

Heliothis (contd)

Life cycle

Heliothis has three generations a year. In the summer, the eggs hatch in about 5 days, the caterpillars develop over 4–6 weeks, and moths emerge from pupae after about 2 weeks. The moths can live for several weeks and are strong fliers. Heliothis hibernate or diapause overwinter in the pupal stage, and the first generation moths emerge from October to December and infest other crops such as tomatoes. Second-generation moths emerge from mid-January to February, and from this time to about April caterpillar populations may increase enough to cause economic damage. Records of second generation flights for a region may provide a means of predicting the onset of damaging infestations in sweet corn.

Damage and hosts

Small Heliothis caterpillars feed on silks and less commonly on leaves higher on the plant and cause holes similar to those formed by loopers. Larger caterpillars tend to burrow into the silks and, when they reach the cob, they damage kernels and contaminate produce with droppings. Some caterpillars bore through the side of the cob. Heliothis has a wide host range but the caterpillars usually prefer fruit and flowers. It is a major pest of tomatoes, sweet corn, beans, and a minor pest of capsicums, peas, lettuce, cabbage, pumpkin, legume seed crops, and many ornamentals. The major plant hosts may provide a source of infestation for other crops.



Heliothis larvae feeding on sweet corn commonly eat their way into the cob.

How to control *Heliothis*

Crop rotation

Continuous cropping with sweet corn and tomatoes may favour *Heliothis*, but moths are very mobile and can also fly in from legume crops, brassicas, weeds and ornamentals.

Ground preparation

Cultivate to a depth of 10–15 cm after harvest to destroy pupal cells and damage the pupa itself. Cultivation may also prevent any surviving adults emerging from the soil.

Biological control

(see also the section “Natural enemies”). Natural enemies attack all stages of this pest but parasitism rates are often low in sweet corn in NZ.

Parasitoids - *Heliothis* eggs parasitised by *Trichogramma* can be recognised when the eggs turn black just before the exit of the adult parasitoid wasp. Rates of parasitism are usually low but occasionally rise exceed 60%. High parasitism may be related to warmer weather or the absence of insecticides. *Heliothis* caterpillars are attacked by three small parasitoid wasps. Each produce different cocoons but the adults are difficult to recognise in the field. Look for the solitary cocoons of *Heliothis* parasitoids. By contrast, the armyworm parasitoid has silky masses of 30–100 cocoons. Low rates of parasitism occur in sweet corn, but the parasitoids may reduce invasions of *Heliothis* from tomato and other crops.

- *Cotesia kazak* lays a single egg in small caterpillars, the parasitoid larva develops inside the caterpillar and then 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.
- *Microplitis croceipes*. This larger wasp (about 7 mm) attacks slightly larger *Heliothis* larvae. It also forms single cocoons but as they are in the soil they are not easily seen.
- *Meteorus pulchricornis*. This wasp has appeared recently and may become a more important parasitoid of *Heliothis*. It is distinguished from other parasitoids by its cocoon that is suspended by a thread.

Several larger wasps (10–20 mm long) attack larvae or attack pupae of *Heliothis*, and emerge from the pupa in the soil. These wasps can sometimes be seen searching in the crop for *Heliothis*.

Predators - several soldier bugs (predatory shield bugs), and a damsel bug are predators of *Heliothis* caterpillars.

Diseases - caterpillars can be infected by fungi and viruses.



Unparasitised *Heliothis* caterpillar (left), cocoon of *Cotesia kazak* beside dead caterpillar (right) and adult *C. kazak* (inset).



Meteorus pulchricornis cocoon suspended by a silken thread.

How to control Heliothis (contd)

Crop management

Monitoring - you can assess the risk of infestation by using the following methods:

- Monitoring moth activity in crops with pheromone traps to identify damaging later generation flights in February and March.
- Measuring temperature accumulations (degree days) to determine when damaging populations have had enough time to develop. This is estimated by accumulating the mean daily air temperature above a base of 11°C (the temperature required for Heliothis to grow). In sweet corn, damage mostly occurs from the 3rd generation which occurs after about 1160 degree days above 11°C.

Development rates and commencement of moth flights, and hence the risk of infestations, vary by several weeks from year to year—so monitoring moth flights or calculating degree days can save time by indicating when to increase the rate of crop scouting.

Crop scouting - prior to mid-February you should also sample plants weekly for caterpillars and identify each species.

From about mid-February, or as indicated by increased pheromone trap catches, sample plants twice weekly.

- Sample at least 50 plants per 5 ha. Examine cobs, especially the silks for small caterpillars. The presence of larger caterpillars is often indicated by feeding damage or frass.



Pheromone trap for Heliothis.

Insecticidal control

Action thresholds for treatment have not been determined but are dependent on the market and end use of the crop. Minor damage at the tip of the cob may be acceptable for some purposes. Caterpillars in silks are difficult to control therefore most infested cobs will be damaged. Keep records to relate infestation levels to damage.

- Count the number of eggs and caterpillars and apply insecticides only if your threshold for the plant stage is exceeded.
- Estimate parasitism by rearing caterpillars and increase action thresholds when parasitism rates are high (above 60%).
- Use different insecticide groups in early and late crops. The resistance management strategy for Heliothis recommends restricting the use of synthetic pyrethroids to after mid-January.
- If early-season applications are needed, the use of more selective insecticides will favour beneficial species.

Several synthetic pyrethroids, organophosphate and carbamate insecticides are registered for control of Heliothis.

Resistance

Resistance to synthetic pyrethroids may limit control. A low frequency of resistance to synthetic pyrethroid insecticides has been detected in Heliothis in NZ. In Australia this resistance has led to control failures in some crops. In NZ, the Heliothis resistance management strategy recommends using crop scouting to minimise pesticide applications, and restricts the use of synthetic pyrethroids until after mid-January.

Key points: Heliothis

- Use pheromone traps to identify risk periods.
- Distinguish Heliothis larvae from other less damaging caterpillars (armyworm).
- Identify natural enemies that will provide biological control.
- Scout crops, especially silks, for Heliothis larvae.
- Keep records of scouting to develop and refine thresholds for your fields.
- When thresholds are exceeded and there are few natural enemies, apply registered insecticides, follow the pyrethroid resistance management strategy, and use selective materials especially early in the season.

COSMOPOLITAN ARMY WORM

Cosmopolitan armyworm (*Mythimna separata*) is named after the large, army-like populations that can sometimes develop when these caterpillars move through grass and cereal crops. It is present throughout the North Island and the north of the South Island. It is a sporadic pest of pasture and grain crops. Populations regularly caused severe defoliation of sweet corn and maize until the mid 1970s when a new strain of the armyworm parasitoid was introduced to NZ. Armyworm is still widespread in sweet corn but, as plants can tolerate some defoliation and biological control is good, insecticidal control is often unnecessary.

What does it look like?

The adults are large sturdy moths, generally a dull yellowish-brown but sometimes varying to a reddish-brown. They have a wing span of 30–40 mm and usually fly at night. The female moths lay pale cream eggs in clusters on the lower leaves of sweet corn and grasses, usually between blades or in sheaths.

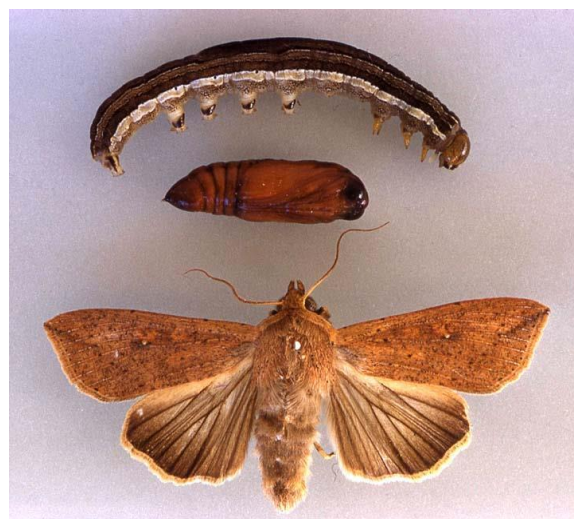
The younger caterpillars are green and develop into larger, pale greenish-brown caterpillars with a thin white line down the back and dark lines on each side of the body. Caterpillars from high-density outbreak populations develop into darker-coloured forms. Fully grown caterpillars are up to 40 mm long. They form a cell in the soil just below ground level, often under stones or debris, and form a reddish brown pupa.

Life cycle

Armyworm does not have a winter diapause, instead caterpillars continue to develop slowly. They pupate in the soil and adults emerge in spring flights. Caterpillars develop in about 1 month, depending on the weather. The development times are greatly extended during the colder winter months. The generation time in summer is 6–8 weeks, which allows 3 or 4 generations in a year.

Damage and hosts

The caterpillars feed on the foliage of sweet corn and maize, small grain crops, and grass in pastures. Typically, armyworm has one damaging generation of caterpillars, which appears after silking in January or February. The caterpillars feed on leaves from the edges towards the midrib. They remove irregular sections of the leaf to give it a jagged appearance, and when populations are dense they leave only the midrib. They feed on the lower leaves first and then move up the plant and may feed on stems, silks and cobs.



Armyworm (*Mythimna separata*) caterpillar, pupa and moth.



Army worm damage to sweet corn ears (above) and defoliation in maize (below).

They can cause major damage to kernels at the tip of the cob in cultivars with open sheaths.

Following the introduction of the parasitic wasp *Cotesia ruficrus*, the incidence of damaging outbreaks has been greatly reduced. Biological control, combined with good identification to separate armyworm from the more damaging corn earworm, has greatly reduced insecticide applications in sweet corn.

How to control cosmopolitan armyworm

Cultural controls

Cosmopolitan armyworm can originate from nearby grasses and cereals, so crop rotation or ground preparation will not prevent moths flying in to initiate infestations. Thorough cultivation may reduce existing populations by damaging caterpillars or pupae. Control of grass weeds in crops may reduce the risk of outbreaks.

Resistant cultivars

Varieties with tight sheathes help to minimise armyworm damage to tip kernels.

Biological control

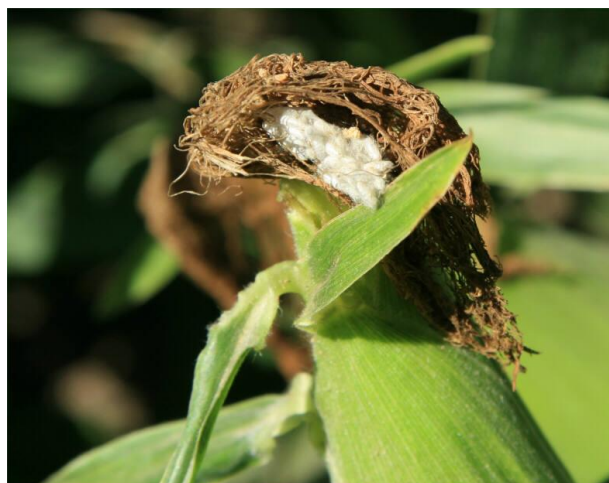
The major natural enemy of cosmopolitan armyworm is the small parasitic wasp *Cotesia ruficrus*. This parasitises small caterpillars, reducing their feeding rate and eventually killing them. This parasitoid now gives widespread control in sweet corn and maize, but occasional outbreaks may still occur.

Small masses of yellowish-white cocoons on sweet corn plants indicate that *Cotesia ruficrus* is active. Larvae of the parasitoid emerge from dying caterpillars and spin the silk cocoons in masses of 30–100. You can also detect the parasitoids in the field by squashing caterpillars to reveal the maggot-like larvae inside. Rates of parasitism are often high (70–95%.)

Small caterpillars and eggs are attacked by lacewings, hoverfly larvae, damsel bugs and spiders. Caterpillars of all sizes are also attacked by soldier bugs. Several larger parasitoids (e.g., orange caterpillar parasite and dusky winged ichneumon) occasionally parasitise up to 30–50% of armyworm pupae. The combined effects of these predators may contribute significantly to control in some situations.

Key points: cosmopolitan armyworm

- Identify cosmopolitan armyworm (by characteristic striped, smooth, green-brown body with four prolegs) and differentiate it from *Heliothis*.
- Moths can fly into the crop from many grass habitats.
- Control of grass weeds within the crop may reduce the risk of outbreak populations.
- Crops should be checked at regular intervals for several weeks following silking.
- The armyworm parasitoid often causes 70–95% mortality and significantly reduces crop damage.
- In maize, when parasitism is high, caterpillar densities of up to 10 per plant do not cause severe defoliation.
- If necessary, spray with registered insecticides.



Maggot-like larvae of the armyworm parasitoid emerge from a caterpillar (above) and then form cocoons on leaves or silks (below).

Crop management

There are no available tools for predicting population outbreaks, so detection relies on scouting. Check crops regularly for several weeks following silking. The decision to spray depends on the age of the crop, the variety of corn, the number of caterpillars and the rate of parasitism. Research in maize suggests that following silking, when parasitism is 70–95%, caterpillar densities of up to 10 per plant do not cause severe defoliation. Defoliation levels in excess of 50% are usually required to cause significant yield reductions in grain maize. In sweet corn, the potential for caterpillars to damage kernels at the tip of the cob will decrease the thresholds compared with maize.

Insecticidal control

Several organophosphate, synthetic pyrethroids and carbamate insecticides are registered for use against armyworm, with recommendations to ensure good penetration of the crop. Good identification of caterpillars to differentiate armyworm from *Heliothis* has resulted in greatly decreased spray applications in sweet corn over the last decade.

Other Lepidoptera–Southern Armyworm

Southern armyworm (*Persectania avera*) has a similar biology to Cosmopolitan armyworm. It occurs sporadically in cooler southern regions. Like cosmopolitan armyworm its pupae are formed in the soil.



Southern armyworm (*Persectania avera*). Photograph courtesy of Landcare Research.

Other Lepidoptera–Green Looper

Green looper (*Chrysodeixis eriosoma*) caterpillars are distinguished by their distinct green colour and looping movements. They are normally restricted to the silks of cobs, cause little damage, and pupate on plants. These should not be confused with the smaller true looper caterpillars (see the proleg illustrations in the caterpillar recognition table). The adult moths are also known as silver-Y moth, because of the marking on their wings.



