Effect of Soil Nutrition and Composition on the Susceptibility of Hayward and Hort16A to Pseudomonas syringae pv. Actinidiae

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Executive Summary

This project determined whether plant nutrition can influence the susceptibility of kiwifruit to *Pseudomonas syringae* pv. *actinidiae* (Psa-V). By assessing the effect of soil nutrition and composition on the susceptibility of both Hayward and Hort 16A seedlings to Psa-V infection we were able to demonstrate that soil nutrition and composition can have a role in the susceptibility of seedlings to this pathogen.

The methodology used was based on growing seedlings in different media and applying various nutrient, elicitor, biological and spray applications known to influence bacterial disease susceptibility in other crops.

Our media study of autoclaved vs. non-autoclaved soil found significantly less Psa-V infection in non-autoclaved soil. This finding indicates that there could be a natural beneficial effect of the soil biota present in the soil on plant susceptibility to Psa-V.

The media component of the study found that the introduction of pulp-mill derived vermicast to soil also had a significant effect on the Psa-V incidence on plants grown in that media. The practical implication of these findings, if validated, may mean that banded applications of media in the orchard could provide a mechanism of delivering the benefits of media amendments in existing production systems.

Plant available mineral nutrition results were significantly complex and difficult to interpret, with significant positive effects being found through the use of high levels of Iodine and Copper in both Hayward and Hort16A. Nitrogen also had a role with higher levels of Nitrate leading to significantly less Psa-V incidence in Hayward seedlings, and high Ammonium giving the same effect in Hort16A. Positive effects of both high and low levels of Iodine are questionable, and therefore we plan to undertake rate experiments to fully understand the role of these elements.

Our work confirms the significantly beneficial role of the elicitor Actigard^{TM}, but has also identified applications of the elicitors Altra ABS and Salicylate as being beneficial, as were applications of Potassium Phosphate. Effective Microorganism (EM) also showed a response, depending on cultivar, with EM1 more effective on Hort16A and EM2 more effective on Hayward.

Results from this current project will be validated in Part 2 of this study. This next stage of the study is based on clonal Hayward and Gold3 on Bruno and Bounty 71. Findings are expected to isolate soil nutrition and composition regimes that can provide practical management tools to the orchardist. However, the current results obtained from the current study should not be used on orchard until they are fully validated, and any possible detrimental effects identified, such as phytotoxicity, reduced yield, fruit quality (e.g. taste), and staining or fruit residue.

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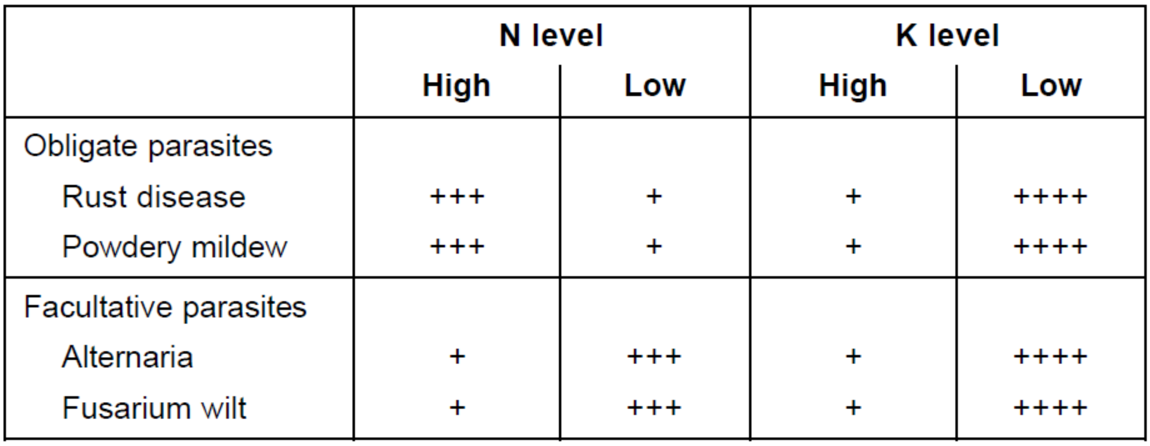
1 Introduction

There is evidence that plant nutritional status and composition affects the tolerance of plants to bacterial pathogens (Marschner 1995). Suppression of plant foliar pathogens, such as *Pseudomonas syringae*, can also be mediated by growing media. For example, pulp fibre residue-based composts (Vallad et al., 2003). Plant nutrition has also been shown to be directly involved in the metabolic pathways associated with plant defence (Graham and Webb, 1991). Mineral nutrient compounds such as phosphites have been found to induce plant resistance to pathogens in crops including citrus(Oren and Yogev, 2002) This project will therefore investigate the role of soil and plant nutrition on the susceptibility of kiwifruit plants to Psa-V.

Kiwifruit have a dimorphic leaf shape with the juvenile leaves tending to be ovate, acute tips, strongly pubescent and with serrated edges. As kiwifruit leaves mature their shape changes to obtuse with cuspidate tips, less hair, and with entire edges (Ferguson, 1990). Although comparative data of normal leaf nutrient levels for either Hayward or Hort16A leaves in the juvenile stage of vine growth is lacking, for the purposes of the current study it is assumed that the leaf nutrient balance may be similar, but not identical to the adult form. A comparison of the nutrient levels between the treatments in this study has been made but from seedlings growing in a naturally high Psa-V exposure environment. However, as leaf nutrient analysis of non-infected vines is not available it is not clear whether Psa-V infection alters the balance of leaf nutrients observed in such a study.

By altering the level of certain nutrients in plants we can alter the susceptibility to specific diseases. Table 1-1 illustrates this effect with regard to nitrogen and potassium levels for obligate (depends on living tissue for survival) and facultative (not dependent on living tissue for survival) parasites (Marschner, 1995). In general, Psa-V could be described as a facultative parasite but its response to nitrogen and potassium has not been defined. In the case of a related olive plant pathogen, *Pseudomonas syringae* subspecies *savastanoi*, it has been shown that foliar application of a high rate of nitrogen in the form of calcium nitrate has a positive effect on pathogen colonisation of leaf surfaces relative to olive plants treated with low or nil rates of foliar calcium nitrate (Balestra and Varvaro, 1997).

Table 1-1 Effect of nutrients on disease expression by different plant fungal pathogens



	N level		K level	
	High	Low	High	Low
Obligate parasites				
Rust disease	+++	+	+	++++
Powdery mildew	+++	+	+	++++
Facultative parasites				
Alternaria	+	+++	+	++++
Fusarium wilt	+	+++	+	++++

Overall, the role of soil and plant nutrition on the susceptibility of kiwifruit plants to Psa-V is not yet known. In this study we are particularly focused on how plant nutrition affects plant disease susceptibility and tolerance. Plant nutrition has been previously shown to influence the metabolic pathways associated with plant defence (Graham and Webb, 1991; Marschner 1995). We have made particular comparison between the severity of disease response and the nutrient levels and in particular the nutrients known to be antagonistic or preventative of plant disease.

Suppression of plant foliar pathogens, such as *Pseudomonas syringae*, can also be mediated by growing media, such as pulp fibre residue-based composts (Vallad, 2003). Phosphites have been found to induce plant resistance to pathogens in crops including citrus (Oren and Yogev, 2002). Plants can naturally defend themselves against bacterial attack by producing salicylic acid. Salicylic acid is a signalling molecule involved in systemic acquired resistance in which a pathogenic attack on one part of the plant induces resistance in the other parts. To help the plant defend itself better, some molecules can be used to activate salicylic acid production or replace the role it plays (Brun, Kay and Max, 2012). Those molecules are called elicitors or activators. It is essential to note that Hayward and Hort16A are kiwifruit from different species, being *Actinidia deliciosa* and *A. chinensis*, respectively. Hort16A may not have a salicylic acid pathway that is as responsive as Hayward, and this could be one reason why it is proving very susceptible to Psa-V infection. Because Gold3 is a cultivar of the species *A. chinensis*, we expect that Gold3 survival and treatment effect will be similar to the Hort16A results, i.e. more susceptible to Psa-V infection than *A. deliciosa.*

Table 1-2 overleaf outlines the nutrients, sprays and media included in this trial, and the published work that cites the variable as a potential affect on the severity of disease infection.

Table 1-2 References relating to nutrients, media and sprays, and effects on disease severity

Nutrients	**Author**	**Plant Species**
Ammonium	Dietrich, Plob and Heil, 2004.	Arabidopsis
Nitrate	Dietrich, Plob and Heil, 2004.	Arabidopsis
Phosphorous	Cao, et al., 2011.	Peach
Potassium	Cao, et al., 2011.	Peach
Calcium	Cao, et al., 2011	Peach
Copper	Masami et al., 2004.	Kiwifruit
Manganese	Huber and Wilhelm, 1988	Various
Boron	Schutte, 1967	Wheat
Magnesium	Cao, et al., 2011.	Peach
Zinc	Graham and Webb, 1997	Various
Iodine	Brenchley, 1936	Tomato
Silicon	Bekker, 2007.	Avocado
Nickel	Graham et al., 1985	Wheat
Soil Acidity	Cao, et al., 2011	Peach
pH	Weaver and Wehunt, 1975.	Peach
Sprays		
Altra ABS		
Salicylate	Galal, 2003.	Cucumber
Nitrogen phosphite	Oren and Yogev, 2002.	Citrus
Copper phosphite	Oren and Yogev, 2002.	Citrus
Ammonium Lingosulfonate (ALS)	Soltani and Lazarovits. n.d.	Potato
Potassium phosphate	Oren and Yogev, 2002.	Citrus
Acibenzolar-S-methyl (Actigard^{TM})	Graves and Alexander, 2002	Tomato
DL-3 Aminobutyric acid (BABA)	Rocha and Hammerschmidt, 2005	Various
Effective microorganisms	Tabra et al., 2003	Banana
Media		
Sawdust		
Vermicast	Theunissen et al., 2010.	Various
Compost		
Peat		
Pulp mill Residue	Vallad, 2003	Tomato

2 Project objectives

There were three key purposes to this work:

1. Develop a rapid methodology for the assessment of nutrients, media and various spray compounds on the susceptibility of kiwifruit seedlings to Psa-V infection
2. Assess the ability of multiple nutrients, media and sprays on Hayward and Hort16A seedlings to reduces susceptibility to Psa-V infection
3. Provide guidance for future experiments assessing individual and multiple treatments on other cultivars of kiwifruit

For the nutrient study, we will particularly consider the following questions:

4. What is the usual nutrient signature in the absence of the bacterial disease Psa-V?
5. Does the presence of Psa-V change this signature?
6. If so are the changes due to either a direct effect of the Psa-V bacterium or is it a plant response to counter the disease?
7. Can various treatments as used in this experiment help or hinder kiwifruit seedling response to counter the disease or can any of these treatments reduce or increase the harmful effects of Psa-V by direct or indirect attack on Psa-V bacteria?

3 Methods

The trial design was based on 10 single pot replicates per treatment. Each pot contained a fixed number of plants transplanted from seedling trays. The kiwifruit seedlings were grown in the amended media at controlled soil moisture until they reached the four-leaf stage.

3.1 Nutrients

Nutrient solutions were made from laboratory analytical grade 1000ppm standard solutions, to allow absolute control of the level of nutrients in the solution. 100 ml of each of these solutions was added twice weekly, and were ceased prior to stab inoculation at Plant & Food Research Ruakura, and were continued each week for four weeks at Plant & Food Research Te Puke.

3.2 Media

Soil, autoclaved soil, pumice, Hauraki peat, compost, pulp mill derived vermicast and untreated pine sawdust were used in different proportions in media mixes. The exact mixes are given in Appendix 1. The soil was a Katikati Sandy Loam obtained from a local Te Puna orchard. The pumice and Hauraki peat were obtained from Gammans, Te Puna. The vermicast is produced from short fibre pulp waste from the Kinleith pulp mill, and compost was made from general green waste, both obtained from Noke Limited. All media was sieved through a 2mm sieve.

3.3 Elicitors, biological treatments and other sprays

These were applied to both Hort16A and Hayward seedlings grown in pumice or both non-autoclaved soil and autoclaved soil according to recommendations, both before Psa-V inoculation and several days after Psa-V inoculation. Table 3-1 overleaf shows the sprays and the rates and timing of applications.

Table 3-1 Spray application products, timing and rates

Spray Product 1	**Conc.**	**Spray Product 2**	**Conc.**	**First Spray**	**Second Spray**	**Third Spray**
Altra ABS	0.10%	Salicylate	50ppm	Foliar spray at 4-leaf stage	Spray 5-7 days post inoculation	
Nitrogen Phosphite	0.15%	Iodine	7.50%	Foliar spray at 4-leaf stage		
Copper Phosphite	1.50%			Foliar spray at 4-leaf stage		
Effective Microorganisms 1	1%			Ground application after seedling emergence	Foliar spray before inoculation	Spray 5-7 days post inoculation
Effective Microorganisms 2	1%			Ground application after seedling emergence	Foliar spray before inoculation	Spray 5-7 days post inoculation
Ammonium Lingosulfonate	4%			Foliar spray before inoculation	Spray 5-7 days post inoculation	
Potassium Phosphate	0.35%			Foliar spray before inoculation	Spray 5-7 days post inoculation	
Actigard^{TM}	40ppm			Foliar spray before inoculation	Spray 5-7 days post inoculation	
DL-3 Aminobutyric acid	2ppm			Foliar spray before inoculation	Spray 5-7 days post inoculation	

4 Seedling establishment

Hayward and Hort16A seed was obtained wet from Kiwifruits NZ processing facility, and dried at low temperature in a Binder oven. The Hort16A seed was treated with hot water in the laboratory prior to sowing to improve germinability.

Media was placed in individual 2.5 litre pots, and then watered to allow settling to occur. On November 29, 2011 seed was then spread on the surface, and a small amount of fine peat was sprinkled on top to help maintain moisture. These pots were then covered with a fabric to also help maintain moisture, and were misted with water regularly to maintain moisture.

Germination occurred within 14-21 days, and was uniform across the pumice grown seedlings. As shown in Figure 4-1 below, there was some variation in the rate of germination and establishment of seedlings on the different media treatments.

Figure 4-1 Germination and establishment of seedlings in different media

Thinning was undertaken to approximately 30 seedlings per pot on 21 December 2011, and ultimately these seedlings were thinned to four seedlings per pot as seedlings began to crowd each other.

5 Results in the nursery

Seedlings grown at the nursery in media containing 75% sawdust, and 100% peat were found to produce such weak seedlings these were discarded before inoculation was undertaken. An example of this weak growth is shown in Figures 5-1 & 5-2.

Figure 5-1 Hort16A grown in 100% peat after 11 weeks

Figure 5-2 Hort16A grown in 75% sawdust after 11 weeks

The 100% peat media formed a hard “cap” on the surface, creating an impervious layer. It is likely that the 75% sawdust media contained large amounts of turpenes etc, which have herbicidal properties, especially on seedlings.

Once plants reached the fully expanded four true leaf stage, they were ready for transportation to Plant & Food Research at Ruakura and Te Puke for exposure to Psa-V.

6 Ruakura glasshouse inoculations

At Ruakura, plants were received in four batches between early February and mid March 2012 and were inoculated within a week of delivery. Full description is given in Appendix 2.

To facilitate inoculation, the plants were transferred to the PC1+ containment glasshouse. A wooden toothpick was dipped in the Psa-V inoculum and gently stabbed into the stem of each plant (~1-1.5 mm depth of penetration), positioned about 1/3 to 1/2 way up the stem of the plant. The toothpick was dipped into the inoculum before inoculating each plant within a pot and a new toothpick was used for each plant pot.

Plants were then placed onto trays on the floor of the glasshouse or on tables. Each pot was placed onto a plastic tray so that water in the large tray (to increase humidity) would not be taken up by the plants. Each replicate was placed onto separate large trays. In order to maintain high relative humidity 4 L of tap water was added to each of the large trays and the tray and plants were covered with a large plastic tent the same size as the tray and 0.8 m high.

The treatments involving post-inoculation foliar sprays had a single application of the respective sprays applied 5-7 days after inoculation.

A temperature and relative humidity recording micro-logger was attached to one of the plant stakes in at least one replicate from each batch of plants, so that environmental conditions could be monitored.

6.1 Monitoring of infection

A range of Psa-V symptoms were observed and recorded after 5, 8, 13 and 19 days for the Hort16A seedlings and after 12, 19 and 26 days for the Hayward seedlings. Psa-V symptoms resulting from the systemic infection of the plants included the following:

- Bacterial (Psa-V) ooze at the point of inoculation
- Bacterial (Psa-V) ooze on the stem away from the point of inoculation and/or on the underside of leaves
- Water soaked appearance of the stem above and below the point of inoculation
- Necrotic tissue lesion forming either side of the point of inoculation
- Water soaked spotting on the underside of leaves
- Necrotic spotting on the underside of leaves
- Collapse of leaf petioles
- Leaf drop
- Collapse and necrosis at the growing tip
- Collapse and necrosis on the stem (often at or near the point of inoculation) leading to lodging (top part of the plant falling over)
- Total plant collapse, most leaves have severe necrosis and petiole collapse, stem fully brown

The number of leaves on each plant was recorded so that percentage infection could be calculated. A maximum of three Plant & Food Research staff carried out all inoculations and visual assessments in order to minimise potential sources of variability.

At the completion of the final assessment plant pots belonging to each treatment were brought together and two photographs were taken to show the physical appearance of the plants. Plants and pots were then disposed of by double bagging and removed from the site by an approved handler.

7 Te Puke research orchard field exposure inoculation

The Plant & Food Research facility at Te Puke is located on No 1 Road, Te Puke, in the centre of the Psa-V priority zone. Because of this, Psa-V was not introduced as stab or spray inoculation, but kiwifruit plants showing clear Psa-V infection symptoms were placed around the perimeter of the shade house in order to optimise chance of inoculum being transferred naturally within the shade house.

Figure 7-1 Bay of Plenty Psa-V Priority Zone shaded pink, with the red start showing the location of Plant & Food Research Te Puke

At the Te Puke Research Orchard the plants also arrived in successive deliveries, Hort16A on 14 and 21 February and Hayward on 29 February and 13 March, 2012.

On arrival the plant pots were laid out in the main shade house in their treatment groups to enable efficient watering of the nutrient treatments using the appropriate solutions. The pots containing the different media were watered with overhead irrigation on a fixed timer (30 min) three times over each 24 hour period.

No additional nutrients were added to the plants and it became apparent that these seedlings were nutrient starved as the media contained no slow release fertilizers.

Psa-V symptoms on leaves were observed and recorded using a 0-5 scale where:

0 = no leaf spotting
1 = 1–5 spots
2 = 6–20 spots
3 = 21–50 spots
4 = 50+ spots
5 = dead plant

Observations were also made on the Hort16A plants on 11 September 2012, with the percentage of plants alive recorded. It was noted that many plants had experienced bud-break, but then rapidly died and expressed bacterial exudates before this observation.

Figure 7-2 Treated plants in Plant & Food Research shade house in Te Puke

8 Assessments

Given the large number of treatments and the complexity of possible interactions, disease severity was scored and analysed in a number of ways:

1. Scoring as undertaken by Plant & Food Research Ruakura (8-26 days after inoculation)
2. Survival percentage, being any plants still alive by Plant & Food Research (13-26 days after inoculation)
3. Principal component score of any collapse by Plant & Food Research (13 and 19 days after inoculation)
4. Survival of plants as of 11 September 2012 at Plant & Food Research Te Puke

The results from each observation date and type of ranking were analysed using Geometric Mean rankings, which results in a composite score to identify the most beneficial treatments.

These composite results are given in Tables 8-1 and 8-2 on the following pages. A low ranking score is indicative of a treatment that had beneficial effect, and may warrant further investigation.

Full results given in Appendix 3, Tables 15-1 to 15-4.

Table 8-1 Geometric Mean Ranks (GMR) for Hort16A and Hayward nutrition treatments

HORT16A	GMR
High Iodine	1
pH = 7.7	2
High Phosphorus	3
Low Phosphorus	4
Bion	5
High Copper	6
High Ammonium	7
Low Iodine	8
Low Copper	9
Low Nickel	10
Altra ABS + Salicylate	11
High Silicon	12
High Zinc	13
Low Magnesium	14
Low Ammonium	15
pH = 5.7	16
Low Silicon	17
pH = 6.7	18
Low Manganese	19
High Nitrate	20
High Calcium	21
High Potassium	22
Low Boron	23
Low Nitrate	24
High Manganese	25
Low Potassium	26
High Nickel	27
Copper Phosphite + Cu	28
Control (optimum)	29
High Boron	30
Low Zinc	31
Nitrogen Phosphite + I	32
High Magnesium	33
Low Calcium	34

Hayward	GMR
Bion	1
High Nitrate	2
Copper Phosphite + Cu	3
Low Nickel	4
Low Potassium	5
Low Boron	6
Low Ammonium	7
Low Zinc	8
High Nickel	9
Nitrogen Phosphite + I	10
High Zinc	11
Low Manganese	12
Low Nitrate	13
High Iodine	14
pH = 6.7	15
High Silicon	16
Low Magnesium	17
Altra ABS + Salicylate	18
High Potassium	19
Low Iodine	20
High Copper	21
High Calcium	22
Low Silicon	23
High Phosphorus	24
Low Copper	25
Low Calcium	26
Low Phosphorus	27
High Magnesium	28
Control (optimum)	29
pH = 5.7	30
pH = 7.7	31
High Manganese	32
High Boron	33
High Ammonium	34

Table 8-2 Geometric Mean Ranks (GMR) for Hort16A and Hayward media treatments

HORT16A	GMR
Soil EM 1	1
75% soil 25% peat	2
100% compost	3
25% soil 75% peat	4
Soil EM 2	5
25% soil 75% compost	6
50% soil 50% compost	7
50% soil 50% peat	8
50% soil 50% sawdust	9
Soil Potassium Phosphate	10
75% soil 25% compost	11
Soil Actigard^{TM}	12
25% soil 75% pumice	13
75% soil 25% pumice	14
50% soil 50% pumice	15
Control Soil	16
100% soil	17
Soil Ammonium Lingosulfonate	18
ACS Potassium Phosphate	19
ACS EM 1	20
50% soil 50% vermicompost	21
100% vermicompost	22
ACS EM 2	23
75% soil 25% vermicompost	24
25% soil 75% vermicompost	25
Control Autoclaved soil	26
Soil DL-3Aminobutyric acid	27
75% soil 25% sawdust	28
ACS Ammonium Lingosulfonate	29
ACS Actigard^{TM}	30
ACS DL-3Aminobutyric acid	31

Hayward	GMR
100% vermicompost	1
Soil Actigard^{TM}	2
50% soil 50% compost	3
25% soil 75% vermicompost	4
50% soil 50% vermicompost	5
50% soil 50% peat	6
25% soil 75% peat	7
75% soil 25% pumice	8
Soil Potassium Phosphate	9
Control Soil	10
75% soil 25% compost	11
Soil EM 2	12
25% soil 75% compost	13
75% soil 25% peat	14
75% soil 25% vermicompost	15
100% compost	16
Soil Ammonium Lingosulfonate	17
ACS Actigard^{TM}	18
100% soil	19
Soil DL-3Aminobutyric acid	20
75% soil 25% sawdust	21
25% soil 75% pumice	22
50% soil 50% sawdust	23
Soil EM 1	24
50% soil 50% pumice	25
ACS EM 2	26
ACS Potassium Phosphate	27
ACS DL-3Aminobutyric acid	28
ACS Ammonium Lingosulfonate	29
Control Autoclaved soil	30
ACS EM 1	31

It is important that we consider the affect of the treatments on both Hayward and Hort16A. The continuing production of Hayward in the industry will be critical for the continuing viability of the industry. Hort16A is the same species (*Actinidia chinensis*) as the new Gold3 and Gold9 cultivars.

