



A LIGHTER
TOUCH

BUTTERCUP SQUASH

Soilborne Disease Toolkit

APRIL 2026

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Reference

Ferguson, D., Lambert, C., Searle, B. and de Villiers, C., (2026). Buttercup Squash Soilborne Disease Toolkit. Prepared for New Zealand Buttercup Squash Council Inc. and A Lighter Touch.

DISCLAIMER

The toolkit and the information it contains is provided in good faith to support the management of soilborne diseases in buttercup squash in New Zealand. While intended as guidance, it is not guaranteed to be complete, accurate, consistent, or current, nor does it guarantee that soilborne disease will not develop or decline. A Lighter Touch, the NZ Buttercup Squash Council, contributing authors, and their affiliated organisations accept no liability for any loss or damage arising from the use of this information.

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Introduction

Buttercup Squash in New Zealand

Buttercup squash (“squash”) production in New Zealand covers about 4,800¹ hectares and produces around 63,000 tonnes for export, mainly to Japan and South Korea. The export value is approximately \$55 million².

The area planted in squash grew significantly during the 1980s when the Japanese export market was developed. At that time, about 70% of the crop was grown in the Pukekohe region. Since then, production has consolidated, and today more than 90% is grown in the Gisborne and Hawke’s Bay regions.

Soilborne diseases in buttercup squash

At a squash grower forum held in September 2020, participants confirmed that crop losses caused by soilborne disease (SBD) were their biggest concern. Losses are estimated to average around 30% each year, costing growers millions of dollars.

Losses occur in several ways:

- **Reduced field yield** as soilborne disease limits growth and weakens plant health, limiting fruit size and number.
- **Fruit losses from sunburn** before harvest when leaf canopy collapses due to early crop senescence.
- **Fruit losses from rots** in the field before harvest or later rejected when packing and repacking.

About this Toolkit

This Grower Toolkit brings together work from the *A Lighter Touch (ALT) Buttercup Squash Soilborne Disease Management Project*. Through an agroecological perspective, the project aims to find alternative ways to manage SBD in squash. It includes a literature review, plant pathology insights, discussions with researchers and industry personnel, as well as trials and demonstrations.

The Toolkit explains the factors that lead to a buildup of pathogens and identifies the main pathogens affecting buttercup squash. It then outlines strategies growers can consider, to reduce the impact of disease, including:

- **Crop rotation** – how current rotation crops influence susceptibility and pathogen hosting, and the suitability of other options.
- **Service crops** – the effect of existing service crops on pathogens and potential alternatives.
- **Biological controls** – an introduction to biological options, key considerations for successful integration, and an example programme.
- **Other approaches** – pathogen testing, crop nutrition, soil amendments, and cultural practices.

The Toolkit will be updated before the Soilborne Disease Management Project concludes in March 2027, as further work is completed within this and other programmes.

At nearly 4,800 hectares, Buttercup Squash is New Zealand’s third largest vegetable crop by area. This large footprint highlights the importance of managing soil health for this crop and others, as it typically sits in a crop rotation.



¹AGRICULTURAL PRODUCTION STATISTICS: YEAR TO JUNE 2024 (FINAL). STATS NZ.

²2023-24 NEW ZEALAND BUTTERCUP SQUASH COUNCIL. EXPORT VALUE IS FREE ON BOARD.



FIGURE 2: DISEASE AFFECTED ROOT IMMEDIATELY POST-HARVEST (LEFT) AND HEALTHY SQUASH ROOTS AT HARVEST (RIGHT). SOURCE: DERECK FERGUSON

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Soilborne Diseases

The Disease Triangle

The incidence and severity of plant disease depend on three key factors: a susceptible host plant, the presence of a pathogen, and favourable environmental conditions. These factors form what is known as the *disease triangle* (Figure 1). All three must be present or favourable for disease to develop. If even one factor is absent, disease cannot occur.

Targeting one or more sides of the disease triangle can help manage or control disease. The host plant can resist infection through genetic traits, physical barriers, or immune responses. The pathogen (inoculum) must be present to infect, replicate, and spread within the host. Environmental conditions include temperature, moisture, relative humidity (RH), free water, soil saturation, air movement, and insect vectors.

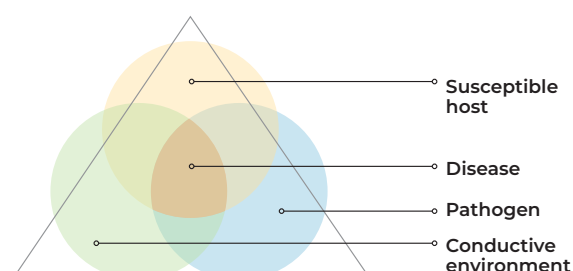


FIGURE 1: THE DISEASE TRIANGLE REPRESENTING THE THREE KEY FACTORS THAT ARE NEEDED FOR DISEASE DEVELOPMENT, NAMELY THE SUSCEPTIBLE HOST, THE PATHOGEN (E.G. FUNGI, BACTERIA, OOMYCETES, VIRUSES, NEMATODES) AND CONDUCIVE ENVIRONMENTAL CONDITIONS.

Fungi generally require at least four hours of high RH and free surface water to infect successfully. When conditions are optimal and inoculum levels are high, disease severity increases. Oomycetes rely on saturated soil to produce zoospores, which move through water towards plant roots. Optimal temperatures for soilborne disease development vary between species.

Recognising typical symptoms of SBD is important for management as it can help to distinguish disease issues from other issues such as nutrient deficiencies.

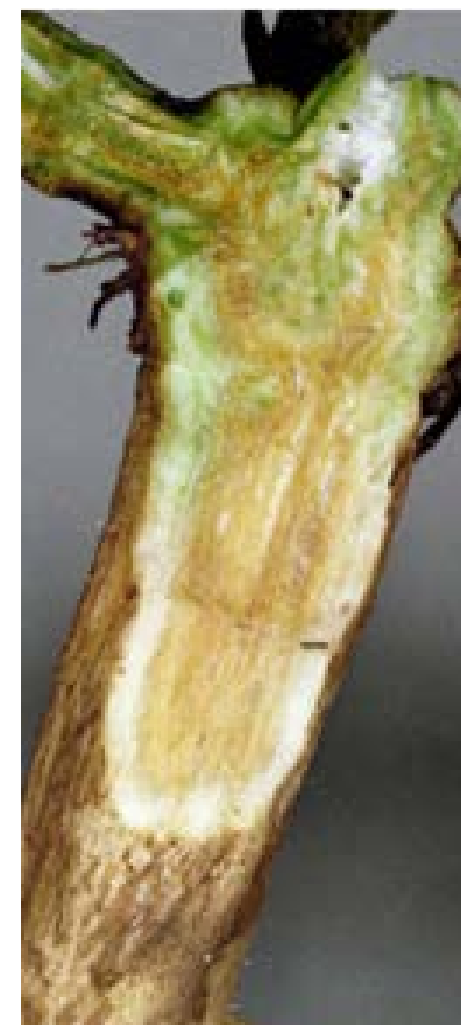


FIGURE 3: VASCULAR BROWNING AT THE BASE OF THE STEM CAUSED BY *FUSARIUM OXYSPORUM*. SOURCE: PETER WOOD/BIOECONOMY SCIENCE INSTITUTE

Leaf & stem symptoms

Initial symptoms of soilborne disease in buttercup squash are usually seen on the foliage above ground. Plants may show poor growth, smaller leaves and stems, and signs of chlorosis and wilting. As the disease progresses, leaf symptoms become more severe, and chlorosis can appear along the vine and stem. Cutting stems at the crown may reveal yellow to brown discolouration inside, indicating cell death and disruption of water, mineral, and sugar movement within the plant. In severe cases, plants may collapse completely.

These symptoms can be mistaken for nutritional disorders, viral infections, or frost damage, so careful diagnosis is important.

Root symptoms

Root infection can occur early in crop growth, particularly with *Pythium* species, although symptoms often take longer to appear. Healthy roots are near-white, but as disease progresses, they change to creamy yellow and eventually darker shades of brown (Figure 2). Infected roots typically lose their fine root hairs and the cortex layer. Cutting into the roots may reveal vascular staining (Figure 3).

In severe cases close to harvest, only the larger fibrous roots remain, showing a pale to dark brown colour.

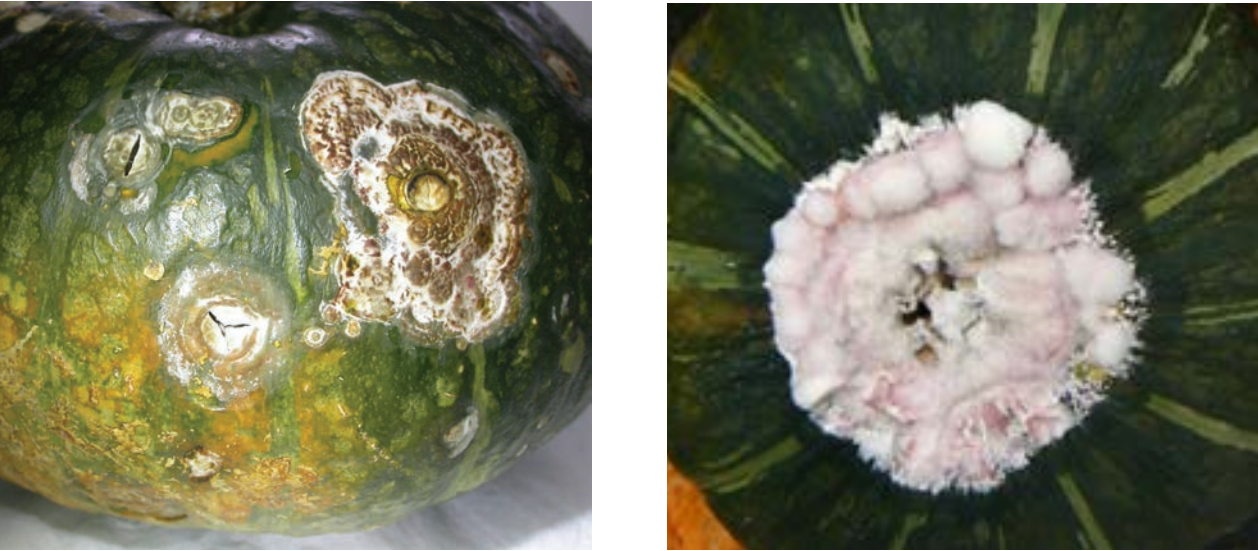


FIGURE 4: FUSARIUM FRUIT ROT OF BUTTERCUP SQUASH⁴. SOURCE: PETER WOOD/BIOECONOMY SCIENCE INSTITUTE

Fruit symptoms

Fruit rot symptoms vary depending on the disease. Most begin as lesions on the fruit or around the stem. The colour, shape, and texture of the lesion often provide clues about the causal pathogen. Some lesions allow secondary pathogens to invade, leading to softening or collapse of the entire fruit.

