

**POCKET GUIDE**

# **PESTS, NATURAL ENEMIES, DISEASES AND DISORDERS OF VEGETABLE BRASSICAS IN NEW ZEALAND**

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Pests, natural enemies, diseases and disorders of vegetable brassicas in  
New Zealand

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## SEASONALITY CHARTS

A chart of seasonality is displayed for many of the pests and diseases in this handbook. Each month of the year is coloured either green, yellow or red. This is to be interpreted as follows:



**GREEN:**

pest is not likely to be present



**YELLOW:** pest is likely to be present,

but may not cause significant damage



**RED:** pest is likely to be present

and may cause significant damage

Note that this is a guide only, with information relating to typical Pukekohe weather conditions and pest pressures. In other regions the seasonality of specific pests and diseases may vary, and a wide range of factors such as rainfall and temperature will result in different pest pressures from year to year.

# SECTION 01

# **PESTS**

**DIAMONDBACK MOTH***(Plutella xylostella)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The diamondback moth is a small greyish moth with a wingspan of about 7 mm. At rest the wings are folded close to the moth's body to give a slim profile, and a diamond-shaped pattern is formed down its back. Adults are nocturnal and the female lays about 100 eggs.

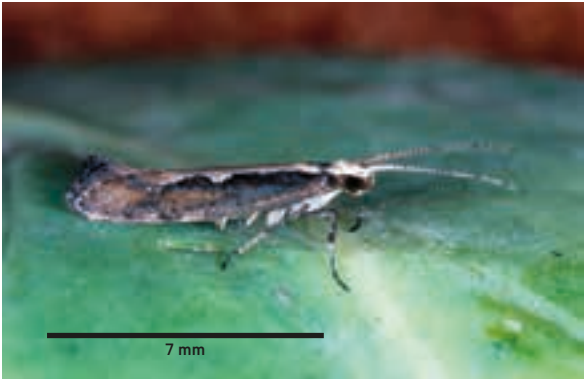
Diamondback moth eggs are yellow ovals less than 1 mm across. They are usually laid under the leaves near the edge of the leaf, or close to the leaf veins, and lie flat on leaf surfaces individually or in small groups. Caterpillars are 8 to 12 mm long when fully grown and their colour varies from light brown with a dark head at hatching, to dark green when fully grown. Caterpillars are widest in the middle, tapering slightly towards each end. They have two prolegs on the last segment of the body which are spread out to form a distinctive V at the caterpillar's rear end. If disturbed, they drop from the leaf on a silk thread.

Fully grown caterpillars construct a loose cocoon in which to pupate. Pupae are about 7 mm long, light green but gradually change to pale creamy-brown with dark markings.

**DAMAGE**

Diamondback moth larvae feed on the underside of leaves and will feed on the growing tips of young plants, preventing further development. Caterpillars burrow into the leaves when they are very small, making small white tunnels - later instars feed on the underside of leaves but do not eat the veins and often do not eat the upper skin of the leaf, which produces a window-like appearance. In broccoli and cauliflower the damage is indirect because they feed on the leaves and not on the commercial flower head.





A diamondback moth adult showing the characteristic diamond-shaped pattern on wings (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).



Diamondback moth larvae. Two prolegs on the last segment are spread apart, forming a distinctive V at the caterpillar's rear end.

Diamondback moth insecticide resistance management rotation strategy for vegetable brassicas (updated March 2012):

INSECTICIDE USE WINDOWS						
Sep-Nov	Dec-Jan	Feb	Mar	Apr	May	Jun-Aug
DIAMIDE/NEONICOTINOID INSECTICIDES						
Transplant drench	chlorantraniliprole + thiamethoxam (Durivo™) <sup>1</sup>					
OR:	imidacloprid (Confidor®)					
Foliar spray	chlorantraniliprole (Coragen®) <sup>2</sup>					
OTHER INSECTICIDE GROUPS <sup>3</sup>						
Apply insecticides only in response to scouting thresholds						
<i>Bacillus thuringiensis</i> (Bt) <sup>4</sup>						
indoxacarb (Steward®)		spinosad (Success® Naturalyte®)				
		fipronil (Ascend®)				
		synthetic pyrethroids <sup>5,7</sup>				
organophosphates <sup>6,7</sup>						
pymetrozine (Chess®) (for aphids only)		pirimicarb (for aphids only) <sup>7</sup>				

- 1 Coragen and Durivo have an active ingredient (chlorantraniliprole) in common. If Durivo is used (as a transplant drench), it should not be followed with Coragen on that crop.
- 2 Coragen can be used (as a foliar spray) in the period 1 December to 30 April, but not on crops treated with Durivo (as a transplant drench).
- 3 From any one insecticide group, use a maximum of two consecutive applications (less than 15 days apart) in the life of a single crop.
- 4 Apply Bt to small larvae on small plants.
- 5 There is resistance to synthetic pyrethroids in some populations of diamondback moth (DBM). The use of this group should be avoided in areas where resistance is known to exist. Consult your local pest control advisor before use.
- 6 Organophosphates are best used sparingly either against high infestations of early season seedling pests or as an end of crop 'clean-up' application.
- 7 Green peach aphid, *Myzus persicae*, and onion thrips, *Thrips tabaci*, are known to be resistant to broad-spectrum insecticides in New Zealand. Unnecessary application of these groups should be avoided as much as possible.



Severe diamondback moth damage on cabbage.



Pupa of diamondback moth covered with loosely spun, white silk threads.

**WHITE BUTTERFLY***(Pieris rapae)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The adult white butterfly has a grey to black body (20 mm long) with four broad white wings with black spots. Adults fly in daylight, particularly during warm, calm, sunny weather. Each female lays 300-400 bullet shaped eggs which stand on end and are easily detected. Eggs are white when laid but turn yellow to orange as they develop.

Caterpillars are dull green and have small hairs that give a velvety appearance. White butterfly caterpillars can be 2 to 30 mm in length. Small caterpillars can be distinguished from other species by their sluggish behaviour when disturbed, and a typical sideways head swing. When fully grown the caterpillar attaches itself to the underside of a leaf and changes into a chrysalis about 20 mm long (see the pupal parasitoid section).



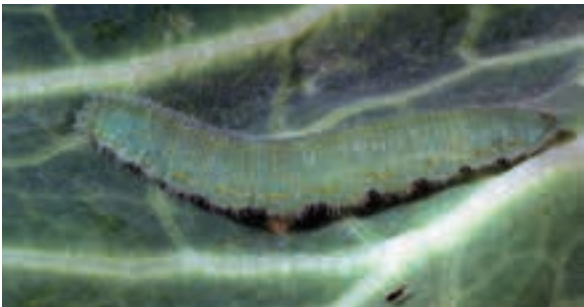
The adult of the white butterfly is a white to yellow butterfly with two or four black spots on the upper surface of the wings.

## DAMAGE

Small caterpillars stay on the underside of the leaf on which the eggs are laid, and then chew large irregular holes in the wrapper leaves or eat into the outer leaves of the head. Large amounts of frass (larval droppings) can stain the heads of cauliflower but are good indicators of the presence of large larvae. Large larvae may damage broccoli heads.



A bullet-shaped egg of the white butterfly (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).



A large white butterfly larva, showing a faint yellow or orange stripe down its back and broken stripes along the sides (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).

**GREAT WHITE BUTTERFLY***(Pieris brassicae)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The adult great white butterfly (GWB), known overseas as large white butterfly, looks very similar to the common small white butterfly (*P. rapae*), but is larger, with a wingspan of 55–70 mm. The main difference in appearance is that the forewing of GWB has a large distinctive black tip. Eggs are bright yellow, bottle-shaped, 1.4 mm high, ribbed vertically and laid upright in clusters of 40-100. Eggs change to bright orange prior to hatching.

Newly merged larvae are yellow with shiny black heads. After the first moult the colour changes to yellowish-green, with yellow lines running the length of the body. Fully fed larvae are 45 mm



Adult female *Pieris brassicae*. Note the distinctive black markings on the tips of the forewings (image courtesy of Richard Toft).





A cluster of eggs of great white butterfly (image courtesy of Department of Conservation).

long, basically olive-green with a pronounced yellow dorsal line, either side of which are black spots. The whole body is covered with fine, hair-bearing tubercles, many of which are also black. The head is bluish-grey with black patches. The larvae are gregarious (stay and feed together) for most of their life, only becoming semi-independent towards the end of the final instar. When fully grown they leave their host plants to find a place to pupate on or under some protective surface off the ground. This may be some distance away from where they fed. Pupae are 20 mm in length and pale green (in non-diapausing) or greyish-white (in the diapausing form), and are dotted with black and yellow markings. This species has a summer aestivation and a winter diapausing form. Thus eggs, larvae and adults are not normally present in February (New Zealand) or in winter.