Green looper caterpillar (*Chrysodeixis eriosoma*).

APHIDS

Two species of aphids are commonly found on sweet corn. Cereal aphid (*Rhopalosiphum padi*) and corn leaf aphid (*Rhopalosiphum maidis*) infect sweet corn crops contaminating plants with sticky honeydew. They also occur on maize, grasses and small grain crops. Neither aphid is recorded as transmitting viruses in sweet corn in NZ; their main importance here is as contaminants.



Heavily infested plants showing honey dew and mould.

What do they look like?

Corn leaf aphid (*Rhopalosiphum maidis*) has an elongated or rectangular soft body about 2 mm long, and is greenish or greenish-blue in colour. It has black antennae, legs and cornicles (a pair of tube-like structures protruding from the rear). The body often appears to have a powdery coating. Feeding aphids secrete honey dew which is often associated with the development of blackish moulds. Winged and wingless females occur, but males are rarely found. Females give birth to live young, called nymphs, without mating.

Cereal aphid (*Rhopalosiphum padi*) has a bulb-shaped body (by contrast with corn leaf aphid) about 2 mm long and is dark green to yellow green with a brown patch on its back. It is found low down on the stems and leaves (except when the populations are large) on all types of cereals. Winged and wingless females, and nymphs, occur in mixed populations.



Corn leaf aphid.



Cereal leaf aphid (photo courtesy of Ric Bessin, University of Kentucky).

Life cycle

Winged adults emigrate from small grain cereal crops and grasses and fly into sweet corn in the spring. Adults produce from 3 to 5 nymphs per day for up to several weeks. This allows for rapid population build-up. The nymphs pass through several instars before moulting into adults in 7 to 12 days. They rapidly produce wingless offspring and appear in clusters on the leaves and the stalk. They may completely cover large areas of the plant. Adult and immature aphids feed on sap sucked from leaves, stems, tassels, and husks through their piercing-sucking mouth parts. Excess water and sugars produce honeydew deposits on leaves which serve as a food source for sooty mould fungi, ants, various beetles, and flies. When aphid numbers increase, winged aphids are formed and they spread to infest more plants in the vicinity.

Damage and hosts

Clusters of aphids may cause leaf curl and yellow patches on leaves. In large numbers, the aphid bodies contaminate cobs so that removal of wrapper leaves or cold treatment and controlled atmosphere storage may be required. Honeydew causes similar problems, and with heavy infestations, sticky accumulations may interfere with pollination. Silks, tassels and cobs may also turn sooty black as mould grows on the honeydew.

There are no studies of the economic importance of aphids in sweet corn in NZ. In normal conditions, in the absence of virus infections, aphid populations are unlikely to cause yield reductions. However, in late-planted crops when large aphid numbers coincide with flowering, some yield reductions may occur.

Cereal aphid is recorded from cereals and grasses, whereas corn leaf aphid is noted from cereals but more often in sweet corn and maize. These hosts provide abundant early season sources of both aphids.

How to control aphids

As aphids may fly into sweet corn crops from many grass and cereal habitats, crop rotations and ground preparation do not contribute directly to control.

Biological control

(see also section **Natural Enemies**) There are several natural enemies that commonly attack both aphid species. (see section **Natural Enemies**). Their impact is unclear, but you should be able to identify these beneficial insects because they probably limit the growth of aphid populations.

Aphid parasitoids - Parasitic wasps lay eggs in aphids, which then hatch into small larvae which eat the body contents and cause it to form into a smooth, black or brown, swollen, mummified dead aphid. These mummies are often abundant and clearly visible in aphid colonies.

Aphidius parasitoids are most common and can be identified by their brown swollen mummies, some with small holes through which the new adult wasps have emerged.

Fungi - Parasitic fungi infect and kill aphids by forming furry, brown mummified aphids and are abundant in moist conditions.

Predators - several predators, especially brown lacewings and hoverfly larvae but also damsel bugs and 11-spotted ladybirds, feed on aphids. The immature stages of these predators have different forms from the adult, so be sure these beneficial insects are not mistaken as:

- Brown lacewings can be the most common predator and the most useful because they occur early in the season and may prevent aphid populations from increasing. The adults and small alligator-like larvae feed voraciously on aphids, and the small stages can penetrate into small spaces under leaves and leaf sheaths.
- Hoverfly adults are easily identified by their hovering flight, but it is the larvae or maggots that are the predators which move and feed within aphid colonies.
- Ladybird beetles are the most recognisable predators but, again, the larvae are not as easily identified. Ladybirds are more common later in the growing season.



Parasitised aphids showing 'mummies' and aphid skins.

Encouraging natural enemies - The activity of natural enemies may be increased by having non-cereal crops nearby to support non-cereal aphids that can act as alternative host insects and food sources. The economic value of these techniques has not been assessed in sweet corn.

- Using non-cereal crops in adjacent fields may attract natural enemies without increasing pest species. For example, hover flies make extensive use of pollen in fields of flowering brassicas and this in turn increases predation of cereal aphids in adjacent crops.
- Some aphid parasitoids can shift between aphids on lucerne and aphids on cereals.
- Predators such as lacewings, damsel bugs, and ladybirds may increase their population levels on aphids in lucerne crops and may then be encouraged to move by harvesting the crop.

How to control aphids (contd)

Crop management

Aim to reduce infestations in crops and monitor aphid infestations to assist control decisions.

- Avoid planting sweet corn near maturing crops of small grains or grass cover crops to minimise aphid flights into sweet corn from nearby fields.
- Ensure good drainage and adequate nutrition to encourage plant health - healthy plants are less attractive to aphids.

Aphid infestations should be monitored along with checks for other pest insects.

- Look for isolated infestations in a field as populations are usually aggregated.
- Check under wrapper leaves
- Monitor the presence of natural enemies.

Flights into individual fields can be monitored by using water filled yellow pan-traps, but trapped aphids will need to be identified.

Insecticidal control

No thresholds for chemical treatment have been identified. Overseas guidelines may not be relevant as they are partly directed at limiting virus infection. Several organophosphate insecticides are registered for chemical control in NZ. Some control will be obtained from treatments directed against caterpillar pests, but these applications will also reduce natural enemy populations.



Immature stages of predators, from top to bottom – lacewing, hoverfly and ladybird.

Key points: aphids

- Aphids in sweet corn do not transmit viruses and are mostly important as contaminants.
- Aphids may fly into sweet corn from nearby, maturing grass crops.
- Monitor aphids along with checks for other pests, and note the presence of natural enemies that may reduce aphid populations.
- No thresholds for insecticidal control have been developed.

OTHER PESTS

Several other pests are regionally or occasionally important in sweet corn.

Australian Soldier Fly (*Ionopus rubriceps*)

Larvae (maggots) of soldier fly can feed on the germinating seed and also feed in large numbers on fibrous roots. This pest can be important in crops sown after pasture that has been heavily infested with soldier fly.



Adult soldier fly

Black Beetle (*Heteronychus arator*)

Black beetle adults may attack early sweet corn plantings in warmer parts of the North Island. The over-wintering adults become active in October and tunnel into the bases of the plants, causing centre leaves to wilt around the four-leaf stage. Plants can die or tiller and become stunted.

Wireworms

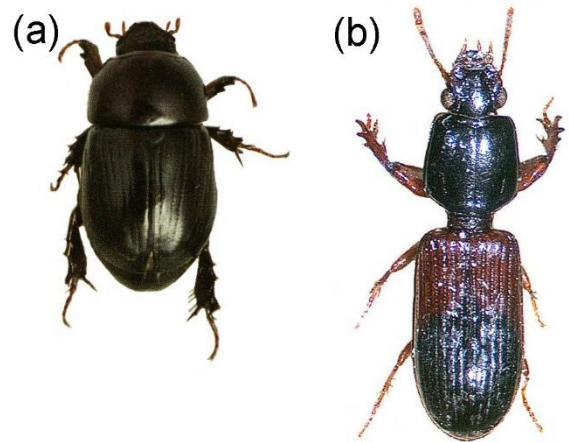
Wireworms are the larval stage of click beetles. They are generalist feeders that damage seed and tunnel at the base of seedlings causing centre leaves to wilt. Two common wireworms are pasture wireworm (*Conoderus exsul*) and variable wireworm (*Agrypnus variabilis*).



Adult, pupa and larva of *Conoderus exsul* (photograph courtesy of Landcare Research).

Maize seed beetles

These ground beetles (*Clivina rugithorax* and *C. basalis*) cause occasional damage to seedlings.



(a) Adult black beetle; (b) *Clivina basalis* ground beetle (photograph courtesy of Landcare Research). NB *C. basalis* is about half the length of black beetle.

Whitefringed Weevil (*Naupactus (=Graphognathus) leucoloma*)

Grubs of whitefringed weevil occasionally attack sweet corn or maize causing damage similar to wireworm.



Adult white fringed weevil

Green Looper and Southern Armyworm are other occasional pests that are described in the section on Lepidoptera, so are not noted here.

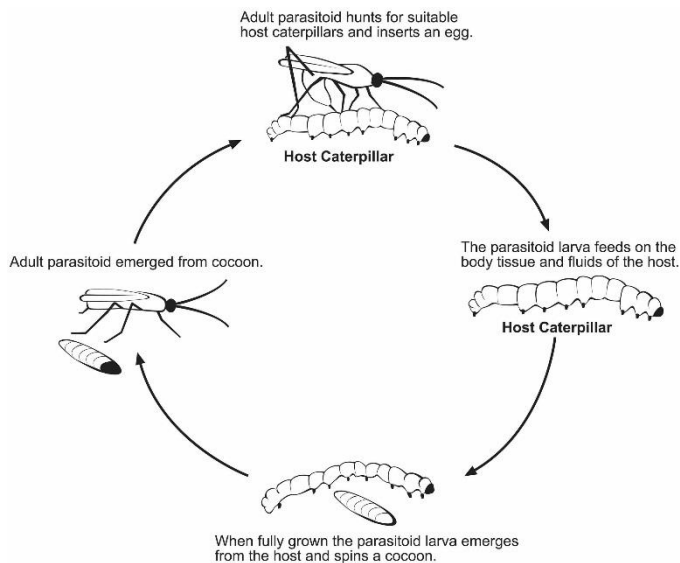
NATURAL ENEMIES

Natural enemies of pests in sweet corn include parasitoids, pathogens and predators. These beneficial species can prevent pests from reaching damaging levels. If you recognise natural enemies and identify the situations where they can give control, you can avoid insecticide use, and build up populations of 'beneficials'. Use of broad-spectrum insecticides kills both pests and natural enemies, but may cause a resurgence of pests because they are first to recolonise the crop.

Parasitoids are usually specific to particular pests, whereas pathogens and predators are often generalists that attack a range of species. Also, because most parasitoids leave their cocoons in the field, their abundance gives a direct indication of their activity. By contrast, the abundance of predators is used to give an idea of their impact. The most important natural enemies in sweet corn are probably the cosmopolitan armyworm parasitoid, general predators such as spiders, and parasitoids, predators and fungi that attack aphids. Recognition of these beneficial species is the first step in utilising natural enemies.

Natural enemies are important because:

- Pest management with natural enemies costs nothing;
- Natural enemies are efficient searchers and find pests at low densities;
- Natural enemies can prevent populations from exceeding economic thresholds;
- Some parasitoids reduce feeding by caterpillars and prevent them reaching damaging size;
- Natural enemies reduce the number of pests surviving and multiplying in the next generation.



Typical parasitoid life cycle.

What do they look like?

Identification is the key to maximising benefits from natural enemies.

Parasitoids

Parasitoids lay their eggs in or on their hosts and use almost the entire body of their host to develop. They lay one or several eggs and these develop inside the host until the parasitoid is fully fed. The parasitoid larvae then emerge and form pupae from which adults emerge. The pupae can be in silk cocoons, but aphid parasitoids use the host skin as a shelter to pupate in (e.g. an aphid mummy) and then emerge as an adult.

Aphid parasitoids - female parasitoid wasps (2-3 mm long) lay eggs singly in aphid nymphs. The wasp larva then consumes the aphid from the inside. As the parasitoid grows and the aphid is killed, the aphid skin is hardened and turns black or brown as it is mummified. After the larva pupates, an adult wasp emerges through an exit hole cut in the mummy. Different parasitoids form black or brown mummies.



Adult *Aphidius* wasp parasitising aphids.



Trichogramma egg parasitoid ovipositing into *Spodoptera* eggs.

What do they look like (cont'd)

Egg parasitoids - *Trichogramma* wasps can complete their development within a single moth egg. Eggs parasitised by *Trichogramma* can be recognised when they turn black just before the exit of the adult parasitoid wasp. These parasitoids attack *Heliothis*, cosmopolitan armyworm, cutworm, green looper and other species.

- Green vegetable bug eggs parasitised by *Trissolcus basalus* also turn black after the tiny adult parasitises all of the eggs in a raft.

Larval parasitoids - several parasitoids attack caterpillar larvae. Some are specific and attack only one pest species, others may attack several species.

- The armyworm parasitoid, *Cotesia ruficrus* (a wasp about 2–2.5 mm long), attacks armyworm, greasy cutworm and green looper. It lays several eggs in each armyworm caterpillar and these produce 30–100 larvae that emerge, killing the host, and then spin a mass of silken yellowish - white cocoons that are easily seen on leaves. One adult parasitoid emerges from each cocoon. Although parasitism rates in armyworm and greasy cutworm can be 80–90%, rates of parasitism in loopers are generally low. Following its introduction in 1971, and dramatic declines in armyworm populations, *C. ruficrus* is considered to be one of the most successful biological control introductions in NZ.

Two small black wasps specifically attack *Heliothis*.

