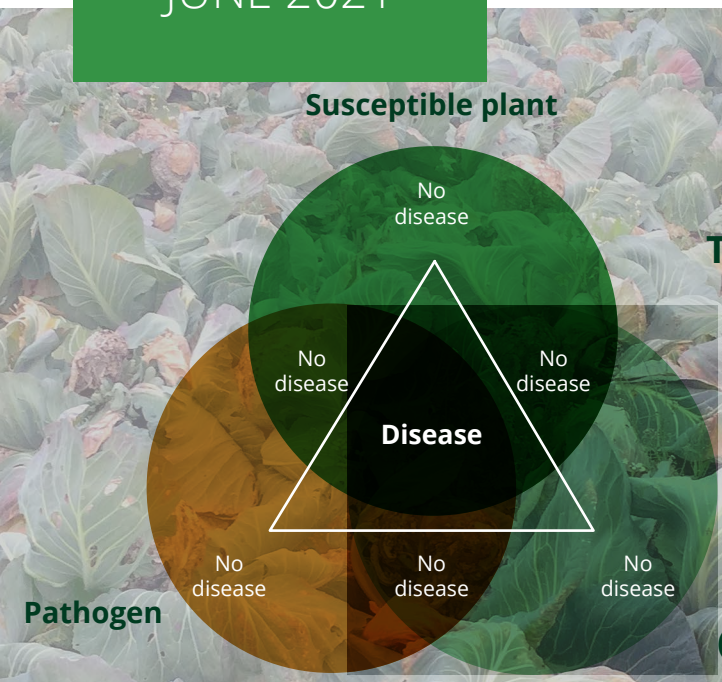
JUNE 2021

SoilWealth NURTURING CROPS

Integrated Crop Protection PROTECTING CROPS



The Disease Triangle

A GUIDE TO PREVENTING LEAF & STEM DISEASES

Photo: Len Tesoriero

This guide gives a brief overview of plant disease, general methods of transmission and a table on pages 5 and 6 (Table 1) which provides an overview of the conditions that foster key diseases of aboveground vegetable plants parts.

KEY MESSAGES

- ✔ **Pathogens, disease causing organisms such as bacteria and fungi, are everywhere**
- ✔ **Not all bacteria and fungi are harmful to plants, some are beneficial**
- ✔ **Healthy, not stressed plants have defence mechanisms against diseases**
- ✔ **Infection mostly occurs via natural openings in the leaf or scars/ wounds**
- ✔ **Dispersal/transmission can be via wind, water, soil, infected plant parts (e.g., seeds), insects, machinery, people or animals**
- ✔ **Infections generally happen when one or more aspects of the disease triangle changes, and conditions become favourable for the pathogen; weakened plants are attacked first**
- ✔ **Prevention, early identification and early treatment of disease(s) are key elements in disease control**

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Plant diseases are caused by living organisms feeding on plants and damaging them in the process. Most can spread from sick to healthy plants by a variety of means. Knowing optimum conditions for infection and disease spread is the first step in disease prevention and control.

Table 1 lists some of the common bacterial and fungal vegetable diseases, the conditions that encourage each organism's proliferation and disease expression, and some management options.

Disease expression involves many complex interlinked factors (the disease triangle, see cover page):

- **a plant may be damaged** in some way, e.g., by insects (allowing direct access by the pathogen)
- there may be nutrient deficiencies or water stress (**weakening the plant's defences**), and/or
- **environmental factors** (water, wind, temperature) may assist spread and infection.

These conditions can be thought of as supporters for the disease, sometimes one supporting factor is not enough, but two or three coming together are.

Choice of plant variety is important. Breeding for disease resistance or tolerance is ongoing. Therefore, it is worthwhile knowing your disease risks and resistance or tolerance traits of the variety you choose.

New growth or young plants are often more susceptible to disease due to their softer tissue and lack of fully developed defence mechanisms. Plant enzymes play one of the most important roles in plant defences against the infection process and disease development (Lebeda et al. 2001). **Healthy plants that grow without stress can develop better defence mechanisms** than weakened plants.