### **DAMAGE**

They are regarded as a serious pest of cabbage, cauliflower and broccoli, but they are highly visible as eggs and larvae. The caterpillars stay in groups on the leaves where they hatch, and as they grow bigger they make bigger holes in these leaves. If not controlled, they can strip growing tips and even whole plants, particularly as large caterpillars.



Caterpillars of great white butterfly on honesty plant (image courtesy of Richard Toft).



Chrysalis (pupa) of great white butterfly (non-diapausing form (left) and diapausing form (right)) (image on left courtesy of Department of Conservation, image on right courtesy of Richard Toft).

**SEMI-LOOPER CATERpillARS****SOYBEAN LOOPER** (*Thysanoplusia orichalcea*)**GREEN LOOPER** (*Chrysodeixis eriosoma*)

Pest	J	F	M	A	M	J	J	A	S	O	N	D
GREEN LOOPER												
SOYBEAN LOOPER												

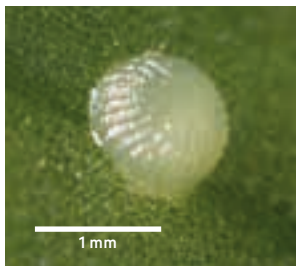
**DESCRIPTION**

Adult semi-looper moths are 18-20 mm long with sturdy bodies, and are predominantly a bronze-brown colour. At rest the wings are folded over the body like a tent. Soybean looper moths have a distinctive gold L-shaped marking on their wings; green looper moths have two silver spots towards the base of the wing.

The eggs of both species are white, round, 1 mm in diameter with vertical ribs, but compared with *Heliothis* eggs (see below) they have a flattened dome. They are usually laid singly on the underside of lower leaves.



Soybean looper moth showing the distinctive gold marking on the forewing.



Looper eggs are more flattened than *Heliothis* eggs (see p.23).



A large looper showing the characteristic looping movement.

The caterpillars of these two species reach 34-40 mm. They are green and the body is wider at the hind end and tapers towards the head, and they have two pairs of prolegs on mid-abdominal segments, and one on the anal segment. There are thin white lines along the body, but small soybean loopers often have more clearly defined black and white lines along the length. A dense covering of coarse black spines occurs on the side and underside of the thorax in soybean looper – this is not seen on the green looper. Soybean looper pupae will be almost entirely wrapped in a leaf tied with silk, whereas green loopers are less thoroughly wrapped. Soybean looper pupae develop to a uniform dark brown, while green loopers are a light green and develop a black back.

### **DAMAGE**

Smaller caterpillars feed mainly on the underside of outer leaves, causing small irregular holes. Larger instars feed on outer and inner leaves forming extensive holes, and can damage the surface of cabbage heads and contaminate heads and cauliflower florets with frass (droppings).

**HELIOTHIS OR TOMATO FRUITWORM***(Helicoverpa armigera)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

Heliothis adults are sturdy moths with a wingspan of about 40 mm. The forewings are typically brown with green, yellow, or red tones. The hind wings are pale with a broad, dark, outer margin. At rest, the wings are folded flat over the body.

A female moth lays up to 1000 eggs, usually singly on the upper surface of leaves but also on stems. Freshly laid eggs are white ribbed domes about 1 mm in diameter and are not as wide as green looper eggs. Close to hatching, they become more yellow and develop an orange ring near the top. Newly emerged caterpillars are about 1.5 mm long and are pale brown with dark heads. Larger caterpillars are up to 50 mm and vary in colour, with a broad, pale

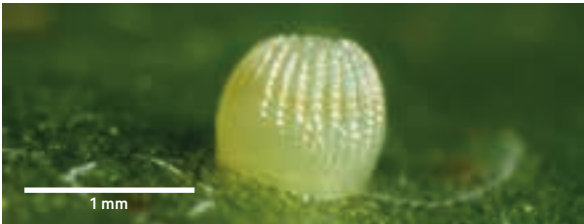


Heliothis adult moth.

band within the coloration along their sides. The caterpillars can be distinguished from loopers by the presence of four pairs of prolegs on the mid-abdomen. The sides of *Heliothis* caterpillars are dotted with black spiracles (circular breathing holes), and the body surface is rough with tiny short spines which are a good diagnostic feature visible with a hand lens. Fully grown caterpillars burrow into the soil and form brown pupae.

### **DAMAGE**

Small *Heliothis* caterpillars feed on outer and inner leaves and cause holes similar to those formed by loopers. Some caterpillars, especially larger stages, tend to burrow more and can severely damage the inner leaves and head, and contaminate produce with droppings.



Side view of *Heliothis* egg showing domed appearance and ridges.



A *Heliothis* caterpillar showing the four pairs of prolegs on the mid-abdomen and characteristic stripes and hairs.

**GREASY CUTWORM***(Agrotis ipsilon)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The greasy cutworm cuts young plant stems close to or just below the ground surface. It is more common in weedy land, including pasture, and can cause problems when this land is used for new crops. Greasy cutworm moths are sturdy, mottled brown to grey, and have large areas of black on the forewings and thorax. The forewings are long and narrow and have a span of approximately 45 mm. During the day they hide among vegetation, but will fly away if disturbed.

Eggs are laid in random clusters or singly, on vegetation or on open ground. The eggs are white when laid but soon turn light brown.



Greasy cutworm caterpillar, showing cutting behaviour.





Greasy cutworm moth (Image courtesy of Merle Shepard, Gerald R. Carner, and P.A.C. Ooi, *Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia*, Bugwood.org).

They are about 1 mm in diameter and a female lays between 600 and 800. Young caterpillars are brown to grey, and larger larvae are a dark, greasy grey with two yellowish longitudinal stripes above and light grey below. They have four pairs of prolegs on the mid-abdomen. Fully grown caterpillars, up to 50 mm long, make an earthen cell in the top 50 mm of soil to pupate, usually under some sheltering vegetation.

### **DAMAGE**

The young larvae feed on leafy growth until they are about one-third grown, when their colour darkens to the typical greasy grey. They then tunnel into the soil, emerging at night to feed, frequently dragging vegetation into their tunnels. Pastures often support many cutworms, and where infested land is adjacent to or converted to cropping, the spread or carryover of greasy cutworm often causes substantial loss. Damage may be more common in spring.

## TROPICAL ARMYWORM OR CLUSTER CATERPILLAR

(*Spodoptera litura*)

J	F	M	A	M	J	J	A	S	O	N	D

### DESCRIPTION

Adults are robust moths with dark forewings and whitish irregular markings, and white hind wings. They lay eggs in a batch covered with a felt of pale brown scales.

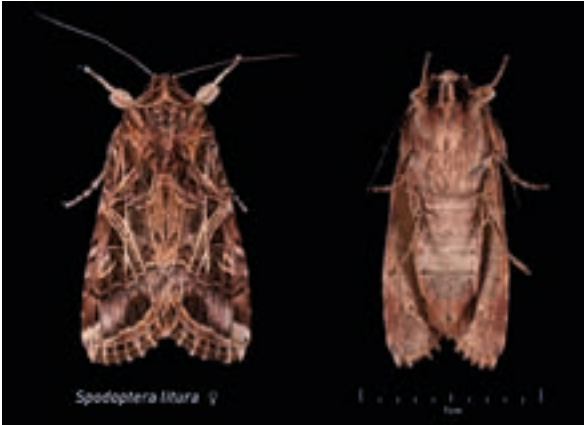
Young caterpillars are pale green and occur in clusters. Older larvae are grey with black and white markings and usually with a conspicuous yellow line down each side of the back. There is always a white dot on each side of the second and third segments of the body from the head. Fully grown larvae reach 50 mm long.



Larva of the tropical armyworm (image courtesy of Merle Shepard, Gerald R.Carner, and P.A.C Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia, Bugwood.org).

## DAMAGE

When caterpillars are small, they may stay together in a mass, causing characteristic, localised damage. As they grow larger they stop feeding in groups, and individuals can eat large leaf areas.



Adult tropical armyworm.

**ONION THRIPS***(Thrips tabaci)*

J	F	M	A	M	J	J	A	S	O	N	D
Yellow	Red	Red	Yellow	Green	Green	Green	Green	Green	Green	Green	Green

**DESCRIPTION**

Female adult thrips are less than 2 mm long, with two pairs of wings fringed with fine hairs that are folded along the back of the insect when at rest. Thrips can be identified by their small size and rapid movement.

Eggs are microscopic and are commonly inserted into leaves or buds. The larvae feed in protected places on leaves and buds and are similar in shape to adults, but are wingless and usually paler. The body is elliptical and slender, with small antennae and dark eyes.

In cooler areas adults overwinter, but in warmer areas all stages of thrips may be found year round.