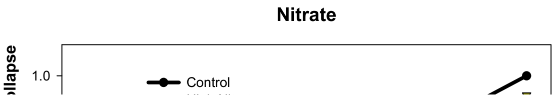
8.1 Nutrients

As outlined before, results from the nutrient experiment were significantly complex. In order to understand the affect of nutrients, each will be discussed in turn. It is also important to note that high, medium or low levels of nutrients applied to the seedling media did not necessarily correlate with leaf tissue results. Leaf samples were collected for mineral analysis from a number of the nutritional treatments based on the plants located at the Plant & Food Research, Te Puke Research Centre (Appendix 18). Data was normalised to a 0-1 scale using the highest and lowest leaf mineral values found in the trial samples (Table 18-3) as well as the range compared against known norms. Polar plots of the normalised leaf tissue mineral content was used to visually compare treatments (Figures 18-1 to 18-5). The summary below indicates the proposed decision to continue or discontinue with a given treatment for any further research. Temporal changes in each treatment are compared against a control nutrient treatment and a Bion® (Actigard™) treatment. Letters are used to denote significant differences between treatments for a given assessment time based on the Student's t-test when $p<0.05$ for each pair.

8.1.1 Nitrogen (Nitrate and Ammonium)

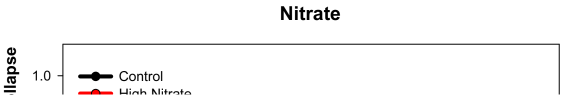
This element is frequently cited as being involved in increased disease severity both when it is in excess and when deficient. An examination of our data indicated no relationship between the survival rates found in the range of leaf nitrogen levels that we examined. For Hayward, there appeared to be a rate response to Nitrate, with the high rate giving a response comparable to application of Bion® (Actigard™). In Hort16A the high ammonium treatment had high survival rates up to 13 days after inoculation, yet this treatment was mid-range of the actual leaf nitrogen content. In contrast, high rates of Ammonium application had a detrimental effect on Hayward survival. Continue high nitrate with Hayward, and high ammonium with Gold3.

Figure 8-1 Rate of Collapse for High and Low Nitrate Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-2 Rate of Collapse for High and Low Nitrate Treatment for Hayward



Letters denote significant difference for proportion of collapse at given assessment time.

Figure 8-3 Rate of Collapse for High and Low Ammonium Treatment for

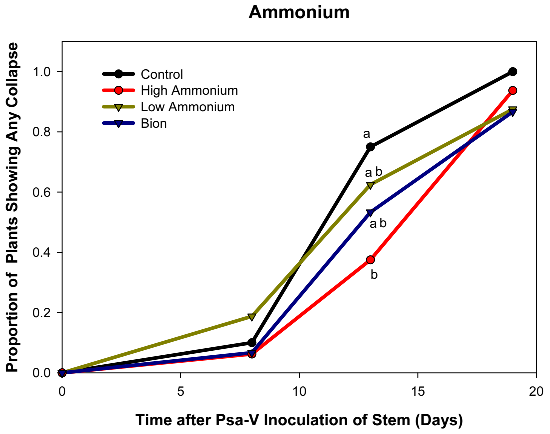
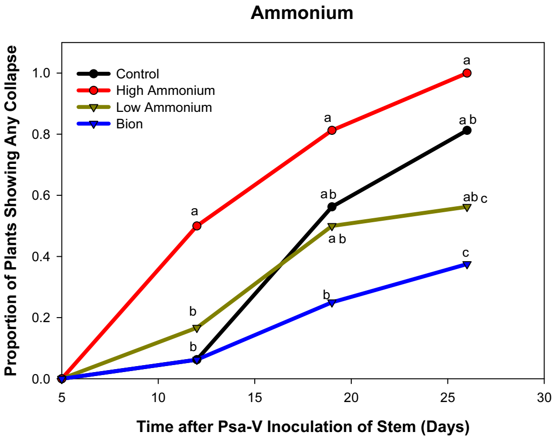


Figure 8-4 Rate of Collapse for High and Low Ammonium Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.2 Phosphorous

Excess phosphorus has been implicated with other disorders affecting kiwifruit i.e. pitting in Hayward (Ferguson, et al. 2001), although this case is not related to pathogenic organisms but due to physiological imbalance of nutrient uptake. Phosphorous levels were well within the normal range for mature vines (Smith, Asher and Clark, 1985). Low levels of Phosphorous showed significantly less collapse than the control, but not significantly less collapse than high Phosphorous. Therefore there did not appear to be an obvious rate response, as the control treatment had moderate levels of Phosphorous. Consider continuing with Gold3.

Figure 8-5 Rate of Collapse for High and Low Phosphorus Treatment for Hort16A

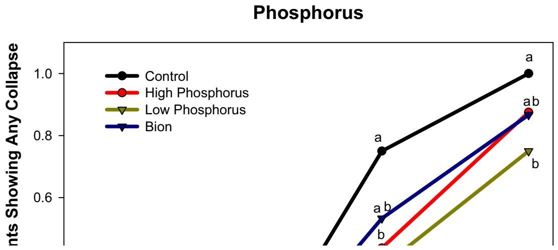
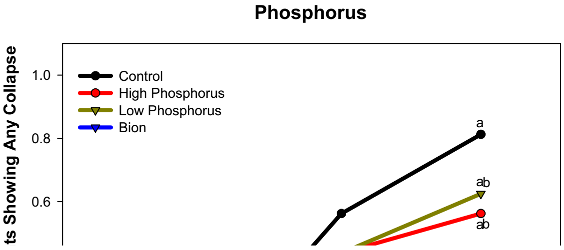


Figure 8-6 Rate of Collapse for High and Low Phosphorus Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.3 Potassium

Neither high nor low levels of potassium applied to the seedling media resulted in lower incidence of Psa-V in either Hort16A or Hayward. There was not a large range of potassium levels found in seedling composition. Discontinue.

Figure 8-7 Rate of Collapse for High and Low Potassium Treatment for Hort16A

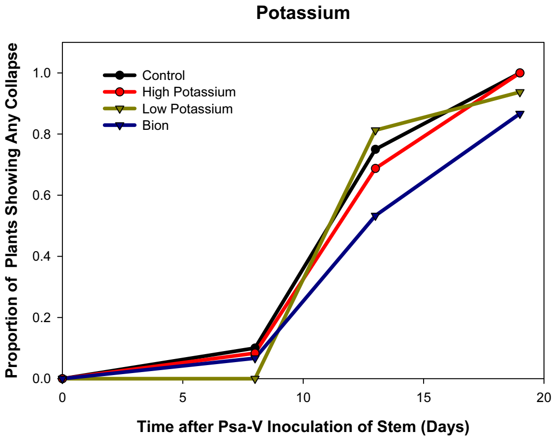
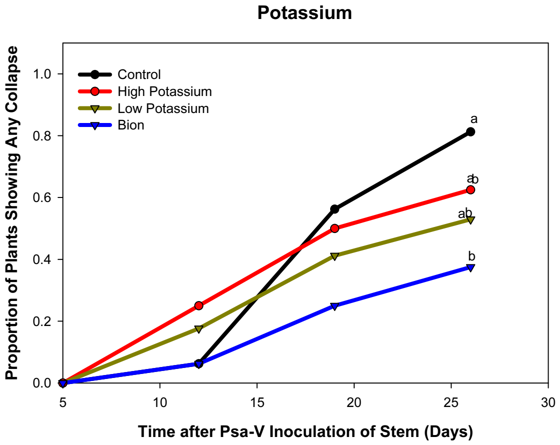


Figure 8-8 Rate of Collapse for High and Low Potassium Treatment for Hayward



No significant difference for proportion of collapse at a given assessment time.

8.1.4 Calcium

Neither high nor low levels of calcium applied to the seedling media resulted in lower incidence of Psa-V in either Hort16A or Hayward. However, calcium leaf analysis results from this trial were below the normal range for mature vines (Smith, Asher and Clark, 1985) although we do not have a normal range for juvenile leaves. Calcium is frequently mentioned as a nutrient that can confer improved resistance to disease through promoting strong cell wall integrity, therefore we examined the experimental data to see if this effect could be seen in Hort16A. The regression analysis of survival rate vs. calcium indicated no relationship between these factors exist (See Table 18-2). Discontinue.

Figure 8-9 Rate of Collapse for High and Low Calcium Treatment for Hort16A

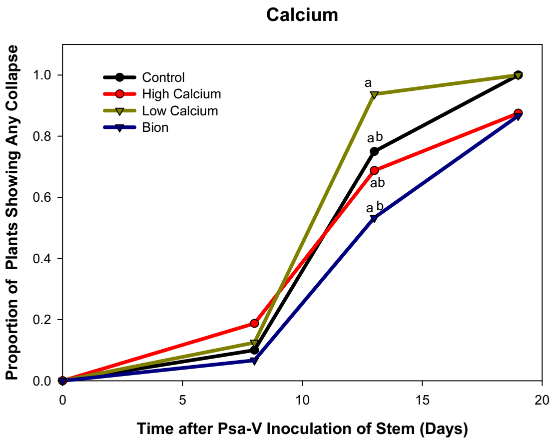
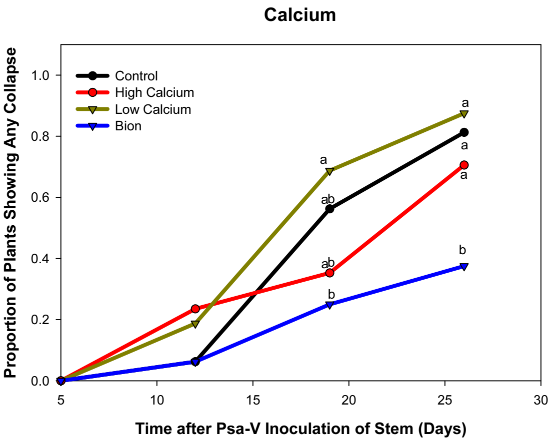


Figure 8-10 Rate of Collapse for High and Low Calcium Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.5 Copper

High levels of copper applied to the seedling media, as well as foliar applied copper phosphite and copper resulted in lower levels of Psa-V incidence. Media applied copper gave significantly higher levels of copper in the seedling, and copper phosphite and copper applications gave hugely increased levels of copper in the tissue. Continue with Hayward and Gold3.

Figure 8-11 Rate of Collapse for High and Low Copper Treatment for Hort16A

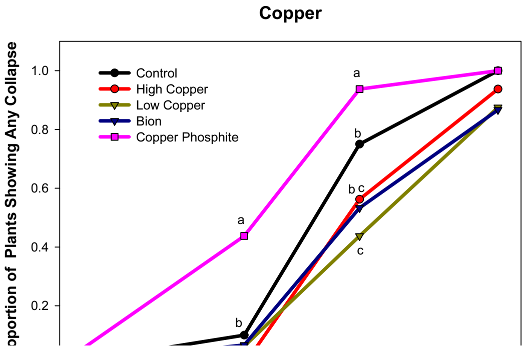
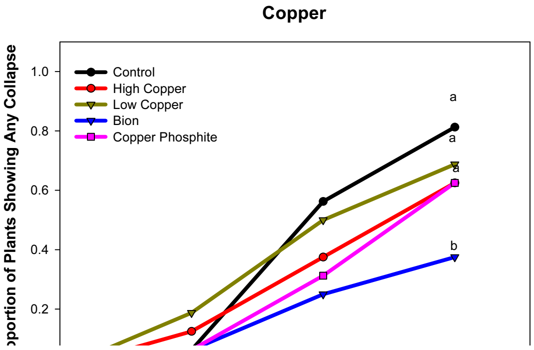


Figure 8-12 Rate of Collapse for High and Low Copper Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.6 Copper phosphite

Copper phosphite treatment produced a marked phytotoxic effect on the Hort16A seedlings. We propose to continue investigating both copper nutrition treatments. Discontinue.

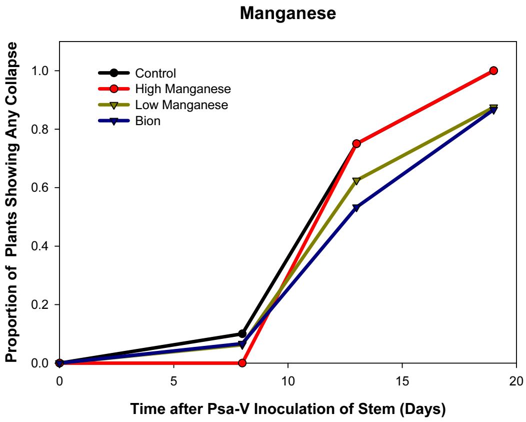
8.1.7 Nitrogen phosphite + Iodine

Showed some reduction in Psa-V incidence, but not as marked as just iodine treatment. Discontinue.

8.1.8 Manganese

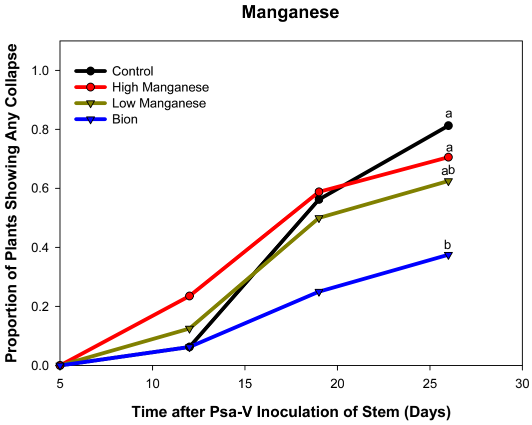
Neither high nor low levels of manganese applied to the seedling media resulted in lower incidence of Psa-V in either Hort16A or Hayward. Levels of manganese in Hayward seedlings were approximately double those found in Hort16A seedlings. Discontinue.

Figure 8-13 Rate of Collapse for High and Low Manganese Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-14 Rate of Collapse for High and Low Manganese Treatment for Hayward

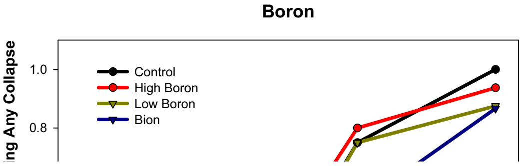


Letters denote significant difference for proportion of collapse at given assessment time.

8.1.9 Boron

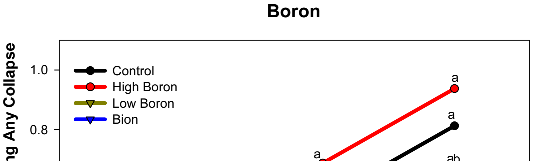
There was no significant difference found between high and low levels of Boron applied to seedlings relative to the control. Levels of boron in Hayward tissue was approximately 25% higher than in Hort16A. Discontinue.

Figure 8-15 Rate of Collapse for High and Low Boron Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-16 Rate of Collapse for High and Low Boron Treatment for Hayward

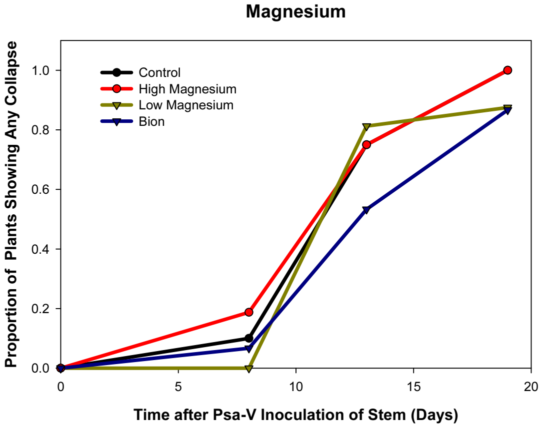


Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.10 Magnesium

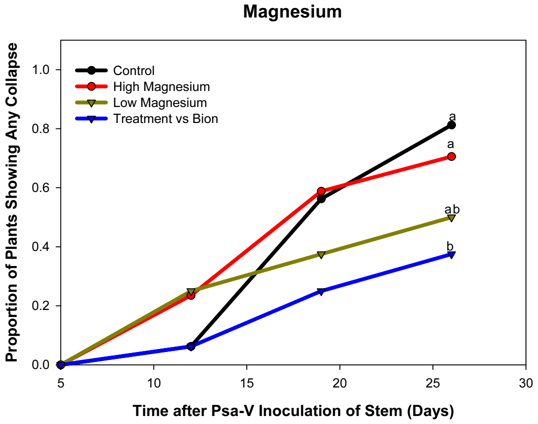
Neither high nor low levels of magnesium applied to the seedling media resulted in lower incidence of Psa-V in either Hort16A or Hayward. Discontinue.

Figure 8-17 Rate of Collapse for High and Low Magnesium Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-18 Rate of Collapse for High and Low Magnesium Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.11 Zinc

Both high and low levels of zinc applied to the seedling media did not result in significantly lower levels of Psa-V incidence in Hayward and Hort16A. Levels of zinc in both Hayward and Hort16A seedlings were relatively uniform. Discontinue.

Figure 8-19 Rate of Collapse for High and Low Zinc Treatment for Hort16A

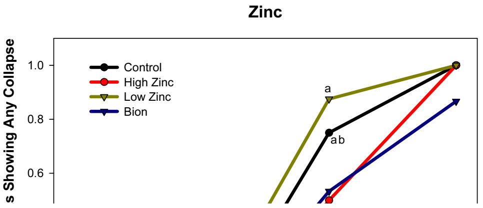
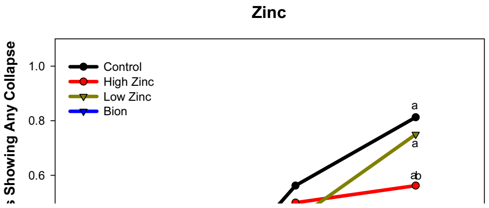


Figure 8-20 Rate of Collapse for High and Low Zinc Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.12 Iodine

High levels of iodine applied to the seedling media resulted in significantly lower incidence of Psa-V in Hort16A seedlings than the control. High levels of Iodine in Hayward seedlings led to phytotoxicity. Low levels of Iodine applied to Hort 16A also showed some benefit up to 13 days after inoculation. The reason for this effect may be due to the known antibiotic effects associated with Iodine. Continue with Gold3 and Hayward.

Figure 8-21 Rate of Collapse for High and Low Iodine Treatment for Hort16A

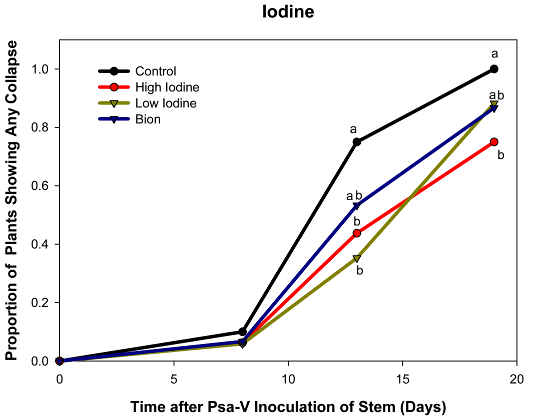
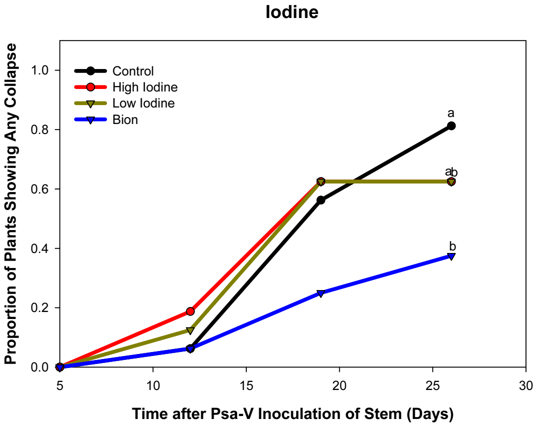


Figure 8-22 Rate of Collapse for High and Low Iodine Treatment for Hayward

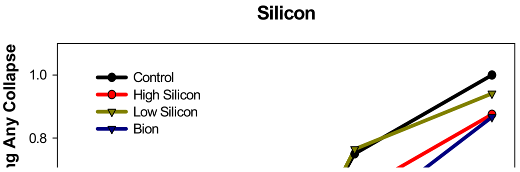


Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.13 Silicon

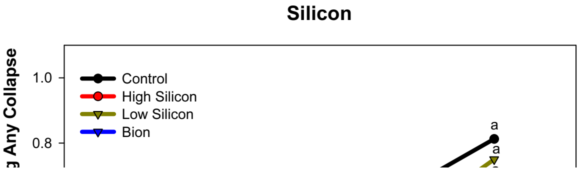
Neither high nor low levels of silicon applied to the seedling media resulted in lower incidence of Psa-V in either Hort16A or Hayward. Discontinue.

