Horticulture Australia project number VG 00044
Clubroot – Total Crop Management

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This report presents a summary of work conducted in Australia during the period July 2000 – June 2003 by the national clubroot research team. The project, a national initiative, has sought to address the short, medium and long-term needs of the brassica industry to manage clubroot by developing management strategies that encompass whole production systems – seed to transplant to mature crop. Whilst every attempt has been made to present as complete a summary as possible, some sections (ie. section 5, Transplant production and farm hygiene, section 6, Monitoring, prediction and decision making and section 7, Treatment selection, application and crop growth) have been restricted to key findings and research highlights to ensure the report is maintained at a manageable size. Details of individual experiments or trials can be obtained on request from the author.

1 Media Summary

Clubroot is the most serious disease of the vegetable brassica crops. In Australia it is estimated that the disease is responsible for losses of 5-10% of the national crop, or approximately $10m annually. This project, a national initiative, has sought to address the short, medium and long-term needs of the brassica industry to manage this disease by developing management strategies that encompass whole production systems – seed to transplant to mature crop. This has been achieved through:

1. Development of best practice protocols for the production of disease free seedlings. This information has been published as a shed poster and accompanying series of 7 fact sheets covering the following aspects of seedling production:
   - Identifying likely sources of clubroot contamination in the nursery.
   - Designing the nursery to minimise clubroot risk.
   - Monitoring and restricting access to the nursery.
   - Washing, sterilising and disinfecting.
   - Keeping seeds, water and soil free of contamination.
   - Monitoring for clubroot in the nursery.
   - Knowing what to do if clubroot is detected.
2. Demonstration of integrated management strategies, including the development of rates, methods and timing of application of limes, fertilisers and fungicides, that are effective in all states.
3. Development of a transplant mounted machine to simultaneously plant and incorporate treatments to control clubroot into the planting row. Advantages of this simultaneous treatment and planting system include labour and cost savings resulting from a single pass operation and improved treatment efficacy, a result of more accurate planting into the treated rows.
4. Optimisation of a molecular diagnostic protocol to quantify the amount of *P. brassicae* in soil and evaluation of it's predictive ability at 54 sites nationally.

Recommendations contained within this report will virtually eliminate clubroot as a problem in nurseries and provide Australian growers with the most advanced in-field methods to combat this disease. Large-scale use of the quantitative diagnostic test has identified issues of concern in some soils and commercialisation has been placed on hold until these can be rectified. As this test represents the missing link in the delivery of a complete integrated management strategy, further development and commercialisation is high priority for future research.

VG 00044 Clubroot – Total Crop Management (Final report).

2 Technical Summary

Clubroot is the most serious disease of the vegetable brassica crops including broccoli, cauliflower, cabbage, Brussels sprouts, Chinese cabbage and other Asian vegetable brassicas. In Australia it is estimated that the disease is responsible for losses of 5-10% of the national crop, or approximately $10m annually. This project, a national initiative involving researchers from 5 states of Australia, has sought to address the short, medium and long-term needs of the brassica industry to manage this disease by developing management strategies that encompass whole production systems – seed to transplant to mature crop. This has been achieved through:

1. Development of best practice protocols for the production of disease free seedlings. These have been published as a shed poster and accompanying series of 7 fact sheets for nurseries.
2. Demonstration of integrated management strategies that are effective in all states.
3. Development of a transplant mounted machine to simultaneously plant and apply treatments to control clubroot.
4. Ongoing development and evaluation of a quantitative diagnostic protocol to predict crop loss due to clubroot on farms nationally.

The management of clubroot disease is a responsibility of both the nurseryman and vegetable grower. This project has sought to provide a holistic approach to the control of clubroot developing management techniques that address the concerns of both these industries.