Symptoms can appear in the field (Figure 4), such as with gummy stem blight and sclerotinia rot, but most develop after harvest during transport and storage.

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Significant pathogens of squash

Squash production faces significant challenges to yield and quality from a range of pathogens, including fungi, bacteria, oomycetes, and viruses. These pathogens use diverse and highly effective survival strategies to persist between growing seasons and during unfavourable conditions, and many can maintain viable populations even without host plants. Several important squash pathogens are present in New Zealand. For the most common diseases, this Toolkit will discuss their life cycles, survival in soil and crop residues, and the role of resting structures.

Plectosphaerella root rot

Plectosphaerella root rot is often found where vine decline and canopy loss are severe. Causal organisms include *Plectosphaerella cucumerina*, *Diaporthe sclerotioides* (Phomopsis black root rot), and a Fusarium complex (*F. oxysporum*, *F. culmorum*, *F. solani*).

Plectosphaerella survives on decayed plant material or in soil as resting spores. Infection can occur after sowing through the seed membrane, especially when seeds are planted deeply. The fungus enters roots, stems, and vascular tissue via wounds or natural openings and thrives in warm, moist conditions. High humidity and excess soil moisture increase risk.

Once inside, water and nutrient uptake are disrupted, causing root rot and vascular staining. Mature plants may show crown rot, severe root rot, and canopy collapse. Fruit can also rot. The fungus grows best at 25°C and pH 7–8.5. Spores spread by water splash and infected soil moved by equipment.

Rotation with non-cucurbit crops for at least two years and choosing sunny, well-drained sites can help^{5,6}.

⁴SOILBORNE DISEASE MANAGEMENT IN BUTTERCUP SQUASH; REES H.J. ET AL 2025

⁵GIRALDO, A., AND CROUS, P.W. 2019. INSIDE PLECTOSPHAERELLACEAE.

⁶RIVEDAL, H.M. ET AL. 2022. IDENTITY AND PATHOGENICITY OF FUNGI ASSOCIATED WITH ROOT, CROWN, AND VASCULAR SYMPTOMS RELATED TO WINTER SQUASH YIELD DECLINE.



PHYTOPHTHORA BLIGHT. CREDIT: GERALD HOLMES, STRAWBERRY CENTER, CAL POLY SAN LUIS OBISPO, BUGWOOD.ORG



PYTHIUM DISEASES. CREDIT: GERALD HOLMES, STRAWBERRY CENTER, CAL POLY SAN LUIS OBISPO, BUGWOOD.ORG

Phomopsis black root rot

Phomopsis black root rot, caused by *Diaporthe sclerotioides*, affects a wide range of hosts worldwide and is linked to severe vine decline and root rot in New Zealand buttercup squash. Seeds sown in infested soil may suffer damping-off or seedling wilt. The pathogen can attack roots, causing yellowing, leaf withering, and plant wilting, especially in waterlogged soils. In mature crops, black root rot often occurs as part of a disease complex, leading to stunted growth and plant decline.

The pathogen likely survives as sclerotia, which are hard resting structures that persist in soil and plant debris for long periods. These can spread easily with soil movement and germinate under favourable conditions^{7,8}.

Fusarium root and crown rot complex & wilt

Fusarium root and crown rot in New Zealand is caused by a complex of species, with *F. oxysporum* (often associated with Fusarium wilt), *F. culmorum*, and *F. solani* being the most common. Other species identified include *F. avenaceum*, *F. acuminatum*, *F. equiseti*, *F. graminearum*, and *F. petrophilum*.

These fungi attack roots and crown tissue, causing root rot, wilting, stunted growth, vine decline, and sometimes damping-off in seedlings. Severe infections can lead to plant death. Disease is most aggressive at 18–25°C, while temperatures above 30°C reduce severity. Excess soil moisture promotes infection.

Fusarium survives for long periods in soil as chlamydospores, which can remain dormant for up to three years.

Fruit rot is common, with *F. culmorum* a major contributor. Overhead irrigation or rain during flowering increases infection risk, as splash disperses inoculum to flowers and the plant base^{5,9}.

Pythium root rot

Worldwide, 24 different *Pythium* species are reported to cause root rot and damping-off in squash seedlings. In New Zealand, *Pythium tracheiphilum* is the most common species identified. Different species may dominate at various times of the year depending on environmental conditions.

Pythium belongs to the oomycota group, which also includes *Phytophthora*. Many species produce motile zoospores that swim through water films and are attracted to root and seed exudates, so wet conditions are essential for infection. The pathogen reduces oxygen around roots, causing damage that allows infection. Symptoms include brown necrotic lesions on roots, stunting, wilting, and chlorosis. A typical sign is threadlike vascular tissue protruding from infected roots. As plants mature, thicker cell walls reduce severity.

Resistant oospores can survive in soil for more than three years. Pathogens spread via water, soil movement, or infected seed^{8,10,11}.

⁷BRUTON, B.D., AND BILES, C.L. 2017. PHOMOPSIS BLACK ROOT ROT OF CUCUMBER.

⁸WICK, R.L. 2017. PLECTOSPORIUM BLIGHT.
⁹MESSELINK, G.J. ET AL. 2020. CUCURBITS.

¹⁰DEADMAN, M.L. 2017. PYTHIUM AND PHYTOPHTHORA DAMPING-OFF AND ROOT ROT.

¹¹KEINATH, A.P. 2017. GUMMY STEM BLIGHT. IN: COMPENDIUM OF CUCURBIT DISEASES AND PESTS, SECOND EDITION.



CHARCOAL ROT ON SUNFLOWER. CREDIT: THIRUNARAYANAN PERUMAL, BANARAS HINDU UNIVERSITY, BUGWOOD.ORG



BLACK ROOT ROT ON WATERMELON CREDIT: GERALD HOLMES, STRAWBERRY CENTER, CALPOLY SAN LUIS OBISPO, BUGWOOD.ORG

Macrophomina vine decline & charcoal rot

Macrophomina phaseolina is a fungus that causes Macrophomina vine decline and charcoal rot, particularly under high temperatures and low soil moisture. Microsclerotia (small resting bodies) are the main source of infection and can form even under low water conditions. Plant stress, such as dryness or damage, increases susceptibility.

Once inside the roots, the fungus disrupts water and nutrient transport, leading to wilting. Microsclerotia return to the soil, where they can start a new disease cycle or survive for up to 15 years. The pathogen spreads through infected soil and crop debris¹².

Thielaviopsis basicola - Black root rot

Thielaviopsis basicola is a soil-inhabiting fungus that affects both young seedlings and mature plants as part of a root and crown rot complex. Heavy or waterlogged soils favour *T. basicola* infection. The fungus colonises root tissue, reducing nutrient uptake and weakening the root system. This leads to cortical cell death, giving roots a brown to black appearance.

Mature plants are also affected, where *T. basicola* is associated with vine decline in combination with other pathogens such as *Plectosphaerella* and *Fusarium*. The fungus produces chlamydospores that can survive for very long periods in soil. Alkaline soil conditions favour disease development and spread¹³.

Gummy stem blight

The genus *Stagonosporopsis* (previously known as *Didymella bryoniae*) is the causal agent of gummy stem blight and is considered an important pathogen of cucurbit species in New Zealand. Typical symptoms include water-soaked lesions on leaves that, with age, dry out, form rings, and produce pycnidia (small black survival structures). Lesions may ooze a characteristic red-brown gummy-like substance.

Although symptoms often appear on fruit, the fungus survives between seasons on infected crop debris. The optimal temperature for infection is between 24°C and 25°C, and at least one hour of leaf wetness is required for infection. Continued wetness is needed for disease development. The fungus can persist in soil, in infected seed, or on crop debris for over a year. Restricting movement of contaminated soil, water, and equipment is recommended to limit the spread of this disease^{8, 10, 14}.



GUMMY STEM BLIGHT ON SQUASH. CREDIT: GERALD HOLMES, STRAWBERRY CENTER, CAL POLY SAN LUIS OBISPO, BUGWOOD.ORG

¹²ALIZADEH, M. ET AL. (2025). BIOLOGY AND HOST RANGES OF THE PLANT PATHOGENIC FUNGUS MACROPHOMINA PHASEOLINA: A COMPREHENSIVE REVIEW.

¹³NEL, W.J. ET AL. (2019). BLACK ROOT ROT: A LONG KNOWN BUT LITTLE UNDERSTOOD DISEASE.

¹⁴SEBLANI, R. ET AL. (2023). GUMMY STEM BLIGHT: ONE DISEASE, THREE PATHOGENS.

Sclerotinia rots

Sclerotinia sclerotiorum thrives in cool, moist conditions and infects plants through wounds, stems, flowers, leaves, or fruit in contact with soilborne sclerotia. These hard, black survival structures (resembling mouse droppings) can persist in soil for up to four years. Infection is favoured by temperatures of 16–22°C and extended leaf wetness or relative humidity above 90%¹⁵.

Symptoms start as soft, water-soaked lesions on stems, leaves, or fruit touching wet soil. White fluffy mycelia and sclerotia may appear on infected tissue, which later collapses and decays. The pathogen can cause fruit rot in the field and post-harvest decay (Figure 6).

Sclerotinia rot is relatively minor in cucurbits, so control measures are not limited. Good canopy management is key: maintain proper spacing for airflow and sunlight, avoid excess nitrogen, and manage weeds. Crop rotation is often impractical due to the wide host range, but deep ploughing and careful irrigation help. Avoid overwatering, plant rows to maximise airflow, and orient rows with prevailing winds.

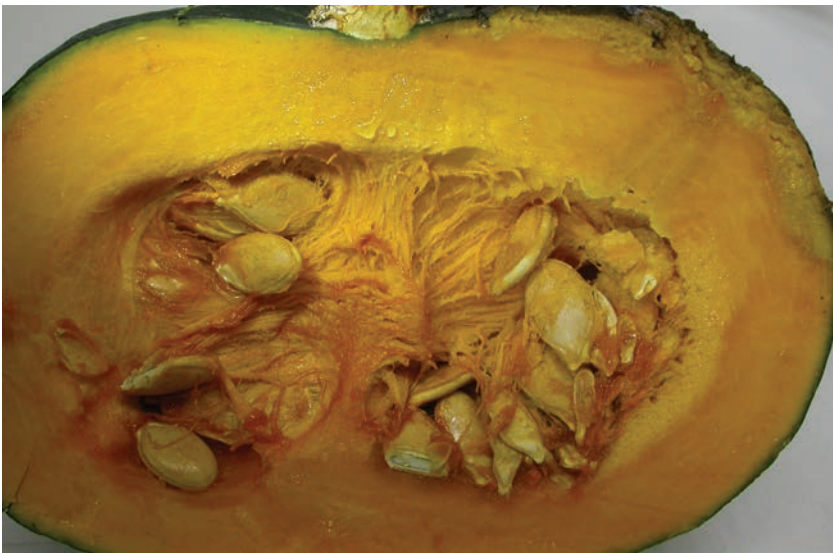


FIGURE 6: SCLEROTINIA FRUIT ROT OF BUTTERCUP SQUASH. SOURCE: PETER WOOD/BIOECONOMY SCIENCE INSTITUTE



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Soilborne disease management strategies

Managing soilborne diseases often involves compromise. Every strategy comes with its own balance of benefits, risks, and costs. Some options deliver quick, short-term gains for current crops, while others focus on building resilience over time.

