Management of apple replant disease in nurseries

Stevenson O

October 2016
Confidential report for:
The Nursery and Garden Industry Association of New Zealand Incorporated
Ref 12-042

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PUBLICATION DATA


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### Final Report Template

**Project Title:** Management of apple replant disease in nurseries  
**Project Number:** 12-042  
**Date of Report:** 12/10/2016

Note: The Final Report is due to your Project Adviser within two months after the project completion date.

If any material supplied in, or attached to, this report contains confidential information, or is otherwise unsuitable for wider dissemination, please clearly mark accordingly and highlight directly with your Project Adviser (including the reason for wishing to treat the material in this manner).

This information from Sections 2 – 5 and Section 11 will be published on the Ministry for Primary Industries (MPI) website unless you advise us otherwise.

### 1. Milestone Summary Table

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milestone 1 (Completed &amp; paid)</td>
<td>Replant sites (Nelson and Hawke’s Bay) prepared for planting and four treatments/techniques applied as per project design agreed by project team (via teleconference). Rootstocks will include ‘M9’ (most commonly used), ‘MM106’ (most susceptible) and others as used by the industry, no less than four but no more than six. Evidence: Minutes of project team meeting.</td>
<td>1/10/12</td>
</tr>
<tr>
<td>Milestone 2. (Completed &amp; paid)</td>
<td>Industry supplied trees planted (500–1000 trees/site) into the treated plots under protocols confirmed by project team at team meeting prior to planting (telephone conference). Evidence: Minutes of project team meeting.</td>
<td>1/08/13</td>
</tr>
<tr>
<td>Milestone 3. (Completed &amp; paid)</td>
<td>First initial tree growth assessment data collected (trunk diameter, tree height and shoot length) and reported – Nelson and Hawke’s Bay. Evidence: Report signed off by project team and provided to MPI. Based on evidence from above and findings of the extended trial block, the group collective would like to pursue further findings of the Ag lime/Nemacur® treatment with a new planting arrangement.</td>
<td>31/05/14</td>
</tr>
<tr>
<td>Milestone 4. (Deleted)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milestone 11. (Extension)</td>
<td>Prepare replant sites (Nelson and Hawke’s Bay) for planting – applying the four treatments/techniques and lease/use of replant land. Evidence: Minutes of project team meeting.</td>
<td>31/07/14</td>
</tr>
<tr>
<td>Milestone</td>
<td>Description</td>
<td>Date</td>
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<tr>
<td>-----------</td>
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</tr>
<tr>
<td>Milestone 12. (Extension)</td>
<td>Planting of industry supplied trees (500–1000 trees/site) into the treated plots. Evidence: Minutes of project team meeting</td>
<td>30/09/14</td>
</tr>
<tr>
<td>Milestone 6. (Varied)</td>
<td>First tree growth assessment data collected (trunk diameter, tree height and shoot length) Nelson and Hawke’s Bay. Evidence: Data provided and signed off.</td>
<td>31/01/15</td>
</tr>
</tbody>
</table>
| Milestone 9. (Original) | Research update provided via:  
- Annual field day for pipfruit nurseries – Nelson and Hawke’s Bay. Invitations will be issued via Pipfruit NZ and NGIA and, where possible, held in conjunction with existing nursery and grower meetings. Targeted proportion of industry to attend would be 80% participation.  
- Newsletter and/or fact sheet posted via email and/or internet using Pipfruit NZ and NGIA systems. Project team meeting (telephone conference and/or in conjunction with the field day). Evidence: Material associated with field day; newsletter and/or fact sheet; minutes of project team meeting. | 31/03/15 |
| Milestone 5. (Varied) | First phytosanitary (plant health such as wilting, disease, pest infestation) assessment data collected (Nelson and Hawke’s Bay). Evidence: Report signed off by project team | 30/04/15 |
| Milestone 7. (Varied) | Second tree growth assessment data collected (Nelson and Hawke’s Bay). Evidence: Report signed off by project team. | 31/05/15 |
| Milestone 13. (Extension) | Tree growth and phytosanitary data analysed for growth comparisons among treatments and sites. Evidence: Report signed off by project team. | 31/07/15 |
| Milestone 14. (Extension) | Third tree growth assessment data collected (Nelson and Hawke’s Bay). Evidence: Report signed off by project team. | 31/01/16 |
| Milestone 15 (Extension) | Final tree growth assessment data collected and phytosanitary (plant health) assessment data collected (Nelson and Hawke’s Bay). Evidence: Report signed off by project team. | 31/05/16 |
| Milestone 16. (Extension) | Research update provided via:  
- Annual field day for pipfruit nurseries – Nelson and Hawke’s Bay. Invitations will be issued via Pipfruit NZ and NGIA and, where possible, held in conjunction with existing nursery and grower meetings. Targeted proportion of industry to attend would be 80% participation.  
- Newsletter and/or fact sheet posted via email and/or internet using Pipfruit NZ and NGIA systems. Project team meeting (telephone conference and/or in conjunction with the field day). Evidence: Material associated with field day; newsletter and/or fact sheet; minutes of project team meeting. | 20/09/16 |