- *Cotesia kazak* was introduced specifically into NZ for biological control of *Heliothis*. It parasitises 60–80% of *Heliothis* in tomatoes, and this may assist control in sweet corn. The adult is a small black wasp about 3 mm long which 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 clearly visible on foliage but less visible in corn silks. The caterpillar usually dies before it is large enough to cause significant damage. A small black wasp emerges from each cocoon.
- *Microplitis croceipes* attacks slightly larger caterpillars. It also forms single cocoons but as they are in the soil they are not easily seen.
- Another small wasp, *Meteorus pulchricornis*, parasitises many caterpillar species, but *Heliothis* is a preferred host. It has appeared recently and may become a more important parasitoid. It can be distinguished by its single oval brown cocoon, which is suspended from a thread anchored to foliage (see the section on *Heliothis*).



Parasitoid emerging from green vegetable bug eggs.



Armyworm parasitoid wasp laying eggs into armyworm.



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

What do they look like (cont'd)

Pupal parasitoids - Several medium-sized wasps (10–20 mm long) attack caterpillars or pupae of several Lepidoptera pests and can sometimes be seen searching the soil and vegetation for hosts. Combined parasitism of up to 30–50% of pupae has been recorded in dense populations. Three examples are:

- Orange caterpillar parasite, *Netelia producta*, is a larger, slender, orange wasp (18 mm long), which attacks medium sized and larger *Heliothis* and armyworm caterpillars. It paralyzes the caterpillars and attaches an egg which develops as a larva externally on the caterpillar. It kills it when it pupates in the soil. The distinctive orange adult can be seen patrolling foliage searching for caterpillars.
- Dusky winged ichneumon, *Lissopimpla excelsa*, has an orange-red body except for the first four abdominal segments which are black with white spots, and the wings are dark and dusky. It attacks *Heliothis* and armyworm caterpillars and emerges from pupae in the soil.
- Banded caterpillar parasite, *Ichneumon promissorius*, is predominantly black, with a white spot between the wing bases of the female and white band on the rear of the abdomen. The antennae of females have a broad white band (but this fades in preserved specimens). It searches the ground to locate *Heliothis* or armyworm pupae, digs into their protective cell in the soil, and lays an egg. The parasitoid develops in the pupa, chews off the head section and the adult wasp emerges through the moth emergence tunnel.



Adult parasitising stem weevil (courtesy of Mark McNeill, AgResearch Invermay, www.forestryimages.org).



A parasitoid that kills pupae, *Ichneumon promissorius*.

Adult parasitoids - Argentine stem weevil is parasitised by a small wasp that lays eggs in adult weevils.

The stem weevil parasitoid, *Microctonus hyperodae*, is a small (<3 mm) wasp that lays an egg in the adult weevil, which is then sterilised and killed. A single parasitoid larva emerges from the weevil.

What do they look like (cont'd)

Fungi

Insect pathogenic fungi attack aphids, thrips and caterpillars.

When aphids are contacted by these fungi, the spores germinate and infest the aphid body, producing a dense, slightly furry, aphid-sized brown mass on leaves. These are sometimes called mummies, but you can distinguish them from parasitoid mummies by their furry surface. Under moist conditions the mummy ejects spores on to the plant or soil surface and infections can spread rapidly in late summer and autumn. Such infections can have a large impact on aphid populations and should be identified while scouting to avoid unnecessary insecticide applications.

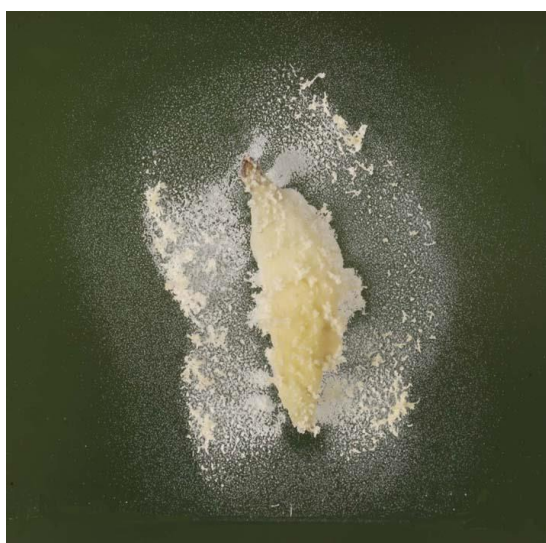
Caterpillars infected by fungi produce spores that give a characteristic fluffy white appearance (*Beauveria bassiana*) or light brown colour (*Zoophthora radicans*) to the dead caterpillar, and spread to other caterpillars. These fungi require moist conditions to develop and are sporadic.

Viruses

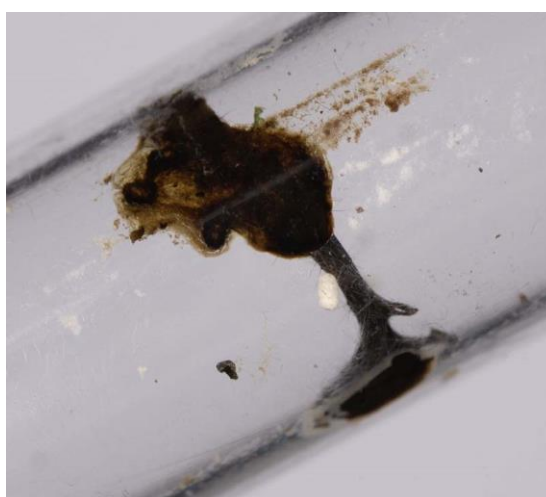
Virus infected caterpillars usually appear as flaccid, limp, larvae sometimes hanging from leaf surfaces. Virus diseases liquify the body contents and the caterpillar skin then bursts, releasing a liquid carrying infective virus particles, over the leaf surface.



Aphid fungal disease showing furry, mummified aphids.



Zoophthora fungus that attacks a range of insect species, including *Heliothis* caterpillars.



The remains of a looper caterpillar infected with a nuclear polyhedrosis virus (NPV) (shown in a tube).

Insect predators

You should recognise both the adult and larval stages of these predators to ensure you conserve the most useful predators.

Lacewings - The Tasmanian or brown lacewing (*Micromus tasmaniae*) is an active aphid predator in temperate climates such as NZ. It is probably the most effective aphid predator and the larvae may occasionally attack small caterpillars. The adult has characteristic lacy wings and lays small white eggs 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 and larva.

Ladybird beetles - The most common ladybird beetle in field crops is the 11-spotted ladybird, (*Coccinella undecimpunctata*). The adult lays small distinctive batches of yellow eggs on the underside of leaves and these eggs hatch into elongated larvae, which are also predatory. Eleven-spotted ladybird feeds mainly on aphids but also attacks small caterpillars. The adults may migrate from over-wintering shelter (particularly in cooler areas) to crops in the spring. Adult beetles occasionally provide some control of aphid populations in late spring and early summer, but may arrive too late to be effective. Development of breeding populations of this predator is favoured in perennial crops or long-duration crops.



The 11-spotted ladybird beetle.

Hoverfly larvae - The small hover fly, (*Melanostoma fasciatum*), produces larvae (maggots) 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 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. The numbers of hoverfly larvae in a crop are often larger if there is a good source of flowering plants nearby that will encourage the adult hoverfly (a pollen feeder) into the area.



Small hoverfly adult..

Insect predators (cont'd)

Predatory bugs - Several predatory bugs that occur in sweet corn crops should not be confused with pest species.

- The soldier bugs (predatory shield bugs), (*Oechalia schellenbergii*) and *Cermatulus nasalis* attack a range of caterpillar larvae.
- The damsel bug (*Nabis kinbergii*) is a predator of both aphids and caterpillars.



Soldier bug (*Oechalia schellenbergii*). Photograph courtesy of Landcare Research.

Predatory beetles - Other general predators occur in the soil and can eat soil-dwelling pests.

- Rove beetles (*Staphylinidae*) eat small stages of soil-dwelling pests such as black beetle.
- Click beetles (*Elateridae*) can feed on pests as well as damage seedlings.
- Ground beetles (Family *Carabidae*) are active in soil and on soil surface, are a small species and can climb plants. They feed on eggs, larvae and pupae of soil dwelling insects, and larger beetles may feed on slugs.



Damsel bug (*Nabis kinbergii*).



Rove beetles (*Staphylinidae*).



Click beetle adult (*Elateridae*).

Insect predators (cont'd)

Spiders and harvestmen - Spiders may be the most common predator in crops and can provide very effective control of pests. They eat moth eggs, small caterpillars, aphids and thrips. Their impact is difficult to measure. Sheet-web spiders are most common and produce webs built on top of soil or amongst foliage close to the ground where they can snare small insects. Wolf spiders are true hunting spiders that hunt both day and night.

Harvestmen (e.g. *Phalangium opilio*), are not true spiders because their body is not divided into two parts but rather one compact structure, They are numerous and widespread in crops and scavenge rather than trap their food.



(a) Sheet-web spider, (b) wolf spider, and (c) harvestman. Photographs (a) and (b) courtesy of Landcare Research.

HOW TO BENEFIT FROM NATURAL ENEMIES

Crop rotation and ground preparation

Minimising pest infestations through non-insecticidal techniques rather than spraying will favour natural enemies. Australian soldier fly, Argentine stem weevil, white fringed weevil and slug populations can be reduced with adequate cultivation. By contrast, reduced tillage, especially in establishment from pasture, is associated with increased pest damage to seedling maize.

- Cutworm caterpillars may be damaged or starved by cultivation and removal of plant matter 7 or more days prior to planting.
- Argentine stem weevil can be almost completely controlled by cultivation and a 4–6 week fallow period during which grass residues have been completely buried.
- Pupae of caterpillar pests may be damaged by autumn cultivation, but there are no specific control recommendations in NZ.

Identify sources of natural enemies

Natural enemies may be present in your crop already. Monitor natural enemies so you can assess their potential impact on pests.

If natural enemies are absent, it may be possible to release them into the crop.

- Egg parasitoids of green vegetable bug have occasionally been available commercially. Experimental releases suggest that early season releases may improve parasitism rates.

Egg parasitoids of *Heliothis* are not commercially available in NZ but have been used in Australia.

Key points: natural enemies

- Identify natural enemies present in your crop.
- Assess their importance from past records for a field and from the time of season.
- Use the relative abundance of pests compared with beneficial species to determine the need for insecticide applications.
- If chemical control is necessary, choose insecticides that favour the predominant natural enemies.

Habitat manipulation

The area surrounding crops, weed margins, or strips within crops may be manipulated to enhance the abundance and effectiveness of natural enemies. Before using additional plants, check they are not a risk as weeds or sources of pests.

Nectar and pollen sources

Several flowering plants provide nectar as an energy source and pollen for development of natural enemies. Commonly used plants include:

- Buckwheat—for lacewings, hover flies, ladybirds and parasitoid wasps
- Coriander—for hover flies and parasitoid wasps
- Tansy leaf (or phacelia)—mainly for hover flies, but also lacewings and ladybirds
- Dill, fennel, parsley, and wild carrot—for parasitoid wasps as well as hover flies

Alternate prey sources

Populations of generalist natural enemies that feed on pests other than those infesting sweet corn, may build up early in the season in nearby crops and then transfer to sweet corn. Lucerne crops are known to harbour lacewings and hover flies that can migrate; however, lucerne also harbours *Heliothis* populations that may provide a risk.

Insecticidal control

Use insecticides only when crop scouting or regional assessments indicate the risk of crop damage is high, and there is inadequate biological control.

- At present there are no selective foliar insecticides registered for use on corn that control the target pest and have minimal impact on natural enemies.
- Imidacloprid used as a seed treatment should have only a minor impact on natural enemies.
- Minimise early applications of broad-spectrum insecticides that kill natural enemies and may lead to a resurgence in pest populations.

FURTHER INFORMATION

- Addison, P. 2000. Argentine stem weevils. Far Arable Update No.21.
- Allan, D.J. 1987. Flight records of four common pest noctuids (Lepidoptera: Noctuidae) in West Auckland 1978-1979. NZ Entomologist 10: 122-127.
- Barker, G.M., R.P. Pottinger, R.A. McGhie, and P.J. Addison. 1984. Slug control in direct drilled maize. New Zealand Journal of Experimental Agriculture 12:155-159.
- Bourdot, G.W. and P.J. Cameron. 2005. Maize: managing pests, diseases and weeds in organic crops. Chapter 10 In Teulon DAJ, Cameron PJ, Bourdot GW, Curtin D. Plant protection in organic arable and vegetable crops - a grower's resource. Christchurch, New Zealand Institute for Crop & Food Research Limited. Pp. 101-114.
- Cameron, P., and J. Rea. 1997. Green vegetable bug. FAR Arable Update - Maize 6:2.
- Cameron, P.J. and G.P. Walker. 2005. *Helicoverpa armigera* resistance management strategy. In: Pesticide Resistance: prevention & management strategies 2005 / editors N. A Martin, R. M. Beresford, K. C. Harrington.—Hastings, N.Z.: New Zealand Plant Protection Society: 55-60.
- Carpenter, A. 1981. The effect of tillage technique on insect pest damage to seedling maize. Proceedings New Zealand Weed & Pest Control Conference 34:180-181.
- Carpenter, A. 1993. Controlled atmosphere disinfection of fresh supersweet corn for export. Proceedings New Zealand Plant Protection Conference 46:57-58.
- Gurr, G.M., S.D. Wratten, N.A. Irvin, Z. Hossain, L.R. Baggen, R.K. Mensah, and P.W. Walker. 1998. Habitat manipulation in Australasia: recent progress and prospects for adoption. Proceedings of Australasian Applied Entomological Conference: Pest Management - future challenges. September 1998:225-235.
- Herman, T.J.B. 1995. Integrated Pest Management for Processing Tomatoes. IPM Manual No. 5 Crop & Food Research, Lincoln.
- Hill, M.G., and A.W. Atkins. 1982. Effects of defoliation by cosmopolitan armyworm (*Mythimna separata* Walker) on maize yield. New Zealand Journal of Agricultural Research 25:251-254.
- Hill, M.G., and A.W. Atkins. 1983. Incidence of the armyworm, *Mythimna separata* Walker (Noctuidae: Lepidoptera), and its introduced parasite, *Apanteles ruficrus* Halliday (Braconidae: Hymenoptera), in maize. New Zealand Journal of Agricultural Research 26:135-138.
- Hill, M.G. 1988. Analysis of the biological control of *Mythimna separata* (Lepidoptera: Noctuidae) by *Apanteles ruficrus* (Braconidae: Hymenoptera) in New Zealand. Journal of Applied Ecology 25:197-208.
- HortNET. HortFACT: Insect Life Cycle Chart Index <http://www.hortnet.co.nz/publications/hortfacts/lcindex.htm> [Online]. Available at HortResearch (verified March, 2006).
- Pyke, N. 1996. Greasy cutworm biology and control. FAR Arable Update No.2.
- Rea, J.H., S.D. Wratten, J.R. Sedcole, P.J. Cameron, and S.I. Davis. 2002. Trap cropping to manage green vegetable bug *Nezara viridula* (L.) (Heteroptera: Pentatomidae) in sweet corn in New Zealand. Agriculture and Forest Entomology 4:101-107.
- Rea, J.H., P.J. Cameron, S.D. Wratten, S.I. Davis, J.R. Sedcole, and R.B. Chapman. 2003. Evaluation of insecticides for control of the green vegetable bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae), on sweet corn, *Zea mays* (L.), in New Zealand. International Journal of Pest Management 49:105-108.
- Scott, R.R., (ed.) 1984. New Zealand Pest and Beneficial Insects. Lincoln University Press, Canterbury, New Zealand.
- Stufkens, M.A.W., and D.A.J. Teulon. 1998. Aphids on cereal crops <http://www.aphidwatch.com/bydv/index.htm> [Online]. Available at Crop & Food Research (verified May.2006).
- Walker, G.P., and P.J. Cameron. 1990. Pheromone trapping and field scouting for tomato fruitworm in tomatoes and sweet corn. Proceedings New Zealand Plant Protection Conference 43:17-20.
- Watson, R.N., and M.G. Hill. 1985. Pests of maize in New Zealand., p. 47-58, *In* H. A. Eagles and G. S. Wratt, eds. Maize - management to market. Agron Soc NZ Special Pub No 4.
- Young, S. 2005. New Zealand Agrichemical Manual AgriMedia Limited, Christchurch.
- Zitter, T.A. 2001. Virus problems of sweet corn http://vegetablemndonline.ppath.cornell.edu/factsheets/Virus_SweetCorn2.html (verified March 2006).