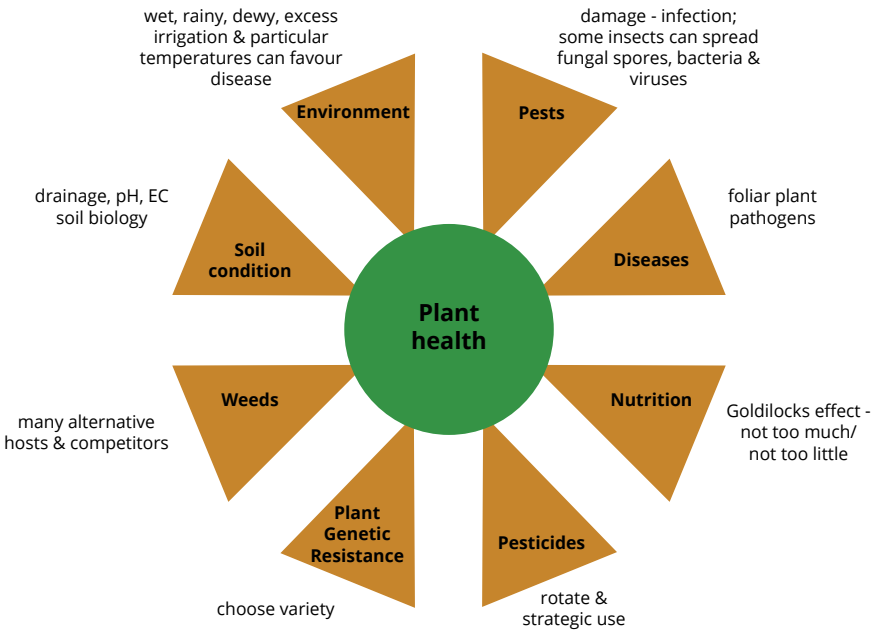

Figure 1. Effects on plant health that a grower can influence (courtesy Dr Len Tesoriero, adapted and used with permission)

The above are all things that affect individual plants, but there are wider considerations as well such as site selection. Both the plant-focussed options and the wider crop/farm management options are illustrated in Figures 1 and 2.

If you know the weather conditions that are likely to result in increased bacterial/ fungal disease (e.g. see Table 1), then you can monitor the weather conditions to predict when you will need to take appropriate preventative action, e.g. spray with preventative fungicide.

There are some predictive models and warning systems available.

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Examples of Management Options	
Cultural	Water - irrigation, drainage Crop rotation Site selection Farm hygiene
Biological	Weed control Pest insect control Soil biology Cultivar selection
Chemical	Fungicides Pesticides pH EC Plant nutrition
Data	Decision support tools Precision technology

Figure 2. Examples of management options for growing healthy plants (using Integrated Pest Management / Integrated Crop Protection principles)

BACTERIA

There are always some bacteria on the surfaces of plants and some of these never harm the plant, others can be helpful in disease suppression.

Bacteria that cause plant damage generally do not form spores like fungi to help them to spread. However they **can remain viable for long periods of time** even under dry conditions. This enables some of them to remain alive for years on plants, e.g., on weeds, in stored seed, other plant products and/or in the soil. **Bacteria usually spread with soil, water, machinery, people and plant matter.**

On leaves, bacteria can cause blights, defoliation/ cankers, galls and leaf spots. **Bacteria are unable to invade healthy plant tissue. They gain access either through natural openings in the leaf** (stomata, lenticels, hydathodes) **or through scars or wounds** (see Figure 3).

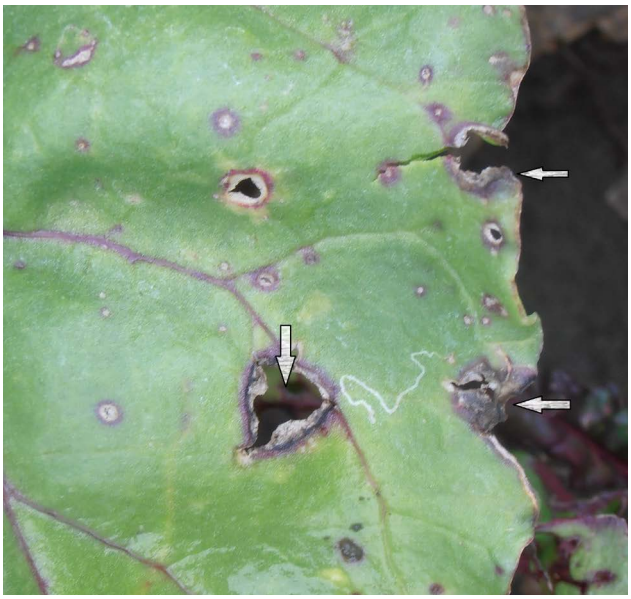

Figure 3. Arrows indicate entry sites for bacterial infection (image: Jeff Miller, Miller Research LLC)

Bacteria can be spread in much the same way as fungi (i.e., water, wind, infected plant material, soil, insects, birds, humans, machinery). Many bacterial diseases are seedborne. Bacteria can therefore be spread by any of the agents which aid seed dispersal.