Feeding damage (scarring) by adult and immature thrips (image courtesy of Whitney Cranshaw, Colorado State University, Bugwood.org).

## **DAMAGE**

Thrips feed by sucking the contents from soft tissues, causing silvery areas with black specks. They can cause bronze, rough areas on and in the onion head. Thrips can normally be found near the borders of fields, feeding on the underside of leaves, and overwinter in weeds and clover fields. Adjacent onion fields can be a major source of contamination.



Onion thrips adult (highly magnified).

**CABBAGE GREY APHID***(Brevicoryne brassicae)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

Cabbage grey aphids are about 2 mm long, dull green to grey, and can form dense colonies that are covered with a whitish waxy powder, similar in appearance to cigarette ash. Adult females may give birth throughout the year to live offspring. Both winged and wingless adult forms and nymphs occur in colonies. Winged adults are grey-green with black markings on the body and do not have the waxy coating characteristic of other individuals of the species. Their very short, barrel-shaped cornicles (two small upright projections from the rear of the body) and general body shape distinguish them from green peach aphid.

**DAMAGE**

Cabbage grey aphids feed by sucking plant juices, causing yellowing, wilting, and curling of leaves. Dense colonies may be seen around the plant's younger leaves and flowering parts. *Cauliflower mosaic virus*, *Turnip mosaic virus*, and *Turnip yellows virus* (= *Beet western yellows virus*) can be spread by cabbage grey aphid.



A dense colony of cabbage grey aphids covered with the typical whitish, waxy, powder coating.



A winged cabbage grey aphid. They have a black thorax and are not covered with wax (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).



Wingless cabbage grey aphids. This species can be distinguished from other aphid species by its very short, barrel-shaped cornicles (two small upright projections from the rear of the body) (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).

**GREEN PEACH APHID***(Myzus persicae)*

J	F	M	A	M	J	J	A	S	O	N	D
Yellow	Yellow	Green	Green	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow

**DESCRIPTION**

Wingless green peach aphid adults have pale-yellow to green bodies about 2 mm long. Winged females have black heads, dark-red eyes, and yellow, brown or green bodies. This species is distinguished by the tubercles (at the base of the antennae), which grow towards each other. The aphids are commonly found on lower leaves and then spread over the plant. Insecticide resistance has been reported in New Zealand for green peach aphid but there are no records of resistance for the other aphid species found in brassicas.

**DAMAGE**

Green peach aphid causes minor leaf distortion and may be a vector of viruses including *Cauliflower mosaic virus*.



Green peach aphid nymphs.





A winged green peach aphid adult (image courtesy of Scott Bauer, USDA Agricultural Research Service, Bugwood.org).

**EUROPEAN LEAF MINER***(Scaptomyza flava)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The leaf miner adult is a small insect similar in appearance to 'vinegar flies'. Its body colour is yellow to brown and the large eyes are bright red. The fly breeds all year. Adult females puncture leaves with their ovipositors to feed on leaf juices, and lay single eggs in some punctures. Eggs hatch into larvae that normally mine the dorsal surface. The fly larvae usually pupate out of host leaves in the soil or plant litter but they sometimes pupate in a leaf mine.

**DAMAGE**

The leaf miner is rarely a problem on cabbage or cauliflower, but can cause problems on young broccoli plants and is a major pest of Asian brassicas. The main plant damage is loss of tissue caused by mining, which can be extensive enough to debilitate the plant. For Asian brassicas, cosmetic damage caused by leaf miner is unacceptable to the market. Young larvae cause thin white mining symptoms. Larger larvae cause 'blotch' leaf mines that are distinctive to this species and can be very obvious on moderately infested plants.



Oviposition and feeding damage by adult leaf miner fly (small holes on right side of leaf).



Leaf miner damage.



European leaf miner adult flies (top) and puparium, and its larval/pupal parasitoid, *Asobara nr. persimilis* (males on left, females on right).

## **CABBAGE WHITEFLY**

*(Aleyrodes proletella)*

### **DESCRIPTION**

Adult cabbage whiteflies are about 1.5 mm long, with wings covered in a white, waxy powder. Tiny eggs are laid on the underside of leaves, often in circles where the adult is feeding. The first instar larva is about 0.3 mm long, flat, oval, and almost transparent. The second, third, and fourth instars are similar in appearance. The larva pupates within the skin of the fourth instar and forms a puparium, from which the adult emerges.

### **DAMAGE**

Whiteflies are piercing, sucking sap feeders, but heavy infestations that may weaken the host plant are unusual. The more usual form of damage is caused by sooty moulds that grow on the honeydew that is secreted by the larval and adult whitefly.



Cabbage whitefly adult. Note the black smudgy patches on the wings.



Cabbage whitefly eggs are laid on their sides and often in circles where the female is feeding.

**SLUGS****GREY FIELD SLUG** (*Deroceras reticulatum*)**BROWN FIELD SLUG** (*Deroceras panormitanum*)

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

The grey field slug *Deroceras reticulatum* is noted as the main pest species of vegetable brassicas. Slug eggs are laid in the soil, and young slugs eat decomposing vegetable matter. As they mature they also feed on plants. Slugs are most active at night, during wet weather, and near water sources. Populations are strongly influenced by the choice of field, and preventative control usually relies on cultivation. A fine soil tilth may minimise soil cracking and reduce crevices for slugs.

**DAMAGE**

Slugs feed on brassica leaves and stems, leaving damaged plants open to infection by bacterial and fungal diseases. Slug damage may be distinguished by silvery mucus trails.





Grey field slug.



Brown field slug.

**GRASS GRUB***(Costelytra zealandica)*

J	F	M	A	M	J	J	A	S	O	N	D

**DESCRIPTION**

Grass grub adults are approximately 10 mm long and are shiny, light to dark brown in colour. Eggs are oval shaped, approximately 1.5 mm in diameter and are creamy white in colour. The eggs are laid in clusters 70-200 mm below the soil surface. Larvae hatch in 16-21 days, depending on soil temperature. Larvae are C-shaped and are creamy white with a light brown head. There are three larval instars; the first instar is approximately 6 mm long and third instars are approximately 10-20 mm long.

**DAMAGE**

Grass grub larvae can be establishment pests of vegetable brassicas, by feeding on young roots, resulting in wilted and stunted plants.



Grass grub larvae (image courtesy of Richard Townsend, AgResearch).



Grass grub adults (image courtesy of Richard Townsend, AgResearch).



SECTION 02  
**NATURAL  
ENEMIES**

## APHID PARASITIDS

Aphid parasitoids are small wasps which lay eggs in aphid nymphs - the wasp larva consumes the aphid from inside, and as the larva matures the aphid is killed. The aphid skin then turns black or brown as it is mummified and, after the larva pupates, the adult wasp emerges. The different parasitoid genera can be distinguished by the form of the mummy stage, which is stuck to the plant leaf.

### APHELINUS SPECIES

These tiny wasps about 2-3 mm long are black, often with yellow markings on the abdomen. The antennae and legs can also be yellow and are short compared with those of *Aphidius* species. They form black mummies the same size as the adult aphid. *Aphelinus* are recorded from several aphids, but usually on alternative host plants.



Aphid 'mummy' parasitised by *Aphelinus*.

### **APHIDIUS SPECIES**

These tiny, slender wasps have longer legs and antennae than *Aphelinus* parasitoids. Their size depends on the size of the host aphid, but the body is usually 2-3 mm. Parasitised aphids form swollen, smooth, brown mummies within the aphid skin. They are recorded from green peach aphid and many other aphid species.



Empty aphid mummy that has been parasitised by *Aphidius* species.

**DIARETIELLA RAPAE**

This small black parasitoid wasp is about 2 mm long, with two pairs of wings normally folded back on top of the body. It attacks cabbage grey aphid. The adult is a weak flyer that can often be seen walking over the cabbage leaves searching for aphids in which it will lay an egg.



A cabbage grey aphid colony with parasitised aphid “mummies” of *Diaeretiella rapae*.



## MOTH EGG PARASITIDS

Parasitism of moth eggs by *Trichogramma* and *Trichogrammatoidea* species can be recognised when the eggs turn black just before the adult parasitoid wasp exits. Generally, the rate of parasitism of eggs is not high in vegetable crops in New Zealand, but this may reflect the susceptibility of these parasitoids to pesticides.



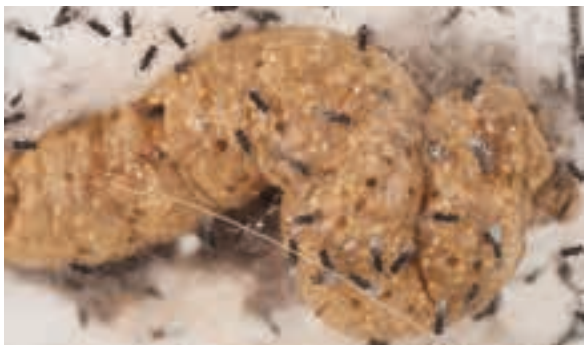
*Trichogramma* egg parasitoid ovipositing into *Spodoptera* eggs.