9 Diseases

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HEAD SMUT

Head smut is caused by the fungus *Sporisorium reilianum*. The disease occurs in all areas in NZ where sweet corn is grown, but is most prevalent in the Gisborne area. Head smut also affects maize, but is more severe on sweet corn.

Spores (teliospores) of *S. reilianum*, present in the soil or on contaminated seed, infect corn plants during seed germination and early seedling growth. Infection does not occur after this time, and there is no spread of disease between plants during the growing season. The fungus grows systemically within developing plants, resulting in infected, smutted ears.

Head smut causes particular problems in sweet corn because smutted cobs are not easily detected at harvest, causing unsightly contamination of other cobs.

Symptoms

Head smut symptoms are normally not evident until ears and tassels are formed. Smutted tassels grow abnormally, developing a brush-like appearance. Infected cobs (ears) are usually smaller, lack silks, appear swollen and distorted, and contain black spore masses under the husks. Ears may be aborted and replaced with abnormal leafy structures (a condition known as phyllody). Infected ears rarely produce grain, so yield losses are proportional to infection levels. Replacement of the tassel with spore-producing structures (sori) can seriously affect pollen production.

In some cases, only part of the cob or just a few grains may be affected and there is little or no external evidence of infection. These partially infected cobs are a particular problem on sweet corn as they may escape detection before being husked for processing. Other common symptoms are severe stunting of infected plants and the presence of light yellow or brown greasy flecks and spots on nodes, stems and along midribs.



Tassels on a sweet corn plant infected with head smut. Note the black spore mass.



Cob from a sweet corn plant infected with head smut. Note the black spore mass.

Infection and disease development

The head smut fungus over-winters as spores in the soil and occasionally on the seed. Sweet corn plants are susceptible to infection only during the short period between seed germination and early crop emergence. Smut spores germinate close to germinating seed, and infect the growing point of young seedlings. The invading fungus then grows systemically through stem and leaf tissues of plants and later into the undifferentiated floral tissues. Part or all of these tissues develop into smut sori - a compact mass of dark brown or black spores covered with a thin grey-white membrane, which ruptures to release the powdery, dusty spores.

Spores can survive in the soil up to 10 years. The small, dry, 'dusty' spores of smut fungi are typically airborne and can be carried over long distances. With combine-harvested sweet corn the majority of spores remain close to where they were formed, either returned to the soil in the same paddock or windblown to adjacent paddocks. Movement to more distant areas is most often due to spores on untreated seed, or the movement of spore-contaminated machinery and soil.

Infection takes place over a temperature range of 14–35°C with an optimum range of 21–28°C. In general, drier soil conditions (15–25% w/w) favour infection of seedlings. Head smut is more prevalent in clay loam soils than in sandy loam or silt loam soils and is accentuated by nitrogen deficiency.

Key points for head smut

- Rotate crops to reduce spore numbers in soil.
- Treat seed with a suitable fungicide (eg. carbendazim or VitaFlo® 200).
- Grow cultivars with resistance/tolerance to head smut.
- Provide growing conditions that promote rapid growth of seedlings.
- Maintain balanced fertility based on a soil test.
- Apply good hygiene practices (e.g. clean contaminated machinery).

Control options for head smut

- Crop rotation: Head smut fungus spores can survive in the soil for three or more years, so do not plant corn for several years in contaminated fields. Infection level is related to the concentration of teliospores in the soil. Rotation of corn with non-susceptible crops is the most effective means to reduce the numbers of spores in soils.
- Crop management: Overseas research found that frequent irrigation (total 15–20 cm of water) for 18–21 days after planting reduced incidence of *S. reiliana* on maize. This is not generally recommended for NZ conditions.
- Crop nutrition: Maintain balanced fertility based on a soil test. In particular, maintain balanced nitrogen levels because stressed crops are predisposed to the disease. Overseas research demonstrated that some fertilisers (eg urea, sulphate of ammonia) can reduce head smut infection, while others (e.g. calcium nitrate) may increase it.
- Seed treatments: Seed treatment with fungicides is the most convenient and economical head smut control option. Fungicides used in seed dressings will normally kill spores on the seed, but not spores in the soil. Carbendazim and carboxin + thiram (VitaFlo® 200) are currently registered in New Zealand for head smut control. Recent New Zealand research demonstrated that flutriafol + imazalil sulphate (Vincit®) and propiconazole (Tilt 250®) both offer viable alternatives to VitaFlo for control of head smut of sweet corn. However, these fungicides are not currently registered for that use in NZ.
- Chemical control: Application of fungicides (e.g. Tilt) directly to the soil has achieved effective control against head smut overseas. Foliar applications of fungicides have not controlled the disease.
- Resistant varieties: Commercial hybrids in NZ vary in tolerance to head smut, and the disease-tolerant ones should be considered in high risk fields. In the long term, use of resistant varieties offers the most economical and sustainable method of control.
- Hygiene: Machinery should be thoroughly cleaned before being moved from smut infested fields to non-infested fields. Seed produced in smut-infested districts must be fungicide-treated before being sown in smut-free areas. Take care to prevent spread of spores in corn/maize stock feed, and in manure from stock fed infected grain.

COMMON RUST

Common rust is caused by the fungus *Puccinia sorghi*. Although widely distributed in sweet corn and maize growing regions of NZ, the incidence of rust is usually low, and it rarely causes significant yield losses. Severe localised outbreaks of the disease do occasionally occur when environmental conditions favour the development and spread of the disease. When epidemics of rust occur, it can cause serious losses in yield and quality. Sweet corn is generally more susceptible than maize.

Recently, common rust has increased in prevalence with an expansion in planting of susceptible sweet corn cultivars. New pathogenic biotypes of the rust fungus have evolved overseas that can defeat single gene resistance within the host.

Increased prevalence of the disease has been assisted by the extension of the sweet corn growing season into autumn when conditions favour rust development. Staggered planting schedules can result in large numbers of rust spores from early planted fields infecting younger plants in nearby fields.

Common rust is estimated to reduce yield about 0.6% for each 1% leaf area infected.



Symptoms of common rust on sweet corn leaves. Note reddish-brown pustules (uredinia).

Control options for common rust

- Resistant varieties are becoming available. Seed companies have developed varieties with mono- and multigenic resistance for late season plantings. These should be planted in areas where rust is prevalent, particularly late in the season when the disease is likely to be problematic.
- **Fungicides** are not required generally in NZ. However, in seasons where rust develops on the lower leaves prior to silking and the weather forecast is for cool, wet weather, chemical control may be necessary. Azoxystrobin is currently registered in NZ for control of rust in sweet corn and maize.
- **Scouting** for rust provides information that will assist in determining whether or not to apply fungicides. If significant amounts are observed in mature early-planted crops, later-planted crops may be at risk. Regular scouting enables prompt application of fungicides.

Infection and disease development

The common rust fungus survives on infected sweet corn and maize residues and volunteer plants. Disease transmission is by air borne spores (urediniospores), which infect the foliage. These spores are produced throughout the summer and infect new leaf tissue. They are responsible for the spread of the disease.

Three main factors interact to influence common rust on sweet corn:

- The quantity of urediniospores available to initiate rust epidemics;
- Environmental factors; and
- The level of rust susceptibility in the sweet corn varieties in use.

Rust development and spread is favoured by prolonged cool temperatures (16 to 23°C) and high relative humidity or prolonged periods of leaf wetness. Susceptible sweet corn varieties can become seriously affected under protracted cool and humid conditions. Losses in plant yield and quality, and delayed maturity can result from early season leaf damage. Older leaves are more resistant to infection than younger leaves.

Symptoms

Although common rust can be found in corn fields any time during the growing season, the disease usually does not appear before tasselling. Rust generally becomes more noticeable towards the end of the season when reddish-brown pustules (uredinia) appear on upper and lower leaf surfaces. The pustules vary from nearly circular to elongate in shape, measuring 1–3 mm in length. The pustules rupture and expose powdery red spores (urediniospores). As the pustules mature, they turn brownish black and release the dark-brown overwintering spores (teliospores).

In severe epidemics, the leaves yellow and become easily tattered in strong winds. Partial resistance to rust is expressed as small chlorotic or necrotic hypersensitive flecks on the leaves, with little or no sporulation.

In years with unusually cool summers, and especially on late-planted sweet corn, yield losses may be expected when the leaves above the ears become severely diseased.

Key points for common rust

- The incidence of common rust is usually low in New Zealand.
- The disease is favoured by cool, wet weather.
- It is more prevalent in late-planted corn.
- Resistant cultivars are the main control measure available.
- Fungicides can help control rust.

NORTHERN LEAF BLIGHT

Northern leaf blight (NLB) of sweet corn is caused by the fungus *Exserohilum turcicum* (previously called *Helminthosporium turcicum*). The disease occurs in all maize growing areas of New Zealand and is particularly common in the Waikato region. Yield losses due to NLB are variable, depending on both climate and cultivar.

Reductions in grain yields mainly depend on the extent of leaf damage and the stage of plant development. This disease rarely causes significant grain yield losses during dry weather, but during wet weather it may result in substantial economic losses if it becomes established on the upper leaves before silking. If leaf damage is minor, or does not occur until later than six weeks after silking, yield losses are minimal.

In addition to losses in ear yields during a severe epidemic, badly infected plants can become predisposed to stalk rots and lodging.



Symptoms of Northern leaf blight: severe, moderate, light infection.

Symptoms

The first appearance of NLB in a sweet corn crop largely depends on the weather. Under favourable conditions the disease may be found before silking, whereas if conditions are unfavourable, such as prolonged hot and dry weather, there may be no disease at all.

The first signs of the disease usually appear within 24 hours of infection as pale green, water-soaked spots on the lower leaves. These spots turn into lesions, typical of NLB, 10-14 days later. The characteristic NLB lesions are elliptical, grey-green to tan-coloured, measuring up to 15 cm in length.

As the disease develops, the lesions become light brown or straw coloured in the centre with grey-green margins, enlarging and coalescing so that much of the leaf area can be killed. The lesions also can spread to the husks. Grey-black spores are produced in abundance on the dead tissue.

The lesions continue to enlarge and coalesce, and much of the leaf area can be killed causing major reductions in yield due to lack of carbohydrates available to fill the grain.

During the growing season the disease progresses upwards on the plant from the lower leaves until, in severe cases, complete "burning" of the foliage is conspicuous. Symptoms on resistant cultivars are restricted to small chlorotic or necrotic spots on the leaves.



Northern leaf blight symptoms on a resistant cultivar; small chlorotic and necrotic spots.

NORTHERN LEAF BLIGHT (CONTD)

Infection and disease development

The fungus causing NLB survives from season to season as spores (conidia) and mycelia on corn debris left on the soil surface. The conidia are transformed into thick-walled resting spores called chlamydospores. Outbreaks of NLB are usually associated with mild, moist weather. During warm, moist weather in early summer, new conidia are produced on infected corn residue. The conidia are carried by the wind or rain to lower leaves of young corn plants.

Disease development is favoured by moderate temperatures (18–27°C) and the presence of free water on leaf surfaces for 6–18 hours. Frequent heavy dews during the growing season are ideal for NLB, whereas dry conditions greatly reduce disease incidence. Secondary NLB infection and spread of the disease within sweet corn fields occurs by conidia produced on diseased leaf tissues.