In the nursery

- Plastic trays returned to the nursery from farms were identified as the highest risk for clubroot incursion.
- High pressure washing was found to be an essential pre-treatment for these plastic trays as the use of biocides or steam sterilisation alone did not eliminate *P. brassicae.*
- Of the commercially available disinfectant solutions, only sodium hypochlorite significantly reduced the viability of *P. brassicae.*
- Resting spores remained viable in water for 2 years and caused symptoms of disease at concentrations as low as 10 spores/mL so the use of dam water in nurseries is not recommended. These spores settled if undisturbed, at a rate of 25 cm/day so if water stored in tanks or dams is being used for irrigation on farms it should be sourced from an undisturbed part of the dam, from a pipe mounted on a float to minimise the amount of spores taken into the irrigation system.
- Hot lime (CaO) added to the planting medium was as effective as the available fungicides at preventing symptoms of clubroot for a fraction of the cost. Such additives however, serve mainly to mask an underlying hygiene problem and are unnecessary if steps are taken to prevent spores of *P. brassicae* entering the nursery production system.
- Simple changes to nursery design, operational procedures and implementation of a monitoring program that minimise the clubroot risk in nurseries have been detailed in a shed poster and series of 7 accompanying fact sheets.

On the farm

- Strategies that include the use of lime, fungicides and plant nutrients (Ca and B) to manage clubroot have been proven and demonstrated nationally.
- Application of many of these products has been optimised with the development of a planter mounted machine to incorporate treatments into the transplant root zone whilst planting. Advantages of this simultaneous treatment and planting system include labour and cost savings resulting from a single pass operation and improved treatment efficacy a result of more accurate planting into the treated rows.
- Forty percent of growers in one of Australia's key brassica export regions have now modified existing transplanting machinery to incorporate fertilisers and/or fungicides at planting. These growers report increased profits of $4000/ha in winter grown cauliflower crops.
- A molecular diagnostic protocol to quantify the amount of *P. brassicae* in soil has been optimised and it's predictive ability tested at 54 sites nationally. Where a positive test result has been obtained, the test has accurately predicted crop loss in the field. However, there have been a number of soils for which a negative test result has been obtained but severe root galling has been observed in the field. Considerable research effort has been dedicated to determining the cause of these false negative test outcomes, however, to date these remain undetermined and further work is required before the test can be commercialised. This work should include a study of the influence of the timing and method of sampling on the test outcome as it is possible that factors such as repeated tillage may reintroduce spores to the upper surface of the soil.

3 General Introduction

The Australian horticultural brassica industry grows produce valued at $134 million annually (Australian Horticultural Corporation, 1998). Broccoli, cauliflower and cabbage are the major brassica vegetable crops. Minor crops include Brussels sprouts, Chinese cabbage and other Asian vegetables.

Clubroot is the most serious soilborne disease affecting brassicas world wide. It is caused by *Plasmodiophora brassicae* Woronin, an obligate biotrophic parasite. Currently considered to belong to the Protoctista, it is neither plant, animal nor fungus (Braselton, 1995).

Clubroot was first reported in Australia in 1890. It is likely to have been brought into the country with the early settlers as diseased planting material (Watson and Baker, 1969), although fodder or grazing animals represent an alternative source of contamination. Recent increases in the prevalence of this disease can be associated with the increased use of transplants, narrow rotations, more extensive cropping on the same soil (in some cases, 4 crops per year) and the suspected increased movement of the pathogen on trucks, bulk bins and other farm equipment.

Surveys (Porter *et al*., 1994) have shown that over 70% of brassica properties in Victoria are affected by clubroot. Crop losses of up to 25 hectares/property have been reported and total national crop loss is estimated at between 5 and 10% of brassica production.

Clubroot is endemic in most of the major production regions of Victoria, New South Wales and Tasmania. Outbreaks have occurred in Stanthorpe (Queensland in 1997), Gatton, (Queensland in 2001) and Manjimup (Western Australia in 1993). Clubroot is now a significant problem in every state of Australia.

