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FACT SHEET | APRIL 2024

CLUBROOT MANAGAMENT IN BRASSICA VEGETABLES

Causal organism: *Plasmodiophora brassicae*

What is Clubroot?

In favourable conditions such as warm, wet, and acidic soils, Clubroot can be a devastating soil-borne disease affecting both Western brassica vegetables (e.g. cabbages, cauliflower, broccoli, kale, and Brussels sprouts) and Asian brassica vegetables (e.g. bok choy, choy sum, and daikon radish) in Australia.

The pathogen (*Plasmodiophora brassicae*) attacks the roots of vegetables. Once plants are infected there are no effective control measures, however, integrated management strategies can help to prevent infection and spread.

How does it spread?

The soil-dwelling fungus-like pathogen can persist in soil for up to 20 years. It is commonly spread by spores carried by the movement of infested soil particles and water runoff. It can also be spread by infested water from irrigation dams and creeks and infected seedlings. Disease outbreaks usually first occur in the low-lying, waterlogged areas of the paddock or crop rows.

KEY MESSAGES

- Clubroot is a soil-borne disease that causes major damage to brassica crops.
- It can exist in soils for up to 20 years and is spread by spores carried by the movement of infested water and soil, and infected seedlings.
- A combination of warm, wet, and acidic soils provides favourable conditions for development and proliferation.
- Aboveground symptoms include wilting, stunting or pale discolouration as daily temperature increases.
- Below ground symptoms include abnormal swelling of the roots, particularly the tap root. The secondary and finer roots become gnarled and stubby or galled.
- One of the most effective management strategies involves manipulating soil conditions through improved drainage and maintaining a desired pH range of 7.0-7.5[1].
- A proactive integrated management strategy that adopts a combination of crop and soil management practices reduces the disease load in the soil.

Hort Innovation

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Identifying Clubroot

Figure 1: Wilting and yellowing of Clubroot-infected Chinese cabbage (L James).

Above ground

Foliage of big or maturing plants infected with Clubroot may appear normal in the morning but wilt and collapse as the day becomes hotter. This condition is usually associated with lower levels of Clubroot spores or inoculum in the soil and infection typically occurs at least six to eight weeks after transplanting, which is the period that normal early root development occurs unhindered. Plants then become stunted or pale in colour (Figure 1 and 2) and collapse permanently as disease severity increases.

Rapid infection is usually associated with high levels of spores or inoculum in the soil and favourable conditions for the disease. In this situation, severe stunting of young or small plants (three to four weeks after transplanting) occurs. These seedlings typically lack vigour, fail to produce many secondary roots, and usually decay, or produce very small sized crops.

Figure 2: Wilting and yellowing of Clubroot-infected cauliflower.

Below ground

When spore and inoculum levels rise enough to cause significant infection of maturing plants, abnormal swelling of the main root (tap root) occurs, and the secondary and finer roots become

gnarled and stubby or galled with lumps or 'carrots' that dangle from the secondary roots (Figure 3). Severely infected roots eventually decay or rot well before normal harvest, resulting in smaller sized crops and/or delayed harvest.

Figure 3: Extensive galls on the root system, typical of higher soil inoculum levels on broccoli (left) and choy sum (right) (L James).

The severity of infection differs between the species or type of brassica crop and the variety (Figure 4).

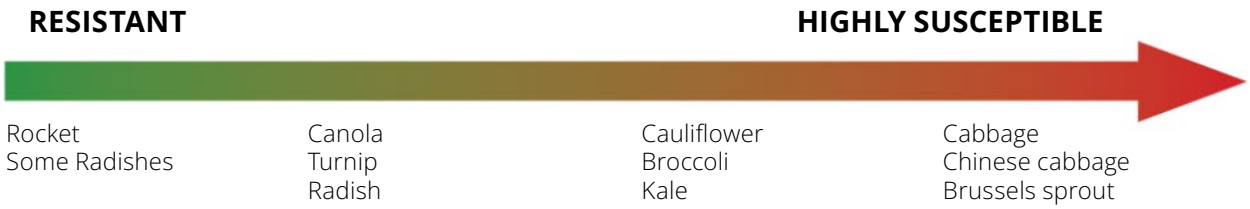

Figure 4: Clubroot susceptibility of various brassica vegetables.