## EGG-LARVAL PARASITOID

*Copidosoma floridanum* is a tiny black parasitoid that lays a single egg in the egg of looper species. This parasitoid allows the caterpillar to develop and then multiplies within the large caterpillar, which bulges with up to 2000 parasitoid cocoons that each produce a tiny wasp.



Soybean looper parasitised by *Copidosoma floridanum*.



*Copidosoma floridanum* parasitoids emerging from the dried body of a looper caterpillar.

## LARVAL PARASITIDS

Several parasitoids attack caterpillar larvae. Some attack only one pest species, whereas others attack several or many caterpillar species.

### **COTESIA KAZAK**

This parasitoid was introduced into New Zealand for biological control of *Heliothis*, and it can assist control in brassicas. This small black wasp, about 3 mm long, lays a single egg in small caterpillars. The parasitoid larva develops inside the caterpillar and emerges to form a single, white silk cocoon (about 3 mm long) that is visible on foliage. The caterpillar usually dies before it is large enough to cause significant damage. A small black wasp emerges from each cocoon.

### **MICROPLITIS CROCEIPES**

This 7-mm wasp was introduced to attack slightly larger *Heliothis* larvae. It also forms single cocoons but as they are in the soil they are not easily seen. Combined parasitism of *Heliothis* from *Cotesia kazak* and *Microplitis croceipes* reaches 60-80% in some crops.



Adult form and cocoon of *Cotesia kazak* (top) and *Microplitis croceipes*, parasitoids of *Heliothis* larvae.

**COTESIA RUFICRUS**

This 2- to 2.5-mm wasp, known as the armyworm parasitoid, also attacks greasy cutworm, soybean looper, and green looper in brassicas. It lays eggs in caterpillars, with its larvae developing inside the host. In greasy cutworm, 30-100 mature parasitoid larvae emerge, killing the host, and spin a mass of silken white cocoons that are easily visible. In looper caterpillar larvae, 5-20 parasitoid cocoons are produced. Although parasitism rates in greasy cutworm can be high, rates of parasitism in loopers are generally low.



Silk cocoons containing developing adult *Cotesia ruficrus*, parasitoids of looper caterpillars.

### **COTESIA RUBECULA**

*Cotesia rubecula* is an effective parasitoid of small white butterfly larvae. It is well synchronised with its host and in unsprayed brassicas rates of parasitism can reach 80-100%. It was introduced into New Zealand in 1994 and is known to be present in Auckland, Waikato, Nelson and mid Canterbury. However, it disperses slowly and is not present in all the important brassica-growing regions.



An adult *Cotesia rubecula* ovipositing into a small white butterfly larva.



A white butterfly parasitoid (*Cotesia rubecula*) has emerged from inside a white butterfly larva and formed a single, white, silken cocoon.

**COTESIA GLOMERATA**

*Cotesia glomerata* is a gregarious species (produces many progeny) and attacks small white butterfly larvae but does not kill them until the caterpillars have grown large and have caused considerable damage. It is not well synchronised with its host and is not an effective natural enemy.



White butterfly parasitoids (*Cotesia glomerata*) that have emerged from inside a white butterfly larva and formed a mass of yellow silken cocoons.

### **METEORUS PULCHRICORNIS**

This recently self-introduced parasitoid is now commonly found in crops that are infested with *Heliothis* larvae, which is a preferred host. It also attacks other exposed small or medium-sized caterpillars found on brassicas, but does not attack white butterfly. However, rates of parasitism of diamondback moth and soybean looper are low. *Meteorus* is relatively easily recognised from its distinctive adult and cocoon. The adult is orange with a body length of about 4 mm, plus long antennae and a pronounced ovipositor. The parasitoid larva develops inside the caterpillar and emerges to form a single oval brown cocoon, which is suspended from a thread anchored to foliage.



*Meteorus pulchricornis* adult about to parasitise a *Heliothis* caterpillar.



*Meteorus pulchricornis* cocoon suspended from a leaf by a silken thread.

**ASOBARA NR. PERSIMILIS**

*Asobara nr. persimilis* is a small wasp that attacks the larval stage of the European leaf miner while it is inside the leaf, and then emerges as an adult from the fly pupa. This is the most common leaf miner parasitoid found in Pukekohe. The parasitoid is active all year round, but is most abundant in late spring and summer. In January, at Pukekohe, it can kill 80% of larvae and pupae of the European leaf miner, but has not been identified as present in other districts.

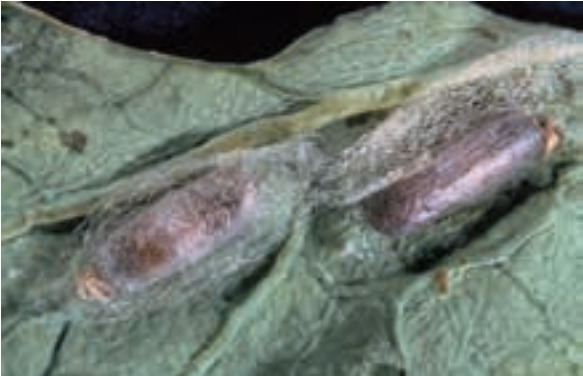


European leaf miner adult flies (top) and puparium, and its larval/pupal parasitoid, *Asobara nr. persimilis* (males on left, females on right).



### **DIADEGMA SEMICLAUSUM**

*Diadegma semiclausum* is an important larval parasitoid of diamondback moth, and can cause up to about 80% mortality in larval populations. The parasitoid is easily recognised as a smooth, brown-coloured, shiny cocoon inside the webbed pupal case of diamondback moth.



Diamondback moth (DBM) parasitised by *Diadegma semiclausum*. The parasitoid is easily recognised as a smooth, brown-coloured, shiny cocoon inside the webbed pupal case of DBM (image used with permission from University of California Statewide IPM Program, E.R. Oatman, photographer).

## PUPAL PARASITIDS

### ***DIADROMUS COLLARIS***

This parasitoid was introduced in 1937 for control of diamondback moth. It is a solitary pupal parasitoid which locates its host by searching brassica leaves for the webbing that covers diamondback moth pre-pupae and pupae. The adult is about the same size as *D. semiclausum* but has orange colouring on its abdomen. There is no obvious evidence that a pupa has been parasitized by *D. collaris* except that emergence is delayed and a wasp emerges rather than a moth.

### ***PTEROMALUS PUPARUM***

Introduced in 1932, *P. puparum* is a gregarious pupal parasitoid that attacks white butterfly at the prepupal or pupal stage. A large number of very small black wasps are produced from the shell of the chrysalis.



The pupal stage of the white butterfly pest (a chrysalis) and an adult wasp of the pupal parasitoid, *Pteromalus puparum*.

## HYPERPARASITIDS

***Trichomalopsis*** sp. is a very small black wasp. It is a hyperparasitoid that attacks the diamondback moth parasitoid, *Diadegma semiclausum*. A number of adult *Trichomalopsis* will emerge from the diamondback moth pupal case instead of *Diadegma*.

***Baryscapus galactopus*** is a hyperparasitoid of *Cotesia glomerata* which also attacks the new white butterfly parasitoid, *Cotesia rubecula*. It is a minute black wasp that attacks the larva of the parasitoid while still inside the white butterfly caterpillar. It emerges from the *Cotesia* cocoons, producing many adults. In late summer and autumn it can adversely affect the populations of beneficial *Cotesia* parasitoids.

***Alloxysta brassicae*** and ***Dendrocerus*** spp. attack the aphid parasitoids and can reduce the populations of aphid parasitoids in late summer and autumn.

## INSECT PREDATORS

### LACEWINGS

The Tasmanian or brown lacewing *Micromus tasmaniae* is predominantly an aphid predator and can be active from spring onwards. Both larvae and adults are aphid feeders. The adult is 7-10 mm long with characteristic lacy wings. Small white eggs are laid on aphid-infested leaves. The small larvae are alligator-like with a large pair of pincers that are used to seize whole aphids while sucking out the body contents.



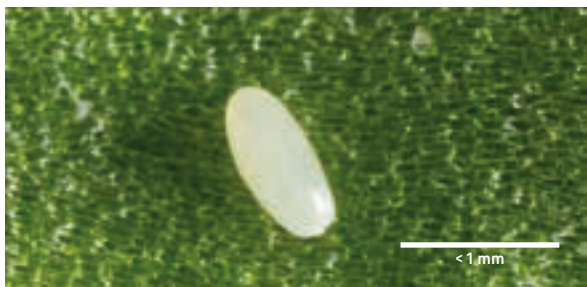
Tasmanian brown lacewing adult with characteristic lacy wings.