Control options for Northern Leaf Blight

- Crop rotation: Fungal mycelia and conidia survive 2 years in debris. Although the spores are easily disseminated by winds, rotating to non-grass and other non-host crops helps reduce disease levels.
- Crop management: The number of spores present in the soil next season can be reduced by early incorporation of stubble. This promotes breakdown of crop debris.
- Crop nutrition: Do not apply excessive nitrogen since this may increase disease infection by promoting excessively lush leaf growth.
- Chemical control: Mancozeb and azoxystrobin are currently registered in NZ for control of NLB. Spray applications should start before tasselling and when disease infection is most likely to occur.
- Resistant varieties: The most effective and efficient means of controlling NLB is to grow resistant hybrids. Most of the commercial (maize) hybrids which are currently grown in NZ have a high level of resistance to NLB. Resistance also is being incorporated into the newer sweet corn cultivars. There are two types of disease resistance to NLB. Genotypes with monogenic resistance have a single gene to combat the pathogen - NLB lesions on plants with monogenic resistance are greatly restricted in size. The emergence of new races of the fungus resistant to monogenic resistance is a constant threat. A plant with polygenic resistance has several genes assigned to fight the disease - a plant with polygenic resistance has fewer lesions.

Key points for northern leaf blight

- Yield losses vary depending on cultivar and climate.
- Severe NLB can cause grain yield loss in maize and we would expect yield losses in sweet corn.
- NLB is favoured by mild, moist weather.
- Main control measures are crop rotation and resistant cultivars.

SEED ROTS, DAMPING-OFF AND SEEDLING BLIGHT

Seed rot, damping-off, and seedling blight of sweet corn can sometimes cause losses in localised fields. Infected seeds may rot and die prior to or shortly after germination, or plants emerge and develop rotting roots and stems, resulting in unthrifty plants that often die. Sweet corn, especially the super-sweet hybrids, is more susceptible to these diseases than maize.

Several species of soil-borne fungi can cause seed rot, damping-off and seedling blight of sweet corn. These fungi (most commonly *Pythium* spp., and *Fusarium* spp., but also *Rhizoctonia* spp., *Penicillium* spp., *Aspergillus* spp., and others) are widely distributed in NZ soils, and have a broad host range. Ear-rotting fungi (mainly *Fusarium* spp.) present in or on seed at planting can also cause seed rot, damping-off, and seedling blight of sweet corn—with disease incidence and severity depending on levels of rots in the seed.

Symptoms

With seed rot disease, the seed rots before germination so no plant emerges. With damping-off, a soft rot of seedling stem tissues occurs near ground level and the plant often falls over. Symptoms on roots initially appear as elongated water-soaked areas. Infected roots turn brown or black and appear water-soaked. Above-ground symptoms of damping-off and seedling blight are seen as stunting, yellowing, and collapse of seedlings.

Infection and disease development

The fungi that cause seed rot, damping-off, and seedling blight of sweet corn survive between crops as dormant resting structures (oospores, sclerotia), in crop debris, and on weeds and other hosts. Under suitable conditions, germinating spores of these fungi infect sweet corn seed and the stems and roots of seedlings.

Seeds may be infected when moisture penetrates the seed coat or soon after as the radicle grows, resulting in rotting of the seed or germinating plant below the soil surface (pre-emergence damping-off). Infected plants that emerge wilt and die (post-emergence damping-off). Seed with surface cracks caused by mechanical harvesting is especially susceptible to seed and seedling rots.

The diseases are more prevalent in poorly-drained soils during extended periods of cold, wet weather. Low soil temperatures (below 13°C) favour seed rot and infection of seedlings, and low-lying areas in fields and soils that have been compacted are more likely to have drainage, and, therefore, seed rot and seedling disease problems.

Disease severity is also affected by planting depth, soil type, seed quality, crusting, herbicide or fertiliser injury, or any factors that delay germination and emergence of corn.



Seedling blight: the plant on the right shows characteristic symptoms (stunted, yellowing).

SEED ROTS, DAMPING OFF, SEEDLING BLIGHT (CONTD)

Disease control

A preventative approach is the best way to deal with these diseases, as nothing can be done once plants become infected.

- Seed: Use high-quality, undamaged seed.
- Seed treatments: Carboxin + thiram (Vitaflo® 200) is currently registered in NZ for control of seed and seedling diseases of maize and sweet corn.
- Cultural practices: Over-sowing by 10-15% is sometimes used as an insurance against losses caused by seed rots and damping-off, as well as other diseases and pests.

Disease risk can be reduced by planting good quality, injury-free seed with high germination rates into well-prepared warm, moist seed beds – conditions that promote rapid seed germination and seedling emergence.

Avoid soil compaction, poor drainage, herbicide injury, and other stresses that delay germination and increase the chance for seed and seedling infection.

Crop rotation: may provide some control of some of the pathogens involved in the damping-off complex, but may not suppress pathogens such as *Pythium* spp. that have very broad host ranges.

Key points for seed rots, damping-off and seedling blight

- Seed rot, damping-off, and seedling blight of sweet corn can occasionally cause localized problems.
- Several species of soil-borne fungi can cause these diseases.
- The diseases are more prevalent when cold, wet weather and water-logging occurs soon after planting.
- Planting depth, soil type, seed quality, injury to seed, crusting, and herbicide or fertiliser injury affect disease incidence.
- The diseases are controlled by planting good quality seed in well-prepared, free-draining seed beds, at soil temperatures above 13°C.

FURTHER INFORMATION

Fowler, M. 1985: Diseases of maize in New Zealand. In: Maize—management to market. Special publication no. 4. Agronomy Society of New Zealand.

Howard, R.J.; Garland, J.A.; Seaman, W.L. 1994: Diseases and pests of vegetable crops in Canada: an illustrated compendium. Canadian Phytopathological Society, Canada.

Pataky, J.K. 1999: Compendium of corn diseases. 3rd edition. Edited by D.G. White. APS Press. St. Paul, USA.

Fullerton, R.A. 2002: A smutty story. *Grower* 57: 44-52.

Wright, P.J.; Fullerton, R.A.; Koolaard, J.P.; 2006: Fungicide control of head smut (*Sporisorium reilianum*) of maize, popcorn and sweet corn. *New Zealand Journal of Crop and Horticultural Science* 34: 23–26.

10 Irrigation and water management

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Sweet corn yields are sensitive to water stress. Wherever possible irrigation should be used to avoid water stress in the crop.

The total amount of water required by sweet corn is modest compared to some crops—but only because the crop is in the ground for fewer days. The water used will vary by region and by sowing date. Compared to late plantings, early plantings will have a full canopy and be filling ears during the heat of summer, so the chances are they will use more water in total.

In most areas it can be assumed that periods of low rainfall will occur and, if crop stress results, it will require irrigation in order to achieve top quality, yield and optimal ear size. Obtaining high yields depends on avoiding water stress **throughout** the growth of the crop. Irrigation can be expensive; over-use can harm profitability as well as the crop and the environment. So the most important irrigation management issues are using the correct amount and optimising the timing of water application.

WHY IRRIGATE?

Plants absorb water from the soil. Most of this water is carried up to the leaves where it evaporates, a process called transpiration. Water is also evaporated directly from the soil surface. The combination of these two processes is called evapotranspiration.

Provided that the soil is not too dry, the evapotranspiration rate depends only on weather conditions and the size of the crop canopy. However, as a soil dries, plants find it harder and harder to absorb soil water. Unless balanced by enough rain, evapotranspiration can dry the soil to a point where the crop cannot absorb soil water fast enough to replace the water it loses through transpiration. This can stress the crop and cause yield loss. In NZ, the aim of irrigation is to supplement natural rainfall, so that the crop is not stressed to the point where yield is impaired.



A glossary of technical terms used for irrigation is at the end of this chapter.



A lateral moving irrigator in use for sweet corn. Photo courtesy of Page Bloomer Associates.

THE IRRIGATION SYSTEM

In NZ these are nearly always overhead sprinkler systems of various types.

Sprinkler systems include travelling irrigators (either a boom or large single jet), hand move, centre pivot or lateral move types. The capital costs per hectare are lowest for hand move, about double for travelling irrigators, and intermediate for centre pivot and power side roll. Hand move, while cheaper, is quite difficult to use in tall sweet corn. The main management issue with single jet rain guns is poor uniformity in windy conditions. Uneven irrigation patterns will not 'even out' over the season. Uniformity can be improved by proper lane spacing and sector angle, and timing irrigation for less windy hours of the day.

Drip irrigation is feasible for sweet corn and widely used in Queensland, but it can be costly and require considerable labour to install and remove drip lines annually. Its advantages include efficient use of water, lack of wind effects, less disease pressure, good for dissolved fertiliser application, and the ability to apply water frequently if needed.

Key point: know your system

- Irrigation works best for growers who know the capabilities of their irrigation system (how many mm of irrigation it applies per hour for instance), and who maintain their system well.

THE BIG AIMS OF IRRIGATION PRACTICE

- Irrigation should be scheduled to meet plant needs and get the best economic return. Growers should be able to demonstrate that they are using irrigation water efficiently with minimal impact on the environment losses from drainage and run-off.
- Irrigation should apply only the minimum amount of water required. Monitoring of soil water status will help avoid under or over-irrigation. At the very least, growers should measure and record daily rainfall, and record irrigation amounts applied, allow for forecast rain events when scheduling irrigation.

If during irrigation there is local water ponding on the soil surface for any time then water will run off rather than into the soil—and the field will become a patchwork of droughted and waterlogged zones. Check your irrigation system does not cause run-off, and if necessary reduce the water application rate or improve the infiltration capacity of the soil.

Growers need to establish when irrigation will be needed, and how much to apply when it is needed. There are many approaches to this. The method we recommend is to use a soil water balance, but other methods exist.

PONDING- BIG PROBLEMS FROM THE SMALL END OF THE SCALE?

Wetting up the soil uniformly, filling up the pores that make up the plant available water storage sounds simple enough, but it is actually much more difficult to do with irrigation compared to rainfall.

Overhead irrigation tends to be applied at much greater intensities and for shorter durations than rainfall. Engineers work hard to make the spatial pattern of water delivery rates as uniform as possible, but inevitably some areas under an irrigator receive water faster than others. Furthermore, the ability of the soil to accept this water as fast as it arrives can vary a lot over short distances too. This often results in unevenly distributed water leaving wet and dry soil patches, runoff and drainage. It is hard to quantify and is only partly addressed by engineer's measures of a system's application efficiency or inefficiency. Basically if you can see ponding on the soil surface it is very likely that not all the irrigation water applied is available for the plants and if it is not managed you will get a lot of variability in yield between areas in a paddock.

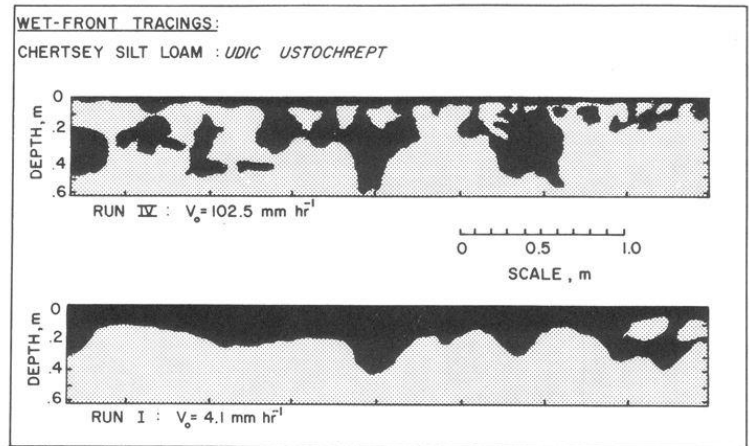
Where does the water go?

When water ponds on the soil surface it means that the water has been applied at a higher rate than the soil can absorb it. In extreme cases water will runoff the paddock taking with it soil and nutrients. Otherwise it may re-distribute to low areas in the paddock, maybe causing waterlogging stresses, and certainly leaving other areas drier than you wanted.

If it doesn't run off, irrigation water will be distributed downwards through the network of soil pores. The best wetting is achieved when the whole size range of soil pores are slowly filled with water from the soil surface. Usually that means that the first pores to fill are the smaller diameter ones that store most soil water that plants can use. However at higher application rates surface water can fall down the larger (macro-) pores before the smaller diameter storage pores get filled. This bypassing of the storage pores in the topsoil often results in deep "fingers" of water with drier spots between the fingers. Solutes moving down the fingers can potentially be lost below the root zone.



Water applied at high application rates does not properly wet up the ridged bed and runs into the furrows. Water in the furrows is re-distributed elsewhere in - or out - of the paddock. Wheeled areas have particularly low infiltration rates



Penetration of water from overhead irrigation into a silt loam. The position of the wetting front was measured on the walls of trenches dug into the soil after irrigation at average rates of 102.5 or 4.1 mm/h. The same total amount of water was applied in each case. Wetted zones are the dark areas along the transect. The trenches and tracings were made by Trevor Webb of Landcare Research, the figure is reproduced by permission of Brent Clothier, of Plant & Food Research.

Little research has been done on this specifically under sweet corn in NZ, but there's evidence of problems for other horticultural crops grown on the same soils. For instance, digging into loose, highly porous, ridged beds under potatoes we sometimes find that much of the soil is still dry after irrigation was applied at relatively high rates. In this case, the water has rapidly moved through the large volume of big pores bypassing the bulk of the soil.

Key point: avoid wetting pattern problems

- To avoid wetting issues, the irrigation application rate and soil infiltration rate or both can be modified or managed.

In general applying water as slowly as possible will result in the most uniform wetting. Options include changing nozzles and running travelling systems more quickly.

Avoid over-cultivating the seed bed. Many of our soils are susceptible to forming compact surface caps that restrict water flow into the soil beneath. These caps form when weakly held soil particles are broken off from soil aggregates by the impact of large water droplets. Well aggregated and structured soils are more resistant to capping and excessive cultivation weakens the structure. Similarly, compaction due to machinery traffic should be minimised. Often wheel tracks are the first to pool water.

SCHEDULING IRRIGATION—WHEN AND HOW MUCH?

Ask the soil?

We can measure **soil water content**. If we measure this on a volume basis (cm^3 water per cm^3 soil) at several depths, it is quite easy to calculate mm of water held in the whole soil profile (see **Glossary**). That is useful as we can compare it directly to rainfall, irrigation or evapotranspiration.