Milestone Description Date

**Milestone 10. (Varied)** Final report and nursery fact sheet produced, peer reviewed by Pipfruit NZ and distributed:  
- Posted on the Pipfruit NZ and NGIA websites  
- Circulated via Pipfruit NZ and NGIA email lists  
Evidence: Final report and nursery fact sheet 24/10/16

**Milestone 11** Final Report to SFF 2/06/16

### Summary of Key Performance Indicators

(NB: This section only applies to projects from 2010 onwards. Outline progress against the KPIs listed in your original project plan, by using direct measures (e.g. percentages, cumulative totals, etc). If a KPI can only be measured in the longer-term, then please note when and how this could be recorded.)

<table>
<thead>
<tr>
<th>KPI Description</th>
<th>Overall Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A fact sheet will be distributed via the Ndelivering problem/solution information in the final year of project delivery</td>
<td>A fact sheet has been circulated via NGIA.</td>
</tr>
<tr>
<td>2. Nursery industry technique/methodology adoption rates will be 80% of industry by 2016</td>
<td>Nursery industry technique/methodology adoption rates are currently 75% of industry</td>
</tr>
<tr>
<td>3. Rootstock use: If a rootstock effect is evident, then the use of the most resistant rootstock will be preferred by nursery operators and growers.</td>
<td>The most susceptible rootstock ('M9') for apple replant disease was used in trials at both sites.</td>
</tr>
<tr>
<td>4. Fumigation increase/decline: If a treatment effect is evident, nurseries will start implement this on a rotational basis with a resulting reduction in fumigation use</td>
<td>Fumigation use reduction: A treatment effect (Ag lime/Nemacur) has led to commercial uptake for the previous planting season and to a small decline in fumigation use. Three of the four major nurseries have indicated greater use for Ag lime/Nemacur treatment for the upcoming planting season.</td>
</tr>
<tr>
<td>5. Commercial application: If treatment effect is evident, growers will trial the use of Ag lime/Nemacur in orchards</td>
<td>Wider application: One large commercial Nelson-based orchardist has planted over 200 trees using Ag lime/Nemacur treatment.</td>
</tr>
</tbody>
</table>

### 2. Project Objectives

(Why did you do this project? What were your key objectives at the start of the project? Outline if any of these objectives changed during the course of the project.)

This project was developed to address alternatives to commercial fumigation and was designed to provide the pipfruit nursery industry with additional options for soil treatment of apple replant disease.

Apple replant disease causes poor plant growth as a result of trees being replanted on sites where the same (e.g. apple) or a closely related species (e.g. pear) had been grown. The symptoms are not clearly identified but appear to be mostly biotic (e.g. changes in the microbial community). Fumigation has been shown to be the most effective tool in overcoming apple replant disease, but it is expensive (>NZ$10,000/ha), hazardous to health, damaging to the ozone layer and often difficult to integrate into the high-density-planted nursery apple beds.
Key objectives of the project were to implement biological control techniques based on research from around the world. The original SFF project was designed to assess a variety of new biocontrol soil treatment methods as alternatives to fumigation with the industry standard chloropicrin. A new treatment Ag lime/Nemacur was included in the second year trials after a positive result from the initial trials.