Small alligator-like lacewing larva about to attack an aphid.



Newly formed lacewing pupa attached to a leaf.



A lacewing egg, showing its smooth and oval appearance.

## LADYBIRD BEETLES

The most common ladybird beetle in brassica crops is the 11-spotted ladybird, *Coccinella undecimpunctata*. These predators lay small distinctive batches of yellow eggs on the underside of leaves and these eggs hatch into elongate larvae, which are also predatory. Eleven-spotted ladybird feeds mainly on aphids and may also attack small caterpillars. Adult beetles may provide some control of aphid populations in late spring and early summer but are less effective in summer.



The 11-spotted ladybird beetle (*Coccinella undecimpunctata*) is the most commonly found ladybird beetle in leafy vegetable crops.



Distinctive batch of yellow ladybird beetle eggs.



The elongated predatory larva of the 11-spotted ladybird beetle.

## HOVERFLIES

The small hoverfly *Melanostoma fasciatum* produces larvae that are one of the most common predators in vegetable crops. The adults are attracted to aphid-infested plants where they lay small, flat, white eggs, often singly but also in small loose groups. The larva or maggot is an effective predator of aphids, and also feeds on eggs, small caterpillars, and thrips. Although the species appears early in the spring, larval numbers may not build up until later in the season.



Small hoverfly adult, *Melanostoma fasciatum*.





Loose group of hoverfly eggs, small, elongated and white with a pitted surface.



Hoverfly larva feeding on an aphid.

## PREDATORY BUGS

Several predatory bugs occur in brassicas but are usually not significant. The soldier bugs (predatory shield bugs) attack a range of caterpillar larvae. The damsel bug is a predator of both aphids and caterpillars.



Soldier bug (*Oechalia schellenbergii*) adult.



The damsel bug, *Nabis kinbergii*, is a predator of both aphids and small caterpillars.

## PREDATORY BEETLES

Other general predators include rove beetles, click beetles and carabid beetles.



A small predatory rove beetle from the family Staphylinidae.



Click beetle, so named for the clicking sound it makes when propelling itself off its back.



Adult carabid beetle (*Megadromus antarcticus*).

## SPIDERS, HARVESTMEN AND PREDATORY MITES

Trials at Pukekohe suggest that harvestmen and spiders may provide good control of small caterpillars in leafy vegetables. The most abundant family found in trials at Pukekohe are the sheetweb spiders and wolf spiders, as well as harvestmen.

Predatory mites are very small (<3 mm) and there are many different species. It is likely that they will predate on springtails as part of their generalist diet.



Sheetweb spiders, common in vegetable crops, use webs to ensnare their prey.



Opiliones or harvestmen are common scavengers throughout many habitats, including vegetable crops.



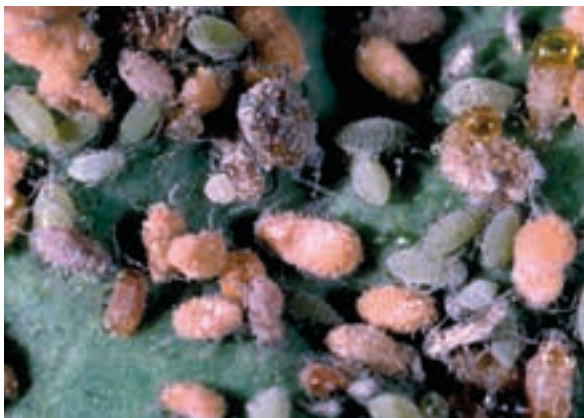
Red predatory mite.

## INSECT PATHOGENS

### ENTOMOPATHOGENIC FUNGI

Aphids become infected when they come in contact with the fungal spores. These germinate and infect the aphid body, producing a dense, slightly furry, aphid-sized brown mass on the plant leaf. Under moist conditions this mummy produces spores that are ejected and spread on to the plant or soil surface – from here they can infect other aphids. This infection normally occurs in late summer, autumn, and in mild winters.

Caterpillars are infected by fungi that produce spores that give a characteristic fluffy white or light brown appearance to the dead caterpillar. These fungi require moist conditions to develop, and in the Pukekohe region it is quite common for fungi to decimate populations of diamondback moth in mid to late summer. When this occurs, populations of diamondback moth are very slow to recover.



A cabbage grey aphid colony infected with a fungal disease (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).





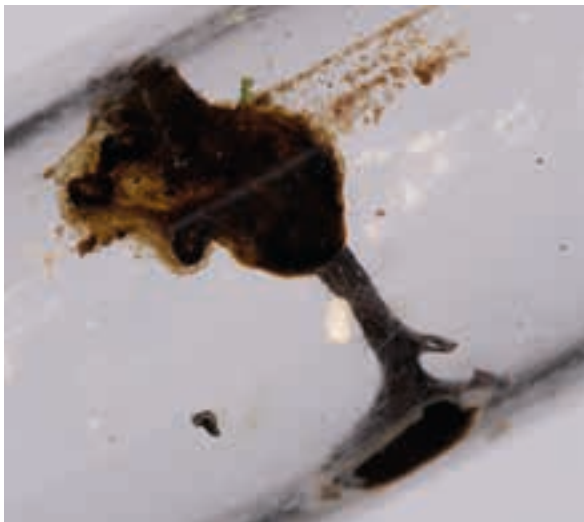
The remains of a diamondback moth larva infected with *Zoophthora radicans*.



*Zoophthora radicans*, a fungus that attacks a range of insect species including diamondback moth (shown here) and *Heliothis* caterpillars.

## VIRUSES

Caterpillars infected with a virus usually appear as flaccid, limp, larvae, sometimes hanging from leaf surfaces. A nuclear polyhedrosis virus (NPV) infects soybean looper in some autumn brassica crops and turns the caterpillar body contents black. Virus diseases liquefy the body contents and the caterpillar skin then bursts, releasing a liquid carrying infective virus particles over the leaf surface.



The remains of a soybean looper caterpillar infected with an NPV virus (in a tube).

SECTION 03  
**DISEASES**

**ALTERNARIA LEAF SPOT***(Alternaria brassicae, Alternaria brassicicola)*

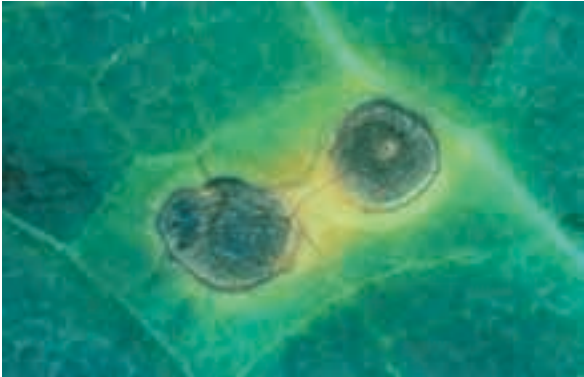
J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Alternaria leaf spot is also known as black mould, grey leaf mould, and black spot. Although leaf spotting is the major symptom associated with *Alternaria* infections, pre- and post-emergence damping-off can also occur. Tiny, dark specks first develop on leaves and later enlarge into circular, tan lesions several centimetres in diameter. Black spores may grow in concentric rings on the lesions, and yellow halos commonly surround the leaf spots. Old leaf spots become papery in texture and may tear, resulting in a “shot hole” effect. Individual spots may coalesce into large necrotic areas.



Alternaria leaf spot symptoms.



*Alternaria* leaf spot symptoms (image used with permission from University of California Statewide IPM Program, J.K. Clark, photographer).

### **TRANSMISSION**

The *Alternaria* fungi persist in crop debris and are commonly transmitted in seed. They may be spread by wind-blown spores from diseased brassica weeds or old brassica crops, by rain splash, or carried on contaminated equipment, or through the movement of humans and livestock. In wet conditions, germinating spores infect plant tissue directly or through natural openings in the leaves and stems. The disease is favoured by mild to warm temperatures (15-25°C) and high humidity.

**BLACKLEG / PHOMA ROT***(Phoma lingam)*

J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Blackleg, also called phoma rot, does not usually cause losses in the field unless it is introduced by infected seed. The blackleg fungus commonly affects plant stems and leaves, and brassicas are susceptible at all growth stages. The first symptoms are small brown spots on leaves and on stems, which may appear in nursery seedlings several weeks before transplanting. In the field, pale brown irregular spots develop on the leaves. Mature lesions become ashen-grey, often more than 1 cm across, and contain numerous pinhead-sized black fungal fruiting bodies. Stem lesions can be seen as elongated, light brown, sunken areas with purplish margins formed on stems near the soil line. They may extend below the soil surface, causing black rot of lower stems and roots. Severely affected plants remain stunted and finally wilt, and plants may fall over from lack of root anchorage. Infection can spread in storage.