Symptoms of disease are restricted to members of the family Cruciferae. Infection can occur at any stage of growth and is restricted to the roots. Infected roots swell forming characteristic galls that may either be large and compact or numerous irregular swellings, depending upon the timing and severity of infection. Infected plants are nutritionally impaired as galled roots have a reduced capacity to assimilate water and nutrients from the soil. The earliest above ground symptom of clubroot is wilting of the leaves of infected plants particularly on warm days. Severely infected plants will be stunted and yield significantly reduced.

Previous research (Porter *et al*., 1997) identified a number of new fertiliser, nutrient and fungicide treatments that reduced yield losses due to clubroot in Victoria and Western Australia. Long –term management strategies based on good farm hygiene, crop rotation , liming, application of calcium and a preventative fungicide were subsequently developed (Donald *et al.,* 2000). A novel method of application was also developed. More recently, a diagnostic test to detect the presence or absence of *P. brassicae* has been developed (Faggian *et al*., 1999; Faggian and Parsons, 2002).

The primary aim of the current project was to develop a holistic approach to the management of clubroot that addressed all aspects of production including seedling production, site selection, treatment selection and application. This was achieved by :
- Development of strategies to eliminate clubroot as a problem *in nurseries*.
- Development and demonstration of integrated management strategies that are effective *in all states*.
- Development of a *transplant mounted* machine to simultaneously plant and apply treatments to control clubroot.
- Optimisation and large scale evaluation of a *quantitative version* of a diagnostic protocol to predict crop loss due to clubroot on farms nationally.

3.1.1 Discussion

The results presented in this report serve as a small snapshot of activities undertaken in the field for the duration of the project. During this time two new treatments have been developed, reports from individual states have been tested nationally and large numbers of growers have participated in field displays and demonstrations.

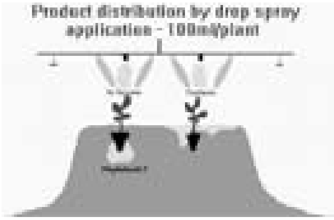
The following generalisations can be made:
- Application of lime as calcium oxide (to increase pH to 7.0-7.5 in responsive soils) is a ‘good value for money’ treatment consistently returning a profit from most field sites nationally.
- Shirlan (fluazinam) applied at 3 L/ha effectively controls clubroot but must be evenly distributed around the transplant root zone at planting. Lower rates (2-3 L/ha) may suffice in the Manjimup district of Western Australia.
- Banded incorporation of Shirlan (3 L/ha) at planting is the most effective method of application of this fungicide.
- Banded incorporation of a very low rate of calcium cyanamide has reduced the cost of treatment from $1600/ha to $112/ha.
- A new fungicide flusulfamide (Nebijin) applied with Du-wett (a wetting agent) has provided good control of clubroot at 0.6 mg/plant in Victoria and Queensland. In these states control has been on par with that provided by Shirlan. The effective rate is twice that recommended by the New Zealand based suppliers (the recommended rate being ineffective). No residues were found in treated produce and negotiations for registration and distribution in Australia are underway. This result was not repeated in Western Australia and the reason for the failure of the product to control clubroot in this state should be further investigated before registration.

3.2 Development of a transplant mounted banding machine

Introduction
A variety of machines have been used at sites around Australia to demonstrate the effectiveness of incorporating treatments into the transplant row.
Band incorporation of products along the transplant row:
- reduces the cost of treatment (Perlka)
- improves product distribution and efficacy (Shirlan)
- minimised the impact of residues from treatments on the environment
- improves availability of fertilisers to young transplants

Commercial banding machines called “precision incorporators” have been produced and used in trial work across Australia (Figure 29).

Figure 29: Precision incorporation machines designed to incorporate products into the transplant rows for improved clubroot control.



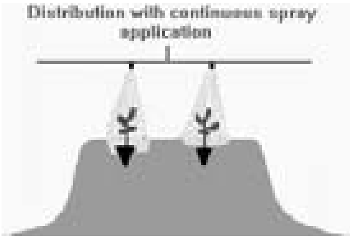
✓ Greater volume of fungicide can be delivered per plant

✓ Transplanting and treatment can be done simultaneously.