Alternatively we can measure the **energy status of the water**. This sounds grand—but really it's just a measure of how difficult it is to remove liquid water from the soil. The values are often called tension or suction and given in pressure units. Whether we measure water content or tension, the values are usually compared to those at field capacity (see **Glossary**). When the difference from field capacity reaches a known trigger point you irrigate to bring the soil close to, but not wetter than, field capacity.

There are many measuring devices available, but, it's hard to recommend one that is cheap, easy, **and accurate**. Cost is important because ideally monitoring is needed at several depths and sites. All of the methods described here are more reliable than using a spade and feeling the soil!

Measuring soil water content

The **neutron probe** is a reliable method for measurements at several depths. The equipment is specialised and expensive, but consultancy services can provide measurements for a competitive cost.

Capacitance probes are cheaper but installation and interpretation of results is just as specialised. Portable makes (e.g. the Diviner) can give depth readings in field-installed PVC tubes much like a neutron probe. Versions that are permanently installed in each location (Enviroscan, Aquaflex) give continuous readings, recorded to a datalogger.

Time Domain Reflectometry is very accurate. It uses steel rods pushed into the soil. The electronic measuring device used on them is expensive.



Tensiometers—one with a vacuum gauge and one where an electronic sensor is connected through a hypodermic needle. In both cases the tube itself is filled with water in contact with the soil through a porous ceramic tip.

Measuring soil water energy status

Tensiometers are cheap but they have a limited operating range and are not well suited to sweet corn. They are best for crops whose soil is kept reasonably moist. Usually, they are installed at two depths, 20-30cm and 60cm. You irrigate to keep the shallower one reading less 50 centibars. A sudden fall in the reading on the lower one indicates drainage - you may have applied too much irrigation. However, sweet corn will often take up water from as deep as 100 cm, and tolerate tensions beyond tensiometer range.

Gypsum blocks or WaterMark™ sensors work on a different principle and have a wider operating range. Irrigation trigger points for these are not well documented in NZ soils. Again it's a good idea to use them at two different depths.



WaterMark™ sensors have a porous ceramic tip that absorbs water from the soil. As it absorbs more water its electronic resistance decreases and that is measured by the meter. Many sensors can be read with the same meter.

Ask the plant?

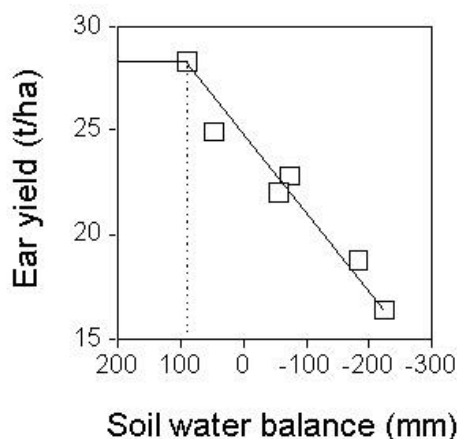
Alternatively we can focus on the plant rather than the soil. Usually these methods measure the plant water potential (energy status of the water) with instruments like the pressure chamber (often called a pressure bomb). Other techniques measure foliage temperature with infrared thermometers. The idea of the latter is that in the sunshine the crop starts to heat up above air temperature if it cannot cool itself by evaporating water from the leaves.

In theory it is good to measure the plant directly to see if it is experiencing water deficit. However, so far the methods are better suited to research rather than practical needs. A further problem is that the techniques do not tell you how much water to apply.

IRRIGATION SCHEDULING WITH A WATER BALANCE

Calculating the daily water balance is a very good method for deciding when **and** how much to irrigate your crop. In this method it is not essential to closely monitor soil water content, but you estimate the mm of water used by the crop each day from PET, as published on web sites and in newspapers. The published PET values are best modified when the crop is small (see example below). To make this approach work best you need to know the maximum amount of water your soil holds that is available for crops. This is termed the available-water capacity (AWC, see **Glossary** for details).

A negative soil water balance reduces sweet corn yield in a predictable manner, beginning when the balance falls below a trigger point of about 60% of AWC. The most cost effective way to irrigate is to use the minimum number of applications that will keep the water level above 60% of AWC.



Effect of the soil water balance on yield of sweet corn (Stone et al. 2000). The starting water balance was the available water capacity (AWC) of 150 mm. There was no effect on yield until the water balance fell below a trigger point of 90mm (about 60% of the AWC). For every 10mm that the balance fell below that trigger yield fell by 350 kg/ha.

Ask the atmosphere?

The third choice is to focus on the weather or, more to the point, on the potential evapotranspiration (PET). This reflects the demand for water to be pulled through the crop and out of the soil (see **Glossary**).

This approach is used very commonly and effectively when growers do **water balance** calculations. The weather data are used to calculate what the soil water content or deficit is likely to be. Often growers pay a commercial company to ground-truth the calculations by measuring actual soil water content (usually by neutron probe).

Key point: the pay off

- Keeping a water balance for your crop and scheduling irrigation from this is effort and money well spent.

If you are considering whether keeping a water balance on your crop is worth the effort consider this calculation we have made:

By irrigating only as needed (not until the water balance is down to the Trigger Point) it is likely that you will keep the crop free of stress with only three irrigations. Being more cautious (using a 120mm Trigger Point, or irrigating on a set schedule) can require five to six irrigations. That could cost an extra \$200-300 per hectare. With a 10ha paddock, an increased profit of \$2,000 would be a good return on the 10-15 hours of total time spent keeping the balance.

WATER BALANCES AND BANK ACCOUNTS

This is like balancing your bank account. The balance changes over time, as water is deposited or withdrawn. Keep track of the water balance, so you know when the trigger point is close and you can irrigate to keep the crop unstressed.

Your **starting balance** equals the amount of plant available water (AWC) that a wet soil holds at the time of planting. AWC values in a full soil profile (1m deep) in typical sweet corn soils are shown in the middle column of the table below. Soils in any region vary, so there are a few cautions to note.

AWC in sandy soils can be as low as 45mm and in peat soils as high as 400mm. If there is a layer of gravel at less than a metre, then only the soil depth above that is used to calculate AWC. The same is true of soils with water tables, so calculated AWC is low or moderate despite the chance that some water may come up from the water table. It is a good idea to have your soil assessed or use information available in soil survey maps. The AWC will not change from year to year.

Withdrawals are the daily water losses from the plants and soil surface. These are calculated from PET, adjusted by a crop factor. You should use the actual daily PET values for your district, which should be available in the news media. Indicative average values of adjusted PET for the whole season are shown in the last column of the table below.

Deposits are rainfall and irrigation. Rainfall is best recorded locally and irrigation amounts (in mm) should be calculated and recorded.

The way to keep the balance is just to add the deposits and subtract the withdrawals. The scheduling aim is to keep above the water balance Trigger Point, 60% of the AWC. You also want to minimise drainage and the risk of waterlogging, so avoid the water balance going above the AWC.

The water balance method is very straightforward and requires little time managing instrumentation. However, it is a good idea to occasionally truth-test the calculated water balance values with direct soil water measurements.

In practice you will want to set up a four column table to list the daily ET, the Adjusted ET, the rainfall or irrigation, and the crop water balance.

➤ Key point: doing the sums for a water balance

Start by finding a day when the soil is close to field capacity (just after heavy rain close to planting. Assume then that the soil water balance (W) is equal to the available water capacity.

Then for each subsequent day calculate:

$$W = W_{\text{day before}} + \text{rain} + \text{irrigation} - (\text{CropFactor} \times \text{ET})$$

For sweet corn, the crop factor is usually 0.6 from sowing to the start of stem elongation, and 1 from then on. If W becomes greater than the AWC then reset it to AWC (in other words assume the excess water drains away quickly). When W is approaching the trigger point of 60% of AWC, irrigation is needed. If you graph W against date you can forecast ahead to see roughly when irrigation will be needed.

How much irrigation should you apply? Well you don't want to return the water balance to the AWC or more. That would return the soil to field capacity and risk waste. So generally we suggest the maximum to apply would be 10–20 mm less than 60% of the AWC.

For seven regions, estimates of 1) the Available-water capacity (AWC) in a 1m root zone in typical sweet corn growing soils, and 2) the average regional value for the Adjusted PET, which is equal to total crop water use.

Region	AWC (mm)	Full-season crop water use (mm)
Canterbury	180	370
Marlborough	150	370
Manawatu	170	280
Hawke's Bay	150	370
Gisborne	170	330
Bay of Plenty	160	310
Waikato	170	280

Key point: Don't overdo it!

- Know how much irrigation your system is applying and make sure it doesn't return the soil water balance to more than the AWC.

When the water balance is equal to the AWC, the soil is said to be at field capacity. Until the crop has a chance to dry the soil some more, any extra irrigation or rainfall will cause drainage. That will leach away fertiliser N especially, and probably other chemicals too. To make matters worse, in many soils that extra water will cause waterlogging damage to the crop and yields will fall.

CRITICAL GROWTH STAGES FOR IRRIGATION?

It is often stated that there are particular growth stages to avoid water stress and you can be less vigilant at other times. **For sweet corn do not let the water balance fall below the Trigger Point at any time during the season.** Research has shown that sweet corn yield can be reduced by water stress at any time during growth.

There is a stage of growth worth noting, however: the start of stem elongation. This is the guide to when the crop factor sweet corn crop hits one. So, from then on, in the water balance chart Adjusted PET is the same as PET. Before that stage the crop has too small a canopy to use water to the full potential, so we use a crop factor of 0.6 to calculate the daily values of Adjusted PET.

WATER QUALITY

Generally, irrigation water in NZ is of very high quality. However, in some small areas water available for irrigation may contain unacceptable concentrations of naturally occurring chemicals. These may cause salt build-up in irrigation equipment (affecting its reliability), nutrient imbalances (including toxicities) in the soil and, in the case of sodium compounds, damage to soil structure.

Growers should arrange for a representative sample of the water to be analysed by an accredited water testing laboratory if previously water quality has been identified as a potential problem, and whenever new sources of irrigation water are being utilised. The water should be used for irrigation only if it meets the accepted quality standards provided by the laboratory.

In interpreting these standards, it must be recognised that:

- Research is still needed to obtain tight definitions of the standards for sweet corn in NZ;
- The standards can vary between regions, according to soil types and climate;
- Sweet corn is probably less sensitive to salty water than orchard crops; and
- An aim of good irrigation management is to minimise leaching of chemicals out of the root zone - so soil retention of chemicals from irrigation water can be considerable in regions of low rainfall.

This will often mean that the acceptable chemical concentrations in the water need to be set lower than for some other crops. For instance, a water conductivity value of 2000 $\mu\text{mhos/cm}$ may be acceptable for potatoes grown in a silt loam in Hawke's Bay, but an upper limit of 1600 $\mu\text{mhos/cm}$ may be more appropriate for apples on the same soil. In Central Otago, where rainfall is generally much less and irrigation applications greater, an acceptable upper limit of 1000 $\mu\text{mhos/cm}$ may be more appropriate.

FURTHER INFORMATION

- Reid, J.B.; Pearson, A.J.; Stone, P.J. 2001. Land Management for Sweet Corn. Recommended best management practices for New Zealand. Crop & Food Research Confidential Report 362. 48pp
- Stone, P.J.; Wilson, D.R.; Reid, J.B.; Gillespie, R.N. 2000. Water deficit effects on sweet corn. I. Water use, radiation use efficiency, growth and yield. Australian Journal of Agricultural Research 52: 103-113.
- Wright, R.; Duff, J.; Deuter, P. ; Walsh, B. ; Napier, T. ; Hill, L.;Dimsey, R.; Learmouth, S. 2005. Sweet corn grower's handbook, Department of Primary Industries and Fisheries, Queensland. 269pp

APPENDIX: GLOSSARY OF IRRIGATION TERMINOLOGY

“Potential evapotranspiration”, or PET, is a measure of how much evapotranspiration you can expect on a given day from a short, well-watered crop that completely covers the ground. In NZ, values of PET are often published in newspapers or are available from crown or commercial organisations. The value of PET depends on the amount of sunlight, air temperature, wind speed and the humidity of the air. The formula used usually in NZ makes an average correction for air humidity and wind speed, and so it can underestimate actual evapotranspiration under hot windy conditions. Over periods of a week or so, PET varies comparatively little across a district, so growers can usually rely on published values for their district.

“Crop factor”, is a term used to correct the standard PET value to a representative value for a particular type of vegetation. Values of the crop factor can vary quite a lot with local conditions, and they are usually smallest early in the season when there is little ground cover. For sweet corn we recommend you use a crop factor of 0.6 for the period from sowing to the start of stem elongation. Thereafter use a crop factor of 1.0.

“Soil water content” is the amount of water held by the soil. It is usually measured as a concentration (cubic metres water per cubic metre of soil). When scheduling irrigation it is better to measure soil water content as the amount of water in the whole soil per square metre of ground area. This gives a measure in easy units - 1 litre per square metre is the same as 1 mm depth of water. Looked at in that way, soil water content will increase by 10 mm during a 10 mm rainfall or when 10 mm irrigation is applied.

“Soil water tension, or suction or potential” is a measure of how tightly the soil is retaining water (and so how difficult it is for plants to absorb the water). Devices for measuring soil water tension are comparatively cheap and simple to use, and can be useful to indicate when irrigation is needed. However, it is not particularly easy to estimate how much water to apply when relying on water potential measurements.

“Field capacity” is the soil water content at which drainage effectively stops. Excessive rain or irrigation may bring the soil to a water content greater than field capacity, and the excess starts to drain away. The drainage rate becomes slower each day, and eventually becomes insignificant. Good irrigation management aims to avoid this drainage because it wastes water and can leach nutrients and agrichemicals into groundwater.

“Soil water deficit” is a measure of soil water content relative to field capacity. It is measured in mm water. It is a negative version of the soil water balance:

- If the soil is wetter than field capacity then the soil water deficit is negative (the water balance is positive) and significant drainage is likely.
- If the soil is drier than field capacity then water deficit is positive, then the soil water balance is negative (the water balance is negative) and drainage is negligible.