The distinctive symptoms of blackleg on the soil line and below-ground plant parts (image used with permission from the University of California Statewide IPM Program, Jack Kelly Clark, photographer).

## **TRANSMISSION**

The blackleg fungus is seed-borne and overwinters in brassica crop residues in the soil. In spring the fungus becomes active and produces spores on infested crop residue or on cotyledons of seed-infected seedlings. These spores may be wind-blown or rain-splashed to other plants and fields. The fungus can also be spread on contaminated farm equipment and footwear. In the presence of free moisture (rain, dew, irrigation) the fungus penetrates leaves directly. If leaf stalks are infected, the fungus usually grows down into the main stems, resulting in 'blackleg' symptoms.



Note the numerous pinhead-sized black fungal fruiting bodies (pycnidia) (image used with permission from the University of California Statewide IPM Program, Jack Kelly Clark, photographer).

**CLUBROOT***(Plasmodiophora brassicae)*

J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Clubroot is the most serious disease of vegetable brassica crops in New Zealand. Once the disease has established in the soil it is almost impossible to eradicate. Above-ground symptoms of the disease include wilting of leaves during hot, dry days. Severely affected plants are generally stunted. Lower leaves may also drop off. Roots become severely distorted and enlarged to form the galls (clubs), which characterise the disease. In severe cases, the swollen roots decay as the plants die.

**TRANSMISSION**

Spores of the pathogen that causes clubroot can survive in the soil for many years. When environmental conditions are suitable, spores germinate, penetrate root hairs, and spread through the root, resulting in gall formation. The disease is favoured by cool, wet conditions, and acidic soils.





Broccoli root systems severely affected by clubroot – note root galls.

**DOWNY MILDEW***(Peronospora parasitica)*

J	F	M	A	M	J	J	A	S	O	N	D
Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red

**SYMPTOMS**

Downy mildew of vegetable brassica crops is widespread and can cause extensive crop damage. The first symptoms of foliar infection are dark specks that are often irregular in shape, may appear net-like, and are usually accompanied by leaf yellowing. These yellow areas enlarge and, on becoming limited by the leaf veins, take on an angular shape. If the disease is severe the yellow lesions coalesce, resulting in much of the leaf becoming brown and papery.



Downy mildew lesions on lower surface of a cabbage leaf (image used with permission from the University of California Statewide IPM Program, Jack Kelly Clark, photographer).



Downy mildew lesions on the upper surface of a broccoli leaf (image used with permission from the University of California Statewide IPM Program, Jack Kelly Clark, photographer).

A greyish-white mouldy growth develops on the undersides of leaves during conditions of high humidity. Downy mildew can also sometimes cause brown discolouration of cauliflower and broccoli heads, and can lead to infection by soft rot bacteria and fungi, which can further rot tissue in the field or after harvest.

### **TRANSMISSION**

Although the downy mildew fungus can survive in crop debris, the main sources of infection are spores from infected brassica debris and plants growing in nearby fields. Extended periods of leaf wetness caused by fog, rain, or dew favour infection and disease development. Downy mildew develops most rapidly when night temperatures are between 10 and 15°C. When night temperatures exceed 24°C, disease development is greatly restricted.

**LIGHT LEAF SPOT***(Pyrenopeziza brassicae)*

J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Light leaf spot can cause severe damage to cauliflower and may occasionally be important on Brussels sprouts, cabbage and broccoli. On cauliflower leaves the disease is first seen as 1-mm white lesions consisting of dense white clusters of spores, resembling dried spray droplets. The spots expand and develop into circular or irregular dark patches with white halos formed by masses of spores. These are easily washed away by raindrops or dew. Infections on petioles and on stems usually cause dark-brown to black lesions that become scar-like as they age. In severe infections the entire basal end of the leaf petioles becomes discoloured. Occasionally, cauliflower inflorescences are infected by the fungus, causing tan to brown discolouration. In instances where the disease is very severe, whole plants can be deformed and their growth stunted.

**TRANSMISSION**

The fungus survives in infected plant debris, on which it may produce small, tan, mushroom-like structures that eject spores into the air. The spores infect plants during cool, wet weather, and fully expanded leaves are more susceptible than young leaves. The disease is subsequently spread by splash-dispersed spores, which cause secondary infections if environmental conditions are favourable. The disease thrives in extended periods of leaf wetness and cool temperatures (optimum 15°C).

# RHIZOCTONIA

(*Rhizoctonia solani*)

J	F	M	A	M	J	J	A	S	O	N	D
Red	Red	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Yellow	Yellow

## SYMPTOMS

*Rhizoctonia solani* is a common soil fungus that can cause several different diseases.

**WIRESTEM:** The most common and destructive rhizoctonia disease of vegetable brassicas. The stems of affected seedlings shrivel and darken above and below the soil line, and the outer stem tissue sloughs off, giving a slender, wiry appearance. Generally, infected plants do not fall over but remain erect. Diseased seedlings are usually stunted and unthrifty, and may die.



Wirestem symptoms on a seedling (image courtesy of Gerald Holmes, California Polytechnic State University at San Luis Obispo, Bugwood.org).

**DAMPING-OFF:** Pre-emergence damping-off occurs when seeds decay and do not germinate, or germinate but fail to emerge. Post-emergence damping-off occurs when the stems of young seedlings are attacked. Light brown and water-soaked lesions appear near the soil line, resulting in rapid wilting and collapse. Damping-off usually occurs in circular 'hot-spots' or along rows.

**BOTTOM ROT:** Elongated black lesions develop on the underside of the midribs of affected leaves, while brown to black sunken, elliptical lesions appear on the lower leaves. Affected leaves wilt, decay, and turn black, but do not drop off. Leaf lesions become papery during dry weather. Some plants may recover and produce heads. In cabbage, bottom rot usually develops into head rot.

**HEAD ROT:** This decay of cabbages develops between early head formation and maturity. The outer leaves of each affected head wilt, become pale, and turn brown to black near the main stem. The head leaves dry at the base and remain attached, while outer wrapper leaves die and drop off, exposing the stem beneath the head. A dark, web-like mould may spread over infected tissues and, in damp weather, between the head leaves, giving rise to masses of 5-mm brown fungal bodies. The head remains upright and dark. Bacteria commonly invade the diseased tissue and rapidly turn an infected head into a slimy, foul-smelling mass.

## TRANSMISSION

The *Rhizoctonia* fungus survives in the soil as small, hard, brown bodies that are extremely resistant to cold, heat, drought, and most chemicals. These germinate in damp weather to form fungal threads that penetrate roots and leaves of susceptible plants. The fungus is active during warm weather (25°C optimum), provided moisture is adequate. Seedlings and mature plants may become infected through direct contact with the fungus in the soil.



Rhizoctonia head rot of cabbage (image courtesy of Eric McKenzie, Landcare Research).

## RING SPOT

(*Mycosphaerella brassicicola*)

J	F	M	A	M	J	J	A	S	O	N	D

### SYMPTOMS

Ring spot is most common in winter and early spring, with symptoms appearing on all above-ground plant parts, although it occurs most often on older leaves. Ring spot lesions are circular, up to 1 cm in diameter, light brown to grey-brown with narrow olive-green borders, and are usually numerous on leaves. The lesions contain very many small, black, pinhead dots in concentric rings much like a target pattern – hence the name “ring spot”. In severe cases the spots coalesce, entire plants may be affected and blackened, and defoliation can occur. Ring spot does not damage cauliflower curds or broccoli heads but can make cabbage heads unsaleable. Severe ring spot can reduce growth, delaying harvesting and causing damage to crops that are harvested in leaf.



Ring spot leaf symptoms.



## **TRANSMISSION**

The fungus survives from one season to the next on diseased plants, in infected crop debris left in fields, and in seed. In cool (15-20°C) moist environments mature leaves are infected, with heavy dews favouring infection, although infection may also occur through wounds sustained during harvest. Ring spot symptoms can continue to develop on plants after they are harvested.



A ring spot lesion. Note the concentric rings of fruiting structures.