Figure 8-23 Rate of Collapse for High and Low Silicon Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-24 Rate of Collapse for High and Low Silicon Treatment for Hayward

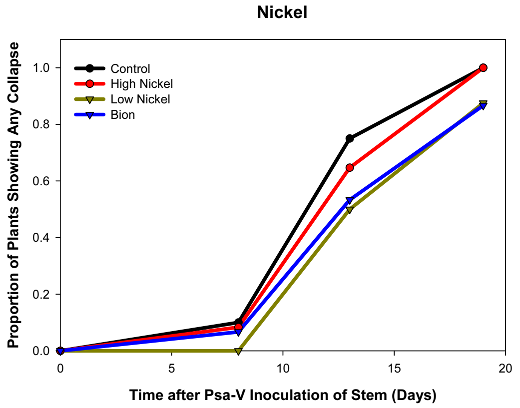


Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.14 Nickel

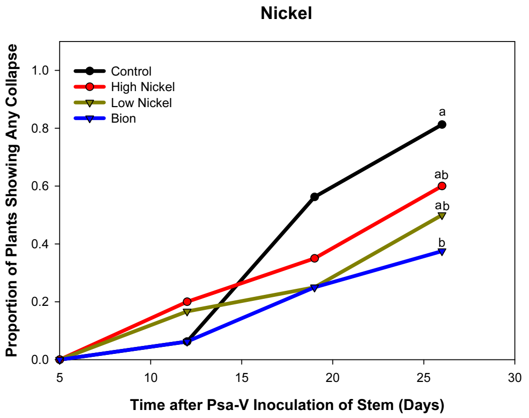
Differing levels of nickel applied to the seedling media did not result in significantly lower levels of Psa-V incidence in both Hayward and Hort16A than the control. With the exception of Auckland and Northland, the soils for kiwifruit orchards have very little Basaltic minerals and therefore natural soil nickel levels would be inconsequential. Nickel is potentially eco-toxic and based on our inconclusive findings of this study, continuing to investigate it is not prudent. Discontinue.

Figure 8-25 Rate of Collapse for High and Low Nickel Treatment for Hort16A



No significant difference for proportion of collapse at a given assessment time.

Figure 8-26 Rate of Collapse for High and Low Nickel Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time).

8.1.15 pH

The lowest incidence of Psa-V across the three pH treatments was the treatment at pH 6.7, which is approximately the pH of soils in the Bay of Plenty. Day 13 incidence of Psa-V in Hort16A was significantly lower in treatments with pH of 7.7 than control (6.7); however, this effect was not sustained through to day 19. Continue high pH (7.7) with Gold3.

Figure 8-27 Rate of Collapse for High, Optimal and Low pH Treatment for Hort16A

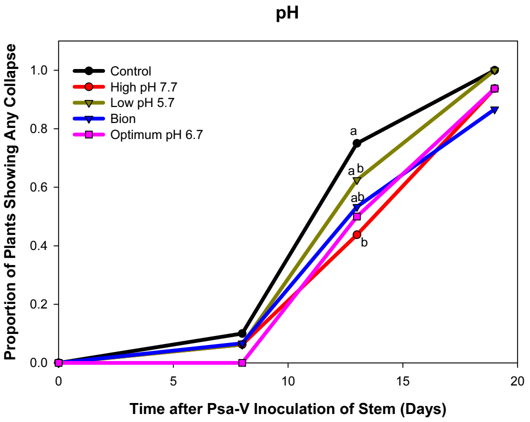
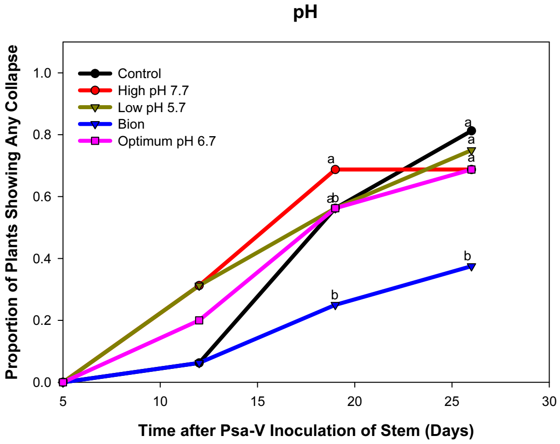


Figure 8-28 Rate of Collapse for High, Optimal and Low pH Treatment for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

8.1.16 Chloride

Although we did not impose different levels of chloride on the seedling media, chloride is considered as a major nutrient and for kiwifruit it is of greater relevance than most other crop species (Smith GS et al. 1988). We found highly significant negative effects with increasing levels of chloride showing reduced plant survival. However, the chloride levels present in the seedlings would not be considered high in mature kiwifruit plants. Discontinue.

8.1.17 Altra ABS + Salicylate

Both Hayward and Hort16A seedlings treated with the elicitor combination of Altra ABS and Salicylate in the pumice-based media used for the nutritional study. Although it showed some reduction in Psa-V incidence, the response was not significant (Data not shown). It is possible that the Salicylate boosts the salicylic pathway defence mechanism present in Hayward, but not present in Hort16A. Because we are finding such good results by using the already registered and proven Actigard^{TM}, we do not recommend pursuing the use of Altra ABS and Salicylate at this stage. Discontinue.

9 Media

It is likely that there will be a need to replant orchards with plants if it is found that plantings of Hayward and/or new varieties on rootstocks fail, and therefore this may be the opportunity to introduce plants grown in a media that imparts some tolerance of Psa-V to the plant.

Other work has shown that it is possible to apply a band of media material, e.g. compost, around mature vines, and feeder roots will grow into this material. This mechanism provides a possible way to impart some tolerance to Psa-V from media materials introduced to established orchards.

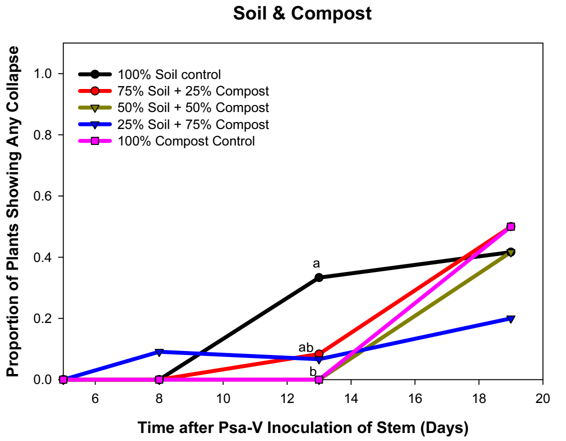
Figure 9-1 Banded pulp mill derived vermicast in Hayward orchard

Figure 9-2 Feeder roots growing into banded organic material

9.1 Compost

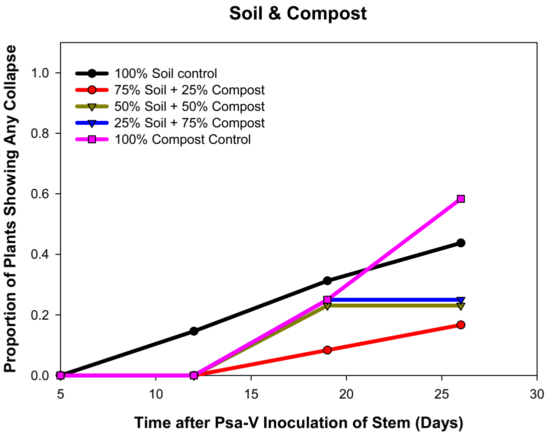
While the results obtained using compost to amend the media are promising, compost has the major drawback of being a material that can change its composition, characteristics and performance depending on the feedstock it is produced from. This feedstock tends to vary depending on the time of year, with large amounts of green, nitrogen rich material present in spring, and large amounts of dry, carbon rich material present in autumn and Winter. Although compost showed some benefit soon after inoculation for Hort16A, given the potentially variable nature of compost between batches this response may not necessarily be repeatable on an ongoing basis. Discontinue.

Figure 9-3 Rate of Collapse in Compost and Soil for Hort16A



Letters denote significant difference for proportion of collapse at given assessment time.

Figure 9-4 Rate of Collapse in Compost and Soil for Hayward



No significant difference for proportion of collapse at a given assessment time.

9.2 Pulp mill derived vermicast

50 and 75% vermicast in media gave good reduction in Psa-V incidence in Hayward, but made little difference in Hort16A. Vermicast made from short pine fibre from both Kinleith and Kawerau pulp and paper mills is a consistent feedstock and produced from the pine plantations in the Central North Island. It is available in large quantities at a competitive price. Given the extraordinary response to 100% vermicast in Hayward, further work on vermicast is warranted to determine if this is genuine. Continue.

Figure 9-5 Rate of Collapse for Vermicompost and Soil for Hort16A

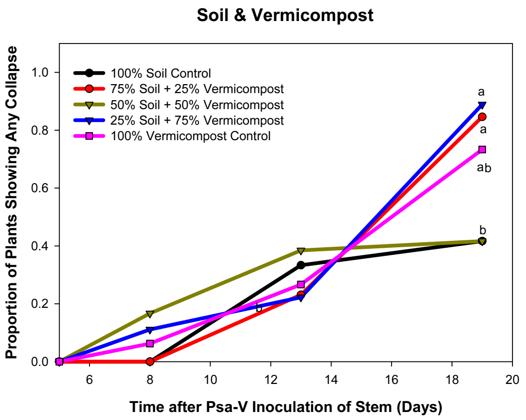
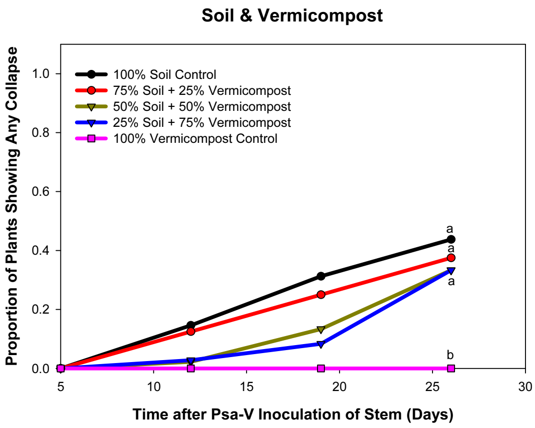


Figure 9-6 Rate of Collapse for Vermicompost and Soil for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

9.3 Peat

25% peat in the media gave some reduced incidence of Psa-V in both Hayward and Hort16A when compared against soil controls. The peat used for this work is Hauraki Peat, readily available and consistent in composition. The treatment containing 100% Peat was discarded before inoculation because the seedling health was so poor. Discontinue.

Figure 9-7 Rate of Collapse for Soil and Peat or Pumice for Hort16A

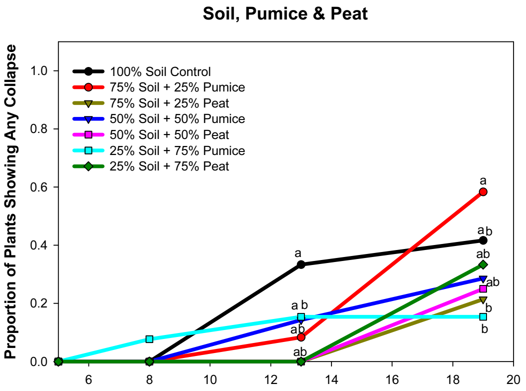
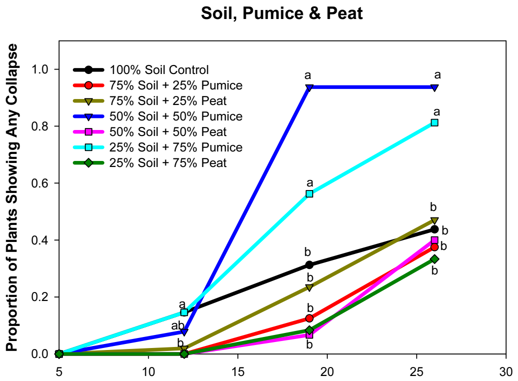


Figure 9-8 Rate of Collapse for Soil and Peat or Pumice for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

9.4

9.5 Pumice

It is likely that the pumice introduced into the media for this work gave a physical affect on the root environment, by increasing drainage and aeration, and therefore possible root growth. It seems unlikely that the pumice had any chemical or biological affect on the incidence of Psa-V. However, this finding supports the belief that good drainage and aeration reduces the chance of bacterial or fungal diseases. Discontinue.

9.6 Sawdust

Sawdust as part of the media had little effect on the incidence of Psa-V at any percentage. The treatment containing 75% sawdust was discarded before inoculation because the seedling health was so poor, and other media containing sawdust showed a definite reduction in plant size and vigour, possibly due to turpenes present. Untreated pine sawdust is also hard to source and we believe it is unsuitable as a soil amendment. Discontinue.

Figure 9-9 Rate of Collapse for Pine Sawdust and Soil for Hort16A

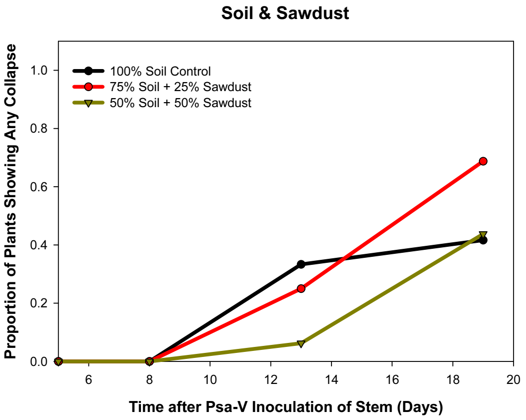
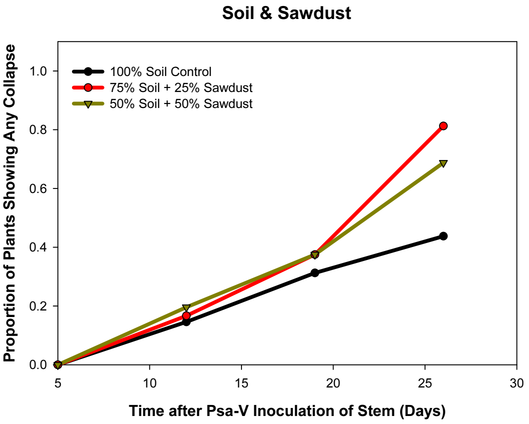


Figure 9-10 Rate of Collapse for Pine sawdust and Soil for Hayward



No significant difference for proportion of collapse at a given assessment time.

10 Elicitors, biologicals and other sprays

In order to assess the effect of difference elicitors, biological and other sprays, each one will be discussed in turn, and a recommendation made whether to continue investigating the role of the compound in Part 2 of this work.

Figure 10-1 Rate of Collapse for Elicitors in non-Autoclaved Soil for Hort16A

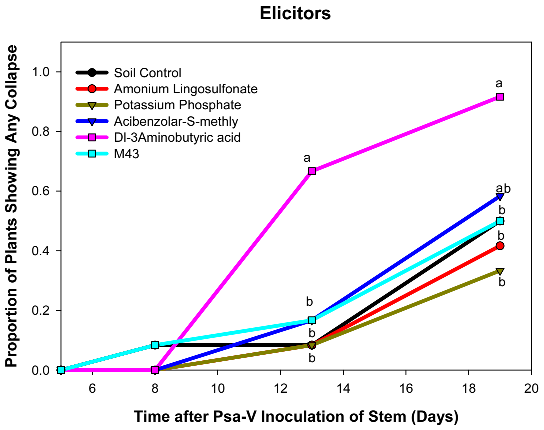
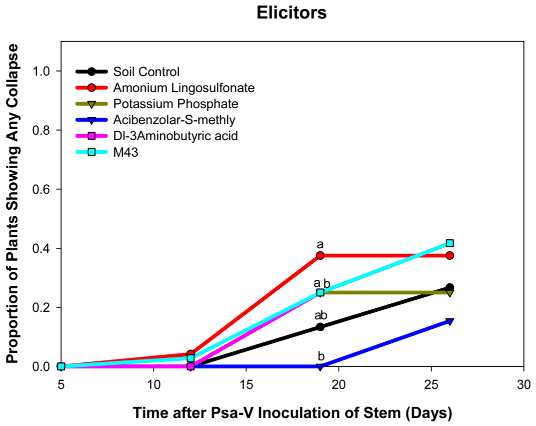


Figure 10-2 Rate of Collapse for Elicitors in non-Autoclaved Soil for Hayward



Letters denote significant difference for proportion of collapse at a given assessment time.

In Part 1 of this study, Actigard^{TM} treatment gave significant difference relative to the control in Hayward, but not Hort16A. However in Part 2 of this study seedlings sprayed with Actigard^{TM} have been compared to seedlings grown in a 100% soil control, and no significant difference was observed.

10.1.1 Ammonium Lingosulfonate

ALS had limited effect on Psa-V incidence in either Hort16A or Hayward, however the Hort16A plants treated showed significant phytotoxic affect. Ammonium Lingosulfonate is a compound extracted during the pine pulp process, and it is possible that the affect is also present in pulp derived vermicast. Ammonium lingosulfonate proved extremely hard to source. Discontinue.

10.1.2 Potassium Phosphate

Applications of Potassium phosphate on soil media showed decreased incidence of Psa-V in both Hort16A and Hayward. Continue.

10.1.3 DL-3 Aminobutyric acid

Very little difference in either Hort16A or Hayward. Discontinue.

10.1.4 Acibenzolar-S-methyl (Bion® / Actigard™)

Application of Acibenzolar-S-methyl gave some of the highest reduction in the incidence of Psa-V in both Hayward and Hort16A seedlings. While there is a large amount of other work on Acibenzolar-S-methyl, we plan to continue to use it as a valuable positive control for Psa-V reduction. Continue.

Figure 10-3 Rate of Collapse for Effective Micro-organisms (EM) in Autoclaved Soil for Hort16A

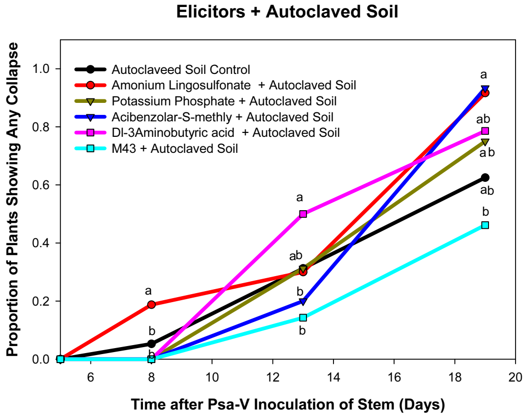
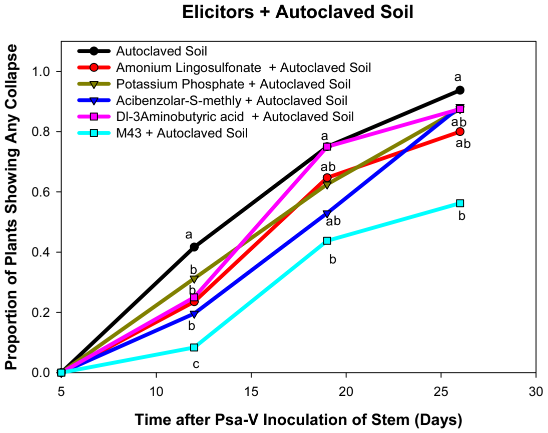


Figure 10-4 Rate of Collapse for Effective Micro-organisms (EM) in Autoclaved Soil for Hayward



Letters denote significant difference for proportion of collapse at given assessment time.

10.1.5 Effective Micro-organisms 1 and 2

Soil treated with either EM1 and EM2 performed well. Autoclaved soil treated with EM1 or EM2 performed poorly, suggesting that there is an interaction between the microorganisms in the EM solutions, and the natural soil biota. There appears to be a varietal difference in response to EM1 and EM2. Continue EM2 on Hayward and EM1 on Gold3.

Figure 10-5 Rate of Collapse for Effective Micro-organisms (EM) in non-Autoclaved or Autoclaved Soil for Hort16A

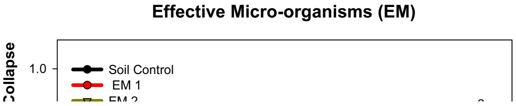
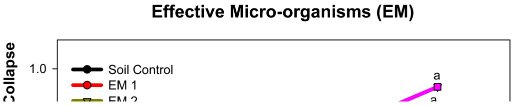


Figure 10-6 Rate of Collapse for Effective Micro-organisms (EM) in non-Autoclaved or Autoclaved Soil for Hayward



Letters denote significant difference for proportion of collapse at given assessment time.

10.1.6 Autoclaved (sterile) soil vs. Non-autoclaved soil

By comparing the pairs of autoclaved soil and natural soil with associated treatments, the natural soil had on average 35.1% greater survival than the autoclaved soil. This result confirms that there are naturally occurring benefits associated with soil as a medium. This may be related to microbial activity soil integrity and autoclaving may also release toxic chemicals otherwise bound to soil particles.

The photos below show the differences between the non-autoclaved soil control, and the autoclaved control.

Figure 10-7 Non-autoclaved soil control

Figure 10-8 Autoclaved soil control

11 Caution

It is critical that we use the findings of this preliminary work with caution. Two of the treatments showing some ability to reduce the incidence of Psa-V in the kiwifruit seedlings are copper phosphite and iodine. However, as 11-1 below shows, copper phosphite has severe phytotoxic affects on Hort16A while phytotoxicity was absent on Hayward. Potential side effects exist for many of the treatments. For examples, raising nitrate levels in kiwifruit tissue can lead to boron toxicity (Sotiropoulos, Therios and Dimassi, 2003). The use of phosphites can lead to residues in the fruit, and applications of heavy metals such as nickel and copper can lead to build-ups and toxicity in the soil. In fact, work has identified that strains of Psa-V have become resistant to continual use of copper sprays (Masami et al., 2004).

Figure 11-1 Copper phosphite phytotoxicity on Hort16A

Iodine showed good potential for control of Psa-V in Hort16A, but Figure 11-2 below shows the adverse effects it has had on Hayward plants grown in hydroponic solutions with increased concentrations of Iodine in the solution.