“Permanent wilting point” is the soil water content at which plants can no longer absorb water from the soil—they wilt and cannot be revived by shading. Permanent wilting point is not the same as the “stress point” that is sometimes used for trigger irrigation. The “stress point” occurs when the plants can still absorb water, but not fast enough to avoid stress—usually that happens when the soil is still wetter than permanent wilting point.

“Available water capacity” is the difference between the soil water contents at field capacity and at “permanent wilting point”. It is a useful indicator of how well a soil retains water for plants. Soils differ considerably in their available water capacity - generally it is greatest in silt loams, and least in sands. The depth of the soil profile itself is also important. As a rule of thumb, in NZ the available water capacity is roughly 0.17 times the rooting depth of the crop. So if roots are found down to 1 m, the available water capacity is about 165 mm. Unless the soil contains strong pans which prevent deep root penetration sweet corn will normally have roots to about 100 cm depth.

11 Harvest and postharvest

Diana Mathers, formerly Heinz Watties Ltd, now Foundation for Arable Research



WHEN WILL THE CROP BE MATURE?

Time to harvest maturity is specific to each variety, and depends on temperature—so it will vary with planting date and weather. Sweet corn matures much faster in warm weather than in cold weather, and any cold weather during the growing season slows its progress to maturity—without necessarily reducing yield.

There are two aspects of maturity to consider.

- The long-term view looks at the total time that the crop has been in the ground.
- The short-term view is how fast the cob is maturing.

Both aspects are dependent on the weather that the crop experiences.

Maturity time is based on cumulative heat units or degree days (see chapter **Crop development and growth**). A heat unit is the average daily temperature minus a constant base temperature.

Each variety has a characteristic time to harvestable maturity – this is constant in degree days but not in calendar days. If the season is hot it takes fewer days to get to the target than if the season is cold. Crops planted early in the season take longer to mature than crops planted later in the season.

As harvest approaches we become interested in two things.

- The harvest order of the crops – will they be harvested in the order planned at planting time? And
- How fast the moisture levels are dropping in the cobs—the moisture % of the kernels is the main quality parameter used to decide if the crop is at harvestable maturity.

The rate at which the cobs mature depends on the weather conditions during this maturity period. In cool, wet conditions they mature slowly and the quality will not be greatly affected if harvest is delayed. However in hot, dry conditions the kernel moisture % can drop rapidly and quality will be quickly lost if there are any delays in harvest.

So - as harvest approaches, keep a close eye on the weather and the crop.

HOW IS HARVEST PLANNED?

Harvest planning begins before planting. The processing companies and large fresh market producers will often use a sweet corn maturity model to plan their harvest strategies so that they have an uninterrupted supply of good quality corn for the season. The harvest schedule in turn determines the planting programme that is put in place for the season.

A maturity model uses daily temperature information to predict when the corn will be ready for harvest. Each variety takes a particular number of heat units to produce cobs to specified moisture levels. The models have a database of variety information and historical temperature data for the region, this information is used to plan for the season.

The planting plan is made by entering the planned harvest dates and the varieties that will be used into the model. The model works backwards from the harvest dates and calculates planting dates for each variety. The model can be updated during the season with actual weather data to give an accurate picture of how the season is progressing and whether there have been any changes to the harvest plan.

A successful planting plan will use a mix of varieties, planted sequentially, to give an uninterrupted flow for harvesting.

The plan, like all plans, is subject to unexpected outside influences, the biggest one being the weather. Stress conditions like frost, or cool, or dry weather, will delay germination and slow down plant growth; and later crops, planted in better conditions, may catch up with the earlier plantings. Furthermore wet weather can cause harvesting delays. When this happens, the crops “bunch up”. In other words, a large number of crops may be ready on the same day, and the harvest plans may go “out the window”. The harvest will be rescheduled so that there is a minimum of “out of spec” corn being harvested and control is regained. In worst case scenarios, over-mature crops will be by-passed in favour of moving back into crops that are within the specified moisture range.

KERNEL MATURITY AND MOISTURE

As sweet corn ripens the silks dry off and turn brown, and the cobs will start filling out. The husk leaves are bright green when the cobs are at good eating maturity, and begin to dry off as the kernel moisture decreases. Pull back the husks of a few cobs to check the kernels at the base of the cob – they should be plump and produce a milky juice if you squeeze them.

Kernel moisture drops between 0.5% (supersweet varieties) and 1% per day (normal sugar and sugary-enhanced varieties), depending on temperature and how mature the kernels are.

The kernel moisture content may not change much during wet weather, but remember that the kernels are still maturing physiologically – when the weather returns to normal, there will be a sudden drop in moisture level. The yield increases as the moisture content drops.

Most of the corn grown for processing will be harvested to meet a raw material specification pertaining to a particular product. For example corn that is being frozen will be harvested less mature than corn that is being harvested for canning or powder production. Normal sweet (su) varieties are ready for harvest at a moisture content of 68–72%, and supersweet varieties are harvested at 75–78%. Corn with a moisture level below 67% is generally too over mature for processing as the pericarp toughens as the moisture level drops.

Crop sampling for determining kernel moisture content begins as the crop approaches its planned harvest date. The sampler will visit the crop several times to collect samples for testing.

Key Point: Silking as an early indicator

- A key indicator for maturity is the date that 50% of the plants are silking.

The crop will be ready for harvest a set number of degree days after this date (often the time lag is three to four weeks depending on the moisture specification for the kernel that is required). Processing agronomists and fresh market growers should record this date, as it gives a good indication whether planting schedules are going to deliver to the planned harvest schedule.

If the crop emerged evenly, silking will occur over a period of 3–4 days and cob moistures will be very even at harvest. If the crop had a patchy emergence pattern it will also have a patchy silking pattern, reflecting the mixed ages of the plants. Cob maturity and quality will be variable.

SAMPLING FOR MOISTURE MEASUREMENTS

Most processors will have developed their own protocols for collecting representative samples from the paddock. Here are some general guidelines.

The most important point to remember is that the sample you are collecting should be representative of the crop. Before you collect your sample think about the following points:

- How big is the paddock; will only one sample give a good representation of the crop?
- Is the crop even or were there parts of the paddock that emerged earlier or later than the majority of the crop? Include some of these cobs in the sample.
- Are there lots of good sized secondary and tiller cobs in the crop? If so then include some of them in the sample.

It is often helpful to stand on a gate post or a high vantage point so that you can look down on the crop; any unevenness is easily seen in the colours of the flowering tops.

Collect 20–25 cobs per sample (avoid the headlands as corn is often more mature on the crop edges).

A quick way of determining the kernel moisture is the microwave method.

Microwave method to determine kernel moisture

Randomly select 20 cobs. Husk them and remove a slice of kernels by running a knife from the top of the cob to the bottom.

Blend the kernels in a food processor until you have a smooth homogenous paste.

Weigh a glass Petri dish. Record the weight to 2 decimal places. This is W1.

Weigh out 10g of corn slurry in the Petri dish. Smooth the slurry over the whole dish so that it is evenly distributed. Weigh and record the weight of the slurry + Petri dish to 2 decimal places. This is W2.

Place the Petri dish in a microwave and heat on 50% power for 6 minutes. The slurry must be completely dry but not burnt.

Cool the Petri dish in a dehumidifier.

When the sample is cool, weigh the dish and the dried slurry to 2 decimal places. This is W3.

$$\% \text{Moisture} = 100 \times (W2 - W3) / (W2 - W1)$$

HARVESTING

Sweet corn can be harvested by hand or machine. Machine harvesting causes little damage to cobs and is used by larger growers and processors because of the lower labour input. Hand harvesting is mostly done by smaller growers growing for the local fresh market.

Machine harvesting is a once over operation. Small areas harvested by hand may be harvested twice.

All of the processing crop and much of the fresh crop is harvested mechanically by self-propelled harvesters. These harvesters harvest multiple rows at a time, with either four-row, six-row or eight-row headers.

The harvester snaps off the cobs, complete with husks, and loads them into a field bin which travels alongside. When full, the bin hydraulically tips the corn into a truck ready for delivery to the factory. A six-row harvester will harvest up to 50 tonnes per hour in a typical crop.

We recommend that the grower should inspect the harvest job—checking for missed cobs, damage to the land etc.

AND OUT OF THE PADDOCK...

After harvest, the cobs are transported to the factory, packhouse, or market in bulk trucks or trailers.

Processing must begin as soon as possible after harvest. Long road hauls in hot weather are undesirable. If the corn is to be left in bulk trucks or trailers for more than an hour, it should be kept from direct sunlight and cooled with water to remove as much of the field heat and heat of respiration as possible.



The good old days?



Harvesting in 2006. Note the tracked vehicle to carry the field bin. The tracks spread the load more evenly on the soil, reducing the potential for serious compaction problems for later crops.

Cob sweetness and tenderness can be lost very quickly. In warm weather, bulk lots of uncooled sweet corn will rapidly overheat because of residual field heat and additional heat produced by respiration. The respiration rate of sweet corn is among the highest of common fruits and vegetables; and it is about eight times faster at field temperatures than at 0°C. Loss of sugar is about four times as rapid at 10°C as at 0°C.

Recognising these characteristics, the sweet corn processing industry in NZ harvests around the clock at a pace to match the factory requirement for constant supply of fresh raw material. The harvested crop is normally processed within a few hours. Under those circumstances postharvest cooling is not necessary.

Key point: Keep it cool

- If there must be an appreciable interval between harvest and processing then make sure you can keep the cobs cool.

The key to maintaining good quality is either processing within a few hours of harvest or rapid removal of field heat after harvesting. It is important to maintain the cool chain from field to consumer.

If you cannot process the corn within a few hours, or you are selling it fresh, then harvesting is best carried out in the cool of the day while the cobs are cool. Rapidly removing the field heat from sun-warmed cobs is expensive and quality losses are nearly unachievable if the cobs are being stored in large field bins. Just putting your bins in a chiller will not be enough for top quality. As soon as possible after harvest bring cob temperature down to near 0°C. Forced-air cooling is the main method but hydrocooling can also be used.

Sweet corn will keep without deterioration for about seven days at 0°C and 90 to 100% relative humidity. The husk on the cob will help prevent the kernels drying out and reduce the rate of warming up once the cob is removed from the cool room. Do not let the temperature fall below 0°C as freezing the cobs will cause the quality to deteriorate.

POSTHARVEST CROP MANAGEMENT

Issues for all growers

When the harvester leaves the paddock it leaves behind residues or the crop stubble. The residue can be taken for silage or grazed, but we recommend they are left behind in the paddock to help maintain soil organic matter levels. Grazing in particular has some important disadvantages. If it rains then stock can do substantial damage to the soil structure by pugging. This increases the amount of cultivation needed to form a seed bed, and increases the risk of poor performance of the next crop.

The residues can be left on the surface to protect the soil from heavy rain. However, usually they will need to be chopped before the next crop can be sown, and that chopping is most easily done when they are still green and straight after harvest. Mulching or chopping residues then can provide a better coverage of the soil surface, and the residues will be easily incorporated when preparing a seed bed for the following crop.

Grass seed can be sown by broadcasting it and mixing with chopped residues.

Usually, the most efficient way of dealing with the crop residue is to mulch and incorporate it back into the soil while it is still green. This allows rapid decay of the old plant and returns a good amount of organic matter to the soil. It also helps with disease and insect control for the following seasons. Note that ploughing inverts the soil and buries the residues in a narrow band – so decomposition can be very slow and the benefits of the added organic matter localised. Many alternative practices, such as discing, distribute the residues better. However, keep the number of cultivation passes to a minimum, and only cultivate at all if the soil water content is suitable.

Once the residue has been worked in, the ground can be prepared for sowing the next crop. Options for winter management are: grass for grazing, cover crops, such as winter oats or a leguminous crop, or brassicas, lettuce or onions.

Specific issues for organic growers.

One of the main issues for organic production is maintaining soil fertility. The addition of composts to the soil and the use of cover crops over the winter will replace depleted soil nutrients and organic matter.

Cover crops that are mixtures of cereals and legumes can improve the soil health. Grasses, such as wheat and rye, produce large amounts of biomass and develop long roots which can bring nitrogen up from deep within the soil. Legumes such as clover and lucerne fix nitrogen from the atmosphere as long as they are actively growing and the soil is not already too rich in N.

The cover crop is planted in early autumn and ploughed in spring.

Crop rotation is the single most important practice in an organic vegetable production system. Crop rotation is the practice of following one annual crop with another crop that is as different from the first crop as possible in terms of nutrient needs, rooting patterns, disease and insect pests, and growth habit. For example, sweet corn may be planted in a 3-year rotation with squash and peas. Rotating fields with soil-improving crops maintains long-term soil fertility. Diversity is the key to stability in a biological system.

Key point: crop residues are not trash!

- The residue left behind by a sweet corn crop is a potentially valuable resource.

Sweet corn crops can leave a lot of residues on the soil surface. On a dry weight basis, the mass of these residues is about equal to the ear yield. A crop that yields say 24 t/ha of ears at 76% moisture content will leave about 6 t/ha of dry residues. The residues are usually made up of stalks (64%), leaves (27%), and unharvested ears (9%). Some parts of those residues such as leaves are readily decomposed by microbes. Other parts such as the stalks are much more resistant. All contribute to the maintenance of soil health by adding to soil organic matter.

The residues contain valuable nutrients (see chapter **Plant nutrition and fertilisers**) and many of these are lost if residues are burnt.



One-pass machinery. In recent years some NZ growers have planted brassicas or grass with one-pass disc, roller and seeder application. Some like this example include rippers as part of the combination to assist in mixing crop residues and easing soil compaction after harvest.

12 Sweet corn deductions

Vanessa France, formerly Raw Materials Coordinator, Cedenco Foods, Gisborne



All incoming loads of sweet corn are inspected to determine their acceptability for processing. The quality assessments are used for the purpose of calculating payments to each grower based on the load defects.