3. Approach
(What did you do – how did you go about it?)

A teleconference held with industry and researchers to gain consensus on trial rootstock selection, treatments and methodology.

- Identified two trial sites in a pipfruit nursery affected by apple replant disease (one each in Hawke’s Bay and Nelson).
- Soil treatments started at the beginning of planting season with industry recommended rootstocks and variety.
- Sites were monitored and results recorded during growing season and best treatments to minimise apple replant disease identified.

Rootstocks were grown on ground treated with Ag lime/Nemacur and compared to the industry standard fumigation method and untreated control. The rootstock “shoot extension growth” was measured over the growing season. At the end of the growing season the tree shoot was “headed back” to approximately 25cm from the ground in preparation for “budding” which involved grafting of the desired variety of scion wood onto the rootstock. The next growing season the scion “shoot extension growth” was measured.

4. What were the main findings from this project?

Results showed that the chloropicrin treated plot plants were taller, but the proportion of healthy plants was much the same throughout the randomised trial plots of both sites (relative to each nursery). It is also apparent that plants at the Nelson nursery were less healthy and generally shorter than those at the Hawke’s Bay nursery.

As with the March and previous year’s results, there was no compelling reason to reject the null hypothesis of no difference between the treatments. The advantage seen for fumigation (or plot location) in 2015 has disappeared.

The extended trial blocks taken on by both nurseries (Waimea and Le Cooke’s) which incorporated Ag lime/Nemacur treatment method have appeared anecdotally promising. These planting sites were part of an industry adoption based on confidence gained from year one extended planting site at Waimea Nursery. These sites have evolved in scale and tree numbers over the last three growing seasons and is also now being tested at a Nelson orchardist property.

The general consensus at the last field day was that we have a significant alternative to commercial fumigation. But it requires further investigation and this involves additional biomass preparation to the Ag lime/Nemacur technique.

5. What difference has this project made to your group / community of interest / industry?
(Include intangible benefits where significant — e.g. “enabled us to develop a strong ongoing working relationship with the scientists”).

This project has significantly helped to build relationships within the nursery industry and has sparked renewed interest in field day participation with the latest field day having almost all of the major nursery owners present and interested in pursuing the Ag lime/Nemacur application technique, as well as introducing a biomass (growing cover crop over resting season) treatment. The group agreed to seek further funding to support this additional biomass method.
6. If you did the project again what would you do differently? 
(i.e. what worked and what didn’t?).
Implementation of scientifically robust methodology treating soil in a commercial nursery environment without causing significant financial risks to the owner is very challenging. The industry participation rate and interest was excellent.

7. Is there anything the SFF could have done differently?  
The timing of funding grants does not always lend itself to a plant growing season. In the initial stages we were behind in our trial planning.

8. Is there anything that you have learnt that would be useful for new project teams?  
Interest and participation from the industry should be harnessed and balanced with the design of scientifically robust experiments.

9. Where to from here – what are the next steps?  
The industry representatives were enthusiastic about testing the Ag lime/Nemacur technique on their properties and also using a cover crop over the resting season as an additional recommendation to the Ag lime/Nemacur method of treatment. The group agreed to seek further funding to test the cover crop method. Further research to understand complex host, pathogen and soil microbial interactions, would be beneficial and would need to have input from experts in microbiology, nematology and soil science.