Figure 11-2 Effects of iodine on Hayward plants

Plant on left grown using solution with less than 0.1 ppb iodine solution,
plant on right grown using 1500 ppb iodine solution

It is essential we evaluate the potential implications of using any of these treatments on plant physiology, as well as possible problems in the food chain, before we recommend their use on orchard.

12 Future steps

Based on the results obtained from this work, we propose Part 2 to determine if treatments and conditions found to reduce susceptibility to Psa-V in the Stage 1 work on kiwifruit seedlings can be validated on clonal plants of Gold3 and Hayward. We have been able to secure a limited number of grafted Hayward & Gold3 plants on Bruno and Bounty 71 rootstocks from Riversun Nursery in Gisborne that will allow us to undertake this work.

This work aims to determine if treatments and conditions found to reduce susceptibility to Psa-V in the Stage 1 work on kiwifruit seedlings can be validated on clonal plants of Gold3 and Hayward. We have been able to secure a limited number (270 plants each of Hayward on Bruno and Gold3 on Bruno; and 230 each of Hayward on Bounty 71 and Gold3 on Bounty 71) of grafted plants from Riversun Nursery in Gisborne that will allow us to undertake this work.

Based on the results obtained from “Effect of Soil Nutrition and Composition on the Susceptibility of Hayward and Hort 16A to *Pseudomonas syringae* pv. *actinidiae* (V11270)”, we propose to four experiments:

Validating previous work

Rate optimisation

Combination treatments

Micro-prill proof of concept

Experiment 1 Validating previous work (75 plants each type)

Experiment 1 aims to validate findings from part 1 of this work. We expect that Gold3 will perform similarly to Hort16A because they are both *Actinidia chinensis*. We propose to place the peat and vermicast on top of the soil in the treatments to replicate a possible delivery method in the orchard. Other nutrients are investigated in greater detail in experiment 2.

Plant types	Hayward on Bruno Hayward on Bounty 71	Gold3 on Bruno Gold3 on Bounty 71
Media	100% Katikati Sandy Loam soil 75% Soil & 25% vermicast	100% Katikati Sandy Loam soil 75% Soil & 25% vermicast
Nutrients	Control High nitrate	Control High ammonium High pH (7.7)
Elicitors, biologicals and other sprays	Control Effective Microorganisms (EM2) Potassium phosphate	Control Effective Microorganisms (EM1) Potassium phosphate

The trial deign is based on 5 replicates per treatment, with each treatment applied to a single grafted plant grown in a 10 litre pot at Riversun Nursery, Gisborne. Plants will also be grown than do not have stab inoculation undertaken, in order to gain a baseline for nutritional composition. Medium levels of other elements including copper and iodine will be added to the treatments.

Experiment 2 Rate optimisation work (90 plants each type)

Results from V11270 found significant affects of different copper, nickel, phosphorous and iodine rates. We propose to attempt to identify optimal rates that provide Psa-V affect, but do not result in phytotoxicity.

Plant types	Hayward on Bruno Hayward on Bounty 71	Gold3 on Bruno Gold3 on Bounty 71
Media	100% Katikati Sandy Loam soil 75% Soil & 25% vermicast	100% Katikati Sandy Loam soil 75% Soil & 25% vermicast
Nutrients	Copper Iodine	Copper Iodine
Rates	High Low	High Low

Medium levels of other nutrients will be applied. The trial deign is based on 5 replicates per treatment, with each treatment applied to a single grafted plant grown a 10 litre pot at Riversun Nursery, Gisborne. Plants from experiment 1 with medium levels of a complete nutrient mix added will be the controls for this experiment.

Experiment 3 Combination Treatments (60 plants each type)

Given the findings of our work “Effect of Soil Nutrition and Composition on the Susceptibility of Hayward and Hort 16A to *Pseudomonas syringae* pv. *actinidiae* (V11270)”, we propose to undertake a combination of media, nutrient and spray treatments to determine if an additive response to Psa-V tolerance can be achieved. These treatments will be made by combining modes of action, being:

media x elicitor x biological x nutrient

3 x 2 x 1 x 2

We will undertake combinations of treatments based on our findings from the seedling treatment experiment. These will comprise the four plant types in three different media, grown with elevated copper and iodine levels and with an application of Effective Microorganism 2 (EM2), with or without applications of the elicitor Actigard^{TM} and Potassium Phosphate (K_2PO_4).

Plant types (4)	Hayward on Bruno Hayward on Bounty 71 Gold3 on Bruno Gold3 on Bounty 71
Media (3)	100% Katikati Sandy Loam soil 75% Soil & 25% Hauraki peat 75% Soil & 25% pulp mill derived vermicast
Nutrients (1)	Both elevated copper & iodine
Elicitor (2)	Actigard^{TM} Control
Biological (1)	EM2
Spray (2)	Potassium phosphate Control

Experiment 4 Micro-prill application of copper (15 plants each, Hayward and Gold3 on Bounty71)

Our initial work has found that increased levels of copper in the plant tissue result in a reduced incidence of Psa-V. Copper application as copper phosphite resulted in severe phytotoxicity is Hort16A, and is likely that this affect would also occur in Gold3 which is also the species *Actinidia chinensis.* The use of phosphite formulations is also likely to result in residues in the fruit. Recent work has developed micro-prills as a way of introducing materials directly into the vascular tissue of plants, therefore reducing the levels of potentially toxic elements such as copper applied to the plant and/or soil.

We propose to carry out a proof of concept investigation on the use of micro-prills in grafted Hayward and Gold3 on Bounty rootstocks, investigating three rates of copper in the prill, and its affect on leaf tissue analysis and Psa-V incidence.

Psa-V Inoculation

Psa-V infection and evaluation of the seedlings will be according to the standard industry protocol, and will be undertaken by Plant & Food Research. This methodology has been proven during the "Effect of Soil Nutrition and Composition on the Susceptibility of Hayward and Hort 16A to *Pseudomonas syringae* pv. a*ctinidiae* (V11270)" work.

At approximately 7, 14, 21 and 28 days after inoculation we will measure leaf infection on the scale:

0 = no leaf spotting
1 = 1–5 spots
2 = 6–20 spots
3 = 21–50 spots
4 = 50+ spots
5 = dead plant

We will also measure tip, stem, petiole and total collapse.

13 Appendix 1 Composition of media mixes

Table 13-1 Percentage composition of media mixes

Treatment Number	Soil	Pumice	Peat	Compost	Vermicast	Sawdust
53	100	0	0	0	0	0
54	0	0	0	100	0	0
55	0	0	0	0	100	0
56	75	25	0	0	0	0
57	75	0	25	0	0	0
58	75	0	0	25	0	0
59	75	0	0	0	25	0
60	75	0	0	0	0	25
61	50	50	0	0	0	0
62	50	0	50	0	0	0
63	50	0	0	50	0	0
64	50	0	0	0	50	0
65	50	0	0	0	0	50
66	25	75	0	0	0	0
67	25	0	75	0	0	0
68	25	0	0	75	0	0
69	25	0	0	0	75	0
70	25	0	0	0	0	75

14 Appendix 2 Psa-V inoculation details (Plant & Food Research Ruakura)

Psa-V inoculum solution was prepared by growing Psa-V culture for 2-3 days on King's B (KB) medium and harvesting the bacteria by washing the plate with sterile distilled water (SDW) to make a turbid stock suspension of inoculum that was visually estimated to be >1 x 10^9 colony forming units (CFU/mL). A sub-sample of this Psa-V stock solution was serially diluted and 10 µL droplets placed onto fresh KB medium so that the actual number of CFU/mL could be counted after two days incubation.

For inoculation of the plants the Psa-V stock was diluted 100-fold to provide an inoculum concentration of > 1 x 10^7 CFU/mL. Each of the four batches of plants was inoculated on two consecutive days using freshly prepared inoculum (Table 14-1). The inoculum concentration ranged from 1.1 to 7.0 x 10^7 CFU/mL with an average of 3.6 x 10^7 CFU/mL.

Table 14-1 Batches of kiwifruit seedlings received for Psa-V inoculation

Cultivar	Batch #	Experiment	Replicates	Date inoculated	Concentration of inoculum (CFU/mL)
Hort16A	1	1	1 & 3	15-Feb-12	1.1 x 10^7
Hort16A	1	1	2 & 4	16-Feb-12	1.7 x 10^7
Hort16A	2	2 & 3	1 & 3	22-Feb-12	2.8 x 10^7
Hort16A	2	2 & 3	2 & 4	23-Feb-12	7.0 x 10^7
Hayward	3	2 & 3	1 & 3	7-Mar-12	3.3 x 10^7
Hayward	3	2 & 3	2 & 4	8-Mar-12	4.0 x 10^7
Hayward	4	1	1 & 3	14-Mar-12	4.6 x 10^7
Hayward	4	1	2 & 4	15-Mar-12	4.3 x 10^7

15 Appendix 3 Composite Results

Table 15-1 Hort16A nutrition Geometric Mean Rank results

	Day 8		**Day 13**						**Day 19**						**11 Sept 2012**		
	Stage		**Survival (%)**		**Stage**		**Any collapse (%)**		**Survival (%)**		**Any collapse (%)**		**Stage**		**Survival (%)**		**GMR**
High Iodine	1.63	14	81.3%	3	3.00	1	43.8%	5	0.0%	7.0	75.0%	1	4.00	1	22.2%	5	**1**
pH = 7.7	1.81	21	87.5%	1	3.25	3	43.8%	5	12.5%	3.0	93.8%	15	4.69	3	11.8%	14	**2**
High Phosphorus	1.63	14	68.8%	12	3.25	3	43.8%	5	0.0%	7.0	87.5%	4	4.63	2	20.0%	6	**3**
Low Phosphorus	1.56	13	81.3%	3	3.44	9	37.5%	3	0.0%	7.0	75.0%	1	5.25	13	13.3%	11	**4**
Bion	1.20	6	60.3%	19	3.52	12	53.3%	12	26.9%	1.0	86.7%	3	4.87	4	20.0%	6	**5**
High Copper	1.13	4	75.0%	9	3.38	8	56.3%	13	0.0%	7.0	93.8%	15	5.00	7	33.3%	1	**6**
High Ammonium	1.44	10	87.5%	1	3.25	3	37.5%	3	0.0%	7.0	93.8%	15	5.25	13	5.9%	28	**7**
Low Iodine	1.54	12	77.5%	8	3.17	2	35.3%	2	0.0%	7.0	88.2%	14	5.02	8	12.5%	13	**8**
Low Copper	0.94	1	56.3%	20	3.50	10	43.8%	5	0.0%	7.0	87.5%	4	5.13	10	10.5%	16	**9**
Low Nickel	1.38	7	81.3%	3	3.50	10	50.0%	9	6.3%	4.0	87.5%	4	5.06	9.00	5.3%	30.00	**10**
Altra ABS + Salicylate	2.00	26	81.3%	3	3.31	6	25.0%	1	0.0%	7.0	100.0%	23	4.94	5	6.3%	26	**11**
High Silicon	1.38	7	75.0%	9	3.63	13	62.5%	14	6.3%	4.0	87.5%	4	4.94	5	10.0%	19	**12**
High Zinc	1.50	11	81.3%	3	3.31	6	50.0%	9	0.0%	7.0	100.0%	23	5.38	18	20.0%	6	**13**
Low Magnesium	1.63	14	62.5%	16	4.31	24	81.3%	28	0.0%	7.0	87.5%	4	5.31	17	28.6%	2	**14**
Low Ammonium	2.13	29	62.5%	16	4.19	22	62.5%	14	0.0%	7.0	87.5%	4	5.25	13	23.8%	3	**15**
pH = 5.7	1.00	2	56.3%	20	4.00	18	62.5%	14	0.0%	7.0	100.0%	23	5.50	25	20.0%	6	**16**
Low Silicon	1.10	3	71.8%	11	3.97	18	76.5%	26	18.8%	2.0	94.1%	22	5.18	12	4.5%	32	**17**
pH = 6.7	1.38	7	68.8%	12	3.75	14	50.0%	9	0.0%	7.0	93.8%	15	5.31	18	11.1%	15	**18**
Low Manganese	1.88	23	68.8%	12	3.94	17	62.5%	14	0.0%	7.0	87.5%	4	5.38	18	13.3%	11	**19**
High Nitrate	1.94	25	56.3%	20	3.94	15	81.3%	28	0.0%	7.0	87.5%	4	5.25	13	10.5%	16	**20**
High Calcium	2.19	30	56.3%	20	4.38	26	68.8%	19	0.0%	7.0	87.5%	4	5.13	10	9.1%	22	**21**
High Potassium	1.15	5	56.3%	20	3.81	15	68.8%	19	0.0%	7.0	100.0%	23	5.56	26	6.7%	24	**22**
Low Boron	1.75	18	43.8%	31	4.50	28	75.0%	21	6.3%	4.0	87.5%	4	5.50	21	5.9%	28	**23**
Low Nitrate	1.75	18	43.8%	31	4.38	24	75.0%	21	0.0%	7.0	93.8%	15	5.50	21	20.0%	6	**24**
High Manganese	1.75	18	68.8%	12	4.00	20	75.0%	21	0.0%	7.0	100.0%	23	5.38	21	10.0%	19	**25**
Low Potassium	1.88	23	62.5%	16	4.06	21	81.3%	28	0.0%	7.0	93.8%	15	5.50	21	6.3%	26	**26**
High Nickel	1.71	17	52.6%	26	4.26	23	64.7%	18	0.0%	7.0	100.0%	23	5.65	27	5.3%	30	**27**
Copper Phosphite + Cu	3.13	34	12.5%	34	5.44	34	93.8%	33	0.0%	7.0	100.0%	23	6.00	33	23.1%	4	**28**
Control (optimum)	1.81	21	48.7%	29	4.41	27	75.0%	21	0.0%	7.0	100.0%	23	5.71	29	10.0%	19	**29**
High Boron	2.04	27	45.3%	30	4.79	32	80.0%	27	0.0%	7.0	93.8%	15	5.68	28	7.7%	23	**30**
Low Zinc	2.38	32	56.3%	20	4.56	30	87.5%	32	0.0%	7.0	100.0%	23	5.75	30	10.5%	16	**31**
Nitrogen Phosphite + I	2.38	32	50.0%	27	4.56	29	81.3%	28	0.0%	7.0	100.0%	23	5.81	32	6.7%	24	**32**
High Magnesium	2.19	30	50.0%	27	4.63	31	75.0%	21	0.0%	7.0	100.0%	23	6.00	33	0.0%	33	**33**
Low Calcium	2.06	28	43.8%	31	5.00	33	93.8%	33	0.0%	7.0	100.0%	23	5.75	31	0.0%	33	**34**

Table 15-2 Hort16A media Geometric Mean Rank results

	Day 8		Day 13						Day 19						11 Sept 2012		
	Stage		**Survival (%)**		**Stage**		**Any collapse (%)**		**Survival (%)**		**Any collapse (%)**		**Stage**		**Survival (%)**		**GMR**
Soil EM 1	0.55	1	100.0%	1	1.45	1	0.0%	1	90.9%	1	9.1%	1	3.48	2	66.7%	25	**1**
75% soil 25% peat	0.79	10	100.0%	1	2.26	7	0.0%	1	78.9%	4	21.4%	4	3.23	1	68.8%	23	**2**
100% compost	0.67	4	100.0%	1	1.67	2	0.0%	1	50.2%	16	50.0%	15	3.50	3	87.5%	6	**3**
25% soil 75% peat	0.75	7	100.0%	1	2.46	10	0.0%	1	64.4%	8	33.3%	7	3.56	5	91.7%	5	**4**
Soil EM 2	0.77	9	100.0%	1	2.22	6	0.0%	1	58.6%	10	40.0%	9	3.69	8	n/a		**5**
25% soil 75% compost	0.98	15	100.0%	1	2.50	11	6.7%	9	80.0%	3	20.0%	3	3.54	4	77.8%	16	**6**
50% soil 50% compost	0.92	13	100.0%	1	2.17	5	0.0%	1	58.5%	11	41.7%	10	3.67	7	75.0%	19	**7**
50% soil 50% peat	1.18	16	91.7%	12	2.92	20	0.0%	1	75.1%	5	25.0%	5	3.75	9	80.0%	13	**8**
50% soil 50% sawdust	2.13	30	100.0%	1	2.94	22	6.3%	8	56.4%	14	43.8%	14	4.13	14	100.0%	1	**9**
Soil Potassium Phosphate	0.83	12	91.5%	14	2.50	11	8.3%	10	67.0%	7	33.3%	7	3.58	6	86.7%	7	**10**
75% soil 25% compost	1.50	21	100.0%	1	2.33	8	8.3%	10	50.2%	16	50.0%	15	4.17	15	85.7%	8	**11**
Soil Acibenzolar-S-methyl	0.67	4	91.5%	14	2.00	3	16.7%	17	42.0%	18	58.3%	18	4.00	12	85.7%	8	**12**
25% soil 75% pumice	1.58	25	92.2%	11	3.09	26	15.4%	16	84.2%	2	15.4%	2	3.96	11	53.8%	28	**13**
75% soil 25% pumice	0.66	3	91.7%	12	2.16	4	8.3%	10	41.8%	19	58.3%	18	4.51	19	73.3%	21	**14**
50% soil 50% pumice	1.21	18	92.7%	10	2.99	23	14.3%	15	71.4%	6	28.6%	6	3.84	10	81.3%	11	**15**
Control Soil	1.50	21	91.5%	14	3.00	24	8.3%	10	50.3%	15	50.0%	15	4.25	16	100.0%	1	**16**
100% soil	1.25	19	75.0%	27	2.83	17	33.3%	28	58.5%	11	41.7%	10	4.00	12	100.0%	1	**17**
Soil Ammonium Lingosulfonate	0.75	7	83.0%	22	2.83	17	8.3%	10	58.7%	9	41.7%	10	4.33	17	81.3%	11	**18**
ACS Potassium Phosphate	0.94	14	61.9%	31	3.06	25	31.3%	26	25.3%	23	75.0%	23	4.94	26	100.0%	1	**19**
ACS EM 1	0.58	2	83.0%	22	2.83	17	25.0%	21	33.6%	21	66.7%	20	4.83	24	22.2%	29	**20**
50% soil 50% vermicompost	1.67	28	83.3%	21	2.92	20	38.5%	29	58.5%	11	41.7%	10	4.42	18	80.0%	13	**21**
100% vermicompost	1.19	17	75.6%	26	2.45	9	26.7%	23	24.2%	24	73.3%	22	4.54	21	73.3%	21	**22**
ACS EM 2	0.70	6	84.8%	20	2.58	13	30.8%	25	7.6%	30	84.6%	25	5.19	28	5.0%	30	**23**
75% soil 25% vermicompost	0.80	11	85.0%	19	2.64	15	23.1%	20	15.7%	27	84.6%	25	4.91	25	62.5%	26	**24**
25% soil 75% vermicompost	1.75	29	88.8%	18	2.68	16	22.2%	19	11.1%	28	88.9%	27	4.52	20	80.0%	13	**25**
Control Autoclaved soil	1.27	20	80.9%	25	2.63	14	31.3%	26	37.8%	20	62.5%	19	4.56	22	61.1%	27	**26**
Soil DL-3Aminobutyric acid	1.58	25	91.5%	14	3.75	31	66.7%	31	8.4%	29	91.7%	28	5.58	30	85.7%	8	**27**
75% soil 25% sawdust	2.50	31	81.2%	24	3.31	28	25.0%	21	31.4%	22	68.8%	21	4.75	23	76.9%	17	**28**
ACS Ammonium Lingosulfonate	1.56	24	74.6%	28	3.38	29	30.0%	24	19.0%	26	91.7%	28	5.44	29	76.5%	18	**29**
ACS Acibenzolar-S-methyl	1.54	23	73.7%	29	3.17	27	20.0%	18	6.7%	31	93.3%	30	5.15	27	68.4%	24	**30**
ACS DL-3Aminobutyric acid	1.66	27	72.1%	30	3.70	30	50.0%	30	21.0%	25	78.6%	24	5.60	31	75.0%	19	**31**