Bacteria which get into the water and food-conducting 'tubes' of plants (xylem and phloem) spread quickly to fruits and seeds. If these are used to produce a new crop, the bacteria will quickly produce diseased seedlings which will not thrive and probably die.

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FUNGI

Generally, fungi produce two types of spores – sexual and asexual. Often the sexual spores 'overwinter', while the asexual spores do not. As these two sporulation stages often look very different, historically, there have been two scientific names for what has subsequently been shown to be the same fungal organism. In some cases, both names are still in use, which can be confusing. Due to new findings, organisms (including bacteria and fungi) can be renamed, which can also be confusing.

Sometimes several different organisms act together in a 'disease complex'.

Fungi enter host plants in a similar way to bacteria (natural plant openings or scars/wounds), though some are able to enter the plant using mechanical pressure (exerted by their hyphae) or secrete enzymes that attack cell walls, the major barrier to entry (Kubickek et al. 2014). **Fungi can be spread by wind, water, growing media (including soil/dust), machinery, seed, infected plants/plant parts/nursery stock/ germplasm, insects, birds and/or humans.**

FUNGICIDES FOR PREVENTION AND CONTROL OF LEAF AND STEM DISEASES

Fungicides prevent, kill, inhibit or mitigate the growth of fungi on plants, but they are not effective against nematodes, or viral diseases, and have minimal success in controlling bacterial leaf diseases. Fungicides can be classified based on several characteristics.

Preventive vs curative fungicides

Most **preventive/protectant fungicides** provide a protective barrier that prevent a fungus from getting into the plant.

Preventive fungicides:

- must come into direct contact with the fungus
- have to be re-applied to new plant tissues ; during rapid growth they may have to be applied more frequently than during periods of slow growth.
- have to be re-applied if the product washes off.

Some preventive fungicides can move in the plant.

Curative/penetrant fungicides affect the fungus after infection. They can slow the disease after an infection has started or after first symptoms have been observed. The earlier the symptoms are found, the better the control suppression and the lower the risk of resistance developing.

As a rule, the same active ingredient of a curative fungicide can only be used twice during a growing season.

'**Mode of action**' refers to how the fungicide affects the fungus. Fungicides may work by

- damaging the cell membrane of a fungus,
- inhibiting single or multiple important process(es) in a fungus

It's important to incorporate active ingredients with different modes of action by using suitable mixtures or by alternating products to maintain effectiveness and prevent fungicide resistance. FRAC (Fungicide Resistance Action Committee) is a good resource for guidance on alternating fungicide modes of action for different diseases.

Mobility in the plant

Contact fungicides (most protectants) stick to plant surfaces and **are immobile** and provide a protective barrier.

Systemic products (penetrants) are absorbed by the plant and **can move from the site of application** to other parts/tissues of the plant, e.g., from older to new growth upwards (acropetally, xylem mobile) or throughout the plant in any direction (phloem mobile) or from the top leaf surface to the underside of the leaf (translaminar). Most systemic fungicides move less than an inch toward the tip of the plant or may just move from the upper to the lower side of the leaf.

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Table 1. Bacterial and fungal leaf and stem diseases of vegetables, their infection conditions and management options including availability of fungicides