## SCLEROTINIA ROT

(*Sclerotinia sclerotiorum*, *Sclerotinia minor*)

J	F	M	A	M	J	J	A	S	O	N	D
Yellow	Yellow	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Yellow	Yellow

### SYMPTOMS

Sclerotinia rot (sometimes called white mould) can cause serious losses in the field, in storage, and in transit. Although sclerotinia rot may occur at any growth stage, most brassica plants are infected as they approach maturity. Infections may occur on plant stems at the soil line, where the foliage comes in contact with the soil, or on the upper leaves. The infections begin as light brown, water-soaked lesions, which become covered by a white, cottony fungal growth. Infected plant tissues turn brown and become soft and watery, and the fungus eventually colonises the entire heads and produces irregularly shaped black structures on the diseased tissue. The foliage becomes greyish-green as necrosis begins, then turns dark brown and withers. Diseased leaves drop off and, if stems are girdled, the plants eventually die.



Sclerotinia rot.

## TRANSMISSION

*Sclerotinia* rot fungi survive in the soil for many years as black, hard-walled bodies that germinate and infect parts of plants that are in contact with the soil. The fungi also produce small, tan, mushroom-like structures that eject spores into the air. These spores are dispersed by wind to infect the upper leaves of brassica plants. Cool (18°C), moist conditions favour infection and disease development.



Sclerotinia rot.

## **WHITE BLISTER**

*(Albugo candida)*

### **SYMPTOMS**

White blister disease symptoms are characteristic white blisters and swellings on the leaves and florets of brassicas.

### **TRANSMISSION**

The white blisters contain very large numbers of spores, which are dispersed by wind upon release. It is important that any new outbreaks of white blister are quickly reported to MPI.



White blister lesions on the undersides of leaves of a broccoli seedling (photo: Dr Elizabeth Minchinton, DPI Victoria, Australia).



White blister on a broccoli head and surrounding leaves (photo: Dr Elizabeth Minchinton, DPI Victoria, Australia).

**BACTERIAL SOFT ROT***(Erwinia carotovora)*

J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Bacterial soft rot is particularly damaging to Chinese cabbage and common cabbage. In the field, the first indication of soft rot is often rapid wilting of the outer leaves of affected plants. Infected plant tissues develop water-soaked lesions that enlarge rapidly in diameter and depth, become soft, and generally turn brown in advanced stages of disease development. Soft rot-infected plants almost always give off an offensive odour because of invasion by secondary organisms, but there is no mould associated with the rot. Plants can be affected at any growth stage, and disease losses from soft rot may occur in the field, in transit, or in storage.

**TRANSMISSION**

Soft rot bacteria are common in the environment and survive in the soil on infected plant debris. The bacteria may be carried on cutting knives used at harvest and are common on cull piles and residues in produce bins. Infection occurs through wounds, and is favoured by wet and humid conditions. Decay can be rapid, especially when temperatures are high (optimum 22-27°C). Postharvest rot caused by these pathogens is common where cool chain conditions are not maintained.

## BLACK ROT

(*Xanthomonas campestris* pv. *campestris*)

J	F	M	A	M	J	J	A	S	O	N	D
Red	Red	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Red	Red

### SYMPTOMS

Black rot is most prevalent in low areas and where plants remain wet for long periods. The first signs of disease often occur at leaf margins. Early seedling infection appears as a blackening along the margins of cotyledons, which later shrivel and drop off. Transplanted infected seedlings are often stunted and may exhibit one-sided growth. Initial symptoms may include a small, wilted, yellowish V-shaped area that extends inward from the leaf edge. As diseased areas enlarge, infected leaf tissues turn yellow to brown and dry out, and the veins of infected leaves, stems, and roots turn black. The blackening of veins within yellow lesions along leaf margins is diagnostic of black rot. If an infected stem or petiole is cut through, the vascular ring often appears black. Late infections of black rot may merely spot the leaves or result in smaller heads. Soft rot bacteria commonly invade black rot lesions.

### TRANSMISSION

The bacteria survive on contaminated seed, in infected crop residues in the soil, and in weeds. Bacteria in the soil can invade roots, but most frequently invade host plants through water pores at the leaf margins. The black rot bacteria are spread in water splash from rain or irrigation, and under warm (25-30°C), moist conditions the disease can spread very rapidly throughout a crop. Free moisture (from dew, fog, rain or irrigation) is required for infection and disease development.



Black rot on a cauliflower leaf.





Black rot lesions on leaf margins.

## HEAD ROT

(*Pseudomonas fluorescens*, *Pseudomonas marginalis*)

J	F	M	A	M	J	J	A	S	O	N	D

### SYMPTOMS

Head rot of cauliflower and broccoli is found in most vegetable brassica production areas of New Zealand. Symptoms of the disease first appear soon after periods of rain, when heads have remained wet for several days. The first symptom is 1 mm water-soaked spots, usually seen on only two to three florets in an infected head. These lesions expand into large, slightly sunken, brown or black, areas of soft decay.

### TRANSMISSION

Head rot bacteria in the soil are splashed up on to the broccoli and cauliflower heads. Disease incidence and severity increase with the presence of prolonged wet, warm weather at head maturity. Head rot develops most rapidly at high temperatures (28°C). There are no effective chemical control measures currently available for bacterial head rot of broccoli.



Severe symptoms of broccoli head rot.

**PEPPERY SPOT***(Pseudomonas syringae pv. maculicola)*

J	F	M	A	M	J	J	A	S	O	N	D

**SYMPTOMS**

Peppery spot, also known as bacterial leaf spot, occurs mainly on cauliflower and to a lesser extent on broccoli, cabbage and Brussels sprouts. This disease is first seen as numerous tiny irregularly shaped, brown to purplish lesions with yellow haloes on the undersides of the outer leaves of cauliflower. The lesions enlarge to form irregular light brown, papery areas with yellow borders up to 10 mm in size. Lesions are confined by the leaf veins, but may coalesce and tear, giving the foliage a ragged appearance. Infection of leaf veins restricts growth and causes puckered foliage when lesions are numerous. Extensive infection may cause leaves to turn yellow and drop off. The pathogen may also cause grey to brown spots on the heads, especially during cool, wet weather or after a frost. The affected tissues are firm at first but may become soft if invaded by secondary organisms.

**TRANSMISSION**

The peppery spot pathogen survives between crops in infected seed and diseased crop residues in the field. The bacteria can remain viable in soil for 2-3 years and are spread by rain-splash, soil-water run-off, blowing leaves, and possibly by insects. Peppery spot development is most prevalent in wet weather, with an optimum temperature of about 24°C.



Peppery spot (image used with permission from the University of California Statewide IPM Program, Robert N. Campbell, photographer).

## CAULIFLOWER MOSAIC VIRUS

J	F	M	A	M	J	J	A	S	O	N	D

### SYMPTOMS

*Cauliflower mosaic virus* causes a leaf mottle or mosaic symptom. Leaf veins are paler in contrast to the darker green leaf and leaves overall become darker, less glossy green in colour. Plant foliage can become distorted, twisted and brittle, and foliage may die prematurely when severely affected.

### TRANSMISSION

*Cauliflower mosaic virus* is spread primarily by cabbage grey aphid and to a lesser extent by the green peach aphid. *Cauliflower mosaic virus* is not known to be seed transmitted.



*Cauliflower mosaic virus* on cauliflower.

## TURNIP YELLOWS VIRUS (= BEET WESTERN YELLOWS VIRUS)

J	F	M	A	M	J	J	A	S	O	N	D
Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green

### SYMPTOMS

*Turnip yellows virus* infections can occur sporadically in regions where forage or seed crucifer crops are grown. *Turnip yellows virus* symptoms in maturing crops of most brassicas are usually confined to the outer leaves. Turnip and swede may show bright yellowish purple leaf margins. Chinese cabbage and radish may show interveinal yellowing and early-season infection may cause plant stunting.

### TRANSMISSION

*Turnip yellows virus* can be spread by many species of aphid; however, the green peach aphid and the cabbage grey aphid are the most important in brassicas. *Turnip yellows virus* is not known to be seed transmitted or spread by mechanical inoculation.



*Turnip yellows virus* (= *Beet western yellows virus*) on turnip.

## TURNIP MOSAIC VIRUS

J	F	M	A	M	J	J	A	S	O	N	D

### SYMPTOMS

*Turnip mosaic virus* symptoms are usually confined to the outer leaves, which develop small, pale spots, sometimes with an indistinct mosaic mottling. In cabbage growing at low temperatures mild mottling / mosaic develops into dark rings and bands round the edges of older leaves, which die off prematurely – this is known as the ‘cabbage black ring spot’ symptom. Chinese cabbage is particularly sensitive, with entire leaves turning yellow, with stunting and crinkling occurring around the edges, especially in heart leaves. Paler internal leaves become soft and water soaked, with a brown flecking in the vascular system.

### TRANSMISSION

*Turnip mosaic virus* can be spread by many species of aphid; however, the green peach aphid and the cabbage grey aphid are the most important. *Turnip mosaic virus* is not known to be seed transmitted.



*Turnip mosaic virus* – cabbage black ring spot symptom on cabbage.