Table 15-3 Hayward nutrition Geometric Mean Rank results

	Stage day 12		Stage day 19		Survival day 19 (%)		Any collapse day 19 (%)		Stage day 26		Any collapse day 26 (%)		GMR
Bion	0.625	1	1.75	1	100.0	1.00	0.25	1.00	2.313	1	0.375	1	**1**
High Nitrate	1.125	3	2.438	7	100.0	1.00	0.3125	3.00	2.875	4	0.375	1	**2**
Copper Phosphite + Cu	0.813	2	2.375	5	100.0	1.00	0.3125	3.00	2.5	2	0.625	13	**3**
Low Nickel	2.107	25.00	2.486	9.00	100.0	1.00	0.25	1.00	3.088	6.00	0.5	3	**4**
Low Potassium	1.406	7	2.434	6	100.0	1.00	0.41176471	10.00	3.012	5	0.5294118	5	**5**
Low Boron	1.261	5	2.143	3	100.0	1.00	0.46666667	16.00	2.677	3	0.6666667	20	**6**
Low Ammonium	1.521	8	2.375	5	100.0	1.00	0.5	17.00	3.313	10	0.5625	7	**7**
Low Zinc	1.375	6	2.313	4	100.0	1.00	0.4375	11.00	3.313	10	0.75	28	**8**
High Nickel	2.036	23	2.508	10	100.0	1.00	0.35	5.00	3.397	13	0.6	12	**9**
Nitrogen Phosphite + I	1.25	4	2	2	87.5	33.00	0.375	7.00	3.188	8	0.625	13	**10**
High Zinc	1.688	11	2.688	12	100.0	1.00	0.5	17.00	3.563	16	0.5625	7	**11**
Low Manganese	1.812	13	2.563	11	100.0	1.00	0.5	17.00	3.25	9	0.625	13	**12**
Low Nitrate	1.987	20	2.875	17	100.0	1.00	0.4375	11.00	3.5	14	0.5625	7	**13**
High Iodine	1.875	16	2.938	22	100.0	1.00	0.625	29.00	3.313	10	0.625	13	**14**
pH = 6.7	1.563	9	2.75	15	100.0	1.00	0.5625	23.00	3.813	23	0.6875	21	**15**
High Silicon	1.812	13	2.875	17	100.0	1.00	0.5625	23.00	3.625	17	0.6875	21	**16**
Low Magnesium	1.75	12	2.875	17	93.8	22.00	0.375	7.00	3.75	20	0.5	3	**17**
Altra ABS + Salicylate	2.277	31	3.293	26	100.0	1.00	0.53333333	22.00	3.627	18	0.5333333	6	**18**
High Potassium	1.875	16	3.375	29	100.0	1.00	0.5	17.00	3.75	20	0.625	13	**19**
Low Iodine	2	21	3.313	27	100.0	1.00	0.625	29.00	3.875	24	0.5625	7	**20**
High Copper	2.063	24	2.688	12	87.5	32.00	0.375	7.00	3.125	7	0.625	13	**21**
High Calcium	1.937	18	2.465	8	94.2	19.00	0.35294118	6.00	3.523	15	0.7058824	25	**22**
Low Silicon	1.625	10	2.688	12	93.8	22.00	0.4375	11.00	4.125	29	0.75	28	**23**
High Phosphorus	2.125	28	3.25	23	93.8	22.00	0.4375	11.00	3.938	25	0.5625	7	**24**
Low Copper	1.813	15	3.25	23	93.8	22.00	0.5	17.00	4	26	0.6875	21	**25**
Low Calcium	1.625	10	2.75	15	93.8	22.00	0.6875	31.00	4	26	0.875	32	**26**
Low Phosphorus	2.25	29	3.313	27	87.5	31.00	0.4375	11.00	4	26	0.625	13	**27**
High Magnesium	1.973	19	2.903	21	94.1	21.00	0.58823529	27.00	3.713	19	0.7058824	25	**28**
Control (optimum)	2.125	26	2.875	17	93.8	22.00	0.5625	23.00	4.125	29	0.8125	31	**29**
pH = 5.7	2.438	32	3.25	23	93.8	22.00	0.5625	23.00	3.813	22	0.75	28	**30**
pH = 7.7	2	21	3.813	32	93.8	22.00	0.6875	31.00	4.313	32	0.6875	21	**31**
High Manganese	2.268	30	3.433	30	94.2	19.00	0.58823529	27.00	4.142	29	0.7058824	25	**32**
High Boron	2.125	26	3.563	31	93.8	22.00	0.6875	31.00	4.813	33	0.9375	33	**33**
High Ammonium	3.125	33	4.625	33	81.3	34.00	0.8125	34.00	5.5	34	1	34	**34**

Table 15-4 Hayward media Geometric Mean Rank results

Hayward	**Stage day 12**		**Stage day 19**		**Survival day 19 (%)**		**Any collapse day 19 (%)**		**Stage day 26**		**Any collapse day 26 (%)**		**GMR**
100% vermicompost	0.64	3.00	0.61	1.00	100.0	1.00	0.0%	1	0.70	1	0.0%	1	**1**
Soil Acibenzolar-S-methyl	0.80	8.00	1.04	3.00	100.0	1.00	0.0%	1	1.33	4	37.5%	11	**2**
50% soil 50% compost	0.26	1.00	0.93	2.00	78.0	13	23.1%	10	1.32	2	23.1%	4	**3**
25% soil 75% vermicompost	0.82	10.00	1.07	4.00	92.2	6.00	8.3%	4	1.32	2	33.3%	8	**4**
50% soil 50% vermicompost	0.54	2.00	1.19	6.00	86.1	11.00	13.3%	8	1.79	8	33.3%	8	**5**
50% soil 50% peat	0.74	7.00	1.27	8.00	92.9	5.00	6.7%	3	1.53	6	40.0%	14	**6**
25% soil 75% peat	1.42	19.00	1.83	15.00	100.0	1.00	8.3%	4	2.17	13	33.3%	8	**7**
75% soil 25% pumice	0.80	8.00	1.33	9.00	92.0	7.00	12.5%	7	1.45	5	37.5%	11	**8**
Soil Potassium Phosphate	0.67	5.00	1.25	7.00	74.8	17	25.0%	12	1.75	7	25.0%	5	**9**
Control Soil	0.64	3.00	1.15	5.00	86.8	10.00	13.3%	8	1.80	9	87.5%	26	**10**
75% soil 25% compost	1.26	17.00	1.76	14.00	89.3	9.00	8.3%	4	1.93	11	16.7%	3	**11**
Soil EM 2	0.88	12.00	1.94	17.00	93.7	4.00	25.0%	12	2.13	12	26.7%	7	**12**
25% soil 75% compost	0.83	11.00	1.58	11.00	83.3	12.00	25.0%	12	1.92	10	25.0%	5	**13**
75% soil 25% peat	0.69	6.00	1.44	10.00	75.2	15	23.5%	11	2.25	15	47.1%	17	**14**
75% soil 25% vermicompost	1.18	16.00	1.95	18.00	68.9	19	25.0%	12	2.20	14	37.5%	11	**15**
100% compost	1.15	15.00	1.74	13.00	76.4	14	25.0%	12	2.57	19	58.3%	20	**16**
Soil Ammonium Lingosulfonate	1.02	13.00	1.71	12.00	70.6	18	37.5%	21	2.25	15	41.7%	15	**17**
ACS Acibenzolar-S-methyl	1.75	22.00	3.20	25.00	53.6	24	52.9%	24	4.29	24	15.4%	2	**18**
100% soil	1.06	14.00	1.88	16.00	75.0	16	31.3%	18	2.56	18	43.8%	16	**19**
Soil DL-3Aminobutyric acid	2.08	25.00	2.25	19.00	91.6	8.00	25.0%	12	2.50	17	86.7%	25	**20**
75% soil 25% sawdust	1.69	20.00	2.81	22.00	62.5	21	37.5%	19	3.94	22	81.3%	23	**21**
25% soil 75% pumice	1.73	21.00	2.45	20.00	64.6	20	56.3%	25	3.48	20	81.3%	23	**22**
50% soil 50% sawdust	2.19	26.00	3.06	24.00	62.5	21	37.5%	19	4.25	23	68.8%	21	**23**
Soil EM 1	1.90	23.00	3.02	23.00	53.4	25	46.7%	22	4.40	25	50.0%	18	**24**
50% soil 50% pumice	1.38	18.00	2.74	21.00	20.4	31	93.8%	31	3.92	21	93.8%	29	**25**
ACS EM 2	2.06	24.00	3.25	26.00	56.0	23	50.0%	23	4.56	26	93.8%	29	**26**
ACS Potassium Phosphate	2.31	27.00	3.50	27.00	37.3	26	62.5%	26	5.13	28	93.8%	29	**27**
ACS DL-3Aminobutyric acid	2.50	30.00	3.50	27.00	37.3	26	75.0%	30	5.19	29	80.0%	22	**28**
ACS Ammonium Lingosulfonate	2.31	27.00	3.82	29.00	27.6	28	64.7%	27	4.81	27	88.2%	28	**29**
Control Autoclaved soil	3.25	31.00	4.75	31.00	24.9	29	75.0%	28	5.75	31	56.3%	19	**30**
ACS EM 1	2.38	29.00	4.63	30.00	24.9	29	75.0%	28	5.31	30	87.5%	26	**31**

16 Appendix 4 Raw Data from Plant & Food Research Ruakura

Table 16-1 Hort16A Nutrients Part 1 (lesion length in mm, WS = water stain)

REML analyses:	**Lesion Length day 8**	**Log Lesion Length day 8**	**WS Lesion day 8**	**log WS Les day 8**	**Lesion Length day 13**	**Log Lesion Length day 13**	**WS Lesion day 13**	**log WS Les day 13**	**Lesion Length day 19**	**Log Lesion Length day 19**	**Stage day 8**	**Stage day 13**	**Stage day 19**
Control	5.37	1.70	24.8	3.19	14.2	2.56	35.8	3.30	34.6	3.36	1.81	4.41	5.71
Low Nitrate	6.56	1.84	23.6	3.13	25.2	3.00	35.4	2.91	23.8	3.12	1.94	3.94	5.25
High Nitrate	11.63	2.34	23.4	2.61	22.8	3.02	32.1	2.63	28.5	3.34	1.75	4.38	5.50
High Ammonium	4.97	1.68	21.1	3.05	13.4	2.47	22.9	2.19	22.0	2.92	1.44	3.25	5.25
Low Ammonium	7.56	1.96	27.6	3.29	15.5	2.66	22.7	1.84	36.8	3.48	2.13	4.19	5.25
High Phosphorus	4.88	1.61	29.3	3.29	12.8	2.37	19.5	2.01	38.0	3.52	1.63	3.25	4.63
Low Phosphorus	6.16	1.77	23.0	2.97	11.4	2.47	24.6	2.27	22.8	3.12	1.56	3.44	5.25
High Potassium	6.22	1.85	26.3	3.04	13.0	2.54	24.5	2.20	34.1	3.52	1.15	3.81	5.56
Low Potassium	5.56	1.76	25.9	3.20	19.1	2.84	31.9	2.64	46.8	3.67	1.88	4.06	5.50
Low Calcium	9.13	2.14	25.1	2.85	13.3	2.54	23.5	2.29	28.2	3.15	2.19	4.38	5.13
High Calcium	7.75	1.96	24.1	3.01	12.5	2.44	32.8	3.15	14.4	2.38	2.06	5.00	5.75
Low Copper	9.13	2.14	21.9	2.93	21.5	3.00	25.5	2.10	48.8	3.88	1.13	3.38	5.00
High Copper	7.88	2.02	22.9	2.92	13.5	2.57	30.0	3.08	32.2	3.43	0.94	3.50	5.13
Low Manganese	7.63	2.01	22.9	2.79	18.1	2.78	28.0	2.63	27.4	3.18	1.75	4.00	5.38
High Manganese	6.50	1.84	24.8	3.14	17.8	2.77	30.6	2.47	29.1	3.28	1.88	3.94	5.38
High Boron	9.28	1.88	20.5	2.85	13.3	2.52	19.2	2.43	33.3	3.43	2.04	4.79	5.68
Low Boron	7.44	2.02	25.4	3.20	19.1	2.86	22.7	2.63	14.2	2.96	1.75	4.50	5.50
High Magnesium	8.81	2.04	20.1	2.58	23.9	3.10	22.1	1.93	n/a	n/a	2.19	4.63	6.00
Low Magnesium	8.31	2.04	25.2	3.17	20.9	3.02	37.4	3.11	70.1	4.25	1.63	4.31	5.31
High Zinc	5.88	1.73	28.0	2.94	15.8	2.53	27.3	2.39	32.9	3.45	1.50	3.31	5.38
Low Zinc	9.19	2.10	24.5	2.89	21.4	3.04	36.1	3.35	52.6	3.97	2.38	4.56	5.75
High Iodine	5.19	1.76	24.6	3.16	10.8	2.38	29.6	2.63	20.0	2.93	1.63	3.00	4.00
Low Iodine	8.10	1.90	25.1	2.88	10.6	2.40	24.7	2.71	27.5	3.18	1.54	3.17	5.02
High Silicon	6.56	1.91	17.0	2.60	18.2	2.81	11.3	1.26	28.4	3.36	1.38	3.63	4.94
Low Silicon	5.51	1.67	21.2	3.04	14.8	2.53	33.1	2.90	33.2	3.43	1.10	3.97	5.18
High Nickel	7.62	1.99	25.9	3.24	17.9	2.86	17.6	1.72	27.7	3.39	1.71	4.26	5.65
Low Nickel	3.31	1.41	25.6	3.05	14.5	2.56	37.1	3.49	32.2	3.41	1.38	3.50	5.06
pH = 7.7	7.25	1.77	28.8	3.27	15.4	2.59	24.7	2.22	32.8	3.33	1.81	3.25	4.69
pH = 6.7	7.19	1.81	30.9	3.28	14.5	2.37	33.2	2.78	27.4	3.18	1.38	3.75	5.31
pH = 5.7	4.69	1.62	24.3	2.98	16.2	2.64	35.6	3.16	35.5	3.53	1.00	4.00	5.50
Actigard™	3.45	1.36	22.9	3.10	14.6	2.51	25.0	2.61	29.0	3.16	1.20	3.52	4.87
Altra ABS + Salicylate	6.81	1.83	23.3	3.08	11.9	2.46	30.5	2.95	41.6	3.59	2.00	3.31	4.94
Nitrogen Phosphite + I	8.75	1.98	22.2	2.75	15.4	2.66	18.1	1.73	12.4	2.13	2.38	4.56	5.81
Copper Phosphite	10.81	2.20	26.1	2.93	10.2	2.33	23.5	1.99	n/a	n/a	3.13	5.44	6.00

Table 16-2 Hort16A Nutrients Part 2 (WS = water stain)

Binomial analyses of whole pot data:	WS leaves% day 13	Necrosis leaf % day 13	Plant total collapse % day 13	Necrosis leaf % day 19	Plant Total collapse % day 19	Plant stem collapse % day 13	Plant any collapse % day 13	Plant stem collapse % day 19	Plant tip collapse % day 19	Plant any collapse % day 19
Control	9.4	39.7	15.2	61.3	80.5	37.0	51.3	9.5	48.2	100.0
Low Nitrate	8.8	31.0	12.5	32.0	68.7	31.2	43.7	12.5	37.6	100.0
High Nitrate	28.7	15.1	31.3	54.6	75.0	25.0	56.2	6.3	62.6	100.0
High Ammonium	14.5	20.9	6.3	49.0	56.2	6.2	12.5	12.5	62.6	100.0
Low Ammonium	12.4	38.7	18.8	56.2	62.5	18.7	37.5	6.3	56.3	100.0
High Phosphorus	17.9	17.4	18.8	36.1	37.5	12.5	31.2	12.5	62.6	100.0
Low Phosphorus	12.0	19.8	18.8	39.0	68.7	0.0	18.7	6.3	37.6	100.0
High Potassium	10.0	27.7	25.0	48.8	75.0	18.7	43.7	6.3	56.3	100.0
Low Potassium	12.3	31.8	12.5	44.9	75.0	25.0	37.5	6.3	50.1	100.0
Low Calcium	13.0	34.0	12.5	44.6	50.0	31.2	43.7	12.5	81.3	100.0
High Calcium	1.7	45.8	50.1	57.5	81.2	6.2	56.2	12.5	31.3	100.0
Low Copper	7.1	19.0	6.3	33.4	56.2	18.7	25.0	12.5	68.8	100.0
High Copper	20.4	11.4	25.0	52.5	50.0	18.7	43.7	25.1	75.1	100.0
Low Manganese	14.7	22.1	18.8	61.0	62.5	12.5	31.2	12.5	68.8	100.0
High Manganese	18.5	23.0	6.3	28.3	68.7	25.0	31.2	6.3	68.8	100.0
High Boron	10.7	29.7	48.1	27.2	80.4	6.9	54.7	6.8	39.8	100.0
Low Boron	19.1	27.1	37.6	23.7	68.7	18.7	56.2	12.5	43.8	93.8
High Magnesium	10.8	42.8	43.8	n/a	100.0	6.2	50.0	0.0	25.1	100.0
Low Magnesium	10.2	41.0	12.5	55.8	62.5	25.0	37.5	18.8	87.5	100.0
High Zinc	23.8	23.1	12.5	50.4	62.5	6.2	18.7	12.5	68.8	100.0
Low Zinc	7.1	46.3	25.0	73.1	81.2	18.7	43.7	12.5	12.5	100.0
High Iodine	14.5	13.1	6.3	42.6	25.0	12.5	18.7	12.5	75.1	100.0
Low Iodine	23.8	13.4	16.9	40.9	52.4	5.7	22.5	0.0	65.0	100.0
High Silicon	14.2	26.5	18.8	37.4	31.2	12.5	25.0	31.3	68.8	93.8
Low Silicon	15.1	26.6	11.2	55.7	52.4	17.2	28.2	11.7	47.4	81.2
High Nickel	20.4	28.6	29.5	72.0	82.5	18.0	47.4	5.8	46.6	100.0
Low Nickel	21.8	21.4	12.5	50.5	50.0	6.2	18.7	18.8	81.3	93.8
pH = 7.7	24.3	22.9	12.5	64.7	25.0	0.0	12.5	25.1	75.1	87.5
pH = 6.7	19.3	21.3	6.3	41.5	62.5	25.0	31.2	6.3	81.3	100.0
pH = 5.7	5.8	23.2	25.0	58.4	68.7	18.7	43.7	12.5	62.6	100.0
Actigard™	7.4	17.6	19.8	18.2	53.1	19.9	39.7	13.0	33.4	73.1
Altra ABS + Salicylate	25.7	17.8	6.3	60.0	43.7	12.5	18.7	6.3	81.3	100.0
Nitrogen Phosphite + Iodine	11.1	31.4	31.3	19.7	87.5	18.7	50.0	6.3	50.1	100.0
Copper Phosphite	4.8	61.7	68.8	n/a	100.0	18.7	87.5	0.0	6.3	100.0

Table 16-3 Hayward Nutrients Part 1 (lesion length in mm, WS = water stain)

REML analyses:	**Lesion Length day 12**	**Log Lesion Length day 12**	**WS Lesion day 12**	**log WS Les day 12**	**Lesion Length day 19**	**Log Lesion Length day 19**	**WS Lesion day 19**	**log WS Les day 19**	**Lesion Length day 26**	**Log Lesion Length day 26**	**WS Lesion day 26**	**log WS Les day 26**	**Stage day 12**	**Stage day 19**	**Stage day 26**
Control	6.06	1.76	14.3	1.78	20.0	2.43	14.2	1.50	18.3	2.66	2.4	0.35	2.13	2.88	4.13
Low Nitrate	7.50	1.96	8.8	1.27	14.4	2.25	5.3	0.67	21.7	2.53	0.4	0.02	1.13	2.44	2.88
High Nitrate	10.90	1.88	13.0	1.56	22.9	2.64	15.0	1.88	28.3	2.56	12.8	1.00	1.99	2.88	3.50
High Ammonium	22.94	2.67	22.0	1.81	31.0	2.89	2.4	0.42	21.9	2.93	-0.8	-0.10	3.13	4.63	5.50
Low Ammonium	8.84	2.08	11.9	1.67	20.0	2.53	6.3	0.95	40.2	2.90	3.8	0.57	1.52	2.38	3.31
High Phosphorus	11.63	1.85	19.2	2.23	17.7	2.41	22.0	2.13	40.9	2.89	2.4	0.33	2.13	3.25	3.94
Low Phosphorus	14.06	2.15	11.6	1.43	18.7	2.56	8.6	1.16	27.7	2.55	7.7	1.32	2.25	3.31	4.00
High Potassium	10.94	2.11	14.8	1.86	13.6	2.19	19.4	2.27	35.8	2.74	1.4	0.29	1.88	3.38	3.75
Low Potassium	4.96	1.58	7.7	1.26	11.4	2.11	7.5	1.16	21.1	2.30	7.9	1.35	1.41	2.43	3.01
Low Calcium	5.94	1.81	12.1	1.66	10.0	2.20	8.7	1.23	15.8	2.63	6.1	0.79	1.94	2.47	3.52
High Calcium	7.50	1.89	10.6	1.10	27.6	3.00	18.3	1.03	47.5	3.37	3.1	0.30	1.63	2.75	4.00
Low Copper	7.31	1.89	12.8	1.33	18.5	2.60	14.7	1.51	41.5	3.29	4.3	0.49	2.06	2.69	3.13
High Copper	6.50	1.83	7.0	1.10	19.0	2.55	20.9	1.71	32.9	3.14	9.5	0.85	1.81	3.25	4.00
Low Manganese	6.35	1.80	9.1	1.29	19.9	2.47	16.7	1.65	40.1	3.13	0.4	0.04	2.27	3.43	4.14
High Manganese	5.94	1.74	8.6	1.13	13.9	2.24	13.6	1.43	44.9	3.00	0.3	0.03	1.81	2.56	3.25
High Boron	18.25	2.16	6.3	0.82	17.9	2.55	14.1	1.23	32.4	2.80	3.9	0.46	2.13	3.56	4.81
Low Boron	4.07	1.55	12.0	1.80	9.3	1.96	17.5	2.23	45.2	3.02	3.5	0.58	1.26	2.14	2.68
High Magnesium	5.91	1.80	11.1	1.60	22.6	2.63	8.1	1.08	47.6	3.14	2.7	0.47	1.97	2.90	3.71
Low Magnesium	7.94	2.00	18.9	2.25	20.0	2.53	8.7	1.34	22.5	2.72	9.8	1.51	1.75	2.88	3.75
High Zinc	5.13	1.59	9.2	1.30	22.8	2.55	13.0	1.38	29.4	2.81	1.4	0.26	1.69	2.69	3.56
Low Zinc	7.38	1.87	13.7	1.77	16.2	2.42	17.6	1.90	37.1	3.07	2.6	0.33	1.38	2.31	3.31
High Iodine	6.06	1.89	12.4	1.88	14.5	2.47	6.2	0.70	43.6	2.81	2.7	0.51	1.88	2.94	3.31
Low Iodine	10.00	2.08	13.4	1.28	25.2	2.75	9.8	1.36	13.8	2.44	0.3	0.06	2.00	3.31	3.88
High Silicon	11.00	2.10	8.6	1.02	18.6	2.48	19.1	1.73	28.8	2.70	4.2	0.59	1.81	2.88	3.63
Low Silicon	10.00	1.92	22.8	2.23	24.0	2.82	25.2	1.83	23.6	2.52	12.3	1.54	1.63	2.69	4.13
High Nickel	7.33	1.86	13.5	1.70	21.1	2.47	7.9	0.97	26.4	2.68	3.8	0.56	2.04	2.51	3.40
Low Nickel	4.03	1.43	22.8	1.85	7.3	1.96	16.1	1.67	18.9	2.50	4.3	0.43	2.11	2.49	3.09
pH = 7.7	11.38	2.09	18.1	1.90	18.2	2.50	15.1	1.55	27.0	2.61	4.0	0.76	2.00	3.81	4.31
pH = 6.7	7.25	2.00	15.1	1.65	23.3	2.89	30.3	2.25	33.2	2.95	10.9	1.10	1.56	2.75	3.81
pH = 5.7	14.19	2.24	18.8	1.56	15.9	2.56	6.1	0.80	31.9	2.97	0.4	0.02	2.44	3.25	3.81
Actigard^{TM}	8.31	1.95	8.9	1.19	9.7	2.01	4.9	0.88	8.1	2.10	2.8	0.58	0.63	1.75	2.31
Altra ABS + Salicylate	12.94	2.33	32.7	2.51	16.1	2.34	16.3	1.70	11.4	2.29	9.4	0.80	2.28	3.29	3.63
Nitrogen Phosphite + I	5.56	1.69	10.2	1.50	17.9	2.67	0.0	0.00	22.2	2.73	2.9	0.62	1.25	2.00	3.19
Copper Phosphite	4.56	1.63	5.1	0.99	6.9	1.72	8.2	1.30	12.2	2.11	4.3	0.75	0.81	2.38	2.50