These choices are rarely straightforward. Alongside potential benefits, there may be downsides, such as crop impacts, production delays, or missed opportunities from using land differently. Most strategies also carry added costs, whether through product purchases or extra passes in the paddock.

The most effective approaches will integrate several strategies in order to balance short-term needs with long-term soil health and crop performance. Agroecology is an example of this, balancing crop diversification, soil health and other field management techniques that supports crop resilience to diseases and other stressors.

Agroecological management practices strengthen cropping systems over time, and requires observation, adaptation and integration of scientific and local knowledge. It offers a long-term strategy for healthier soils and more resilient crops.

The Toolkit focuses on the following SBD management strategies:

- Crop rotation
- Service crops
- Biological controls
- Crop nutrition

¹⁵AGRIOS (2024). AGRIO'S PLANT PATHOLOGY, 6TH EDITION.



Service crops are those grown in rotation with cash crops that provide other value to cropping systems, such as improved soil health. It includes cover crops, green manures, biofumigants etc.

For more information go to section 6 (page 22).

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Crop rotation

Crop rotation is the practice of growing different cash crops in succession before returning the same crop to the land. These cash crops may be interspersed with service crops (Section 6).

The purposes of crop rotation include:

- Improving soil health (aggregate stability, organic matter, and soil microflora diversity)
- Enhancing soil fertility
- Better weed, pest, and disease management
- Managing income and environmental risk
- Supporting workflow planning.

Crop rotation is one of the most important methods for managing soilborne disease. If the host plant is absent for the required period, pathogen inoculum levels decline. Rotation works best when the pathogen has a narrow host range and depends on living plants for survival. Where pathogens infect weeds, survive on plant debris, or form long-lived survival structures, rotation is less effective or impractical. Even then, it can still reduce pathogen populations and lower disease incidence and severity.

Practical considerations include profitability, planting logistics, and harvest management. Designing a rotation should factor in service crops and requires detailed knowledge of the issues being addressed

and the crops that can mitigate them individually and collectively. For soilborne pathogens, precise understanding of the pathogen’s lifecycle, survival structures, and persistence in soil is essential.

In Gisborne and Hawke’s Bay, intensive cropping limits rotation options. Low returns and lack of markets or processing facilities often restrict choices, leading to rotations dominated by maize and squash, with some sweetcorn, onions, peas, tomatoes, brassicas, and leafy greens. Poor rotation contributes to a build-up of host-specific pathogens and can degrade soil structure, organic matter, and porosity.

Further reading:

Rotations and their Impact on Soil Health. Dr Charles N Merfield, The BHU Future Farming Centre, September 2019.

A long-term vegetable crop rotation study to determine effects on soil microbial communities and diseases of potato and onion. Peter J. Wright, Richard E. Falloon & Duncan Hedderley. 2016

Disease management in Buttercup squash; Rees H.J. et al 2025

Current crop rotation risks & opportunities

Crops most often rotated with squash include ryegrass and maize. Other crops sometimes included in a rotation with buttercup squash are listed in Tables 1 and 2. These tables also show which crops currently used in rotation are susceptible to, or host, the main soilborne pathogens of buttercup squash.

Susceptibility to disease increases when conditions favour it. This may include warm and wet conditions, warm and dry conditions, or other situations. Specific knowledge of the crop type and pathogen is required.

TABLE 1: Current crops used in rotations with buttercup squash that are susceptible to, or host, the main (non-Fusarium) pathogens of buttercup squash crops (✖), are moderately susceptible and present moderate risk to squash (⚠) or are not susceptible to the pathogen (✓).

Pathogen	<i>Plectosphaerella cucumerina</i>	<i>Diaporthe sclerotioides</i>	<i>Pythium species</i>	<i>Macrophomina phaseolina</i>	<i>Thielaviopsis basicola</i>	<i>Stagonosporopsis cucurbitacearum</i>
Common name	Root or crown rot	Black root rot	Damping off	Charcoal rot	Black root rot	Gummy stem blight & black rot
Maize	✓	✓	⚠	✖	✓	✓
Ryegrass	✓	✓	⚠	✖	✓	✓
Sweetcorn	✓	✓	⚠	✖	✓	✓
Barley	⚠	✓	⚠	✓	✓	✓
Onion	✓	✓	✖	✓	✓	✓
Pea	✓	✓	✖	✓	✖	✓
Tomato	✖	✓	✖	✖	✖	✓
Lettuce	⚠	✓	✖	✓	⚠	✓
Broccoli	⚠	✓	⚠	✓	✓	✓
Cabbage	⚠	✓	⚠	⚠	✓	✓

Pythium species are often found as complexes of species²⁶. These species tend to produce overlapping symptoms on crops, and studies suggest it is best to consider them as a complex rather than individual species²⁸. There are few options among the currently used crops that can break the disease cycle if *Pythium* is present in the soil.

Many *Fusarium* species infect crops, and some are quite specific to a crop. The susceptibilities of current crops to key *Fusarium* species are highlighted in Table 2, which shows the value in understanding which species are present in the soil. Where the specific species of *Fusarium* is not known, it is best to assume a complex of *Fusarium* species and that a crop is likely to be affected.

Fusarium oxysporum is further categorised into *formae speciales*, which are host-specific variants. Several of these are highly specific to cucurbits, so outside this family other crops are unlikely to be affected. Other *formae speciales* may target different crop families or have broader host ranges.

Soilborne pathogens are often found as complexes of different species. Since many crops currently used in rotation are susceptible to most or some of the key pathogens (Tables 1 and 2), it is important to rotate crops and introduce different species into the system to help break the disease cycle.

TABLE 2: Current crops used in rotations with buttercup squash that are susceptible to, or host, the main *Fusarium spp.* pathogens of buttercup squash crops (✖), are moderately susceptible and present moderate risk to squash (⚠) or are not susceptible to the pathogen (✓).

Pathogen	<i>Fusarium oxysporum</i>	<i>Fusarium avenaceum</i>	<i>Fusarium solani</i>	<i>Fusarium graminearum</i>
Maize	✖	⚠	⚠	⚠
Ryegrass	⚠	⚠	✓	⚠
Sweetcorn	✖	⚠	⚠	⚠
Barley	✖	✖	✖	⚠
Onion	✖	⚠	⚠	✓
Pea	✖	✖	⚠	✓
Tomato	✖	✖	⚠	⚠
Lettuce	✖	✓	✓	✓
Broccoli	✖	✓	✓	✓
Cabbage	✖	✓	✓	✓

²⁶BICKEL, J.T., & KOEHLER, A.M. (2021). REVIEW OF PYTHIUM SPECIES CAUSING DAMPING-OFF IN CORN.

²⁸CALLAGHAN, S.E. ET AL. (2022). DIVERSITY AND PATHOGENICITY OF PYTHIUM SPECIES ASSOCIATED WITH REDUCED YIELDS OF PROCESSING TOMATOES (SOLANUM LYCOPERSICUM) IN VICTORIA,

Suggested rotation lengths for squash pathogens

Creating a break in the build-up of disease by using a non-host or non-susceptible crop in the rotation is a very important part of managing crop diseases. This helps minimise the increase in the population of pathogens in the field.

The rotation lengths before squash or other cucurbits are grown again in the field is suggested to be approximately 4 years or more as a general rule however durations vary between pathogens and conditions (Table 3).



TABLE 3: Suggested rotation lengths for the different crop pathogens.

Pathogen	Survival mechanism	Recommended rotation length
<i>Plectosphaerella cucumerina</i> ¹⁶	Soil & plant debris	Minimum of 3 years with non-cucurbit crops.
<i>Diaporthe sclerotioides</i> ¹⁷	Sclerotia	Long-term rotation required, at least 4+ years. Lack of research for confirmation.
<i>Fusarium oxysporum</i> ^{18, 19}	Chlamydo-spores	4–7 years. Capable of causing disease in many crops currently grown. Difficult to manage through rotation alone.
<i>Fusarium graminearum</i> ^{20, 21}		3–4 years. Avoid cereal, grains and grasses in the rotation. Include dicotyledonous crops.
<i>Fusarium avenaceum</i> ^{22, 23}		2–3 years. Avoid cereal crops in the rotation. Weed species common in cereal crops can also act as hosts, particularly grasses.
<i>Fusarium solani</i> ^{24, 25}		4–7 years. Capable of causing disease in many crops currently grown. Difficult to manage through rotation alone.
<i>Pythium species</i> ^{26, 27, 28, 29}	Oospores	Pythium has a broad host range. As well as rotation, soil drainage should be improved.
<i>Macrophomina phaseolina</i> ^{30, 31, 32}	Sclerotia	3 years. Has a wider range of hosts, where possible select poor host crops.
<i>Thielaviopsis basicola</i> ³³	Resistant spores	Possibly 5 years, but further research is required.
<i>Stagonosporopsis cucurbitacearum</i> ³⁴	Plant debris & seed	2–4 years. Use non-cucurbit crops in the rotation.

¹⁶ENGLAND G.K. ET AL. (2007). PLECTOSPORIUM BLIGHT OF CUCURBITS.

¹⁷SHISHIDO, K. ET AL. (2016). EFFECT OF SOIL INOCULUM DENSITY AND TEMPERATURE ON THE INCIDENCE OF CUCUMBER BLACK ROOT ROT.

¹⁸MARBURGER, D.A. ET AL. (2015). CROP ROTATION AND MANAGEMENT EFFECT ON FUSARIUM SPP. POPULATIONS.

¹⁹DOU, Y. ET AL. (2025). CROP ROTATIONS REDUCE PATHOGENIC FUNGI COMPARED TO CONTINUOUS CROPPING. RHIZOSPHERE 34:101074.

²⁰LEPLAT, J. ET AL. (2013). SURVIVAL OF FUSARIUM GRAMINEARUM, THE CAUSAL AGENT OF FUSARIUM HEAD BLIGHT. A REVIEW.

²¹MARBURGER, D.A. ET AL. (2015). CROP ROTATION AND MANAGEMENT EFFECT ON FUSARIUM SPP. POPULATIONS.

²²KOLLMORGEN, J. F. (1974). THE PATHOGENICITY OF FUSARIUM AVENACEUM TO WHEAT AND LEGUMES AND ITS ASSOCIATION WITH CROP ROTATIONS.

²³TILLMANN, M. ET AL. (2017). CROP ROTATION EFFECTS ON INCIDENCE AND DIVERSITY OF FUSARIUM SPECIES COLONIZING STEM BASES AND GRAINS OF WINTER WHEAT.