Integrated management strategies

Clubroot management involves an integrated approach, combining several strategies that target the soil and plant at various stages of crop development[2] (Figure 5). It also includes operational strategies such as crop rotations, soil and irrigation management, and on-farm biosecurity hygiene practices to limit the impact of Clubroot. These strategies are explained in more detail below.

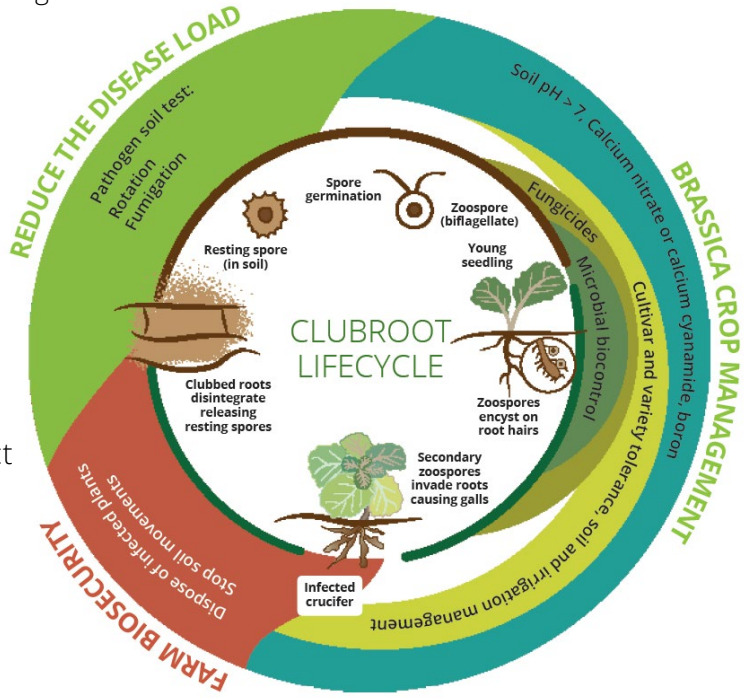

Figure 5: Integrated management options for Clubroot lifecycle stages in brassica vegetables.

Clubroot diagnostics and soil testing

Sending samples to a reputable diagnostic laboratory can help to ensure that the symptoms visible in the crop are caused by the Clubroot pathogen *(Plasmodiophora brassicae)* and not other soil-borne pathogens. Confirming the pathogen that is causing the symptoms in the crop is important as it can help inform management decisions.

Some nutrients, such as boron, have been shown to reduce the development of Clubroot. However, soil moisture levels can affect the uptake of boron and other cations. Work with your local crop advisor or consider taking a sample and sending it to a reputable diagnostic laboratory to determine what is best for the situation.

1. Crop and soil management

Good Clubroot management involves manipulating soil chemistry and physical conditions by incorporating calcium oxide before transplanting, applying boron and calcium fertilisers at transplanting, and having good drainage.

Soil amendments

Lime

- Maintaining a soil pH of between 7.0–7.5 by incorporating lime products is usually the most effective and cheapest way to reduce the impact of Clubroot.
- Amending soil with the more reactive lime products (e.g. quicklime, hot lime or ground burnt agricultural lime) is most efficient.
- The recommended, most effective treatment for Clubroot control in medium- to high-risk soils (wet, warm, and acidic) is to incorporate calcium oxide seven days prior to transplanting.
- The Neutralising Value (NV) of commercial calcium oxide products is usually between 130-150, depending on particle size. The optimum rate required is dependent on soil type. Seek advice from your agronomist on rates suitable for the soil.
  N.B. Quicklime is a hazardous substance. Safety directions must be followed when handling and using this product.
- Incorporate products at least one week prior to planting to avoid crop phytotoxicity[1].
- Other lime products such as hydrated lime and agricultural lime (NV typically 95-98) are also effective at raising the soil pH but need a longer incorporation lead time before planting.
- Quicklime and hydrated lime can also assist to dry-out wet soils.
- Calculated, repeated soil applications of calcium cyanamide (refer to fact sheet on this topic) can be used on moderate- to high-risk Clubroot soils. While it reacts quickly and can increase soil calcium, nitrogen, pH, and beneficial soil microbes, it is a hazardous substance and should be used with caution. Incorporation followed by irrigation 7-10 days prior to transplanting is recommended.
- pH above 7.5 can reduce the availability of several micronutrients including iron, manganese, boron, zinc, and copper, causing deficiencies.