Disease	Comment	Crop	Plant part	Spread	Infection conditions		Management (apart from good hygiene, rotation, resistant cultivars, etc.)	Do growers rely on regular preventive sprays?*	Are curative / systemic fungicides available?*
					moisture and other	temperature			
BACTERIAL LEAF & STEM DISEASES									
Bacterial leaf spots, streaks & black rot (*Xanthomas* spp., *Pseudomonas* spp.)	serious in brassica vegetables	lettuce, brassica , beans, peas, capsicum, carrot, celery, cucurbits, corn	stems, petioles, leaves	(seed) water splash	wet, humid, windy splashing from rain, over irrigation	warm (25-30°C) for carrots, cool for lettuce)	keep dry, avoid rain splash & overirrigation	copper used in some crops	no
Bacterial soft rot (*Pectobacterium* spp. [previously *Erwinia*], *Dickea* spp., *Pseudomonas* spp.)	field infection, then often occurs as issue after harvest	cabbage, other vegetables (beans, cucurbits)	roots, stems, heads, all via wounds	water, weeds, decaying vegetable matter	wet	often high temperate, but some species like it hot, others cold	keep dry, good airflow, sanitation, avoid plant damage by insects	no	no
Bacterial wilt (*Ralstonia solanacearum*)	can be significant	wide host range, especially Solanaceae	infected via root damage but bacteria travel into shoots causing wilt	running water, soil movement, root to root contact, seedlings	wet soil	30-35°C ideal	strategic fumigation best followed by compost, manage N fertilisers carefully	no	no
Phytoplasmas (big bud, little leaf diseases)	bacteria without a cell wall (can't multiply outside insect/plant)	wide host range - but especially eggplants, celery, lettuce (Solanaceae, brassicas/cruciferous)	stems, leaves	insects, seed, weeds	dry, low humidity, vector dependent	moderate (20-25°C), definitely <40°C	control insect vector, and wild reservoir plants/hosts (in grapes yanga bush & saltbush species/ leafhoppers)	potential improved disease tolerance with arbuscular mycorrhizal (AM) fungi, gibberellic acid or salicylic acid	no
FUNGAL LEAF & STEM DISEASES									
Alternaria leaf spot/head rot (various *Alternaria* species)	common (minor)	brassica, cucurbits, leeks, carrots, capsicum internal fruit rot	leaves, fruit	(seed) water splash, air currents	6-8 hrs. leaf wetness	20-30°C	fungicides	yes	not enough information
Botrytis cinerea	very common	all fruiting vegetables, brassica, lettuce	flowers, fruit, leaves, stems, tubers/roots	wind	dew , humidity, wet & shady areas, poor airflow	cool to warm temperatures	fungicides, manage humidity	yes	yes (resistance develops quickly)
Downy mildew (crop specific genera)	can be major issue	brassica , lettuce, peas, cucurbits, beets, spinach, corn	leaves, stems	(seed) water splash, air currents, wind, oospores	leaf wetness, poor airflow	(8)15-20°C, depending on type of mildew & crops	seed treatment, fungicides	yes	yes (resistance develops quickly)
Fusarium cob rot (asexual stage *Fusarium verticillioides*, sexual stage *Gibberella moniliformis*) plus *F. proliferatum* & *F. subglutinans*	can be significant	corn, maize	cobs	airborne spores, seed	soil moisture stress	high temperatures	irrigation scheduling & monitoring, insect control	no	no
Leaf, stem & pod blight (disease complex involving *Ascochyta pisi*, *Mycosphaerella pinodes* &/or *Phoma pinodella*)	usually not severe but can spread widely	peas	leaf, stem & pod	wind, on seed	showery weather, high humidity, poor airflow	warm temperatures	seed treatment	yes	yes, needs very early application and is better used as preventative

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LEAF & STEM DISEASES
June 2021

Disease	Comment	Crop	Plant part	Spread	Infection conditions		Management (apart from good hygiene, rotation, resistant cultivars, etc.)	Do growers rely on regular preventive sprays?*	Are curative / systemic fungicides available?*
					moisture and other	temperature			
Light leaf spot (*Cylindrosporum concentricum*; sexual stage - *Pyrenopeziza brassicae*)	common	brassica	leaves	wind, water, rain splash	free water, 6 hrs. leaf wetness at 16°C or longer if cooler	cool temperatures 5-15°C	good airflow, wider spacing when crop is expected to close up during cooler weather	yes (UK)	yes (some resistance in UK)
Phoma lingam / blackleg (*Phoma lingam* asexual stage; *Leptosphaeria maculans* - sexual stage)	common in cooler climates	brassica	leaves, stems	seed, crop residues, soil, rain, irrigation, wind	leaf wetness	15-20°C	seed treatment	no	no
Powdery mildew diseases (several genera)	most common disease	most vegetables, especially artichokes, carrots, some brassicas, parsnips, capsicums, peas, cucurbits, beans, lettuce	leaves, stems, fruit/pods	air currents, wind	light dew, fog, condensate (not much free moisture)	warm (20-25°C), dry, overcast	preventative and curative fungicides, UV radiation	yes	yes
Ringspot (*Mycosphaerella brassicola*)	can be significant in cool, wet areas	brassica	leaves	wind (seed)	wet	cool temperatures	fungicides	yes	yes
Rusts (*Puccinia* spp., *Uromyces* spp.)	*Puccinia* spores cannot survive for very long without living plants	beans, corn, endive (also asparagus, peas, eggplant, Jerusalem artichoke, okra, onions, sweet potatoes)	leaves, stems	*Puccinia* wind, alternative hosts, *Uromyces* wind, seed, crop residues/ volunteers	rain, dew (*Puccinia* 4-6 hours of leaf wetness)	warm (15-35°C, depends on rust species)	manage volunteers, fungicides	yes	yes[3]
Septoria spot (*Septoria lactucae*)	can be major issue	lettuce	leaves	spores, seed	wet, windy, splashes (high humidity, high rainfall), poor airflow	10-15°C	fungicides	yes	no
Turcicum/corn leaf blight (asexual stage *Exoserohilium turcicum*, sexual stage *Setosphaeria turcica*)	common	corn, maize	leaves	spores	wind, rain	warm	early planting	no	no
White blister (rust) (*Albugo candida*)	significant, can become systemic	serious in brassica vegetables	heads, leaves, stems, flowers	water, wind (zoospores, oospores)	fog, mist, dew (wet leaves >2hrs), overhead irrigation, wind	preferred 13-25°C, can infect at lower temperatures	Fungicides, care with overhead irrigation	yes	yes (resistance develops quickly)
White leaf spot (asexual stage *Pseudocerosporella capsellae*, - sexual stage *Mycosphaerella capsellae*)	most significant in winter	leafy Asian veg	leaves	water, wind (seed)	moist to wet weather	cool temperatures	fungicides	yes	yes
FUNGAL LEAF & STEM DISEASES (SURVIVING IN SOILS)									
Sclerotinia minor	common	most vegetables	leaves, stems	wind	dew, rain, fog, rain, humid, needs living tissue for food source	>10°	fungicides, timing & penetration essential, manage stubble etc.	yes	yes (some resistance)
Sclerotinia sclerotiorum	very common	most vegetables	leaves, stems, (flowers, pods)	wind (spores)	dew, rain, fog, rain, humid, needs living tissue for food source	>10°	fungicides, timing & penetration essential, manage stubble etc.	yes	yes (some resistance)
Verticillium wilt (various *Verticillium* species)	can be major issue	mainly Solanaceae, but wide host range including weeds	roots (if damaged)	common soil inhabitant, microsclerotia (seed)	lack of rotation, wet	cool temperatures (16-25°C)	fumigation, increase rotations, avoid root stress	no	no