²⁴RUPE, J.C. ET AL. (1997). EFFECT OF CROP ROTATION ON SOIL POPULATION DENSITIES OF FUSARIUM SOLANI AND HETERODERA GLYCINES AND ON THE DEVELOPMENT OF SUDDEN DEATH SYNDROME OF SOYBEAN.

²⁵PÉREZ-HERNÁNDEZ, A. ET AL. (2017). SURVIVAL OF FUSARIUM SOLANI F. SP. CUCURBITAE AND FUNGICIDE APPLICATION, SOIL SOLARIZATION, AND BIOSOLARIZATION FOR CONTROL OF CROWN AND FOOT ROT OF ZUCCHINI SQUASH.

²⁶BICKEL, J.T., & KOEHLER, A.M. (2021). REVIEW OF PYTHIUM SPECIES CAUSING DAMPING-OFF IN CORN.

²⁷BOIE, W. ET AL. (2024) AN ASSESSMENT OF THE SPECIES DIVERSITY AND DISEASE POTENTIAL OF PYTHIUM COMMUNITIES IN EUROPE. NATURE COMMUNICATIONS 15(1):8369.

²⁸CALLAGHAN, S.E. ET AL. (2022). DIVERSITY AND PATHOGENICITY OF PYTHIUM SPECIES ASSOCIATED WITH REDUCED YIELDS OF PROCESSING TOMATOES (SOLANUM LYCOPERSICUM) IN VICTORIA.

²⁹TOPOREK, S.M., & KEINATH, A.P. (2021). A DIAGNOSTIC GUIDE FOR PYTHIUM DAMPING-OFF AND ROOT AND STEM ROT OF CUCURBITS.

³⁰ALMEIDA, Á.M. ET AL. (2008). EFFECT OF CROP ROTATION ON SPECIALIZATION AND GENETIC DIVERSITY OF MACROPHOMINA PHASEOLINA. TROPICAL PLANT PATHOLOGY 33:257-264.

³¹MENGISTU, A. ET AL. (2024). COVER CROP AND CROP ROTATION EFFECTS ON TISSUE AND SOIL POPULATION DYNAMICS OF MACROPHOMINA PHASEOLINA AND YIELD UNDER NO-TILL SYSTEM.

³²SINGH, S.K. ET AL. (1990). INFLUENCE OF CROPPING SYSTEMS ON MACROPHOMINA PHASEOLINA POPULATIONS IN SOIL.

³³DELGADO, A. ET AL. (2005). INCIDENCE OF COTTON SEEDLING DISEASES CAUSED BY RHIZOCTONIA SOLANI AND THIELAVIOPSIS BASICOLA IN RELATION TO PREVIOUS CROP, RESIDUE MANAGEMENT AND NUTRIENTS AVAILABILITY IN SOILS IN SW SPAIN.

³⁴GUMMY STREM BLIGHT OF CUCURBITS. VEGETABLE PATHOLOGY FACTSHEETS. NC SATE EXTENSION PUBLICATIONS.



6

Service crops

“Service crop” is a modern umbrella term for beneficial plantings grown between cash crops. It includes several more specific categories³⁵:

- **Cover crop:** A crop grown to cover or protect the soil, the opposite of bare soil or fallow. Secondary benefits may include building soil carbon and improving aggregate stability.
- **Green manure:** Generally, a legume-based crop grown to increase soil nitrogen and improve soil health.
- **Mulch crop:** A bulky crop grown to create a dead mulch on the soil surface from residue, often for weed control. Living mulches may be grown alongside cash crops for similar purposes.
- **Catch crop:** Usually a quick-growing crop that absorbs nutrients in the soil that might otherwise leach away.
- **Biocontrol crop:** Plants grown to boost populations of beneficial invertebrates (e.g. pest predators and parasitoids), often around crop perimeters.
- **Biofumigant crop:** Specific plants that produce biofumigants intended to kill pathogens when mulched and incorporated into the soil.

The purpose of a service crop is to provide benefits to the wider farm system. While a crop may have a primary objective, it often delivers several outcomes, both intended and unintended. Typical benefits sought from service crops are similar to those achieved through good crop rotation planning and include:

- Improved soil aggregate stability and reduced compaction
- Increased soil organic matter and nitrogen levels
- Prevention of soil erosion, nutrient runoff, and leaching
- Weed suppression and improved abundance and activity of soil microbes.

Service crops may not directly earn income for the grower, as they are often terminated before harvest. Their benefits are usually indirect, through improvements to soil health and subsequent cash crops. Some service crops can provide income, such as those grown for livestock grazing or harvested as supplementary feed for sale.

Service crops can be grown at any time of year, but in a squash context they are usually grown from autumn to early spring between squash and other summer crops.

Growers need to weigh up the costs and benefits of service crops, carefully considering management requirements and any unintended consequences³⁶.

³⁵MERFIELD, C. N. (2023). AN INTRODUCTION TO THE PRINCIPLES OF SERVICE (COVER) CROPS AND INTERCROPPING.

³⁶REES H.J. ET AL (2025). SOILBORNE DISEASE MANAGEMENT IN BUTTERCUP SQUASH.

Design of a suitable crop rotation

A crop rotation that seeks to reduce, or at least avoid worsening, disease issues must consider both cash crops and service crops.

1. Identify key soilborne threats. Know what pathogens are in the field, particularly the key pathogens identified in Table 1.

2. Avoid repeated squash (or other cucurbits) in the same paddock. Ideally do not replant in cucurbits for 3-4 years.

3. If a field has *Fusarium* and/or *Thielaviopsis*, integrate oats as a non-host service crop into the rotation.

4. Integrating mustards depends on the pathogen involved. *Brassica juncea* should not be used if the pathogen is *Plectosphaerella* and may not be suitable if *Macrophomina* is present. *Sinapsis alba* has a mitigating effect on *Pythium*, *Fusarium*, *Macrophomina*, and *Thielaviopsis*. Avoid using mustards in paddocks where other brassica species are grown frequently.

TABLE 6: Service crops that may reduce the risk of the main buttercup squash pathogens.

✔ Highly beneficial ✔ Beneficial ◻ No information/neutral ✖ Host to the pathogen

Pathogen	<i>Plectosphaerella cucumerina</i>	<i>Diaporthe sclerotioides</i>	<i>Pythium species</i>	<i>Macrophomina phaseolina</i>	<i>Thielaviopsis basicola</i>	<i>Stagonosporopsis cucurbitacearum</i>	<i>F. oxysporum</i>	<i>F. avenaceum</i>	<i>F. solani</i>	<i>F. graminearum</i>
	Root or crown rot	Black root rot	Damping off	Charcoal rot	Black root rot	Gummy stem blight and black rot	Fusarium wilt	Fusarium crown and root rot		
Oat	◻	◻	✔	✔	◻	◻	◻	✖	✔	✖
Indian mustard	✖	◻	✔	✔	✔	◻	✖	◻	✔	◻
White mustard	✖	◻	✔	✔	✔	◻	✖	◻	✔	◻
Sorghum	◻	◻	✔	✔	◻	◻	◻	✖	✔	✖
Sunn hemp	◻	◻	✔	✔	✖	◻	◻	◻	✖	◻
Hairy vetch	◻	✖	✔	✔	✖	◻	✔	✔	✔	◻
Annual ryegrass	◻	◻	✔	✔	◻	◻	◻	✖	✔	✖
Perennial ryegrass	◻	◻	✔	✔	◻	◻	◻	✖	✔	✖



Effects on soilborne diseases of conventional service crops

Service crops commonly grown with butternut squash include annual and perennial ryegrass, and oats. Perennial ryegrass is often used for longer term grazing, annual ryegrass for winter grazing or a mulch crop, while oats are typically grown as a mulch crop.

The effects of these service crops on key pathogens are shown in Table 5. Not all service crops work against all diseases. In some cases, they may have no effect or even be detrimental if not managed properly.

TABLE 5: Effects of conventional service crops on pathogens affecting squash crops.

PATHOGEN	ANNUAL RYEGRASS	PERENNIAL RYEGRASS	OAT	PRACTICAL CONSIDERATIONS
<i>Plectosphaerella cucumerina</i>	Moderate suppression through resource competition. Root exudates can inhibit pathogen growth. Best when terminated 3–4 weeks before planting of squash.	Moderate suppression through resource competition. Can improve soil microbial diversity.	Effective biofumigant as green manure, lowering pathogen inoculum. Contains avenacins ³⁷ targeting fungal pathogens with moderate inhibition of <i>F. oxysporum</i> and <i>solani</i> . Plant in autumn, terminate in spring (4–6 weeks pre-planting to allow residue breakdown).	Combine winter oats with spring annual ryegrass for improved soil microbiome outcomes. Use roll-crimp termination to maintain surface residue. Surface residue of oats or ryegrass reduces splash dispersal of pathogens.
<i>Diaporthe sclerotioides</i>	Limited direct effect, but not a known host. Root density may help dry soils, reducing pathogen survival. Better in sandy soils than clay soils, include with good drainage management.	Limited direct effect, but not a known host. Use for long rotation break for best suppression. Combine with proper drainage management.	Limited direct effect, but not a known host. Can cause moderate suppression as green manure due to incorporation of beta-glucans that stimulate beneficial microbes. Plant in autumn and incorporate before seed set in spring, as the crop has best carbon ratio for decomposition at that time.	Combine crops with proper drainage management, avoid wet soils. Terminate ryegrass or oats approximately 3–4 weeks before sowing squash.
<i>Fusarium species</i>	Avoid ryegrass if a <i>Fusarium</i> complex. Can be positive if only <i>F. solani</i> is present.	Avoid long-term perennial ryegrass in <i>Fusarium</i> -prone fields.	Oats can have a suppressive effect on <i>Fusarium oxysporum</i> and <i>solani</i> . Use high yielding varieties. Incorporate at flowering stage. Residues contain antifungal compounds. Root exudates can also stimulate the microbiome.	Use oats if fields have a <i>Fusarium</i> history.
<i>Pythium species</i>	Ryegrass may increase <i>Pythium</i> risk in poorly drained soils.	Perennial ryegrass may increase <i>Pythium</i> risk in poorly drained soils.	Oats are susceptible to <i>Pythium</i> under cold wet conditions.	Use only if soil drains well.
<i>Macrophomina phaseolina</i>	Ryegrass is not a host but causes limited direct suppression. If crop results in a drier soil from strong root system, it can reduce risk.	Ryegrass is not a host but causes limited direct suppression. If crop results in a drier soil from strong root system, it can reduce risk.	Oats are not hosts. Can cause strong suppression especially with higher yielding varieties. Oats produce compounds from roots and biomass decomposition that affect sclerotia.	Avoid excessive irrigations. Manage oat crop to avoid stress.
<i>Thielaviopsis basicola</i>	Not a host. Can become a host if the crop is stressed in any way.	Not a host. Can become a host if the crop is stressed in any way.	Not a host. Can provide high suppression as a green manure.	Oats would be preferred in high-pressure fields. Terminate oats at flowering and when soil temperature is above 15°C for best decomposition.
<i>Stagonosporopsis cucurbitacearum</i>	Not a host. May reduce inoculum through lack of susceptible tissue. Reduces splash dispersal. Maintain residue on soil surface.	Not a host. May reduce inoculum through lack of susceptible tissue. Reduces splash dispersal. Maintain residue on soil surface.	Not a host. Can disrupt pathogen lifecycle. Best to incorporate residue into soil for optimum decomposition.	Remove cucurbit debris between seasons. Maintain 2-year rotation away from all cucurbits for best outcomes. Consider strip-till planting into terminated ryegrass residue.