Boron

- Adequate calcium and boron levels can inhibit the infection and development of Clubroot and can be applied to the soil in combination with calcium nitrate fertiliser. Boron enhances root health and calcium movement within the plant.
- Calcium nitrate and boron can be applied

to maintain high calcium and boron levels in the first three weeks after transplanting, to enhance healthy root establishment.

- As boron has a narrow optimum range, conducting a soil test before application is recommended to determine boron levels (and other nutrients). Further application may send it into a toxic range.

Fungicides

- Fungicides will not cure the disease once it is established. However, they can provide a certain level of protection when spore or inoculum pressure is low to medium.
- Fluazinam-based fungicides can be effective in reducing Clubroot infection when applied either as a seedling tray drench[1] or as a soil drench at transplanting[2,4]. Collar drenching of individual transplanted seedlings *in situ* is labour intensive.
- Fluazinam protects the plant root hairs from primary infections by the pathogen's motile spores. This is a critical step in managing the disease as once root hairs are infected, spores multiply and a secondary release into the root zone infects the roots, later causing gall formation and loss of root function (Figure 5).
- Fluazinam is best applied by incorporating it in a band along the crop row. Band treatments can reduce the cost of the product by up to 60%. Product efficiency is improved as it provides a reliable pattern of distribution and reduces soil residues.
- As with all banding treatments in higher inoculum soil, control is usually effective until the roots grow out of the treated, protective band and then become infected. Crops will then display wilting symptoms, especially in the hotter parts of the day.
- Wider band widths are preferable but the economics of applying more fungicide must be considered. Specialised banding machinery that sprays or spreads the product and incorporates it into the soil in the same pass is required.
- Narrower band widths are feasible with quicker growing crops, e.g. radish.

Recycled organic compost

- Recycled organic composts that meet the Australian Organics Recycling Association's Compost for Soils Standard (AS4454) improve soil structure, biology, and drainage. Excellent brassica crop growth has been achieved when banding recycled organic compost in soils with high Clubroot inoculum levels.
- Once the roots grow out of the protected banded area, they become infected, and the plant vigour and crop marketability begin to decline. The cost of broadcast incorporation compared to that of cheaper and effective liming materials needs to be considered.

Brassica choice

- Brassica vegetables vary in susceptibility to Clubroot (Figure 4), and cultivar choice should be carefully considered in high-risk scenarios.
- Clubroot-resistant cultivars should be used as part of an integrated management strategy. However, repeated planting of resistant cultivars may result in a loss of resistance. At this stage, Clubroot-resistant cultivars remain unpopular commercially.

Biological products

- Soil amendments with commercially available microbial products may improve soil conditions and suppress plant pathogens, however there are no conclusive

reports of their effectiveness for Clubroot control under Australian conditions.

Soil and irrigation management

- The key to improved drainage is increased bed height and not over-watering.
- During wet weather events or prolonged periods of rainfall, an operational drainage system and avoidance of compaction in saturated soils are important.
- Test irrigation water quality to ensure clean, uncontaminated irrigation water is used.
- Manage irrigation to avoid over-watering and drying soil, preventing plant moisture stress.
- Conduct soil testing to ensure fertility is optimal for plant uptake and development.
- Take steps to improve soil structure (e.g. increasing soil organic matter by incorporating green manure crops, cover crops or recycled organic compost).

2. Reduce the disease load

Rotations

- Rotations of more than seven years are recommended between brassica crops to reduce resting spores. However, this is usually not practical or feasible on intensive mixed brassica vegetable farms and market gardens, so treatment incorporations are usually required.
- When part of an integrated management strategy, a minimum of two years between brassica crops may be used.
- Avoid brassica cover crops such as Caliente™ (Indian mustard) or Nemat™ (rocket).
- Crop rotation with non-host species. Allium crops in particular can reduce resting spore levels and therefore reduce the risk of disease in the following brassica crop[5].