*Turnip mosaic virus* on wasabi.



*Turnip mosaic virus* on Chinese cabbage plant.



# SECTION 04

# **DISORDERS**

## NITROGEN DEFICIENCY

### SYMPTOMS

Foliar symptoms include a uniform pale colour and yellowing of lower leaves. A purple flush is often seen on leaves and/or midribs, petioles, and stems lacking in nitrogen.

Nitrogen deficiencies can be caused by a range of factors including insufficient application of nitrogen fertiliser, incompletely decomposed organic matter applied to the crop, and soils low in organic matter. Leaching and/or denitrification after waterlogging can be a factor, as can a lack of nitrate movement to the roots in dry soil. Low soil temperature may also play a role, as mineralisation of organic matter can be restricted.



Nitrogen deficiency (image courtesy of Carl Rosen, University of Minnesota).

## PHOSPHORUS DEFICIENCY

### SYMPTOMS

Symptoms of phosphorus deficiency include reduced growth rate and a purpling or dull bluish green colour in older leaves. Cauliflower curd may become red.

Phosphorus deficiencies can be caused when phosphorus fertilisers are not used, soils are acidic and rich in iron and aluminium oxides, soils are calcareous, or when soils are strongly adsorbing clays or peats.

## POTASSIUM DEFICIENCY

### SYMPTOMS

Symptoms of potassium deficiency are a marginal chlorosis or scorch of older leaves. Scorched margins may also curl up or down. Blotch chlorosis may be present on old leaves. Potassium deficiencies can be related to sandy and chalky soils, but are rare in intensive horticulture because of regular potassium fertiliser applications.



Potassium deficiency. Note leaf edge scorch due to potassium deficiency (image courtesy of Yara).

## MAGNESIUM DEFICIENCY

### SYMPTOMS

Symptoms of magnesium deficiency show as an interveinal chlorosis beginning on older leaves, giving a mottled appearance. Characteristically, the leaf margin remains green. The undersides of brassica leaves may develop orange, yellow and purple colours.

Magnesium deficiencies may be related to sandy soils low in available magnesium, soils high in available potassium, or poor soil structure affecting root growth.



Magnesium deficiency on broccoli (image courtesy of Yara).

## **BORON DEFICIENCY**

### **SYMPTOMS**

Brassica crops are sensitive to boron deficiency. Boron deficiencies are often common in areas of high rainfall and on soils with a high pH (over 6.5). Symptoms also occur after a drought period and can be aggravated by recent high nitrogen use and liming.

Symptoms are numerous and include convex cupping of new leaves on seedlings, marginal chlorosis with red and yellow colours on broccoli, cracked and corky stems, petioles and midribs, hollows in the stems of cabbage and cauliflower, and cauliflowers with browning of the curd.



Boron deficiency (image courtesy of Yara).

## CALCIUM DEFICIENCY

### SYMPTOMS

Calcium deficiencies are often associated with rapid growth in hot weather, and dry soil. Deficiencies are most often due to antagonism from other cations such as magnesium, potassium and ammonium.

Symptoms include cupping, distortion and tip-burn of young leaves, leaves exhibiting a pale marginal band, leaves, petioles, or stems appearing water-soaked, which may lead to collapse.



Calcium deficiency (image courtesy of Yara).



## **IRON DEFICIENCY**

### **SYMPTOMS**

Symptoms of iron deficiency appear as interveinal or uniform chlorosis of young leaves, which can become progressively yellower or whiter as the deficiency becomes more serious. Iron deficiencies can be associated with calcareous soils, cold soil, and excess heavy metals such as copper, cadmium, nickel, and zinc.

## **MANGANESE DEFICIENCY**

### **SYMPTOMS**

Manganese deficiency can be common on peaty soils above pH 6.5, and on calcareous soils with poor drainage.

Symptoms include interveinal chlorosis of all leaves, giving them a freckled appearance, affected areas having an olive green colour, or olive green colouration giving a reticulated pattern in the very finest veins.

## **MOLYBDENUM DEFICIENCY**

### **SYMPTOMS**

Molybdenum deficiency can occur on acid soils (below pH 5.0). However, whiptail of cauliflower can occur up to pH 7.0.

Symptoms are most common in cauliflower and include interveinal chlorosis or whitening of leaves of young plants, especially near the leaf margins. Twisting and distortion may occur in the laminae of new leaves, with the leaves becoming brittle and reduced until only the midrib appears - this symptom is commonly referred to as 'whiptail'. As well as this, the growing point of the plant may become 'blind' (absent), and leaves may be cupped or elongated.

## **ZINC DEFICIENCY**

### **SYMPTOMS**

Symptoms are most common in cabbage. Leaves can become cupped with outwardly curved margins of expanding leaves. Zinc deficiency can be common on soils of high pH or high phosphate content.

## **COPPER DEFICIENCY**

### **SYMPTOMS**

Symptoms are seen in cabbage as diffuse interveinal chlorosis of expanding and mature leaves. Copper deficiency is rare and only observed on peat soils that have not received recent copper applications.

## SULPHUR DEFICIENCY

### SYMPTOMS

Sulphur deficiency is occasionally found on light soils and may appear when fertilisers with low sulphur content are applied.

Symptoms are most often seen in young leaves as interveinal chlorosis or cupping, deformation and eventually failure to grow.



Leaf cupping due to sulphur deficiency (image courtesy of Yara).

## TIP-BURN

### SYMPTOMS

Tip-burn is a non-pathogenic internal disorder that is associated with the death of leaf tissue, usually along the leaf margins in the interior of the heads of cabbage. Leaf tissue may be a light brown colour, turning to dark brown or black. Affected tissue loses moisture and becomes papery in appearance. Because tip-burn cannot be detected externally, the head must be cut open to determine whether the disorder is present.

Tip-burn can be caused by a lack of calcium in the soil, but usually results from the plant's inability to move sufficient calcium to the young, actively growing, inner head leaves.

## **OEDEMA**

### **SYMPTOMS**

Oedema can be most serious in white cabbage. The symptom of oedema is the production of calluses. Calluses are the result of cell expansion and may be yellow, brown, or black in colour and of a rough corky texture.

Oedema can be caused by thrips that invade the crop in the field and continue feeding after storage. Thrips control is therefore important in cabbage production.

## **HOLLOW STEM**

### **SYMPTOMS**

Hollow stem can occur in cabbage, cauliflower and broccoli during periods of rapid growth. In affected plants, the interior tissue of the stem or head is collapsed or cracked and often hollow. Hollow stem is usually not visible until the head or stem are cut open. It is commonly associated with high temperatures, in combination with high concentrations of nitrogen and large stem diameters. Boron deficiency may also exhibit symptoms similar to those of hollow stem. Keeping nutrients at recommended concentrations and avoiding excessive rates of growth can help to prevent hollow stem.

## **BUTTONING**

### **SYMPTOMS**

Buttoning can occur in broccoli. It causes the production of small exposed heads, and occurs when large transplants which were raised under protection are transplanted into cool field environments, which leads to rapid head induction. Once a plant has initiated a head, it will produce no more leaves. It is often associated with conditions restricting vegetative growth, e.g. poor soil structure, nitrogen deficiency, or low soil moisture. Buttoning can be minimised by using smaller transplants, minimising transplant shock, and ensuring conditions for adequate vegetative growth are provided.

Buttoning can also occur in cauliflower, and appears when the curd is prematurely exposed from the covering leaves. It is caused by curd initiation and growth before the leaves have developed sufficiently to support full curd formation. Buttoning in cauliflowers can be affected by cultivar and environmental conditions. It is particularly important in early summer cauliflowers. Therefore, careful choice of sowing date is important. Plants should be kept moist but not overwatered, and nitrogen applied before planting.

## **'RICEYNESS' OF CAULIFLOWER**

### **SYMPTOMS**

Symptoms of 'riceyness' of cauliflower are exhibited as an uneven and grainy surface on the curd. Floral parts may also start to grow up through the head prematurely. To avoid 'riceyness' of cauliflower, cultivars that are less likely to develop this disorder should be chosen and planted at a time when the curd will not be exposed to temperatures that are greater than the optimum for curd development.

## **BRACTING**

### **SYMPTOMS**

Bracts can become visible around individual florets of cauliflower. Bracting can become a problem if temperatures are slightly greater than the optimum for curd development. The incidence of this problem is dependent on the growing conditions and/or the cultivar grown.

## **PEPPER SPOT**

### **SYMPTOMS**

Pepper spot can arise in stored cabbage heads. Individual specks can develop randomly over the outer and inner head leaves. The cause of pepper spot is unknown, but it has been associated with high rates of fertiliser and with temperature fluctuations. To reduce the incidence of pepper spot, cultivars that are less susceptible should be chosen.

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