10. Financial summary  
Provide a brief comment as to whether the project was completed on budget; whether there is any grant money left unspent. Please provide a financial statement to summarise the incomings/outgoings over the life of the project – you can either attach a copy of your own financial statement or use the “final financial template” available at our website http://www.mpi.govt.nz/sff/

11. List and attach any major outputs from the project.  
Examples could include:
- Scientific reports
  SFF 2016 Sard report trial
  SFF  2016 may Sard report trial
  SFF 2015 Sard report trial
  SFF 2015girth data report
  SFF 2014 Sard trial
- Fact sheet “Soil disinfestations for apple replant disease”

If appropriate, we would like to publish a copy of the above on our website: please provide an electronic copy for this purpose preferably in Word format.
Report Confirmation

<table>
<thead>
<tr>
<th>Name [Project Manager]</th>
<th>Confirmation</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I hereby confirm the above information is true and correct:</td>
<td></td>
</tr>
</tbody>
</table>

Submission Notes:

1. **Final Reports should be sent electronically** to the MPI SFF Fund Administrator and your Project Adviser (in the same e-mail as the final Request for Payment form and invoice). Also attach electronic versions of any resources developed.
   
   **Please ensure you put your project number in the e-mail’s subject line:**
   
   e.g., 09/999 Final report 2011.

2. **Hardcopies of any project resources** developed should be **posted** to the Fund Administrator and your Project Adviser.
STATISTICAL APPROACH

These data are from the same plants as the 2015 data, but represent the heights and survival after the rootstock growth has been cut and the buds allowed to grow. Thus the analysis approach was the same as previously. That is, proportion of healthy plants and mean height of live and healthy plants were modelled separately for each site by fitting mixed models with treatment as the fixed effect and rep and blk\(^3\) as random effects.

All analyses, including graphics, were undertaken using R 3.2.2 [2] and the mixed models were fitted using the asreml package [1]. The code used in the analysis and preparation of this report is available on github.

RESULTS

March 2016

For interest, scatter-plots comparing the 2015 and March 2106 data were prepared (Figure 1). These showed that the plants were taller, but the proportion of healthy plants had dropped.

As with the previous year’s results, there was no compelling reason to reject the null hypothesis of no difference between the treatments. It is perhaps interesting to note that the plants in the fumigated (and end) plots were only marginally taller than those in the other plots, which contrasts with the 2015 results.

Given the inconsistency between the sites with respect to ranking of the treatments one would not expect a combined analysis to lead to more conclusive results.

May 2016

For interest, scatter-plots comparing the March 2016 and May 2106 data were prepared (Figure 3). These showed that the plants were taller, but the proportion of healthy plants was much the same. It is also apparent that plants at Waimea were less healthy and generally shorter than those at Cooke.

As with the March and previous year’s results, there was no compelling reason to reject the null hypothesis of no difference between the treatments. The advantage seen for fumigation (or plot location) in 2015 has disappeared.

\(^3\)The designs were row-column.
Figure 1: Scatter-plots showing the comparison between the 2015 and March 2016 datasets. The points have been colour-coded for site, and different symbols used for the different treatments. The grey lines are those of equality (i.e., the plants were less healthy but taller in March 2016 compared to 2015).
Figure 2: Best linear unbiased estimates for proportion of healthy plants, mean height (mm) and mean height (mm) of healthy plants at Cooke (left) and Waimea Nurseries (right) for each treatment at each site. The bars represent one standard error of the difference, left and right.
Figure 3: Scatter-plots showing the comparison between the March and May 2016 datasets. The points have been colour-coded for site, and different symbols used for the different treatments. The grey lines are those of equality (i.e., the plants were taller in May than March, but their healthy status was much the same).
Figure 4: Best linear unbiased estimates for proportion of healthy plants, mean height (mm) and mean height (mm) of healthy plants at Cooke (left) and Waimea Nurseries (right) for each treatment at each site in May 2016. The bars represent one standard error of the difference, left and right.
Given the inconsistency between the sites with respect to ranking of the treatments one would not expect a combined analysis to lead to more conclusive results.

Peter Alspach

REFERENCES


SFF 2016 SARD TRIAL

Report for Owen Stevenson
June 15, 2016

STATISTICAL APPROACH

These data are from the same plants as the 2015 data, but represent the heights and survival after the rootstock growth has been cut and the buds allowed to grow. Thus the analysis approach was the same as previously. That is, proportion of healthy plants and mean height of live and healthy plants were modelled separately for each site by fitting mixed models with treatment as the fixed effect and rep and blk as random effects.