Clubroot weed hosts

- Control volunteer and brassica weeds such as shepherd's purse (*Capsella bursa-pastoris*), turnip weed (*Rapistrum rugosum*), wild radish (*Raphanus raphanistrum*) and wild turnip (*Brassica rapa*), which host Clubroot during fallow and non-brassica crop phases.

Fumigation

- Fumigation can be helpful when pathogen inoculum load is high. However, consideration should be given to the negative impacts on soil health, variable efficacy across different soil types, cost, and concerns with user safety.
- Fumigants such as dazomet (and metham sodium) can control Clubroot, weed seeds and nematodes effectively[1].

3. Farm biosecurity

Stop soil and plant movement

- Clubroot can only move small distances on its own and is spread mostly within farms by infected soil and water movement. It spreads onto farms via infected seedlings.
- Follow biosecurity hygiene procedures to minimise infected soil and plant movement[6].
- Isolate, quarantine, and contain infected areas, remove all plants from within any infected areas/paddocks, disinfest the contaminated area with dazomet and reduce surface runoff to stop spore movement to other areas of the farm.
- If only a small area is infected, dispose of infected plants. Alternatively, the diseased crop can be sprayed-off with an appropriate herbicide. Do not rotary hoe or disc infected crops back into the soil bed. Do not irrigate quarantined, treated areas.

Biosecurity hygiene practices

- Prepare a Farm Biosecurity Action Plan.
- Good, rigorous biosecurity hygiene practices and programs are essential in preventing the spread of Clubroot and keeping it off farm. E.g. monitor and restrict access to the property, high-pressure wash-down machinery and equipment, minimise the movement of soil from one site to another and insist on the cleanliness of shared equipment.

Evaluating Clubroot Risk

Table 1 highlights management practices and environmental conditions that either decrease or increase risk of Clubroot infection. This should be used as a guide to help reduce the risk of infection to brassica vegetables.

Table 1: Summarised management practices that decrease or increase Clubroot risk.

Decrease Clubroot Risk	Increase Clubroot Risk
Liming soil to maintain pH of 7.0-7.5[1].	Warm (temperatures 17-25°C)[4], wet, acidic soils (pH <6).
Raised crop beds to improve drainage.	Poorly drained wet soils and over-irrigation.
Good, rigorous biosecurity hygiene practices, including minimising infected soil movement.	Lack of biosecurity hygiene practices and movement of infected soil from one site to another.
Regular soil and/or irrigation water testing for the detection and risk of Clubroot, especially during or after wet weather events.	Lack of regular soil and/or irrigation water testing, especially during or after wet weather events.
Using disease-free seedlings.	Choosing a highly susceptible brassica crop e.g. cabbages or Brussels sprouts.
Paddock has not grown a brassica crop in the last seven years or never grown a brassica crop.	Paddock has grown a brassica crop in the past two years.
Fumigating with dazomet or metham sodium[1].	Compacted soils.
Applying fungicide as a seedling drench or applying band treatments (e.g. fluazinam[1]).	Brassica cover crops, including biofumigants.
Early application of a combination calcium oxide (quicklime), calcium nitrate and boron[1].	Fertilisers containing ammonium[2].

Further resources

Table 2: Further learning resources for Clubroot management.

Topic	Resource
Farm biosecurity action plan	AUSVEG DIY Biosecurity, Farm biosecurity action plan for the vegetable and potato industries
Preparing for pest and diseases	AUSVEG Pest and disease preparedness: How to protect your farm
Calcium cyanamide use in vegetables	Soil Wealth ICP fact sheet
Cover crops for Australian vegetable growers	Soil Wealth ICP poster
Cover crop termination guide	Soil Wealth ICP poster
Cover crop herbicide guide	Soil Wealth ICP poster
Recycled organics compost for vegetable growers	AHR and NSW EPA fact sheet

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