Table 16-4 Hayward Nutrients Part 2 (WS = water stain)

	WS leaves % day 12	Necrosis leaf % day 12	WS leaves % day 19	Necrosis leaf % day 19	WS leaves % day 26	Necrosis leaf % day 26	Plant collapse % day 26	Plant tip collapse % day 12	Plant any collapse % day 12	Plant tip collapse % day 19	Plant any collapse % day 19	Plant stem collapse % day 26	Plant tip collapse % day 26	Plant stem collapse % day 26
Control	24.4	18.6	25.3	31.9	7.3	33.1	37.6	6.2	6.2	25.1	31.4	37.6	81.3	6.2
Low Nitrate	11.3	2.8	20.2	11.1	8.1	12.2	25.0	0.0	0.0	18.8	31.4	12.5	37.6	0.0
High Nitrate	30.0	7.6	17.9	27.7	10.8	12.6	37.6	0.0	0.0	25.1	37.6	18.8	56.3	0.0
High Ammonium	28.7	12.2	21.0	16.8	3.1	20.0	68.8	6.2	25.0	6.3	68.8	12.5	100.0	18.7
Low Ammonium	11.5	9.9	12.1	27.1	6.3	26.8	31.3	16.6	16.6	37.6	37.6	18.8	50.1	0.0
High Phosphorus	32.2	2.7	25.7	10.5	7.3	18.1	31.3	0.0	0.0	12.6	31.4	18.8	56.3	6.2
Low Phosphorus	20.8	11.0	15.9	14.0	14.8	8.5	31.3	12.5	18.7	12.6	37.6	6.3	50.1	12.5
High Potassium	17.7	7.6	13.6	8.9	8.4	7.2	37.6	0.0	0.0	0.0	31.4	12.5	50.1	0.0
Low Potassium	11.4	10.1	16.0	15.4	4.7	4.9	28.8	6.1	6.1	21.9	33.7	22.8	51.5	0.0
Low Calcium	16.7	13.1	6.9	33.3	1.1	18.2	28.8	5.4	5.5	34.5	34.4	34.7	63.6	5.8
High Calcium	9.5	12.5	9.1	33.8	4.9	32.6	25.0	18.7	18.7	50.1	50.1	31.3	62.6	6.2
Low Copper	17.6	9.3	20.4	25.7	8.7	29.3	12.5	6.2	6.2	25.1	31.4	43.8	62.6	12.5
High Copper	18.1	9.5	20.0	34.5	13.1	20.4	31.3	6.2	6.2	18.8	37.6	31.3	68.8	6.2
Low Manganese	20.6	15.3	15.9	23.0	15.8	21.7	40.5	10.8	11.0	34.5	57.6	17.3	63.6	5.8
High Manganese	14.9	15.4	10.5	31.7	3.2	23.8	25.0	6.2	6.2	37.6	37.6	37.6	62.6	0.0
High Boron	24.0	15.9	29.8	24.5	6.6	28.4	50.1	18.7	18.7	25.1	50.1	37.6	87.5	6.2
Low Boron	10.4	11.1	14.7	12.5	5.7	15.9	0.0	14.6	14.4	48.3	48.2	60.9	61.5	0.0
High Magnesium	12.9	14.2	8.4	29.5	4.2	19.5	28.8	18.3	18.2	39.1	39.5	28.6	63.4	5.9
Low Magnesium	18.3	10.9	16.1	21.9	13.9	7.6	37.6	6.2	6.2	12.6	31.4	0.0	43.8	6.2
High Zinc	13.2	17.5	10.4	25.7	7.5	21.6	31.3	0.0	0.0	25.1	37.6	25.1	56.3	0.0
Low Zinc	11.6	12.4	8.8	23.4	2.5	12.0	31.3	6.2	6.2	31.4	31.4	37.6	68.8	0.0
High Iodine	17.9	16.6	15.1	23.6	4.0	26.6	25.0	6.2	6.2	25.1	43.9	25.1	50.1	0.0
Low Iodine	16.8	12.8	10.5	12.7	15.4	11.9	43.8	6.2	6.2	25.1	43.9	12.5	56.3	0.0
High Silicon	23.6	12.4	19.3	27.3	7.6	19.3	31.3	6.2	6.2	31.4	43.9	31.3	62.6	0.0
Low Silicon	11.5	12.3	8.2	24.2	6.6	13.0	50.1	0.0	6.2	18.8	37.6	18.8	75.1	6.2
High Nickel	42.8	1.4	30.0	19.8	22.3	24.3	18.5	15.7	16.5	27.9	27.5	23.5	41.2	0.0
Low Nickel	31.3	13.6	22.7	29.7	23.9	21.3	16.7	0.0	0.0	16.8	16.8	33.4	50.2	0.0
pH = 7.7	15.4	17.7	14.9	14.8	10.3	9.7	50.1	24.9	25.0	18.8	56.4	18.8	68.8	6.2
pH = 6.7	11.7	15.5	19.4	15.8	7.6	15.2	37.6	6.2	6.2	31.4	43.9	25.1	62.6	0.0
pH = 5.7	22.0	22.2	10.3	23.4	9.3	3.6	43.8	0.0	6.2	25.1	56.4	25.1	75.1	6.2
Actigard™	3.7	0.0	18.7	0.0	15.9	2.8	12.5	0.0	0.0	18.8	25.1	25.1	37.6	0.0
Altra ABS + Salicylate	27.6	12.0	25.5	8.5	23.0	2.0	40.9	0.0	14.4	20.5	48.2	13.7	54.8	0.0
Nitrogen Phosphite + I	8.4	7.6	30.6	15.1	18.7	8.6	18.8	6.2	6.2	25.1	31.4	31.3	56.3	12.5
Copper Phosphite	3.4	7.8	25.9	16.49	20.4	10.6	6.3	6.2	6.2	12.6	18.8	50.1	56.3	0.0

Table 16-5 Hort16A Biologicals Part 1 (lesion length in mm, WS = water stain)

	Lesion Length day 5	Log Lesion Length day 5	WS Lesion day 5	log WS Les day 5	Lesion Length day 8	Log Lesion Length day 8	WS Lesion day 8	log WS Les day 8	Lesion Length day 13	Log Lesion Length day 13	WS Lesion day 13	log WS Les day 13
Control Soil	2.63	1.23	9.3	1.60	4.00	1.49	21.6	2.43	15.0	2.56	34.8	2.85
EM 1 Soil	2.12	1.12	8.0	1.40	4.01	1.52	15.9	2.12	8.1	2.08	38.2	3.38
EM 2 Soil	2.31	1.19	9.1	1.67	3.36	1.41	16.8	2.15	9.7	2.17	31.7	2.82
Ammonium Lingosulfonate Soil	2.54	1.23	9.5	1.44	4.02	1.51	10.2	1.50	8.2	2.06	31.2	2.74
Potassium Phosphate Soil	2.46	1.23	7.6	1.47	3.17	1.36	17.5	2.31	6.6	1.82	43.1	3.50
Acibenzolar-S-methyl Soil	2.46	1.23	7.9	1.39	3.17	1.38	19.3	2.62	13.8	2.48	28.1	2.90
DL-3Aminobutyric acid Soil	2.67	1.29	11.3	1.88	2.58	1.25	15.0	2.21	15.2	2.46	23.8	2.56
Control Autoclaved Soil	2.22	1.15	4.4	1.03	4.31	1.59	10.5	1.65	10.0	2.18	13.6	1.89
EM 1 Autoclaved Soil	3.35	1.43	6.4	1.34	4.98	1.72	10.2	1.75	11.0	2.28	16.9	2.09
EM 2 Autoclaved Soil	2.30	1.15	5.6	1.21	3.09	1.33	9.5	1.62	6.9	1.84	23.9	2.78
Ammonium Lingosulfonate Autoclaved Soil	2.44	1.22	4.6	1.06	3.75	1.49	10.5	1.74	10.1	2.13	15.6	1.96
Potassium Phosphate Autoclaved Soil	2.16	1.12	6.6	1.41	3.00	1.31	11.0	1.92	7.7	2.06	23.4	2.61
Acibenzolar-S-methyl Autoclaved Soil	2.16	1.14	6.8	1.45	3.96	1.53	16.8	2.44	11.5	2.34	24.9	2.62
DL-3Aminobutyric acid Autoclaved Soil	1.77	1.00	6.6	1.26	2.69	1.25	12.6	2.01	6.2	1.89	17.2	2.12

Table 16-6 Hort16A Biologicals Part 2 (WS = water stain)

	Lesion Length day 19	Log Lesion Length day 19	WS Lesion day 19	log WS Les day 19	Stage day 5	Stage day 8	Stage day 13	Stage day 19	WS leaves % day 8	WS leaves % day 13	Necrosis leaf % day 13	Necrosis leaf % day 19	Plant collapse % day 19	Plant any collapse % day 13	Plant stem collapse % day 19	Plant any collapse % day 19
Control Soil	27.2	3.25	61.3	3.53	0.42	1.50	3.00	4.25	18.4	14.4	19.3	44.0	8.3	8.5	41.4	49.7
EM 1 Soil	21.8	2.93	67.0	3.96	0.36	0.55	1.45	3.48	6.8	4.8	13.9	32.1	9.0	0.0	0.0	9.1
EM 2 Soil	18.7	2.82	52.8	3.68	0.51	0.77	2.22	3.69	28.9	10.2	16.1	33.9	0.0	0.0	41.8	41.4
Ammonium Lingosulfonate Soil	15.2	2.68	63.1	4.10	0.42	0.75	2.83	4.33	14.2	5.0	21.3	36.9	24.9	17.0	16.5	41.3
Potassium Phosphate Soil	12.3	2.39	77.4	4.37	0.17	0.83	2.50	3.58	22.7	6.1	18.9	41.0	0.0	8.5	24.8	33.0
Acibenzolar-S-methyl Soil	24.9	3.03	45.1	3.33	0.42	0.67	2.00	4.00	13.2	7.6	19.5	38.7	0.0	8.5	58.0	58.0
DL-3Aminobutyric acid Soil	11.9	2.17	36.4	3.80	0.08	1.58	3.75	5.58	26.2	0.0	94.6	71.5	66.6	8.5	24.8	91.6
Control Autoclaved Soil	15.2	2.54	37.3	3.63	0.44	1.27	2.63	4.56	11.0	3.6	35.3	49.9	37.4	19.1	24.8	62.2
EM 1 Autoclaved Soil	16.5	2.82	41.8	3.87	0.57	0.58	2.83	4.83	25.0	10.8	15.0	39.4	24.9	17.0	41.4	66.4
EM 2 Autoclaved Soil	31.9	3.61	33.9	2.38	0.17	0.70	2.58	5.19	16.4	2.3	28.6	38.2	46.4	15.2	69.7	92.4
Ammonium Lingosulfonate Autoclaved Soil	14.7	2.58	48.6	3.80	0.69	1.56	3.38	5.44	22.8	7.0	48.2	71.7	62.4	25.4	18.6	81.0
Potassium Phosphate Autoclaved Soil	10.1	2.35	39.2	3.58	0.31	0.94	3.06	4.94	27.5	3.1	21.4	36.8	37.4	38.1	37.2	74.7
Acibenzolar-S-methyl Autoclaved Soil	28.0	3.31	58.5	4.07	0.07	1.54	3.17	5.15	19.6	6.3	25.1	29.9	46.4	26.3	46.7	93.3
DL-3Aminobutyric acid Autoclaved Soil	4.0	2.02			0.30	1.66	3.70	5.60	20.9	0.0	82.7	51.6	78.8	27.9	0.0	79.0

Table 16-7 Hort16A Media Part 1 (lesion length in mm, WS = water stain)

	Lesion Length day 5	Log Lesion Length day 5	WS Lesion day 5	log WS Les day 5	Lesion Length day 8	Log Lesion Length day 8	WS Lesion day 8	log WS Les day 8	Lesion Length day 13	Log Lesion Length day 13	WS Lesion day 13	log WS Les day 13
Control	2.29	1.17	10.4	1.83	4.00	1.54	22.1	2.72	10.0	2.15	25.2	2.75
Treatment 54	2.38	1.21	6.0	1.20	2.75	1.28	16.0	2.27	7.3	1.95	37.5	2.89
Treatment 55	3.02	1.29	5.8	1.22	4.73	1.57	16.8	2.22	18.7	2.51	35.7	2.99
Treatment 56	2.39	1.19	6.0	1.30	5.57	1.75	20.7	2.76	9.4	2.13	28.3	2.98
Treatment 57	2.47	1.22	10.0	1.60	4.20	1.59	13.2	1.91	8.8	2.17	27.0	2.84
Treatment 58	2.54	1.23	10.1	1.80	3.00	1.36	17.9	2.37	11.7	2.05	43.0	3.26
Treatment 59	2.36	1.20	6.3	1.29	3.88	1.52	19.3	2.42	10.6	2.36	26.9	3.13
Treatment 60	2.50	1.22	1.9	0.53	3.63	1.45	6.9	1.34	8.6	2.06	14.2	2.19
Treatment 61	1.81	1.01	6.6	1.32	3.19	1.38	17.1	2.30	7.0	1.93	24.1	2.45
Treatment 62	2.38	1.20	10.4	1.70	3.96	1.50	20.3	2.45	8.3	2.07	27.9	2.62
Treatment 63	2.63	1.24	9.3	1.75	3.25	1.37	16.7	2.14	9.1	2.12	40.8	3.41
Treatment 64	1.88	1.03	3.5	0.90	2.67	1.22	13.4	1.92	5.8	1.85	20.8	2.64
Treatment 65	2.69	1.29	2.8	0.71	3.19	1.38	9.3	1.82	6.0	1.78	15.8	2.53
Treatment 66	2.17	1.13	8.1	1.48	2.67	1.25	15.4	2.09	11.6	2.33	33.6	2.72
Treatment 67	2.25	1.16	7.8	1.17	7.30	1.86	23.3	2.95	21.2	2.88	49.6	3.48
Treatment 68	2.99	1.30	7.4	1.56	4.33	1.55	16.5	2.00	12.1	2.25	29.5	2.85
Treatment 69	2.64	1.28	7.0	1.48	3.61	1.49	21.0	2.23	8.7	2.22	39.6	3.36

Table 16-8 Hort16A Media Part 2 (lesion length in mm, WS = water stain)

	Lesion Length day 19	Log Lesion Length day 19	WS Lesion day 19	log WS Les day 19	Stage day 5	Stage day 8	Stage day 13	Stage day 19	WS leaves % day 8	WS leaves % day 13	Necrosis leaf % day 13	Necrosis leaf % day 19	Plant collapse % day 19	Plant any collapse % day 13	Plant stem collapse % day 19	Plant any collapse % day 19
Control	17.3	2.82	60.9	4.15	0.33	1.25	2.83	4.00	14.0	8.4	17.9	28.7	33.3	25.0	8.3	41.5
Treatment 54	12.9	2.57	76.0	4.36	0.25	0.67	1.67	3.50	17.4	10.2	12.2	20.9	8.3	0.0	33.1	49.9
Treatment 55	26.2	3.22	68.7	4.31	0.19	1.19	2.45	4.54	17.1	7.4	14.4	53.5	25.3	24.4	45.3	75.8
Treatment 56	11.5	2.46	46.4	3.87	0.18	0.66	2.16	4.51	0.0	8.1	20.0	42.1	8.3	8.3	49.8	58.2
Treatment 57	16.6	2.72	49.9	3.13	0.15	0.79	2.26	3.23	11.8	5.3	23.1	40.0	0.0	0.0	20.8	21.2
Treatment 58	7.1	1.94	63.6	4.11	0.33	1.50	2.33	4.17	14.4	9.9	18.6	48.8	16.6	0.0	24.8	49.9
Treatment 59	16.7	2.79	52.6	4.30	0.38	0.80	2.64	4.91	19.2	8.3	33.9	45.5	38.2	15.0	45.4	84.3
Treatment 60	14.2	2.57	23.4	3.33	0.19	2.50	3.31	4.75	16.3	2.7	69.3	82.5	24.9	18.8	43.5	68.6
Treatment 61	15.1	2.71	39.2	3.41	0.14	1.21	2.99	3.84	15.9	15.8	23.0	57.3	0.0	7.3	28.9	28.6
Treatment 62	13.0	2.52	68.6	4.23	0.33	1.18	2.92	3.75	17.8	10.1	22.0	47.9	8.3	8.3	16.5	24.9
Treatment 63	16.1	2.69	60.0	3.66	0.08	0.92	2.17	3.67	20.4	7.7	10.8	36.0	8.3	0.0	24.8	41.5
Treatment 64	8.7	2.14	39.5	3.64	0.17	1.67	2.92	4.42	24.1	0.0	48.1	51.6	33.3	16.7	8.3	41.5
Treatment 65	10.3	2.26	22.2	3.10	0.19	2.13	2.94	4.13	29.7	2.8	63.2	67.0	24.9	0.0	18.6	43.6
Treatment 66	17.0	2.81	62.8	4.16	0.34	1.58	3.09	3.96	14.9	5.1	43.1	68.2	15.6	7.8	0.0	15.8
Treatment 67	20.6	2.92	83.8	4.49	0.27	0.75	2.46	3.56	22.7	6.6	37.3	65.8	0.0	0.0	29.9	35.6
Treatment 68	16.7	2.54	61.5	3.82	0.14	0.98	2.50	3.54	19.7	3.4	24.2	35.1	6.7	0.0	13.3	20.0
Treatment 69	1.9	1.62	45.4	3.69	0.54	1.75	2.68	4.52	0.0	7.5	19.8	24.8	11.1	11.2	77.8	88.9

Table 16-9 Hayward Media Part 1 (WS = water stain)

	Stage day 12	Stage day 19	Stage day 26	WS leaves % day 12	Necrosis leaf % day 12	WS leaves % day 19	Necrosis leaf % day 19	WS leaves % day 26	Necrosis leaf % day 26	Plant collapse % day 26	Plant stem collapse % day 19	Plant tip collapse % day 19	Plant any collapse % day 19	Plant stem collapse % day 26	Plant tip collapse % day 26	Plant any collapse % day 26
Control	1.06	1.88	2.56	17.0	15.0	2.8	25.6	8.5	16.6	31.2	0.0	12.5	25.0	0.0	12.5	43.8
Treatment 54	1.15	1.74	2.57	18.0	2.3	13.1	13.2	4.6	29.2	0.0	0.0	23.2	23.7	0.0	48.2	51.6
Treatment 55	0.64	0.61	0.70	3.8	1.3	3.2	1.1	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Treatment 56	0.80	1.33	1.45	8.9	4.7	1.2	10.1	2.2	9.9	0.0	8.4	7.4	8.0	8.4	35.4	38.6
Treatment 57	0.69	1.44	2.25	11.9	5.7	4.0	16.6	3.0	19.4	6.2	0.0	24.4	24.8	0.0	36.5	43.1
Treatment 58	1.26	1.76	1.93	12.8	4.8	9.9	4.9	6.4	13.2	0.0	0.0	9.9	10.7	0.0	9.8	10.7
Treatment 59	1.18	1.95	2.20	19.7	14.3	1.6	8.3	1.4	11.8	32.3	16.7	0.0	31.1	0.0	14.6	45.7
Treatment 60	1.69	2.81	3.94	12.4	20.2	3.2	28.3	2.3	28.0	37.4	12.6	12.5	37.5	18.9	37.5	81.2
Treatment 61	1.38	2.74	3.92	8.2	25.4	3.9	30.9	3.9	28.8	29.3	27.4	66.6	79.7	41.7	54.5	94.1
Treatment 62	0.74	1.27	1.53	10.7	0.0	5.6	5.5	4.5	12.9	0.0	0.0	7.2	7.1	0.0	41.8	45.5
Treatment 63	0.26	0.93	1.32	1.4	0.0	1.1	4.7	1.1	10.4	0.0	0.0	22.6	22.0	0.0	22.3	21.9
Treatment 64	0.54	1.19	1.79	5.8	0.0	6.0	6.0	7.1	1.0	6.4	0.0	13.9	13.9	0.0	27.5	33.6
Treatment 65	2.19	3.06	4.25	7.0	27.8	3.1	30.4	0.0	23.9	56.2	18.8	12.5	37.5	6.3	6.3	68.7
Treatment 66	1.73	2.45	3.48	18.0	19.1	3.9	37.3	7.4	28.4	42.5	16.7	25.0	35.4	5.2	36.0	79.5
Treatment 67	1.42	1.83	2.17	17.9	8.4	11.4	12.1	11.3	11.6	0.0	0.0	0.0	0.0	8.4	16.7	25.1
Treatment 68	0.83	1.58	1.92	10.5	0.0	8.9	3.4	8.8	4.3	0.0	0.0	16.6	16.7	0.0	25.0	25.1
Treatment 69	0.82	1.07	1.32	11.9	0.0	8.8	3.0	9.1	0.0	10.0	0.0	7.6	7.8	0.0	23.8	34.9

Table 16-10 Hayward Media Part 2 (lesion length in mm, WS = water stain)