X Can be phytotoxic if transplant placed directly on treated area (eg in furrow application.

X Treatment may not reach target area due to surface run off along presswheel tracks.

Treatment effects can be variable, and dependent on equipment and soil type.

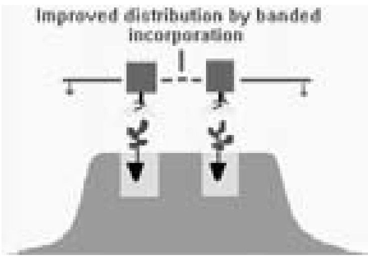


✓ Ease of application.

✓ Can use or adapt existing machinery.

X Poor infiltration and distribution in heavy soils.

Less effective in heavy soils.



✓ Even distribution of fungicide around transplant root zone.

✓ No phytotoxicity or run off.

✓ Suitable for application of liquids and granules.

✓ Treatment and planting can now be done in a single tractor pass (see fig. 32).

Cost effective method suitable for all soil types.

Figure 34: The effect of different methods of application on distribution (and efficacy) of Shirlan.

Reducing soil residues
The efficacy of either lime or Perlka was not significantly changed by band incorporation, compared to broadcast incorporation in Victorian trial work. However, in each case the amount of product used was reduced by approximately two thirds. This has not only reduced the cost of treatment but has reduced the amount of potential carry over into subsequent crops. This is an important consideration for some rotation crops. Potatoes for example, are more susceptible to scab diseases at high soil pH.

Improved availability of fertilisers to young transplants
Incorporation of base fertiliser into the transplant row at transplanting increased the total yield of winter cauliflower by approximately 10 t/ha (Fig. 35) and caused the crop to mature 9 days earlier than the crop treated in the traditional way.

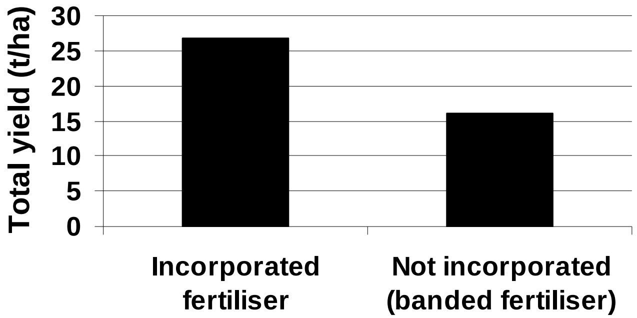


Figure 35: The effect of incorporation of base fertiliser into the transplant row at transplanting compared to the traditional banded method of fertiliser application. Winter cauliflower trials, Manjimup.

A modified transplanter designed to incorporated liquid and/or granular products into the planting row at transplanting was built for the project in 2000 (Fig. 36), however, problems with the Victorian Workcover Authority prevented the use of this machine in field trials and demonstrations in that year. These problems were rectified and the Authority approved the machine for use in subsequent trials and demonstrations.

Figure 36: Transplant mounted machines for simultaneous treatment and planting. Victoria (left) and Western Australia (right).

These machines were used the 2001/02 and 2002/03 seasons trials and demonstrations (see field reports) and were as effective as previous two part units. The advantages of the transplant mounted models for commercial operators are:

- single pass treatment and planting saving fuel, tractor wear and labour
- single pass treatment and planting ensures that plants are always placed in the centre of the treated row. This is particularly important on sloping ground or where formed beds are not used making it difficult for the operator to plant accurately into the treated bands.

Since the release of these results many growers, particularly those in the Manjimup district, have converted existing transplant machines to apply fertiliser in this way (Fig. 37). These growers have been unanimously pleased with their investment in this type of machine and report increased profits of approximately $4000/ha using this method of application. (see brassica IPM video).

Figure 37: Grower designed and built modified planter in use – Manjimup WA.

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