato
Tomato spotted wilt virus (Tospovirus)	Thrips (persistent, propagative)	Wide range of hosts among vegetable, ornamental and weed species
Tomato yellow leaf curl virus (Begomovirus)	Silverleaf whitefly (*Bemisia tabaci*) (persistent)	Tomato, bean, capsicum, several weed species
Turnip mosaic virus (Potyvirus)	Aphids (non-persistent)	Brassicas, lettuce, rhubarb
Watermelon mosaic virus (Potyvirus)	Aphids (non-persistent)	Cucurbits
Zucchini yellow mosaic virus (Potyvirus)	Aphids (non-persistent)	Cucurbits

Certain viruses need to multiply in the cells of the insect vector as the virus circulates before transmission can occur. This type of transmission is termed circulative propagative transmission.

Viruses can also be spread through vegetative propagation using infected plant parts (e.g. bulbs, corms, cuttings and tissue-cultured plantlets) and some are also transmitted through seed, contact or infected pollen.

Table 1.3 summarises how some important plant viruses occurring in Australia are spread.

Symptoms caused by viruses are varied and several viruses infecting one crop type may have similar symptoms, requiring laboratory tests to determine which virus is present. Symptoms of virus infection are sometimes difficult to separate from those caused by chemical damage, insect feeding and nutrient imbalances.

Viroids are smaller than viruses and are among the smallest infectious agents known. A viroid consists of a small, circular, infectious nucleic acid and is entirely dependent on the host for its reproduction. Viroids spread from plant to plant in infected propagation material and in infected sap carried on hands or on cutting and pruning instruments. Viroids occurring in Australia include avocado sun blotch, citrus exocortis, potato spindle tuber and pear blister canker.

NEMATODES

Nematodes are microscopic, non-segmented roundworms that belong to the animal kingdom. They occur in almost every soil and water habitat in the world and most nematode species feed on bacteria and organic matter. Nematodes attacking plants have a hollow, spear-like structure (stylet) near the mouth, used to pierce the wall of plant cells and ingest cell contents. Feeding often results in the formation of galls or lesions on roots or distortion of other plant parts. Nematodes move by swimming in films of water between soil particles or on plant surfaces. They spread by water, movement in infested soil and on contaminated machinery, and in infected planting material.

Plant-parasitic nematodes are grouped according to their feeding behaviour. **Ectoparasites** feed from the outside of the root and do not enter the plant tissues, whereas **endoparasites** enter the root or shoot tissues and feed within the plant. In addition, they may be **sedentary,** establishing specific feeding sites where they remain until they die, or **migratory,** feeding while moving through the plant tissue. Table 1.4 lists some plant parasitic nematodes affecting vegetable crops in Australia.

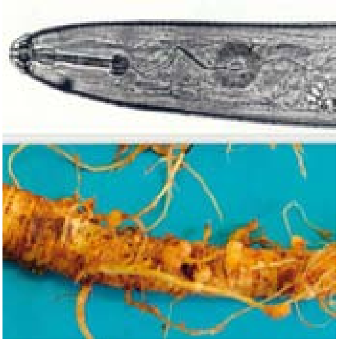

Fig 1.18 The head of a plant parasitic nematode showing the stylet, a spear-like stucture. Left: Root-knot nematode symptoms.

SYMPTOMS OF DISEASE

The first step in the diagnosis of a disease is recognising the visible signs or symptoms in the plant. Symptoms are the results of disturbing one or more of the vital functions of the plant, such as:

- water and mineral uptake by roots (e.g. root rots).
- carbohydrate, water and mineral translocation (e.g. vascular wilts and cankers).
- photosynthesis and respiration (e.g. leaf blights, leaf spots, mosaics).
- reproduction (e.g. fruit rots, smuts).

Most diseases produce characteristic symptoms that allow an accurate diagnosis or, alternatively, narrow it down to a few possibilities. Sometimes a definite diagnosis can be made only by using laboratory tests that allow the pathogen to be isolated from diseased tissue and identified. These tests should always be done if there is any doubt about the cause of a particular disease or if problems are being encountered during its control. Information that helps identify the cause of a disease includes the cultivar affected, location of affected plants in a field, weather conditions, crop sequences, and fertiliser and chemical treatments applied to the crop.

Table 1.4 Plant-parasitic nematodes of Australian vegetable crops

GENERA	COMMON NAME	MODE OF PARASITISM	SYMPTOMS
Meloidogyne	Root-knot nematodes	Sedentary endoparasites of roots	Plant stunting Plant wilting Root galls Root distortion
Heterodera *Globodera*	Cyst nematodes	Sedentary endoparasites of roots	Root galls/cysts Root distortion
Rotylenchulus	Reniform nematodes	Sedentary semi-endoparasites of roots	Plant stunting
Pratylenchus	Root-lesion nematodes	Migratory endoparasites of roots	Plant stunting Root lesions
Radopholus	Burrowing nematodes	Migratory endoparasites of roots	Root necrosis Plant lodging
Hemicycliophora	Sheath nematodes	Migratory ectoparasites of roots	Root tip swelling Root stunting Plant stunting
Trichodorus *Paratrichodorus*	Stubby root nematodes	Migratory ectoparasites of roots	Plant stunting Plant wilting Stubby roots
Tylenchorhynchus *Merlinius*	Stunt nematodes	Migratory ectoparasites of roots	Plant yellowing Plant stunting
Paratylenchus	Pin nematodes	Migratory ectoparasites of roots	Plant yellowing Plant stunting Root stunting
Rotylenchus *Helicotylenchus*	Spiral nematodes	Migratory ectoparasites of roots	Root lesions
Ditylenchus	Stem and bulb nematode		

DISEASE DEVELOPMENT AND MANAGEMENT

All diseases caused by pathogens are the result of an interaction between the host plant, a pathogen, and environmental factors such as light, temperature and moisture. Environmental factors affect the development of both the host and the pathogen. This interaction is known as the ‘disease triangle’ and all components must be compatible for a disease to develop (Fig 1.3).

Disease management strategies aim to favour the host plant’s growth and development while attacking vulnerable stages in the life cycle of the pathogen to prevent or restrict its development. The three key means of disease management are: exclude the pathogen; reduce inoculum levels of the pathogen; and protect the host plant.

Exclusion or eradication

- Pathogen-tested seed and vegetatively propagated materials are used (e.g. budwood, cuttings and nursery trees produced under strict hygiene procedures).
- Quarantine, including international, national and State quarantine zones, prevents movement of infected plant material. Illegal movement of material is a major threat to several of Australia’s horticultural industries.
- The eradication of a pathogen before it becomes widespread. This is more likely to succeed if an incursion is detected soon after it has occurred and the pathogen cannot be dispersed by air-borne spores or insect vectors.

Reduce inoculum levels

- Crop rotation reduces pathogen populations during the growth of non-susceptible crops. For soil-borne pathogens, crop rotation produces the greatest result for pathogens that survive only on living hosts or on host residues. Crop rotation is less effective for pathogens that can persist in the soil for long periods in the absence of a susceptible host.
- Incorporating organic manures into the soil increases the activity of microorganisms antagonistic to soil-borne plant pathogens.