³⁷TÜRK, F.M. ET AL. (2005). AVENACIN A-1 CONTENT OF SOME LOCAL OAT GENOTYPES AND THE IN VITRO EFFECT OF AVENACINS ON SEVERAL SOILBORNE FUNGAL PATHOGENS OF CEREALS.



FIGURE 7: SEEDLING HAIRY VETCH. HAWKE'S BAY DEMONSTRATION TRIAL 23RD MAY 2025. PLANTED 16TH APRIL 2025.



FIGURE 8: HAIRY VETCH (LEFT), RYEGRASS (RIGHT). HAWKE'S BAY DEMONSTRATION 4TH AUGUST 2025.

Potential service crops to mitigate soilborne disease

The literature review conducted as part of *A Lighter Touch (ALT) Butternut Squash Soilborne Disease Management Project* highlighted several species of service crop that have significant potential in mitigating SBD in squash. Their services and management considerations are profiled below.

Hairy vetch (*Vicia villosa*)

PROFILE:

Hairy vetch is a winter-active, hard-seeded annual legume with a sprawling growth habit. It has a thin taproot with strong lateral and secondary roots and can be sown as a pure stand or mixed with oats or ryegrass to improve early ground cover and provide structural support for its climbing vines.

As a service crop, hairy vetch fixes atmospheric nitrogen, with strong nodulation observed over winter and most nitrogen fixation occurring during spring as temperatures rise and dry matter production increases. International studies have shown substantial late-spring dry matter and nitrogen accumulation. Seed may require inoculation with pea-type rhizobia.

The crop improves soil structure and organic matter, enhances water infiltration, and provides vigorous winter and spring cover that suppresses weeds where spring growth is rapid. It can contribute to SBD suppression through several mechanisms.

Its residues can suppress pathogens when incorporated or rolled into moist soil, with demonstrated reductions in *Fusarium oxysporum* in watermelon, powdery mildew in pumpkin, and septoria leaf blight in tomatoes³⁸. These residues release phenolic acids and flavonoids that inhibit fungal spore germination of *F. oxysporum* and *Rhizoctonia solani*. Root exudates can also promote beneficial rhizosphere microorganisms that support pathogen suppression. Currently, little to no research is available on effects in butternut squash systems in New Zealand.

MANAGEMENT:

Seed germinates best between 15-23°C³⁹ but will germinate slowly at temperatures as low as 4°C. Plant from post-harvest in summer through to early April; later sowing results in slower emergence, growth and ground cover. Sow at 15-25mm depth into a medium seedbed. Seed is 3-5mm in diameter, with approximately 35,000 seeds/kg. Typical sowing rates are 15-20kg/ha, establishing around 50 plants/m² in a pure sward. The crop performs poorly in soils where drainage is inadequate and should be avoided on sites prone to waterlogging. Seed supply may be limited and may contain weed seeds, so check quality with the supplier.

Hairy vetch is slower to establish than ryegrass but becomes competitive with weeds once it reaches seven nodes (10-15cm). Slow establishment is more likely in poorly drained soils. In Hawke's Bay, mid-April trial plantings achieved ground cover by late June. It generally does not require fertiliser on land with normal cropping fertility, but will respond to phosphorus, potassium, and sulphur. Mixed swards can be grazed, though grazing beyond seed set

is not recommended as seeds contain anti-nutritional compounds.

There are no selective broadleaf herbicides registered for hairy vetch in New Zealand. Clethodim is suitable for selective grass and cereal control, supported by overseas work. Australian literature notes several pre- and post-emergence broadleaf options, including bentazone and variety-specific registrations of flumetsulam, though these are not currently registered in New Zealand. Hairy vetch can also become a weed itself if allowed to set seed.

Terminate hairy vetch before seed set to avoid volunteer weeds⁴⁰. Terminate using any one or more of these options, glyphosate, glufosinate, cultivation, mowing to near ground level, or roller-crimping once flowering begins. Residue decomposes rapidly due to a low carbon:nitrogen ratio (8:1 to 15:1). For *Fusarium* suppression, incorporation after desiccation or mowing is recommended rather than leaving residue as a surface mulch. Where *Pythium* issues have occurred, allow several weeks between incorporation and planting the next crop.

Hairy vetch and other service crops can create volunteer weed problems. Ideally, they should be terminated or mowed at early flowering to prevent seed set.

³⁸SOILBORNE DISEASE MANAGEMENT IN BUTTERNUT SQUASH; REES H.J. ET AL 2025.

³⁹HAIRY VETCH PLANT GUIDE; USDA NATURAL RESOURCES CONSERVATION SERVICE, MAY 2023.

⁴⁰MANAGING WEEDS IN VETCH ROTATION CROPS; GRAHAM CHARLES, NSW DEPT PRIMARY INDUSTRIES APRIL 2006.

Mustards

(*Brassica juncea* and *Sinapis alba*)

PROFILE:

Mustards used as service crops include Indian mustard (*Brassica juncea*) and white mustard (*Sinapis alba*). Both are winter active annual brassicas with an erect, branching growth habit. They produce substantial aboveground biomass while having relatively modest root systems for their size. Their rapid cool season growth makes them suitable for green manure use and biofumigation.

Mustard establishes quickly and closes canopy rapidly, providing effective weed suppression. When residues are incorporated into the soil, they contribute organic matter and can improve soil structure and nutrient cycling.

A key service crop function of mustards is their biofumigation potential. When the crop is finely chopped and incorporated into moist soil, glucosinolates within the tissue hydrolyse to isothiocyanates, which can suppress soilborne pests and pathogens such as nematodes, *Pythium spp.* and *Fusarium spp.* White mustard generally produces higher concentrations of isothiocyanates, but both species can be effective. Maximum biofumigant activity occurs at flowering: early flowering for *S. alba* and mid flowering to around 50–75% bloom for *B. juncea*. Effective fumigation relies on good crop health, adequate biomass, and soil moisture above approximately 60% field capacity at incorporation.

MANAGEMENT:

Seeding rates depend on purpose. Species specific stands of *B. juncea* or *S. alba* intended for biofumigation are typically sown at 2–3 kg/ha from autumn to spring. General green manure mustard crops, where rapid biomass and canopy development are the main objectives, are commonly sown at 8–10 kg/ha.



Mustard germinates best at soil temperatures of 13–18°C and will germinate more slowly at temperatures down to 4°C. Emergence normally occurs within a week, and growth accelerates rapidly at 15–25°C. The crop can be sown by direct drilling or into a fine seedbed at a depth of 10–15 mm. Mustard is well suited to late April or May sowings for overwintering ahead of strong spring growth.

Fertility requirements are modest. Mustard generally does not require fertiliser on land with typical cropping fertility, although nitrogen may be applied where additional biomass is desired. Sulphur can be used to increase glucosinolate concentrations and enhance biofumigation effectiveness. Growth is moderate initially but becomes rapid once plants exceed about 8 cm in height. Late-autumn sowings often reach only 20–40 cm by late winter, followed by rapid spring growth. Mustard does not tolerate prolonged wet conditions and performs poorly on heavy or poorly drained soils.

Weed control is seldom required because mustard establishes quickly and is a strong competitor. Clethodim can be used for selective control of grasses and cereal volunteers if needed.

Termination should be carried out before seed set to avoid volunteer problems. The crop can be terminated using glyphosate or glufosinate, cultivation, or mowing or roller-crimping once flowering has begun. Early terminated crops decompose quickly because of their low carbon:nitrogen ratio (around 14:1). Mulching or incorporation should not occur when soils are wet, so sowing and termination timing must be planned carefully.

Biofumigation requires a specific termination approach. Crops should be chopped at flowering when glucosinolate concentrations are highest. Soil moisture must be adequate; incorporation should not proceed in dry soil. The crop should be finely mulched to rupture plant cells and immediately incorporated, as most fumigant release occurs within the first 20 minutes after chopping. Residues should be incorporated into the top 20 cm of soil using discs or a rotary hoe, followed by rolling to retain volatiles. Ploughing is not recommended. The field should remain undisturbed for 14 days after incorporation to allow residues to break down fully and avoid injury to the following crop.

Mustard varieties that are not specifically bred with biofumigant properties are unlikely to contain high enough glucosinolate levels to offer disease suppression in this manner. Other soil improvements can still be achieved with non-biofumigant mustards.

Further reading:

If using *Brassica juncea* in a rotation

Lazzeri, L., & Manici, L. M. (2001). Allelopathic effect of glucosinolate-containing plant green manure on *Pythium sp.* and total fungal population in soil.

Ashiq, S., Edwards, S., Watson, A., Blundell, E., & Back, M. (2022). Antifungal effect of brassica tissues on the mycotoxigenic cereal pathogen *Fusarium graminearum*.

Ashiq, S., Edwards, S., Watson, A., Blundell, E., & Back, M. (2022). Antifungal effect of brassica tissues on the mycotoxigenic cereal pathogen *Fusarium graminearum*.

If using *Sinapis alba*

Mattner, S. W., Porter, I. J., Gounder, R. K., Shanks, A. L., Wren, D. J., & Allen, D. (2008). Factors that impact on the ability of biofumigants to suppress fungal pathogens and weeds of strawberry.

Brown, P. D., Morra, M. J., McCaffrey, J. P., Auld, D. L., & Williams III, L. (1991). Allelochemicals produced during glucosinolate degradation in soil.

Rahman, M., Khatun, A., Liu, L., & Barkla, B. J. (2018). Brassicaceae mustards: Traditional and agronomic uses in Australia and New Zealand.

Sekaran U, Karuppanan K, Raja V, Chellappa J, Qin R., and Felix J. 2024. Bio fumigation cover crops: Enhancing soil health and combating pests.



Sunn hemp (*Crotalaria juncea*)

PROFILE:

Sunn hemp (*Crotalaria juncea*) is a warm season annual legume grown as a service crop for its rapid biomass production, nitrogen fixation, and ability to improve soil condition. It performs best from spring through to autumn under frost-free conditions and establishes quickly, developing a strong, deep root system that contributes to improved soil structure, enhanced water infiltration, and increased soil organic matter following incorporation.

As a legume, sunn hemp fixes atmospheric nitrogen, which becomes available to the following crop once residues have broken down. Its vigorous growth and dense canopy provide effective ground cover and weed suppression during the growing period, achieving useful biomass within a relatively short timeframe. Sunn hemp residues also contain pyrrolizidine alkaloids; compounds associated with suppression of certain soilborne pathogens. Incorporating the crop before planting the next rotation can help reduce pathogen populations in the soil.