	Lesion Length day 12	Log Lesion Length day 12	WS Lesion day 12	log WS Les day 12	Lesion Length day 19	Log Lesion Length day 19	WS Lesion day 19	log WS Les day 19	Lesion Length day 26	Log Lesion Length day 26	WS Lesion day 26	log WS Les day 26
Control	4.38	1.58	6.6	1.17	10.00	1.96	11.4	1.82	11.0	2.09	14.3	1.56
Treatment 54	3.08	1.32	4.9	0.81	8.39	1.88	8.8	1.22	14.5	2.36	3.7	0.60
Treatment 55	2.62	1.27	2.9	0.72	3.06	1.31	3.8	0.93	4.5	1.59	3.8	0.80
Treatment 56	3.27	1.43	7.7	1.46	3.34	1.46	8.3	1.57	14.3	2.06	7.5	1.42
Treatment 57	3.63	1.47	5.3	1.01	11.56	1.93	8.8	1.43	22.5	2.49	6.3	1.08
Treatment 58	4.58	1.63	5.3	1.12	4.20	1.69	5.8	0.99	12.4	2.09	3.7	0.61
Treatment 59	3.96	1.50	7.7	1.13	10.45	1.93	8.9	1.62	7.2	1.66	4.5	1.07
Treatment 60	3.78	1.45	6.9	1.21	10.48	2.21	3.4	0.50	13.3	2.31	8.0	0.86
Treatment 61	3.44	1.41	7.8	1.17	18.03	2.42	2.8	0.46	16.1	2.26	4.1	0.60
Treatment 62	3.42	1.41	5.8	1.27	7.24	1.75	6.4	1.21	10.5	1.99	2.6	0.54
Treatment 63	2.47	1.23	6.2	1.21	4.02	1.48	8.3	1.37	9.2	1.83	10.7	1.40
Treatment 64	2.89	1.32	7.4	1.52	6.58	1.71	12.9	1.64	7.3	1.93	4.6	0.83
Treatment 65	2.50	1.23	1.9	0.45	6.88	1.95	0.2	0.02	6.9	1.75	0.3	0.16
Treatment 66	4.02	1.50	1.3	0.33	9.77	2.05	6.7	0.75	11.5	2.09	4.5	0.69
Treatment 67	3.50	1.45	3.8	0.80	15.75	2.11	12.0	1.66	20.2	2.37	8.9	1.41
Treatment 68	4.00	1.50	5.3	1.20	6.33	1.76	9.9	1.01	9.7	2.05	3.3	0.50
Treatment 69	3.17	1.37	5.2	1.25	3.72	1.43	11.9	1.58	3.9	1.56	7.7	1.54

Table 16-11 Hayward Media Part 3 (WS = water stain)

	Stage day 12	**Stage day 19**	**Stage day 26**	**WS leaves % day 12**	**Necrosis leaf % day 12**	**WS leaves % day 19**	**Necrosis leaf % day 19**	**WS leaves % day 26**	**Necrosis leaf % day 26**	**Plant collapse % day 26**	**Plant stem collapse % day 19**	**Plant tip collapse % day 19**	**Plant any collapse % day 19**	**Plant stem collapse % day 26**	**Plant tip collapse % day 26**	**Plant any collapse % day 26**
Control	1.06	1.88	2.56	17.0	15.0	2.8	25.6	8.5	16.6	31.2	0.0	12.5	25.0	0.0	12.5	43.8
Treatment 54	1.15	1.74	2.57	18.0	2.3	13.1	13.2	4.6	29.2	0.0	0.0	23.2	23.7	0.0	48.2	51.6
Treatment 55	0.64	0.61	0.70	3.8	1.3	3.2	1.1	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Treatment 56	0.80	1.33	1.45	8.9	4.7	1.2	10.1	2.2	9.9	0.0	8.4	7.4	8.0	8.4	35.4	38.6
Treatment 57	0.69	1.44	2.25	11.9	5.7	4.0	16.6	3.0	19.4	6.2	0.0	24.4	24.8	0.0	36.5	43.1
Treatment 58	1.26	1.76	1.93	12.8	4.8	9.9	4.9	6.4	13.2	0.0	0.0	9.9	10.7	0.0	9.8	10.7
Treatment 59	1.18	1.95	2.20	19.7	14.3	1.6	8.3	1.4	11.8	32.3	16.7	0.0	31.1	0.0	14.6	45.7
Treatment 60	1.69	2.81	3.94	12.4	20.2	3.2	28.3	2.3	28.0	37.4	12.6	12.5	37.5	18.9	37.5	81.2
Treatment 61	1.38	2.74	3.92	8.2	25.4	3.9	30.9	3.9	28.8	29.3	27.4	66.6	79.7	41.7	54.5	94.1
Treatment 62	0.74	1.27	1.53	10.7	0.0	5.6	5.5	4.5	12.9	0.0	0.0	7.2	7.1	0.0	41.8	45.5
Treatment 63	0.26	0.93	1.32	1.4	0.0	1.1	4.7	1.1	10.4	0.0	0.0	22.6	22.0	0.0	22.3	21.9
Treatment 64	0.54	1.19	1.79	5.8	0.0	6.0	6.0	7.1	1.0	6.4	0.0	13.9	13.9	0.0	27.5	33.6
Treatment 65	2.19	3.06	4.25	7.0	27.8	3.1	30.4	0.0	23.9	56.2	18.8	12.5	37.5	6.3	6.3	68.7
Treatment 66	1.73	2.45	3.48	18.0	19.1	3.9	37.3	7.4	28.4	42.5	16.7	25.0	35.4	5.2	36.0	79.5
Treatment 67	1.42	1.83	2.17	17.9	8.4	11.4	12.1	11.3	11.6	0.0	0.0	0.0	0.0	8.4	16.7	25.1
Treatment 68	0.83	1.58	1.92	10.5	0.0	8.9	3.4	8.8	4.3	0.0	0.0	16.6	16.7	0.0	25.0	25.1
Treatment 69	0.82	1.07	1.32	11.9	0.0	8.8	3.0	9.1	0.0	10.0	0.0	7.6	7.8	0.0	23.8	34.9

Table 16-12 Hayward Biologicals (WS = water stain)

	Stage day 12	Stage day 19	Stage day 26	WS leaves % day 12	Necrosis leaf % day 12	WS leaves % day 19	Necrosis leaf % day 19	WS leaves % day 26	Necrosis leaf % day 26	Plant collapse % day 26	Plant stem collapse % day 19	Plant tip collapse % day 19	Plant any collapse % day 19	Plant stem collapse % day 26	Plant tip collapse % day 26	Plant any collapse % day 26
Control Soil	0.64	1.15	1.80	8.7	0.0	7.4	2.0	11.7	4.8	0.0	0.0	13.3	13.2	6.8	20.3	26.7
EM 1 Soil	1.90	3.02	4.40	28.4	20.5	4.7	46.5	2.8	42.8	26.4	0.0	46.6	46.6	0.0	47.2	73.5
EM 2 Soil	0.88	1.94	2.13	9.8	5.7	4.3	18.8	1.0	22.7	6.3	6.2	0.0	6.3	6.2	25.0	37.6
Ammonium Lingosulfonate Soil	1.02	1.71	2.25	20.5	1.3	4.9	10.3	4.5	1.1	11.9	0.0	30.4	29.5	6.8	11.9	30.2
Potassium Phosphate Soil	0.67	1.25	1.75	10.8	0.0	5.9	4.7	8.3	4.6	0.0	0.0	25.1	25.2	0.0	25.0	25.1
Acibenzolar-S-methyl Soil	0.80	1.04	1.33	6.6	1.6	3.8	3.5	3.4	4.3	0.0	0.0	0.0	0.0	0.0	15.2	15.2
DL-3Aminobutyric acid Soil	2.08	2.25	2.50	23.0	28.7	5.5	41.2	6.8	35.9	0.0	0.0	8.4	8.4	0.0	0.0	0.0
Control Autoclaved Soil	3.25	4.75	5.75	29.7	27.0	4.7	41.8	16.7	12.6	87.6	31.2	25.1	75.1	6.2	6.3	93.8
EM 1 Autoclaved Soil	2.38	4.63	5.31	34.6	14.9	5.8	20.2	4.5	5.2	62.7	56.2	0.0	75.1	24.7	25.0	93.8
EM 2 Autoclaved Soil	2.06	3.25	4.56	19.2	13.2	2.4	21.3	4.5	25.3	31.4	37.4	12.5	44.0	37.1	12.5	75.1
Ammonium Lingosulfonate Autoclaved Soil	2.31	3.82	4.81	41.5	10.0	9.4	27.8	11.6	14.3	54.2	30.5	30.0	72.4	16.8	12.2	83.0
Potassium Phosphate Autoclaved Soil	2.31	3.50	5.13	25.0	17.6	5.3	47.1	3.6	8.0	75.1	12.5	31.3	62.7	6.2	6.3	87.5
Acibenzolar-S-methyl Autoclaved Soil	1.75	3.20	4.29	19.4	14.3	2.7	15.8	4.8	5.5	46.6	29.7	5.8	46.4	18.2	29.2	88.1
DL-3Aminobutyric acid Autoclaved Soil	2.50	3.50	5.19	32.3	26.1	8.9	40.2	8.5	27.2	62.7	6.2	43.9	62.7	6.2	6.3	75.1

17 Appendix 5 Nutrient Solution Concentrations & Results

Table 17-1 Concentrations of nutrient solutions in PPM

	Low	Medium	High
Nitrate-N	8	16	24
Ammonium-N	8	16	24
P	30	45	60
K	30	90	60
Mg	500	1000	1500
Ca	1250	1875	2500
Mn	22	33	40
B	0.8	1.2	1.4
Cu	2.0	6.0	10.0
Zn	3.0	8.5	14.0
I	0.1	0.5	2.5
Si	5.0	10.0	15.0
Ni	1.0	5.0	15.0

18 Appendix 6 Seedling mineral composition

Table 18-1 Seedling mineral composition

		N	Phosphorus	Potassium	Sulphur	Calcium	Magnesium	Sodium	Iron	Manganese	Zinc	Copper	Boron	Chloride	Nickel
		%	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg
Hort16A	**Control**	1.63	0.18	1.87	0.15	0.80	0.31	0.08	162.00	54.00	26.67	1.00	16.00	0.41	0.38
Hort16A	**High ammonium**	1.80	0.14	2.47	0.19	1.17	0.28	0.06	83.67	33.00	24.33	4.00	16.33	0.30	
Hort16A	**High boron**	1.73	0.22	2.20	0.14	0.75	0.35	0.08	113.67	59.67	24.33	2.00	18.00	0.47	
Hort16A	**High calcium**	1.77	0.19	1.97	0.14	0.79	0.28	0.08	152.33	69.33	23.67	1.00	17.67	0.48	
Hort16A	**High iodine**	1.57	0.17	1.83	0.14	0.70	0.27	0.09	84.67	78.33	28.33	1.33	16.00	0.37	
Hort16A	**High magnesium**	1.73	0.22	2.23	0.17	0.90	0.38	0.09	175.00	85.67	29.00	2.33	18.00	0.53	
Hort16A	**High phosphorous**	1.60	0.17	2.00	0.13	0.64	0.24	0.07	94.33	64.33	22.00	1.00	15.67	0.42	
Hort16A	**Low Calcium**	1.87	0.21	2.43	0.13	0.80	0.30	0.08	199.00	83.33	28.67	1.33	18.00	0.55	
Hort16A	**Low nickel**	1.77	0.19	2.20	0.13	0.63	0.20	0.08	162.00	94.67	25.00	1.00	16.33	0.45	0.15
Hort16A	**pH 7.7**	1.67	0.19	2.17	0.13	0.65	0.24	0.06	150.67	76.67	26.33	1.67	16.33	0.35	
Hayward	**Actigard™**	2.33	0.38	3.43	0.20	0.85	0.29	0.05	135.00	141.33	34.33	2.33	21.00	0.43	
Hayward	**Control**	2.10	0.30	3.23	0.17	1.03	0.31	0.06	190.67	123.00	26.00	2.33	22.00	0.49	0.39
Hayward	**Copper Phosphite + C**	2.43	0.37	3.77	0.21	1.04	0.33	0.06	225.33	191.00	32.67	12.33	24.00	0.49	
Hayward	**High ammonium**	2.57	0.43	3.37	0.19	0.82	0.34	0.06	247.67	174.67	34.33	3.00	25.00	0.50	
Hayward	**High copper**	2.73	0.45	3.77	0.21	0.97	0.31	0.07	215.67	149.67	33.00	3.00	23.67	0.49	
Hayward	**High nickel**	2.30	0.39	3.83	0.20	1.09	0.32	0.08	166.00	122.33	29.67	2.00	22.67	0.47	0.54
Hayward	**Low ammonium**	2.27	0.33	3.17	0.17	0.83	0.27	0.05	137.67	141.00	28.00	1.67	20.67	0.50	
Hayward	**Low boron**	2.20	0.35	3.30	0.17	0.77	0.27	0.07	102.33	115.67	25.33	1.67	19.67	0.50	
Hayward	**Low calcium**	1.97	0.34	3.27	0.17	0.95	0.33	0.07	110.00	89.33	28.00	2.00	21.00	0.48	
Hayward	**Low copper**	2.10	0.41	3.47	0.19	0.97	0.35	0.05	120.00	126.67	29.00	2.67	21.33	0.48	
Hayward	**Low Mn**	2.43	0.40	3.60	0.21	0.87	0.33	0.07	124.00	127.33	29.33	2.33	21.33	0.44	
Hayward	**Low nickel**	2.00	0.34	3.10	0.15	0.83	0.27	0.05	114.33	109.33	27.67	1.33	19.33	0.38	0.27
Hayward	**Low zinc**	2.53	0.34	3.47	0.21	0.89	0.28	0.05	89.00	106.00	28.67	2.00	18.67	0.59	
Hayward	**Nitrogen Phosphite + I**	2.93	0.35	3.87	0.26	1.30	0.42	0.08	126.00	188.00	30.67	2.33	25.00	0.52	
Hayward	**pH 7.7**	2.73	0.42	4.03	0.22	1.08	0.38	0.06	344.00	208.67	32.67	2.00	23.33	0.53	

Table 18-2 Linear Regression Survival Rate of Hort16A Vs Nutrients

Linear Regression (OLS) Survival Rate of Hort16A Vs Nutrients (Ranked P then R)"							
Nutrient	Units	N	Coefficient	R	R2	P	Significance
ilr5 (N +S)/Cl Ratio		30	55.974	0.611	0.374	0.000	HS
Chloride	g/Kg	26	-11.98	0.607	0.368	0.001	HS
ilr7 ((K +Na)/(Ca + Mg))Ratio		30	47.934	0.558	0.311	0.001	HS
ilr8 (Ca/Mg) Ratio		30	63.256	0.515	0.265	0.004	HS
Magnesium	g/Kg	30	-12.164	0.503	0.253	0.005	HS
Phosphorus	g/Kg	30	-24.289	0.470	0.221	0.009	HS
Iron	g/Kg	30	-174.418	0.450	0.202	0.013	S
ilr9 (Cu+Zn+Mn)/Fe Ratio		30	24.49	0.450	0.202	0.013	S
ilr12 (Nutrients/Filling) Ratio		30	-49.207	0.375	0.141	0.041	S
Boron	g/Kg	30	-3315.789	0.347	0.120	0.06	NS
Nickel	g/Kg	6	-82214.224	0.769	0.591	0.074	NS
ilr4 (N+S+Cl) / P Ratio		30	39.261	0.267	0.071	0.154	NS
Sodium	g/Kg	30	-21.247	0.226	0.071	0.156	NS
Copper	g/Kg	30	4260.011	0.243	0.059	0.195	NS
ilr2 (Majors/Boron) Ratio		30	-50.084	0.217	0.047	0.249	NS
ilr11 (Cu/Zn) Ratio		30	10.279	0.204	0.042	0.279	NS
ilr10 (Cu+Zn)/Mn Ratio		30	7.043	0.158	0.025	0.405	NS
ilr6 (N/S) Ratio		30	-23.051	0.136	0.019	0.473	NS
ilr1 (Majors/Minors) Ratio		30	-8.949	0.132	0.017	0.487	NS
Zinc	g/Kg	30	-521	0.120	0.014	0.528	NS
Nitrogen	g/Kg	30	-1.008	0.118	0.014	0.534	NS
ilr3 (Anions/Cations) Ratio		30	8.877	0.092	0.009	0.628	NS
Manganese	g/Kg	30	-60.393	0.069	0.005	0.715	NS
Sulphur	g/Kg	30	3.562	0.056	0.003	0.769	NS
Calcium	g/Kg	30	-0.185	0.020	0.000	0.916	NS
Potassium	g/Kg	30	0.064	0.013	0.000	0.945	NS
"Significant Negative Relationship"		"Highly Significant Negative Relationship"		"Significant Positive Relationship"		"Highly Significant Positive Relationship"	

Table 18-3 Seedling Mineral Compositional Range Compared Against Norms*

Element	Units	Trial Range	Normal Hort16A Range	Normal Hayward Range
Nitrogen	%	1.3 - 3.2	1.5 - 2.0	2.0 - 2.7
Phosphorus	%	0.15 - 0.53	0.13 - 0.22	0.18 - 0.30
Potassium	%	1.5 - 4.4	1.4 - 2.3	1.8 - 3.0
Sulphur	%	0.1 - 0.28	0.22 - 0.40	0.30 - 0.60
Calcium	%	0.51 - 1.42	2.2 - 4.0	2.5 - 4.0
Magnesium	%	0.19 - 0.45	0.35 - 0.50	0.35 - 0.70
Sodium	%	0.03 - 0.14	0.0 - 0.05	0.0 - 0.05
Iron	mg/kg	58 - 534	50 - 120	65 - 150
Manganese	mg/kg	41 - 270	50 - 200	50 - 200
Zinc	mg/kg	20 - 39	15 - 30	15 - 30
Copper	mg/kg	0.5 - 17	7 - 15	7.0 - 12
Boron	mg/kg	13 - 26	20 – 40	30 - 50
				31

***Norms based on the Hills Laboratories Kiwifruit Crop Guides (http://www.hill-laboratories.com/file/fileid/21679; http://www.hill-laboratories.com/file/fileid/21680)**

Figure 18-1 Comparison of Hort16A Seedling Mineral Composition Represented on a Normalised Scale (0-1) for Control, Calcium, Ammonium and pH Treatments.

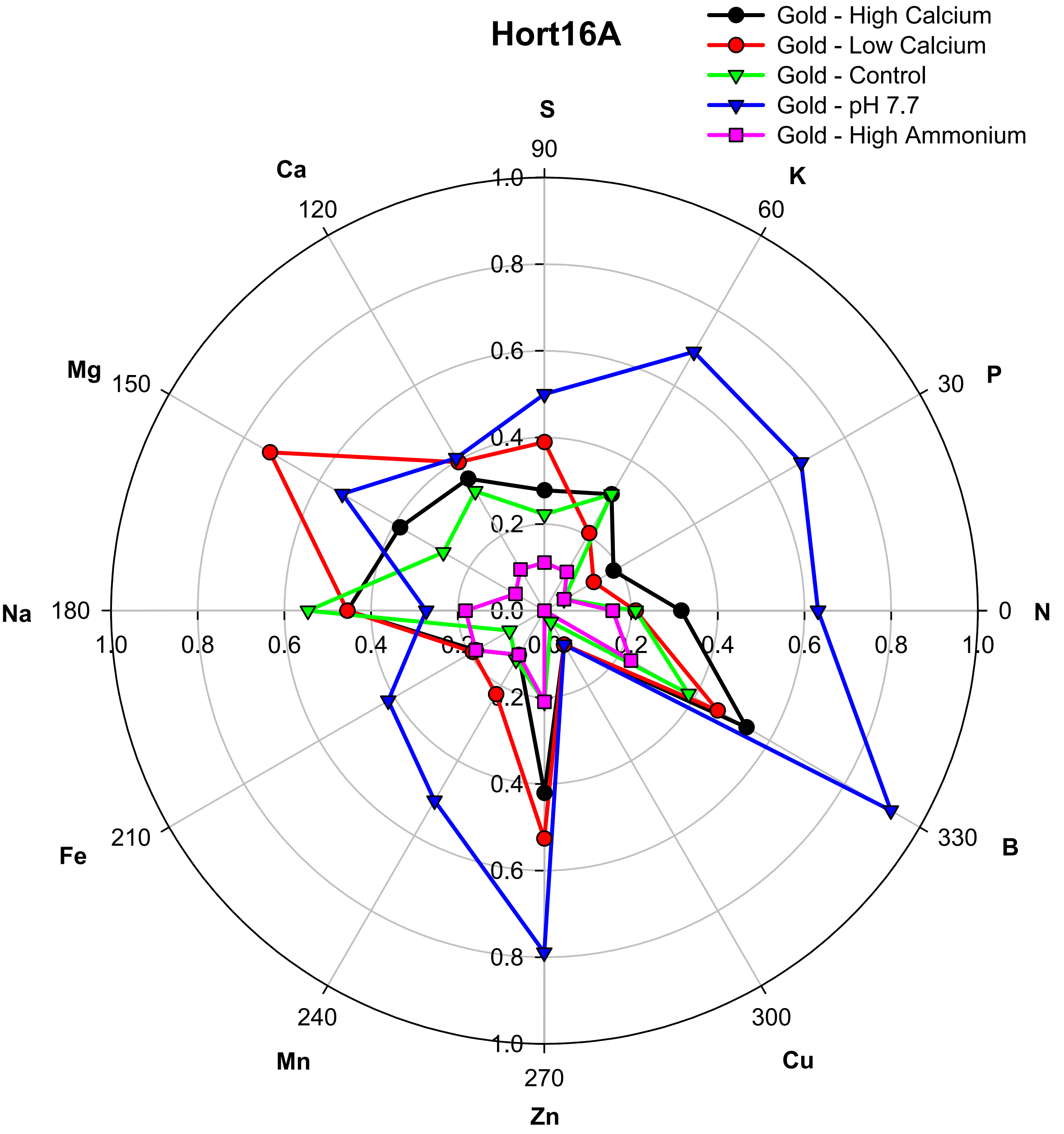


Figure 18-2 Comparison of Hort16A Seedling Mineral Composition Represented on a Normalised Scale (0-1) for Phosphorus, Boron, Magnesium, Iodine and Nickel Treatments.