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Given the inconsistency between the sites with respect to ranking of the treatments one would not expect a combined analysis to lead to more conclusive results.

Peter Alspach

REFERENCES


SFF 2015 SARD TRIAL

Report for Owen Stevenson
August 15, 2015

STATISTICAL APPROACH

Proportion of healthy plants and mean height of live and healthy plants and mean diameter (all four per plot) were modelled separately for each site by fitting mixed models with treatment as the fixed effect and rep and blk\(^1\) as random effects.

All analyses, including graphics, were undertaken using R 3.1.2 [2] and the mixed models were fitted using the asreml package [1].

RESULTS

The only statistically significant differences between the treatments was at Cooke where the fumigation treatment resulted in the tallest plants (P<0.001) (Figure 1). Unfortunately, this treatment was tacked onto the end of the trial and thus confounded with location in the field. That is, it is difficult to state how much of the improvement in height was due to the treatment and how much was due to location. In an attempt to resolve this, the raw data for plant height at Cooke was plotted against plant position, and colour-coded for treatment (Figure 2). The height for the fumigation treatment is clearly higher on average but appears to rise smoothly rather than abruptly. This might indicate a change in the field conditions is responsible for the improvement (since this would be expected to be gradual), but it might also indicate an edge effect from the adjoining plot (with a less effective treatment). Given other knowledge about the effectiveness of fumigation, it seems likely that at least some of the improvement in height was due to the treatment.

Given the inconsistency between the sites with respect to ranking of the treatments one would not expect a combined analysis to lead to more conclusive results.

Peter Alspach

REFERENCES


\(^1\)The designs were row-column.
Figure 1: Best linear unbiased estimates for proportion of healthy plants, mean height (mm), mean height (mm) of healthy plants and mean diameter (mm) at Cooke (left) and Waimea Nurseries (right) for each treatment at each site. The bars represent one standard error of the difference, left and right.
Figure 2: Plant height (mm) plotted against position in the row at Cooke, colour-coded for treatment as in Figure 1.
SFF SARD Trial

Report for Owen Stevenson
August 1, 2014

Statistical Approach

Proportion of healthy plants and mean height of healthy plants (both per plot) were modelled separately for each site by fitting mixed models with treatment as the fixed effect and row and rep as random effects.

All analyses, including graphics, were undertaken using R 3.1.0 [2] and the mixed models were fitted using the asreml package [1].

Results

The differences between the treatments for the proportion of healthy plants were not consistent across the sites (Figure 1). At Cooke, the proportion was higher than the other sites, with the aglime treatment having the lowest proportion of healthy plants and the untreated control was one of the better treatments \((P = 0.028)\). In contrast, at Waimea the untreated control was the worst treatment with respect to this variate, although the differences were not statistically significant \((P = 0.349)\). At Fenwick, which was not randomised, the differences were again not statistically significant \((P = 0.534)\) and this time the fumigation treatment was the worst. Given the inconsistency between the sites with respect to ranking of the treatments one would not expect a combined analysis to lead to more conclusive results\(^1\).

With respect to mean plant height, the ranking of the treatments was similar at both Cooke and Waimea (Figure 1), with the fumigation treatment resulting in the most growth and the aglime treatment the least \((P < 0.001\) and \(= 0.034\) at Cooke and Waimea respectively). At Fenwick, the differences were not statistically significant \((P = 0.315)\). Both the proportion of healthy plants and the height of healthy plants at Fenwick were consistent with a trend across the field, rather than a treatment effect \emph{per se}. However, given the lack of randomisation, any attempt to determine the real causes of the observed variation would be highly speculative.