MANAGEMENT:

Sunn hemp is usually sown from spring to autumn, provided conditions are frost-free. It establishes reliably at a sowing rate of approximately 2.5 kg/ha. The crop is fast growing, with typical growth durations of 45–60 days before termination, making it suitable for short rotation windows or as a warm season soil-conditioning crop.

For best results, sunn hemp should be incorporated into the soil before it begins to set seed. Terminating the crop at this stage maximises both biomass return and disease suppression potential and helps avoid volunteer plants in subsequent crops. Incorporation also enables the breakdown of pyrrolizidine alkaloids, which contribute to pathogen suppression in the soil.

As with some other service crops, seed availability can be limited in New Zealand, so sourcing seed may require forward planning. Sunn hemp performs best in warm conditions; it is not tolerant of frost, and sowing should be avoided in periods where cold snaps are likely. It is generally a low input crop, though standard seedbed preparation and good soil moisture at planting support even establishment.

Further reading:

Paudel, R. *et al.* Subbing Sunn Hemp with Sorghum in Fusarium Soils. Cooperative Extension.

Olczyk, T. *et al.* (2005). Using cover crops to improve vegetable production in South Florida.

As warm season crops, sunn hemp and marigold may not fit with conventional service crop timings in a squash crop rotation.

Marigold (*Tagetes spp.*)

PROFILE:

Marigolds (*Tagetes spp.*) can be used as a service crop for their ability to suppress pests and improve soil condition⁴¹. When grown and incorporated as green manure, marigolds release alpha thiophene, a compound known to inhibit nematodes. They have also been shown to reduce certain soilborne diseases, including clubroot in Chinese cabbage, although the mechanisms are not well understood and there is no research specific to buttercup squash.

Root exudates from marigolds can stimulate soil microbial activity and contribute to improvements in soil structure and organic matter. Marigolds may also be used as an intercrop with commercial crops, where they may offer some protection against nematodes and soil diseases.

MANAGEMENT:

When used as a service crop, marigolds should be sown densely at 15–20 kg/ha, ideally about two months before the subsequent crop. Incorporation into the soil as a green manure should occur one to two weeks before sowing the main crop. Incorporation is best timed at mid flowering (around 50–75% bloom) to avoid seed set and reduce the risk of volunteers in following crops.

Where used as an intercrop, marigolds are established within the commercial crop to provide some ongoing suppression of soil diseases and nematodes⁴². Ensuring adequate plant density remains important for effectiveness.

⁴¹HUANG, F. ET AL. (2022). EFFECT OF MARIGOLD (*TAGETES ERECTA* L.) ON SOIL MICROBIAL COMMUNITIES IN CONTINUOUSLY CROPPED TOBACCO FIELDS.

⁴²LI, Y. ET AL. (2020). INTERCROPPING WITH MARIGOLD PROMOTES SOIL HEALTH AND MICROBIAL STRUCTURE TO ASSIST IN MITIGATING TOBACCO BACTERIAL WILT.





TABLE 7: Categories used for "biological", modified from Pringle, unpublished.

BIOLOGICALS					
	Biopesticides (biofungicides)	Biostimulants			
Target	Fungal, bacterial & oomycete pathogens	Abiotic stress (temperature, moisture, phytotoxicity)	Nutrient use efficiency (biotic, abiotic)	Soil health (microbial physical)	Root establishment, growth
Microbial	Bacteria, fungi, oomycetes, bacteriophages	Arbuscular mycorrhizal fungi, rhizobacteria, endophytes			
Non-microbial	Plant/animal extracts, metabolites, RNAi, peptides	Plant/seaweed/animal extracts, metabolites, amino acids/peptides, nucleic acids, vitamins			

Perceived advantages of biologicals include their safety for operators, lower residues on food, and reduced impact on the environment. They are generally less harmful to beneficial insects, making them highly compatible with Integrated Pest Management (IPM) programmes. Biologicals often have complex modes of action that target pests in multiple ways, which means the risk of resistance developing is very low. Many microbial products can also proliferate in soil, giving longer-lasting effects, although in some cases this may disrupt soil microbiomes.

There are also drawbacks. Biologicals typically provide limited efficacy and can be inconsistent in their results. However, because there are currently few synthetic options available for managing soilborne disease in buttercup squash, this inconsistency is less of a constraint than it might be in other crops. Biologicals are usually more expensive on a per hectare basis, as their production systems are

often more complex and less scalable than synthetic pesticides. Additional considerations include compatibility with tank-mix partners, along with specific shelf life or storage requirements.

Biopesticides are generally short-lived when exposed to high temperatures or ultraviolet radiation, and they can be washed off plants during irrigation or rainfall. These issues are largely mitigated when products are incorporated into the soil. This makes biologicals one of the more promising tools for soilborne disease management, particularly given the limited alternatives available.

Most registered biopesticides in New Zealand can be used in squash production, as they are typically exempt from MRLs or have short pre-harvest intervals. However, it remains essential to confirm that products are approved for all relevant export markets before use.

7

Biological control strategies

Introduction to biological control techniques and products

Biologicals present an opportunity for managing soilborne disease in squash because existing chemicals are limited. Biologicals can complement current cultural practices by supporting an agroecological approach that focuses on soil health, crop resilience and long-term sustainability. While they are not a stand-alone solution, they may also form part of an integrated approach where multiple tools are combined to improve the overall robustness of the squash production system.

Terminology for biological plant protection products can be confusing, but they can generally be grouped into two broad categories: **biopesticides** and **biostimulants**. Biopesticides aim to directly target pathogens or competitively exclude them from infecting plants. Biostimulants focus on producing healthy, resilient crops with improved nutrient uptake efficiency and better stress tolerance.

To help classify and understand these products more clearly, they can also be grouped by their target pest or growth-limiting factor, or by the origin of the active ingredient. One important distinction is that biopesticides are typically registered products, meaning their pesticidal claims have been assessed under New Zealand's Agricultural Compounds and Veterinary Medicines (ACVM) regulations.

TABLE 8: New Zealand registered and/or commercial products that may be suitable as part of a programme to manage soilborne disease in squash. Inclusion of products in this list does not indicate testing on buttercup squash or endorsement for this purpose. Growers should seek advice before use.

Category	Example Product	Active ingredient	Claimed effect
Microbial	Actinovate	<i>Streptomyces lydicus</i>	Antagonistic to pathogens through antibiotic production
	Serenade Opti	<i>Bacillus subtilis</i> (QST 713)	Directly attacks SBD pathogens. Induces plant to protect itself and improves nutrient access.
	Terracin	<i>Bacillus amyloliquefaciens</i> (BS1b)	Colonises root zone (competitive exclusion)
	PP9	<i>Pseudomonas putida</i>	Improved root development, induced systemic resistance to improve immunity
	Tenet	<i>Trichoderma atroviride</i> (strain Iu132)	Colonises root zone (competitive exclusion)
	Connectis	<i>Rhizophagus irregularis</i> DAOM 197198 strain	Increases plant rhizosphere, solubilises bound minerals
Non-microbial	Trichomax	<i>Trichoderma harzianum</i>	Increases nutrient and water uptake through plant roots. Increases biomass and microbiological activity in soil.
	LignoHumate	Humic/Fulvic Acids	Stimulation of biological activity in soil, improved soil structure and root growth stimulation.
	Megafol	Peptides, vitamins, amino acids	Activation of genes responsible for anti-stress response in plants
	NZBioAmino	Amino acids	Support soil microbial activity and improve plant resilience to stress
	NZBioActive	Seaweed derivatives	Promotes growth, improves nutrient uptake and stress tolerance
	Actisil	Orthosilic acid & Calcium	Osmotic stress relief, improved cell wall structure
	ARMOUR-Zen	chitosan	Inhibitory to <i>Botrytis</i> and <i>Sclerotinia</i> sp.

Candidates for biological SBD mitigation in squash

Many species or compounds have been identified (Table 8) as having a mitigating effect on soilborne disease development, including *Fusarium* spp. Their effects may arise through direct action on pathogens,

through competition for space or access to crop roots that prevents infection, or through indirect benefits to plant health. These indirect effects include improved nutrient uptake and reduced impact of stresses that can make plants more susceptible to disease.

Integration of biologicals into a buttercup squash programme

There are numerous opportunities within a typical squash production system where biologicals can be incorporated. Soilborne diseases are most effectively managed with treatments that act below ground, although products that influence above-ground plant health may also have indirect effects on soil and root interactions. Many of the application methods suitable for biologicals are already used for routine operations, meaning they can often be integrated with only the added cost of the product itself.

Biologicals can be applied as seed treatments, in-furrow applications such as through a Gandy box, or applied to soil before final cultivation passes. They can also be delivered through fertigation or via systemic products that redistribute within the plant to reach the roots. Applying biologicals in these ways helps ensure they reach their target and are protected from unfavourable environmental conditions, which can prolong their effectiveness and, in some cases, support natural proliferation in the soil. Applications to the soil surface after planting may also provide some benefit if rainfall or irrigation washes the product into the soil profile soon after application.

Many biostimulants contain small amounts of plant available nutrients, but their primary role is to improve plant health or growth in ways that exceed their direct nutritional value. Although it can be difficult to pinpoint or quantify their exact effects, there is increasing evidence that biostimulants can be a useful addition to soilborne disease management programmes. As with biopesticides, many microbial biostimulants can be applied directly to the soil, while others are applied to foliage and exert systemic effects. Nutrition also plays a critical role in supporting plant health, and several

nutrients, including calcium and potassium, are known to influence disease outcomes and fruit storability.

To establish microbial inoculum effectively, further applications may be useful, although diminishing returns are likely with each additional treatment. Once the crop canopy is established and access to the soil surface is limited, soil applied products become less effective. At this stage, attention should shift to systemic disease control options and biostimulants that support optimal growth or help mitigate stress, including stress linked to foliar diseases. Fruit loading can place considerable demand on the plant by diverting water, carbohydrates, and nutrients away from roots and foliage towards fruit. This added stress can increase susceptibility to soilborne disease and contribute to early canopy senescence.

Inoculation of beneficial microbes is also possible with applications of compost and manures. If organic inputs such as compost are planned, they should be applied and incorporated well before planting. This reduces the risk of introducing microbes of food safety concern and ensures that nutrient contributions, which are often significant, are properly distributed and reflected in soil tests before cropping. This enables growers to more accurately tailor fertiliser programmes for the upcoming crop.

Soil inoculation with beneficial microbes can be achieved with compost or similar organic amendments. To ensure food safety, apply these 120 days or more before the estimated harvest date of the next squash crop (or any other crop with edible portions of the plant in contact with soil). To account for additional nutrients, a pre-plant soil test is advised.

Example squash programme incorporating biologicals

Most existing operations conducted on a squash crop provide opportunities to incorporate biological products without the need for extra passes. However, in some cases it may be worthwhile to apply products separately, regarding optimal timing or known product compatibility issues. An example of a typical squash crop and its operations is listed below, along with suggestions for biologicals integration.