*There are biological products that may be of use but have not been registered. The SWICP Biologicals Database detailing many of these products is available here: https://www.soilwealth.com.au/resources/global-scan-and-reviews/biological-products-database/

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REFERENCES AND USEFUL RESOURCES

Department of Primary Industry and Fisheries NT (2014) **Field Guide to Pests, Beneficials, Diseases and Disorders of Vegetables in Northern Australia.** Available here: https://industry.nt.gov.au/__data/assets/pdf_file/0009/227772/vegfieldguide-sml.pdf

FRAC (Fungicide Resistance Action Committee) - including downloadable **app** (available on home page: https://www.frac.info), poster of fungicide groups/ mode of action (https://www.frac.info/docs/default-source/publications/frac-mode-of-action-poster/frac-moa-poster-2021.pdf?sfvrsn=a6f6499a_2), up to date **resistance and suggested management information by mode of action group**: https://www.frac.info/fungicide-resistance-management/by-frac-mode-of-action-group

Hort Innovation 2014-2021 **SARP reports (Strategic Agrichemical Review Process)** for various vegetables. These detail the chemicals available (and potentially available) for use in Australia for each disease and vegetable.
Available here: https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/vegetable-strategic-agrichemical-review-process-reports/

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Manners, Andrew and Sarah Dodd (2019). Fungicides, Resistance and their Management in Production Nurseries (factsheet). Produced for the nursery industry under Hort Innovation funded project 'Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry (NY15002). It contains **useful list of fungicides** and their actions, also **a good resource list**.
Available here: https://www.horticulture.com.au/globalassets/hort-innovation/resource-assets/ny15002_fungicides_factsheet.pdf

Our thanks to Dr Len Tesoriero (Plant Pathologist, NSW DPI) for his valuable input to this guide, and also to Cathryn Todd (Horticulture Pathologist, SARDI) for her comments and feedback.

This factsheet has been adapted from Kerruish, R. M., Unger, P. W., & Walkington, A. L. (2010). *Plant protection: 1 - Pests, Diseases and Weeds*. Hughes, A.C.T: RootRot Press ACT. Available here: https://www.appsnet.org/Publications/Kerruish/PP1.pdf

This factsheet complements "**Soil borne diseases in vegetable crops** - A practical guide to identification and control", available on the SWICP website as individual chapters here: https://www.soilwealth.com.au/resources/articles-and-publications/soil-borne-diseases-in-vegetable-crops-a-practical-guide-to-identification-and-control/

If you know of details that are inaccurate or incomplete, please get in touch - rm@rmcg.com.au