Peter Alspach

References


\(^1\)And it didn’t, although the MET analysis undertaken was quite simplistic.
Figure 1: Best linear unbiased estimates for proportion of healthy plants (top) and mean height (mm) of healthy plants (bottom) for each treatment at each site. Sites are colour coded: Cooke (black), Waimea (grey) and Fenwick (green). The bars represent the average standard error of the difference between two means, left and right.
Soil Disinfections for Apple Replant Disease

This project is aimed at improving cost and best practice options for the Pipfruit nursery who supply trees for the NZ Pipfruit industry.

This project carries out a series of simple field trials to investigate the effect on tree establishment success and growth of alternatives treatment options to chloropicrin applied to known replant sites.

Organic soil amendments have often been promoted as a means to control soil borne plant diseases. Application of organic amendments to soil systems has the potential to alter both the structure and function of resident microbial communities.

The pursuit of the most effective combination of biological and conventional treatments will be sought by working with the industries concerned and using locations as similar to industry standard as possible.

The Nursery & Garden Industry New Zealand (NGINZ) represents the nursery industry in New Zealand. It is not a regulatory body, but collects and disseminates information that is of assistance to its members, furthers education and training for the industry and notifies members of incidence of disease (see the website www.nginz.co.nz).

There are three large commercial nurseries which produce approximately one million pipfruit trees every year. In addition, there are a number of smaller pipfruit nurseries that produce only rootstocks. The pipfruit nurseries are located in Hawke’s Bay, Nelson and Waikato. However, replant disease affects the wider plant community and any progress towards reducing high costs for chemical sterilization will be shared gratefully across the wider community.

Also developing the ability to use alternative replant treatment methods will relieve health and safety issues for pipfruit nurseries from surrounding urban neighbours (which is becoming more of an issue due to increased urban growth).

At present chemical soil sterilization creates potential health dangers for users and surrounding neighbours, unfortunately this process is the only known effective option for pipfruit nurseries with high land turnover. Due to increased land prices and subsequent land lease availability it is becoming more critical to recycle areas of land in use rather than sourcing expensive land with unknown plant growth limitations.

Therefore pursuing new options for environmentally safer land recycling is vital for the future of this industry and the wider community.
EXPECTED OUTCOMES FROM
THE ALTERNATIVE TREATMENT OPTIONS

PRODUCTION

→ Industry adoption
→ Reduction in planting time constraints
→ Equivalent shoot growth production compared to conventional fumigation treatments
→ Ability to use alternative treatment where conventional treatments are not possible
→ Utilizing abundant New Zealand resource for treatment options
→ Reduction in cost per hectare for alternative treatment options
→ Utilizing nursery equipment/technology to apply alternative treatment options
→ Ability to re-enter known replants sites otherwise earmarked for fumigation

NURSERY BUSINESS OUTCOMES:

→ Higher net margin, profit, provision of reinvestment capital arising from
  Reduction in cost of production per ha
→ Added flexibility of treatment options for known replant sites
→ Industry growth potential is less constrained by poor production economics and low ROI

OTHER PRODUCTION SYSTEMS IMPROVEMENTS CONTRIBUTING TO IMPORTANT SECTOR STRATEGIES:

→ Production footprints are reduced
→ Reduction in waste plastic from conventional fumigation treatments
→ Amenable to future automation and other mechanisation innovations

ALTERNATIVE OPTIONS INVESTIGATED

→ Ag Lime combined with Nemacur
  Rates: Nemacur applied at 1Litre per 25L of water (500L water per hectare)
  Ag Lime 20-30 tonne per hectare

→ Hydrated mussel shells combined with Nemacur
  Hydrated Mussel shells 1 tonne per hectare
  Nemacur applied at 1Litre per 25L of water (500L water per hectare)

→ Nemacur
  Nemacur applied at 1Litre per 25L of water (500L water per hectare)
  Applied with broadcast herbicide unit then rotary hoed in to achieve best results

→ Multi Cover Crop
  Oriental mustard (Brassica juncea) green gas
  Marigold (natural nematocide)
  Black oats or Le jewain wheat (green crop biomass forming)

→ Dutch Trench
  Cultural mechanical farm practice of exposing old plant root zone to weathering seasons for soil remediation.