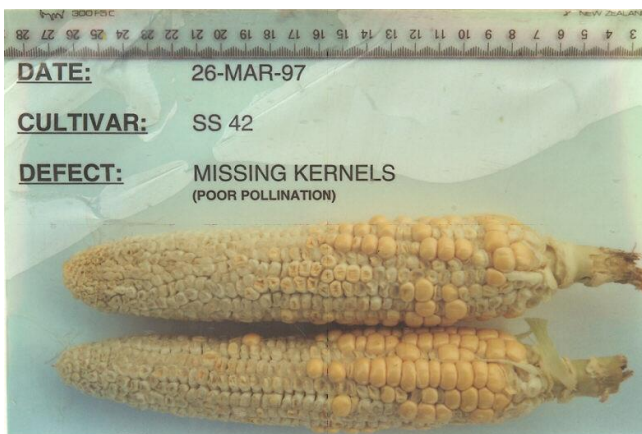
Detailed procedures are used by the weighbridge Quality Assurance staff for determining deductions with each defect weighed to proportion it across the load. These deductions are made so the factory is not paying for any defects that cannot be used in the process that the crop has been assigned to (e.g. canning, IQF, Powder or Retort). Each process has slight variations to defect tolerances depending on its requirements.

The most usual types of deductions are described in the following sections.

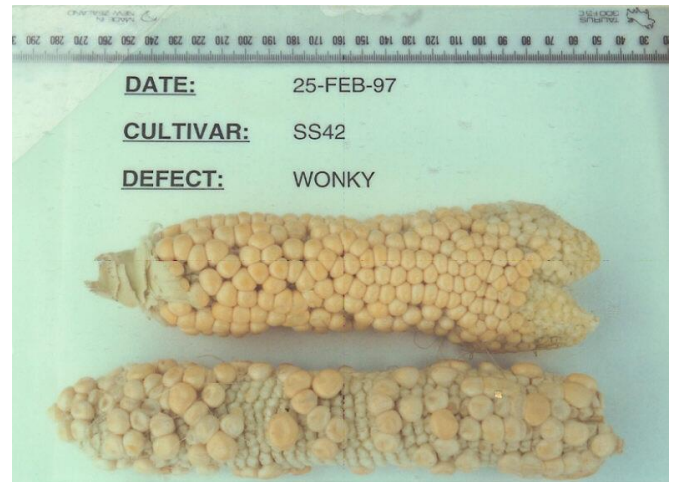
UNUSABLE COBS

This includes cobs that are

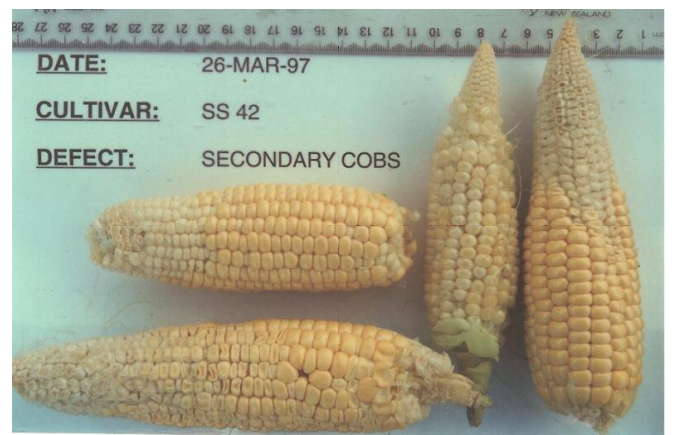
- **Undersized** where the overall length is less than 120mm.
- **Immature** the kernels are not fully developed
- **Over-mature** – past optimum maturity and dimpled in appearance.
- **Misshapen** – bowed, bulbed, beaver foot or double cobs.
- **Abnormally developed** unusual shaped or cross-pollinated kernels, poorly pollinated cobs, and may include secondary cobs.
- **Poor tip fill** – the tip of the cob has no kernels that have developed.



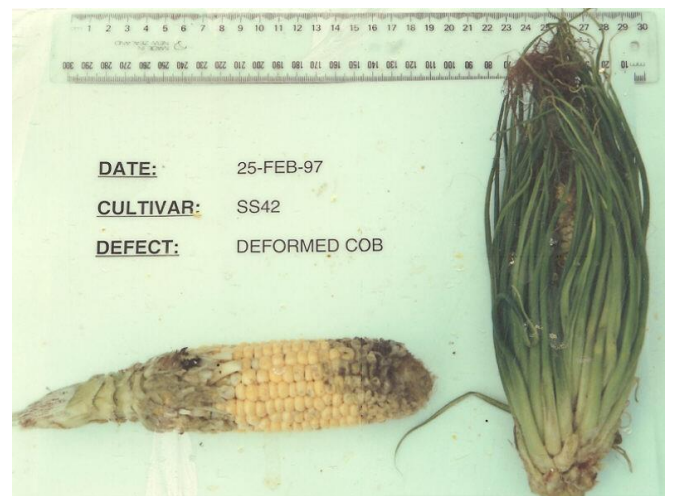
Abnormally developed cobs, in this case from poor pollination.



Abnormally developed (misshapen) cobs.



Other abnormally developed cobs, these are all secondary cobs with poor pollination and tip fill.



More examples of abnormally developed cobs.

HEAD SMUT

This is where a cob is showing black sooty mould. Accidentally letting these into the processing line necessitates expensive and time-consuming clean-up procedures in the factory.



Cobs badly affected by smut.

DAMAGED KERNELS

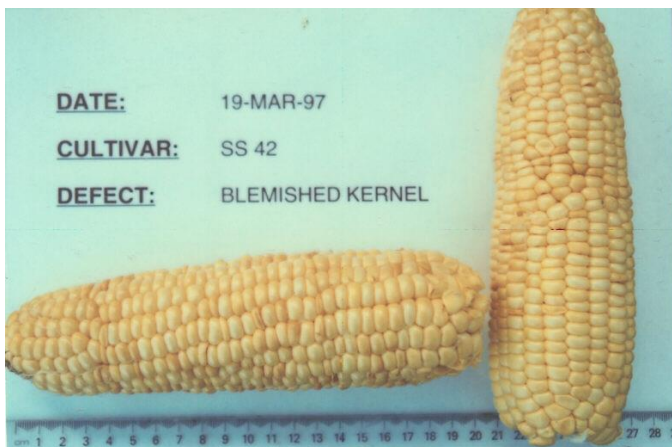
Damage is shown in crushed or split kernels caused by birds, insects or livestock. This does not include any damage done through harvesting.



Damage done by a caterpillar. The caterpillar damage is the darkened area on the cob. This cob also has poor tip fill.

BLEMISH COBS

Blemish is classified as a diseased or shrivelled kernel. This can be subtle or very obvious.



Cobs rejected because of blemished kernels.



Cobs rejected because of blemishes caused by disease (in this case soft rot).

GREEN VEGETABLE BUG

The bug pierces the kernels and sucks out their contents. Initially the kernels go translucent but they will mark and discolour, ruining the cob.



Damage from green vegetable bug.



A close up of kernels discoloured by attack from green vegetable bug. These kernels were photographed after freezing.

FOREIGN MATERIAL

This includes any glass, stones, metal, plastic, animal droppings etc found amongst the cobs. The foreign material can be discrete items within the load or contamination on the cobs themselves.



An example of a cob rejected for foreign material. This cob was probably contaminated with grease.

LEAF AND STALK

This includes stalk and leaf from the sweet corn and long shanks attached to the cob.

EXTRANEIOUS VEGETABLE MATTER

This includes other plant material that is not from the sweet corn plant, i.e., maize, weeds, squash.

13 Trouble shooting your crop



This chapter develops further some of the key points in the other chapters, and will remain a work in progress. Let Horticulture NZ and your processing company know what else you would like to see here—and remember to use the “Notes” sections on each page to handwrite questions and tips for yourself.

WHAT IF THE GERMINATION TEST % IS LOW?

Processing companies differ on the requirements for this so be careful to check with your agronomist.

Some companies are happy for you to increase the planting rate to compensate for the seeds that aren't expected to germinate. For example, if the germination rate is 90%, we need to plant 66,666 (= 60,000 x100/90) seeds to achieve the desired population.

This may work well if the germination percentage is high (say more than 90%). However, some companies consider that this brings other risks and discourage the practice. Their rationale is that if the percentage is low then there is a risk that by increasing the seeding rate you will get a crop that behaves like a higher population crop but has many gaps. This could adversely affect ear quality.

DIAGNOSING AN EMERGENCE PROBLEM

Diagnosing emergence problems early is critical to determining whether the problem can be remedied or if replanting should be done.

Here's a few common things to look for:

1. There is no seed present. May be due to:
 - planter malfunction
 - bird or rodent damage
2. The coleoptile (shoot) has unfurled underground. May be due to:
 - premature exposure to light in cloddy soil
 - planting too deep
 - compaction or soil crusting
 - extended cool wet conditions
 - a combination of several of these factors
3. Seed has poorly developed roots or coleoptiles, or the coleoptile tip is brown or yellow. May be due to:
 - seed rots
 - seed with low vigour
4. The seed has swelled but not sprouted. May be due to:
 - poor seed-to-soil contact (causing inadequate moisture)
 - seed with low vigour
 - shallow planting, seed swelled then dried out
5. Uneven emergence. May be due to:
 - soil moisture and temperature variability within the seed zone
 - poor seed to soil contact caused by cloddy soil
 - soil crusting
6. Plants are wilting or have been broken off at the soil surface. May be due to:
 - cutworm damage
 - argentine stem weevil damage
 - bird damage

WHAT IF A CRUST HAS DEVELOPED?

If a crust has developed on the soil surface before the crop has emerged, check if the seeds have started to germinate and emerge:

- If they have not begun to push towards the soil surface then a very light harrowing could break the crust without damaging the seeds. Try this on a small area and check the seeds before deciding whether to do the whole crop.
- If the seeds have already begun to push towards the soil surface or some seeds have already emerged then cultivation is out of the question. A light irrigation though will reduce the crust strength and help the plants to emerge.

Keep an eye on the achieved population – you may need to replant.

IS FROST DAMAGE FATAL?

Sweet corn growers are sometimes quick to replant a crop that has been exposed to frost. Anxiety about the crop is understandable, because sweet corn is originally a tropical or sub-tropical grass, and dead areas can be seen on the leaves within a few days of frost.

However, until the plants have about six fully expanded leaves (or 10 visible leaf tips) the shoot's growing point or meristem is below ground. There it is relatively protected from the frost. So, even if you can see dead areas of leaves the crop may produce new leaves and grow through the set-back. The final leaf area and yield will be less than if the crop had not been frosted—but it may still be more economic to accept that yield than replant.

So, if your crop is frosted, leave a replanting decision for 7–10 days, and look for evidence of new leaf production.

UNUSUAL FOLIAGE OR PLANT HEIGHT?

Walking through your crop you may sometimes notice areas where the crop is noticeably shorter or where the leaves have different colours. Often the cause of these problems can be worked out by looking for patterns in where the crop is worst.

Does the pattern reflect the landscape?

Often, areas of poor or unusual growth reflect differences in soil characteristics, especially surface height. In wet weather, low points in the landscape may become waterlogged. This can cause a wide diversity of symptoms, depending on other conditions.

As an example, look at the leaves in the figure to the right. Bronzed, stunted plants were found in patches in a paddock. Compared to plants elsewhere in the paddock the bronzed plants' leaves had greatly elevated concentrations of the micronutrients Cu, Mn, Zn and Fe (N, P, K and Mg concentrations were unaffected). You could worry a lot about how these imbalances arose and waste much money on trace element fertilisers in an attempt to correct them.

However, a bigger picture view revealed that the affected plants were in significant low points of the paddock. Digging down to about half a metre showed the subsoil was very wet and gleyed (slightly blue grey background colours). Most likely in these poorly-drained areas, waterlogging increased the availability of many micronutrients, and some, particularly Cu, were taken up in such large amounts by the plants that metabolism was severely disrupted.

SHOULD I REPLANT?

The decision to replant a poorly established or frosted crop will usually be made between the grower and the processor and should not be made lightly. It is often better to live with a slight to moderate reduction in plant population, than to replant.

Factors that should be taken into account are:

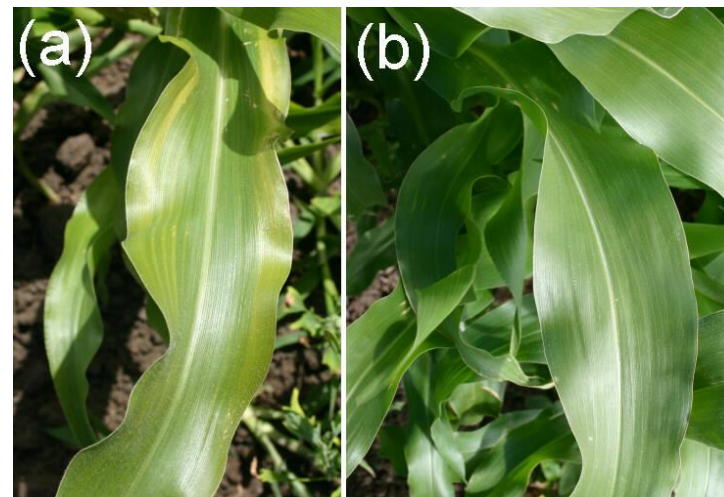
The costs that will be incurred for reworking the ground, new seed and planting. Do they outweigh the expected loss in yield from the reduction in plant number?

The timing of the replant. Planting schedules are usually tight and the replant may not be able to be scheduled until the end of the season, when there will be real impact on the potential yield of the crop.

Does the pattern follow drill lines?

Prior to tasselling, differences in plant height may be due to delayed emergence due to a crust or deeper depth settings on the seed drill. While obvious during the period of rapid stem extension, these differences usually disappear around tasselling. The different areas may continue to differ in cob maturity however.

If fertiliser rate setting changed (or the planter ran out of fertiliser towards the end of some runs) then you can expect yield differences between the two areas to persist.



A complex problem with micronutrients and soil water content (a) stunted plants producing leaves with unusual bronzing, and (b) leaves from a normal plant elsewhere in the same paddock.

14 Contacts

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