Burn-down:

Non-selective herbicides are often used for fallow winter management or termination of previous cash/service crops. There is an opportunity to apply (spray) microbes that speed up the residue breakdown of previous plant material, or simply to add or augment favourable microbes.

Pre-cultivation:

Applications pre- or during cultivation will be incorporated into soil, where they have better access to roots, target pathogens, and more favourable environmental conditions exist for survival and/or proliferation.

Planting:

Certain formulations can be incorporated at planting in-furrow or banded using insecticide hoppers, or liquid fertiliser setups. There are also commercially available biological seed treatments available for squash.

Pre-emergence herbicide:

Many biological solutions are compatible with pre-emergence herbicides but check prior to use. Depending on the specific product, incorporation (mechanically or through rain/irrigation) can improve weed control and improve the coverage and longevity of inoculants.

Irrigation:

Fertigation of biological products can be achieved through overhead irrigation or drip-tape.

Pre-row closure cover sprays:

This is generally the last opportunity for overhead soil inoculation and will require timely rain or irrigation to incorporate into soil. If targeting foliage, suitable foliar biostimulants can be applied to mitigate stress or otherwise stimulate healthy growth.

Post-row closure cover sprays:

Access to soil is limited at this stage and mitigations using soil inoculum are unlikely to offer much value for the current crop. Instead, focus on foliar health which is the source of carbohydrates (food) for roots and valuable soil biology.

Product compatibility

Compatibility issues may occur when two products in a tank mix interact physically or chemically. Some combinations may cause foaming or may flocculate, forming clumps that settle out of suspension. For biological products in particular, certain synthetic chemistries may reduce their biological activity. Similarly, some biologically derived products may bind with synthetics and reduce their efficacy. Most suppliers carry out some level of compatibility testing, and this information is often available on their websites, in technical sheets, or by speaking with their representatives. A simple jar test can be a helpful way to check for physical incompatibility. If there are any concerns, it is recommended that products are applied separately, with suitable tank cleaning between applications.

High sprayer pressure may also negatively affect organisms applied as sprays. If you are unsure, check the product label or speak with the supplier.

Unless biological inoculum is protected from unfavourable environmental conditions such as heat or ultraviolet light, it is unlikely to provide residual control. Incorporation into soil or use in protected production systems can buffer organisms from these conditions. If products are applied to the soil surface, they should be incorporated through irrigation or light cultivation as soon as practicable.



8

Crop nutrition

Nutrients are required for crop growth, yield, and fruit quality. Plant diseases can reduce nutrient availability, uptake, distribution, or utilisation within the plant. This section focuses on how nutrition and soil pH influence the expression of soilborne diseases. Nutrient manipulation through fertilisation, or modifying the soil environment to influence nutrient availability, is an important cultural tool for disease management. Cultural practices such as crop rotation, organic amendments, liming to adjust pH, tillage to reduce compaction, and irrigation can all influence disease expression by altering the availability of mineral nutrients.

Both over and under supply of nutrients can increase the susceptibility of squash crops to soilborne pathogens. Soil pH, the form of nutrients applied, timing relative to crop growth stage, and the balance between nutrients in an interdependent system can all influence nutrient uptake and disease susceptibility. Understanding how individual nutrients interact with disease development allows growers to modify plant, pathogen, and environmental factors to improve disease control.

Several laboratory and in field tests are available to support nutrient management for both yield and disease considerations before planting and throughout crop growth.

- **Soil testing before planting:** Used to determine nutrient levels, including those that may become available during the season (for example, the Potentially Mineralisable Nitrogen test).
- **Plant tissue testing:** Confirms plant nutrient status during crop growth and allows comparison with benchmark levels.
- **Quick Nitrate Tests:** Provide an indication of soil nitrogen during the season to guide supplementary applications.

Nutrients and their effect on soilborne disease

Nitrogen drives vegetative growth and supports fruit yield. However, excessive nitrogen can push plants into overly vegetative growth at the expense of fruit production, while insufficient nitrogen weakens plants, accelerates leaf senescence, and increases susceptibility to disease.

Nitrogen supplied as urea or ammonium (including the ammonium nitrogen in DAP) can intensify *Fusarium* wilt symptoms by locally lowering soil pH around the root zone. In contrast, nitrate nitrogen (such as that supplied in Nitrabor) may favour the development of other diseases, including Verticillium wilt, although this pathogen is not commonly isolated from squash in New Zealand⁴³. Nitrate also enhances the uptake of key positively charged nutrients, including calcium (Ca²⁺), magnesium (Mg²⁺), and potassium (K⁺).

Most horticultural starter fertilisers contain a mixture of ammonium and nitrate forms of nitrogen, and applying these in roughly equal proportions is generally recommended. Growers should understand which soilborne pathogen poses the greatest risk in their cropping system and adjust nitrogen sources and rates accordingly.



Phosphorus supports energy transfer within the plant, particularly the movement of energy produced during photosynthesis. It stimulates early root development, promotes strong vegetative growth, and is a key contributor to fruit yield. Deficiency restricts plant growth and fruit production and may cause premature fruit ripening and early leaf senescence.

Phosphorus influences disease expression indirectly. Adequate phosphate supply can enhance plant resistance mechanisms, reducing susceptibility to pathogen infection. It also supports the activity of beneficial microbes in the rhizosphere, helping to strengthen natural disease-suppressive capacity.

Potassium plays an important role in the accumulation of nitrogen compounds, protein synthesis, and the development of cell walls. It also helps maintain cell wall rigidity, which supports overall plant structure and resilience.

An adequate supply of potassium can reduce the incidence of fruit storage rots. Potassium deficiency produces plants with weak stems, short root systems, and thin cell walls, which increases vulnerability to disease. A New Zealand study found that fruit potassium levels explained about 10 percent of the variability in storage rots, with all nutrients combined accounting for 38 percent of the variation.

Potassium sulphate is the preferred source of potassium because it avoids the risk of chloride toxicity that can occur with potassium chloride.

Sulphur is a component of several amino acids in plant proteins and plays an important role in plant energy producing processes. Deficiency typically appears as yellowing in the younger leaves.

⁴³PLANT DIAGNOSTICS LTD, NEW ZEALAND (PERSONAL COMMUNICATION).

Sulphur influences disease expression indirectly by improving overall plant health when applied as a soil fertiliser.

Magnesium is a key component of chlorophyll and is involved in enzyme activation and photosynthesis. It is very mobile within the plant, so deficiency symptoms usually appear first in older leaves. Magnesium deficiency can occur when high rates of potassium are applied, because potassium can displace magnesium from cation exchange sites. A soil magnesium to potassium ratio of approximately 2:1 is generally recommended, although maintaining an adequate supply of available cations in the root zone, including potassium, calcium, magnesium and manganese, is the most important factor.

Magnesium influences disease indirectly because it is essential for many plant processes. Adequate magnesium supply can reduce the severity of *Fusarium* wilt, and it can increase the resistance of plant tissues to degradation by some soft rotting pathogens such as *Rhizoctonia* species. Excessively high magnesium levels, which are not commonly encountered in New Zealand, may interfere with calcium uptake and increase the incidence of some diseases.

Calcium is involved in many fundamental plant processes, including cell elongation, cell division, germination, pollen growth and senescence. One of its most important roles is maintaining membrane permeability and cell integrity. Calcium also promotes the aggregation of soil particles. Uptake occurs passively through growing roots, likely only in the region just behind the root tip, so any factor that inhibits root growth also restricts calcium uptake. Calcium moves almost exclusively in the plant xylem and is not readily redistributed once deposited in a tissue, for example from leaves into developing fruit.

Calcium has a direct influence on several soilborne diseases. High calcium levels in plant tissues are associated with improved resistance to macerating pathogens such as *Fusarium solani*, *Pythium* species, *Rhizoctonia solani* and *Sclerotinia minor*. Calcium-related disorders often arise from poor root growth rather than inadequate soil supply. A New Zealand study showed that fruit calcium levels explained 23 percent of the variability in storage rots, with nutrients overall accounting for 38 percent of the variation. Fruit containing less than 6.5 mg per gram fresh weight calcium were more prone to infection by *Fusarium* root rot.

Applications of calcium nitrate to the soil have been shown to reduce symptoms of *Fusarium oxysporum* and other soilborne diseases. Foliar calcium sprays may provide limited benefit because calcium is not redistributed from leaves into fruit, and fruit are typically shaded beneath the leaf canopy.

Sodium is not an essential nutrient for plant growth. In some temperate plant species, sodium can partially substitute for potassium in maintaining certain physiological processes. However, high sodium levels are reported in the literature to be toxic, as they can impair enzyme activity and reduce water uptake by lowering the water potential around roots. Sodium is not recommended for buttercup squash production in New Zealand.

Sodium can influence soilborne pathogens directly. Very high sodium levels can suppress some pathogens by creating osmotic stress, although the concentrations required are also likely to harm plant growth. Some soil fumigation practices make temporary use of elevated sodium levels to reduce pathogen activity before planting.

Boron is involved in several key plant processes, including protein synthesis, sugar transport and the metabolism of plant hormones. It plays an important role in the formation of cell walls in rapidly growing tissues and supports flowering and fruit set. Boron deficiency can reduce calcium uptake and limit the plant's ability to utilise calcium effectively. Uptake occurs passively through the xylem, and boron is relatively immobile within the plant, so it is not readily moved from older leaves to younger tissues.

Boron influences disease expression both indirectly and directly. Indirect effects occur through improved plant health and stronger tissue development. In some cases, boron can directly inhibit certain pathogens, for example reducing infection by clubroot in brassicas. Foliar applications are effective for correcting boron deficiency.

Chlorine plays a role in photosynthesis, the movement of water and nutrients within the plant, and the regulation of stomatal activity.

Chlorine influences soilborne diseases indirectly by supporting general plant health. It is not commonly deficient in soils and is often supplied as a secondary component in fertilisers, for example muriate of potash.

Copper is an essential component of several plant enzymes and is required for chlorophyll production.

Copper influences soilborne diseases indirectly by supporting overall plant health. When applied as a preventative contact foliar fungicide spray, copper can kill pathogens on the plant surface. However, copper is not effective for managing soilborne pathogens because it must come into direct contact with the target organism in the soil environment.

Iron is essential for chlorophyll synthesis and is required for the activation of several enzymes involved in key metabolic processes, including respiration. Deficiency typically appears as chlorosis in the younger leaves. Iron deficiency can be induced in high pH soils where iron becomes less available and is outcompeted by other cations such as calcium, magnesium and potassium. Toxicity may occur in waterlogged soils where iron becomes overly soluble.

Manganese is involved in photosynthesis and in the metabolism of nitrogen and carbohydrates. Manganese uptake can be reduced in high pH soils, through competition with calcium ions, and in cold, dry soils during spring. It is only somewhat mobile within the plant, so deficiency symptoms, typically chlorosis, often appear first in younger leaves.