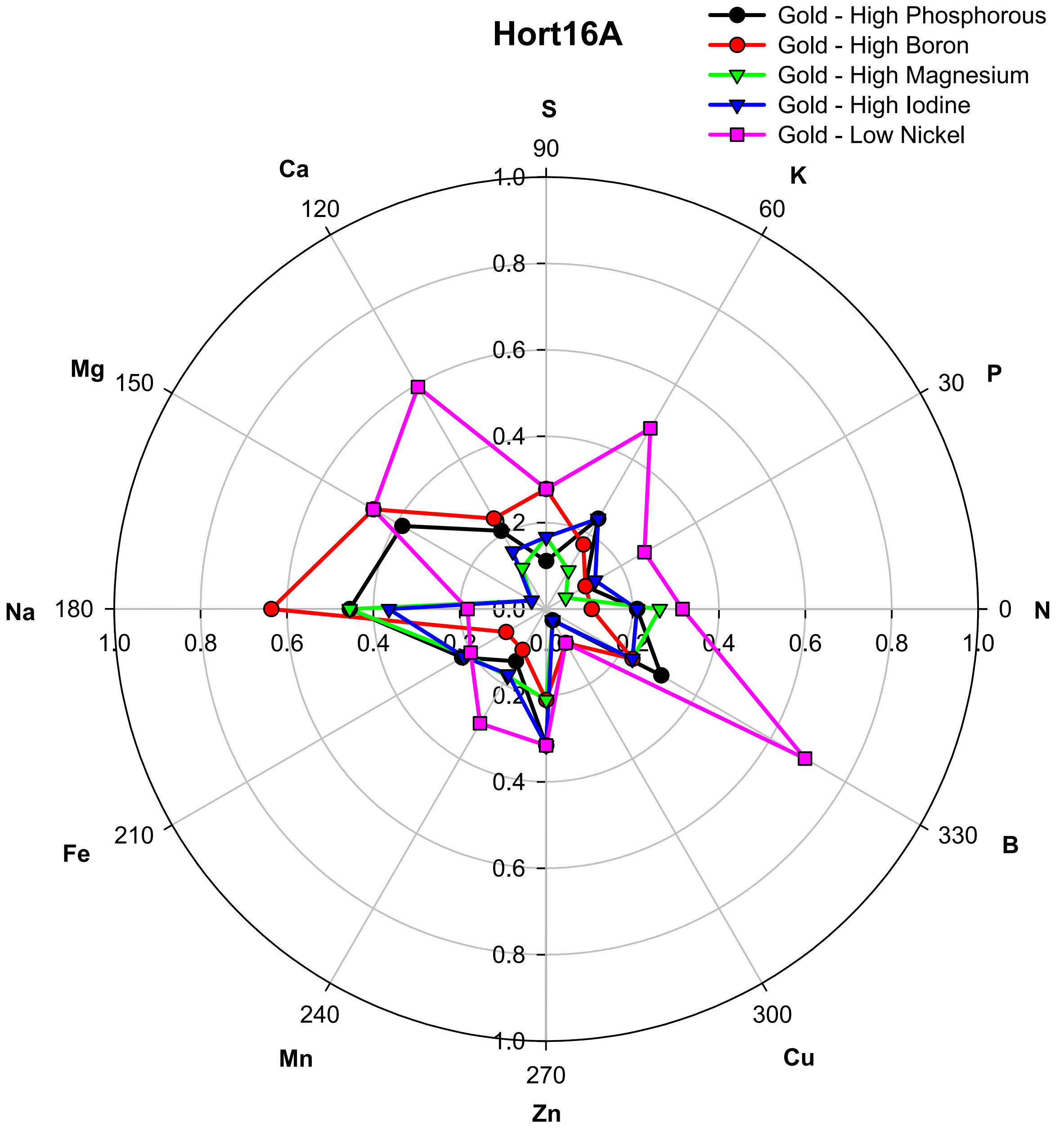


Figure 18-3 Comparison of Hayward Seedling Mineral Composition Represented on a Normalised Scale (0-1) for Control, Ammonium, Calcium, pH and Manganese Treatments.

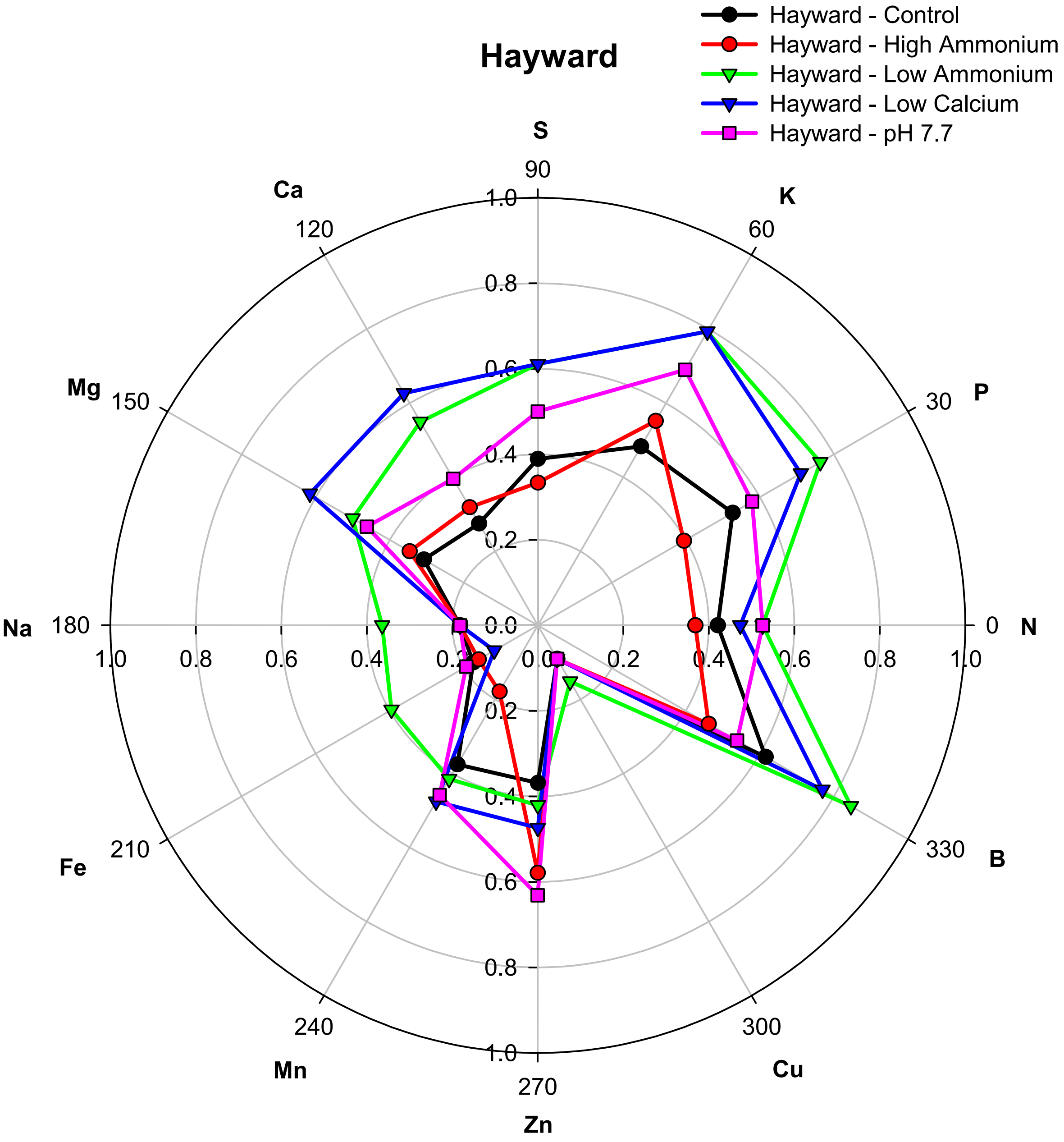


Figure 18-4 Comparison of Hort16A Seedling Mineral Composition Represented on a Normalised Scale (0-1) for Copper, Boron, Nickel Treatments.

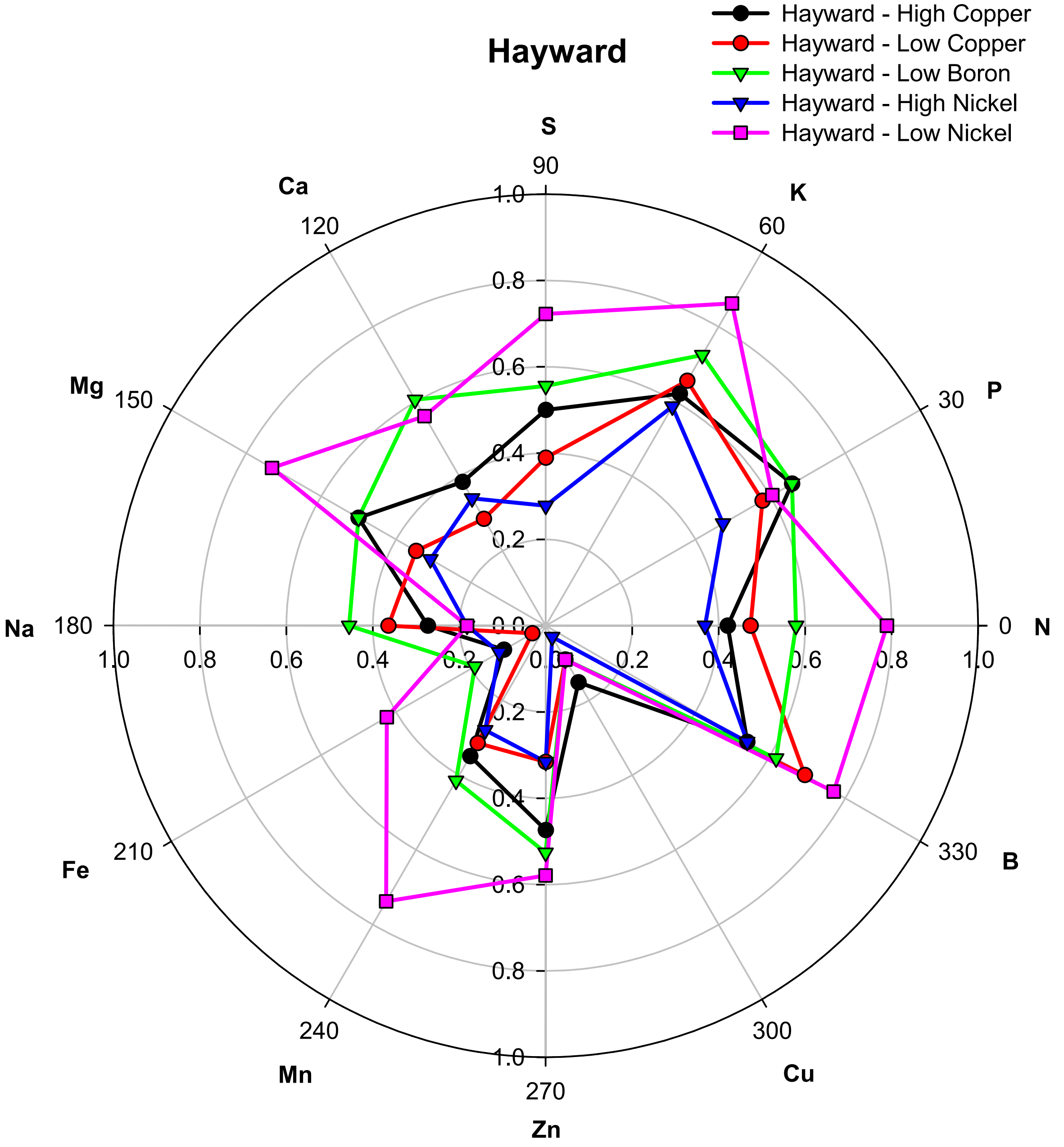
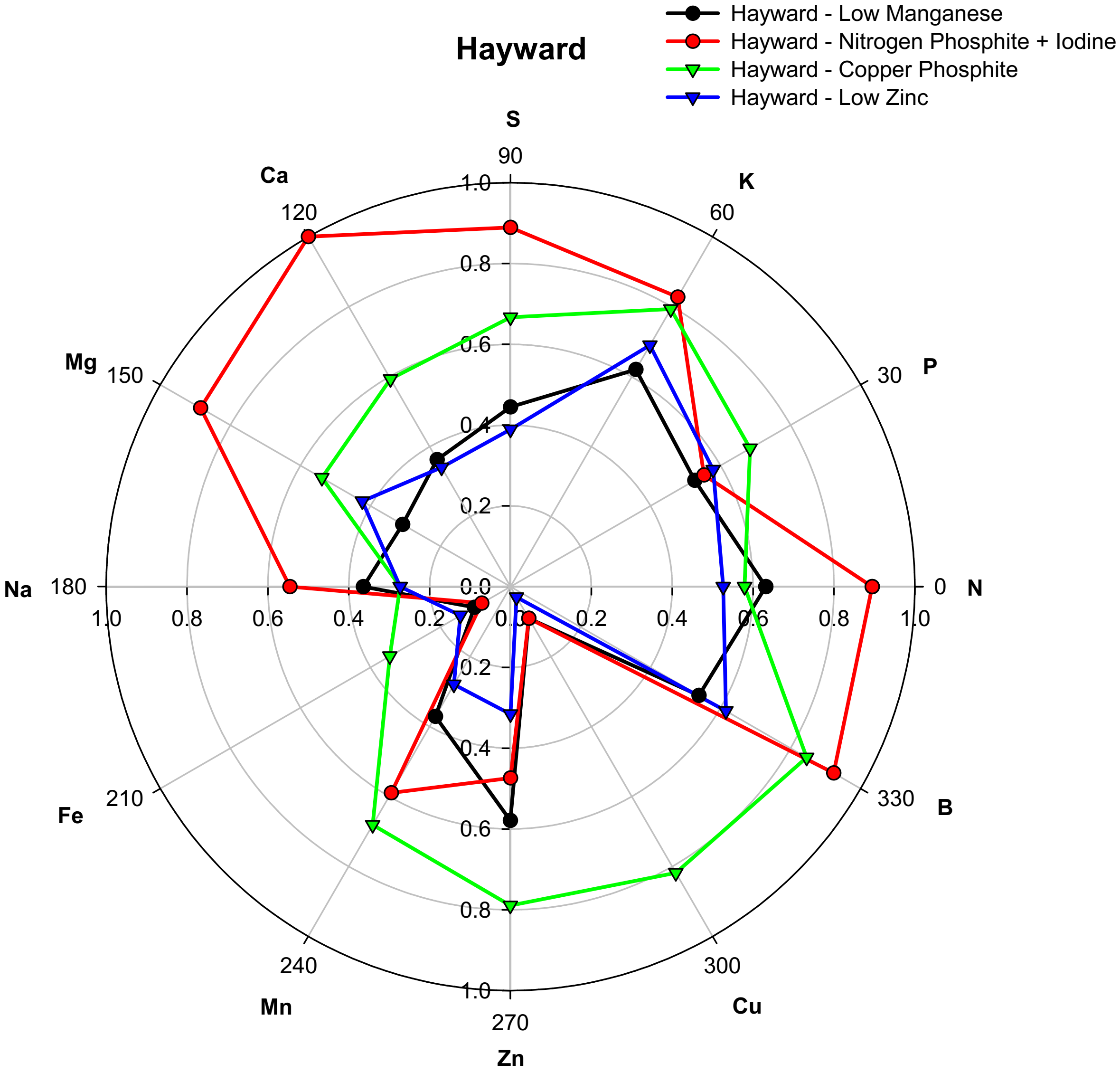


Figure 18-5 Comparison of Hort16A Seedling Mineral Composition Represented on a Normalised Scale (0-1) for Manganese, Nitrogen Phosphite + Iodine, Copper Phosphite and Zinc Treatments.



19 Appendix 7 Representative Photos from Plant & Food Research Ruakura

The photos below were taken in March 2012, and show the seedlings before and after inoculation with Psa-V at Plant & Food Research, Ruakura.

Figure 19-1 Hort16A plants grouped according to replicate and awaiting inoculation

Figure 19-2 Hort16A plants from Batch 1, 16 days after inoculation

Figure 19-3 Water soaking and necrosis on a Hayward leaf 15 days after inoculation

Figure 19-4 Petiole and tip collapse on a Hayward seedling 26 days after inoculation

20 Appendix 8 Seedling Photos from Plant & Food Research Te Puke

The photos below were taken on 16 May 2012, and show the differences observed in the treatments on the plants in the shade house at Plant & Food Research, Te Puke.

Figure 20-1 Hayward control

Figure 20-2 Hayward low boron

Figure 20-3 Hayward high copper

Figure 20-4 Hayward copper phosphite

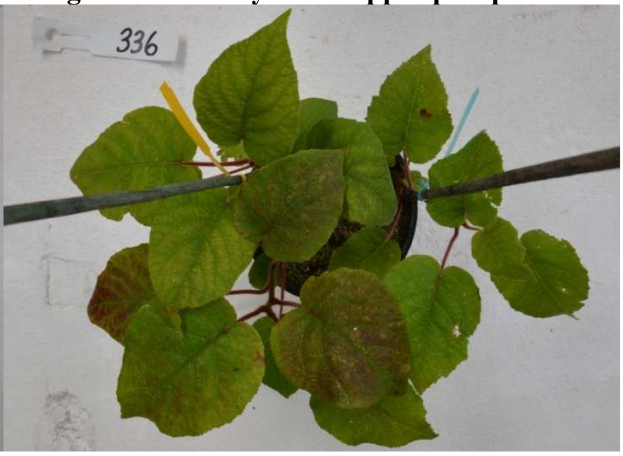


Figure 20-5 Hayward low nickel

Figure 20-6 Hayward high nickel

Figure 20-7 Hayward nitrogen phosphite

Figure 20-8 Hayward Actigard™

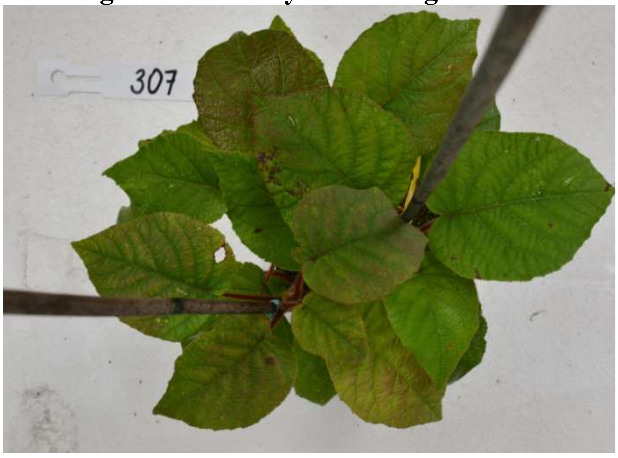


Figure 20-9 Hort16A control

Figure 20-10 Hort16A high copper

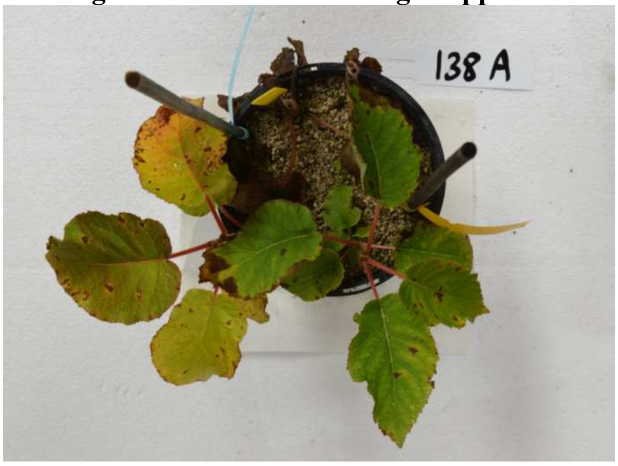


Figure 20-11 Hayward high copper

21 Appendix 9 Inoculation Statistical analysis

21.1 Ruakura Glasshouse Inoculation

An estimate of the stage of disease development was derived from the data by noting the most advanced Psa-V symptom for each plant at each assessment date and structuring this so that stage of disease development could not decrease between successive assessment dates.

The categories used for this were:

0 = none of the below
1 = ooze spreading above/below wound
2 = leaves with water soaked spots present
3 = leaves with necrotic spots present
4 = petiole collapsed
5 = stem collapsed
6 = plant collapsed

Lesion measurements for water soaking and necrosis on stems and the stage of disease development were analysed with REML (Restricted Maximum Likelihood) using Genstat (ver. 12). REML was chosen because of the (at times) unbalanced nature of the data (e.g. number of plants/pot) and because it allows for spatial and temporal correlations within the data.

Two different standard error of the difference (seds) were generated for interpreting the data. The more correct, but more conservative, one is Dunnet's LSD which is used for comparing any other treatment with the control when there are a large number of treatments. This analysis guards against chance significant differences caused by having a large number of treatments in the analysis (with 20 comparisons you would expect to get one significant difference that is not real but occurs just by chance).

For comparison, the normal t-test LSD has also been calculated. This should be treated with caution and especially if the overall treatment F-probability is non-significant then these differences should be ignored (this is called a protected t-test). T

In addition to the REML analysis, a binomial regression analysis was carried out on a whole pot basis for the proportion of leaves with water soaking or necrosis and for proportion of plants with tip, stem or total (or any) collapse.

The overall level of treatment significance (the F-probability value, F-probability) is provided for each experiment and for the main factors within an experiment (e.g. soil v. autoclaved soil). This includes F-probability values for the difference between the low and high values of a nutrient (Experiment 1). In this case if there are no significant differences for a nutrient that would suggest there is no significant response to varying the level of that nutrient.

Also included in the analysis are replicate means, seds and F-probability values to indicate which Psa-V symptoms appear to vary significantly depending on the replicate. This replicate effect is a measure of variability at several levels, and includes; differences between the replicate trays (e.g.

position in the glasshouse), different people inoculating the plants, different inoculum concentration and different people assessing the plants.

21.2 Te Puke Research Orchard field exposure to Psa-V

A similar REML analysis to that described above was performed on the leaf spotting scores recorded on the replicates delivered to Te Puke. A binomial regression analysis was performed on the % dead plants for the last assessment in the Hort16A. Analysis was performed both including the dead scores (5) and excluding the dead scores (i.e. mean score for those remaining alive).

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