Manganese influences disease expression indirectly. Adequate manganese levels help trigger compounds that support the plant's response to, and recovery from, pathogen attack. Sufficient manganese can also stimulate secondary root formation, which aids recovery after root-infecting diseases. Foliar applications are effective for correcting manganese deficiency.

Molybdenum is essential for the formation of proteins from soluble nitrogen compounds. It is a key component of several enzymes involved in nitrogen metabolism, including those required for nitrate reduction.

Molybdenum affects disease expression indirectly by supporting overall plant health and growth. Foliar applications are an effective method for correcting molybdenum deficiency.

Zinc is a component of many plant enzymes and supports the production of plant hormones involved in stem elongation and leaf expansion. Zinc deficiency can inhibit fruit initiation and limit fruit growth.

Zinc affects disease expression indirectly. It plays an important role in plant signalling pathways and contributes to the plant's defence response, including maintaining membrane integrity, which helps resist pathogen attack. Zinc deficiency can be corrected through either soil or foliar applications.

Silicon is not essential for cucurbit crops, but cucumbers, pumpkins, melons and watermelons can take it up and deposit it in leaf tissues. Uptake occurs as monosilicic acid, the soluble form found in soil.

Silicon can help cucurbits tolerate drought, heat and salinity by supporting better water balance and reducing oxidative stress. Responses are most likely where soil silicon levels are low or where crops are under stress.

It does not act as a direct control for soilborne diseases, but improved plant health can reduce the impact of pathogens such as *Pythium*, *Fusarium* and *Phytophthora*. In cucumber, silicon has reduced *Fusarium oxysporum* wilt severity in some studies, although results vary by environment.

Silicon can be supplied through fertilisers or soil amendments such as calcium silicate to increase plant available silicon in the root zone.

While visual symptoms can suggest nutrient deficiencies, they are often difficult to interpret accurately in the field and indicate yield potential has already been impacted. For reliable diagnosis, growers should send plant tissue samples to commercial laboratories for nutrient analysis before symptoms appear.

For further reading on squash nutrient management and the effects of nutrient levels on disease development:

Reid & Morton (2019). Nutrient Management Guide for Vegetable Crops In New Zealand.

Huber & Haneklaus (2007). Managing Nutrition to Control Plant Disease.

Huber & Jones (2012). The Role of Magnesium In Plant Disease.



Soil pH

Soil pH directly affects nutrient availability, the uptake of nutrients by plants, and the activity of soilborne pathogens. Cucurbits generally perform best at a soil pH between 6.4 and 6.8, where nutrient solubility and uptake are optimised. When soil pH drops below 6.0, deficiencies of nutrients such as magnesium and molybdenum can become more common, and manganese toxicity may occur. Alkaline soils, with pH values above 7.0, can also create nutrient-availability issues.

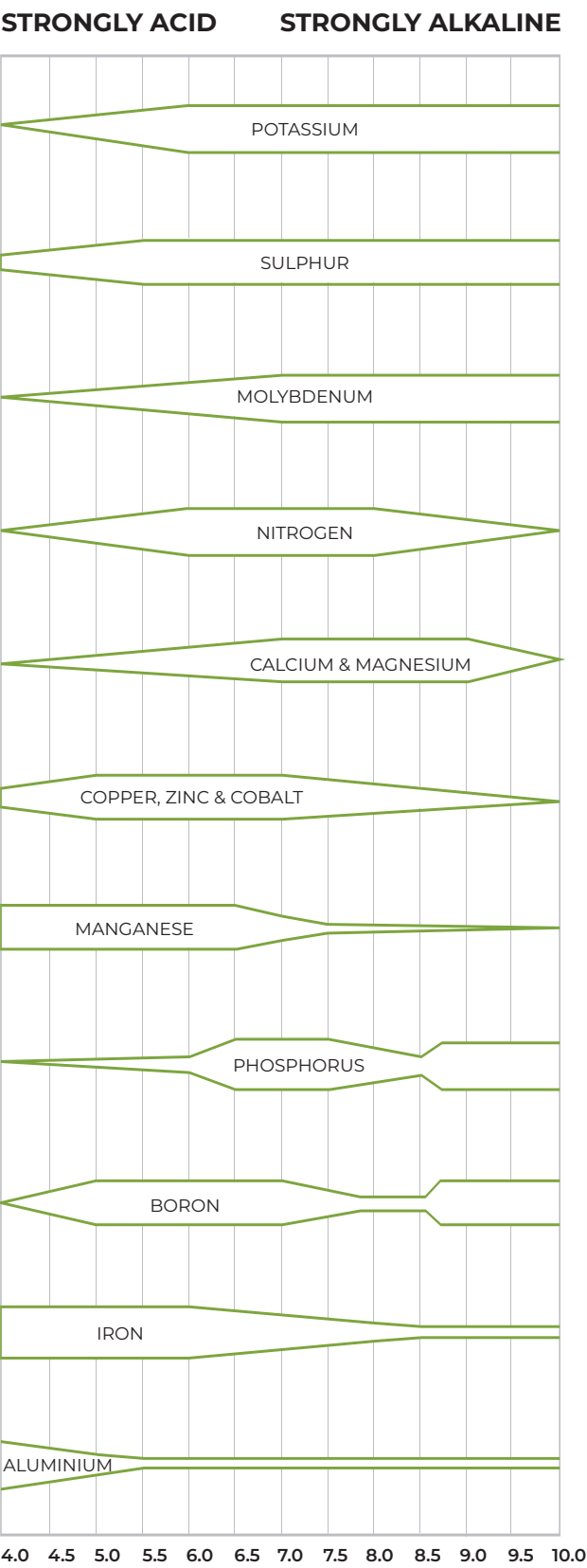
If soil pH is below the target range, it can be corrected by applying lime to raise pH or by supplying additional nutrients in forms that remain available for plant uptake at lower pH levels.

Like nutrient uptake, soilborne pathogens also have preferred pH ranges (Table 10). Conditions outside these preferred ranges tend to reduce pathogen virulence and disease severity rather than eliminate infection entirely. Infection risk in the root zone is influenced by chemical reactions, such as the acidifying effect of ammonium nitrogen.

In general, fungal species tend to be more active at lower pH levels, while bacteria are more prevalent at higher pH. Fungi also tolerate a wider pH range for optimal growth compared with most bacteria.

High soil pH resulting from liming can sometimes limit the availability of micronutrients that pathogens require for growth, sporulation and virulence. This is particularly relevant for diseases such as Fusarium wilt. The effect is due to reduced micronutrient availability rather than increased availability of other nutrients such as calcium or magnesium.

TABLE 9: Effect of pH on the availability of nutrients in soil⁴⁴.



⁴⁴ADAPTED FROM BLAKEMORE, L.C. ET AL. (1987). METHODS FOR CHEMICAL ANALYSIS OF SOILS. NEW ZEALAND

TABLE 10: Common squash pathogens and their optimal pH ranges for disease establishment.

Pathogen	Preferred pH range	Comment
<i>Fusarium spp.</i>	<5.5	
<i>Macrophomina phaseolina</i>	6 - 7	Virulence decreases above or below the preferred range
<i>Stagonosporopsis cucurbitacearum</i>	5 - 6	The alkalising effect of Nitrate N increases fungal growth, Ammonia decreases growth.
<i>Diaporthe sclerotioides</i>	<6.5	
<i>Thielaviopsis basicola</i>	>7	Little or no growth <5.5
<i>Pythium spp.</i>	3.6 - 7.2	
<i>Plectosphaerella cucumerina</i>	7 - 8.5	





9

Cultivation, canopy, and crop residues

Cultivation best practice

Cultivation has a major influence on soilborne disease outcomes. Healthy soil with good porosity, drainage and structure supports rapid and extensive root development, which reduces the likelihood of plants succumbing to soilborne diseases.

Significant long-term damage can occur when soils are cultivated while too wet or too dry. Working soil under these conditions can reduce the surface area available for root growth, limit porosity for air, moisture and soil biology, and increase compaction.



FIGURE 9: THE 'WORM' TEST, A PRACTICAL METHOD FOR DETERMINING SUITABILITY FOR CULTIVATION.

Compacted soils restrict root penetration and reduce drainage, both of which increase the risk of soilborne disease.

When soil moisture is at an optimal level for cultivation, the workable window is short, so timely operations are essential. The worm test (Figure 9) can be used to assess whether soil moisture is suitable for primary cultivation. For seedbed preparation, dropping spade slices of soil from waist height and observing how easily the clod breaks apart provides a further guide for secondary passes⁴⁵.

Correct timing of cultivation reduces the number of passes required and helps preserve soil aggregates and organic matter, both of which are important for maintaining a healthy root zone and reducing soilborne disease pressure.

Vehicles and cultivation equipment can also spread pathogens between crops. Whilst strict sanitation protocols between plantings are difficult to implement, avoiding cultivation in wet soils will reduce the amount of soil that adheres to equipment and is then transferred between paddocks. Additional care is needed when working in blocks with a history of severe soilborne disease; avoid cultivating these areas when soils are wet, and ensure equipment is cleaned before moving to other paddocks.

Crop canopy management

Although the focus is on root health for managing soilborne disease, crop canopies and foliage play a vital role in supplying carbohydrates to the root system and the beneficial microbes that support it. A healthy canopy also protects fruit from issues such as sunburn or bronzing, which can occur when early senescence is triggered by soilborne disease.

A robust powdery mildew (and broader foliar disease) programme is essential for maintaining adequate leaf area. Prioritise preventative applications and be prepared to shorten spray intervals as disease pressure increases.

Healthy canopies also depend on balanced nutrition. Leaf or petiole testing is a practical way to detect nutrient shortfalls early, and many deficiencies can be quickly corrected with foliar nutrition before symptoms appear. Small canopies struggle to support root growth and fruit development,

while overly vigorous canopies increase humidity and reduce sunlight penetration, encouraging diseases such as powdery mildew and *Sclerotinia*. For these reasons, it is important to apply nutrients appropriately and avoid excessive applications, particularly of nitrogen.

Post-harvest crop residue management

Pathogens require a susceptible host to survive. Crop residues left after harvest can therefore maintain, or even increase, pathogen populations in the absence of a growing crop. For this reason, residues should be destroyed promptly and incorporated into the soil so they can break down quickly. Decomposition is fastest where moisture, aeration, temperature and biological activity are favourable, rather than when residues are left on the soil surface or buried too deeply.

Residue breakdown rates vary with species partly because of differing carbon-to-nitrogen ratios. High-carbon residues typically decompose more slowly. Applying organic amendments or microbial inoculants at the time of residue incorporation may supply additional nitrogen or stimulate soil biological activity, helping to speed up decomposition.

Be aware that unmarketable fruit or plants left to mature in the field can increase the risk of volunteer squash plants emerging in subsequent seasons. These volunteers act as primary hosts for soilborne pathogens and can contribute to ongoing disease pressure.

⁴⁵VISUAL SOIL ASSESSMENT: VOLUME 2



A LIGHTER
TOUCH