Project Title	*Cordyline* and *Phormium*: Investigation of causes of tip burn and yellow leaf spot syndrome
Project number:	HNS 171a
Project leader:	Jill England, ADAS Boxworth
Report:	Year 2 report, October 2012
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Location of project:	East Malling Research, East Malling, West Malling, Kent, ME19 Stoneyfield Nursery, Eastergate Lane, Chichester, West Sussex, PO20 3SL Palmstead Nurseries Ltd, Harville Road, Wye, Ashford, Kent TN25 5EU
Industry representative:	Mr David Hooker, Hillier Nurseries, Romsey, Hampshire, SO51 9PA Dr Steve Carter, Fleurie Nurseries, Eastergate Nurseries, Church Lane, Eastergate, Chichester, W. Sussex PO20 2XD Mr Chris Bowman, John Woods Nurseries Ltd, Main Road, Pettistree, Woodbridge, Suffolk IP13 0HH
Date project commenced:	1 May 2010
Date completion due:	31 July 2014

[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Jill England
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ADAS

Signature ..... Date .....

Report authorised by:

Tim O'Neill
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GROWER SUMMARY

Headlines

Application of calcium nitrate (foliar and liquid feed) and potassium nitrate (liquid feed) may reduce both tip burn and yellow leaf spot symptoms.

Background

Cordyline yellow leaf spot syndrome and tip burn in both *Cordyline* and *Phormium* have been identified as major problems to the horticulture industry, affecting production with no clearly established causes, leaving growers unable to take reliable practical courses of action to address them (England 2009). An estimated 1 million and 1.24 million *Cordyline* and *Phormium* plants are grown each year respectively.

Tip burn

No clear cause has previously been established for tip burn in *Cordyline* and *Phormium*. Study HNS 171 estimated the value of *Cordyline* and *Phormium* crops affected by tip burn in excess of £1 million (England 2009). Leaf margin and tip browning symptoms in plants can be caused by nutrient imbalance including calcium, potassium and boron deficiency, and boron and fluoride toxicity, of which fluoride toxicity has been reported in *Cordyline* (Conover and Poole 1971), but not in *Phormium*. Typical macroscopic symptoms of fluoride toxicity are tip and margin necrosis (tip burn) with a distinct reddish-brown line separating it from healthy tissue in both monocotyledons and broad leaved plants (Fornasiero 2001).

Nutrient feeding trials carried out in year 1 of this project proved inconclusive. A large proportion of the *Cordyline* and *Phormium* plants were damaged during severe cold weather experienced during the winter, before the final results could be recorded. Plant tissue analysis revealed that fluoride accumulation in leaves increased with fluoride dose rate. Results also suggested that tip burn was associated with higher calcium levels, possibly through a reduction in potassium uptake, however no firm conclusions could be drawn.

Cordyline yellow leaf spot syndrome

Cordyline yellow leaf spot syndrome is a condition of unknown cause that reduces the quality and profitability of these plants. The symptoms are unsightly yellow leaf spots, initially small raised pustules, apparently water soaked, that sometimes turn necrotic (Figure

1). Sales losses have been reported by nurseries throughout the UK, and HNS 171 estimated the loss across those Cordyline producers who responded to the survey, at £119,437 each year. Additional losses are likely to be incurred once plants are distributed to retail nurseries and garden centres as larger plants appear to be affected more than plugs and liners (England, 2009).

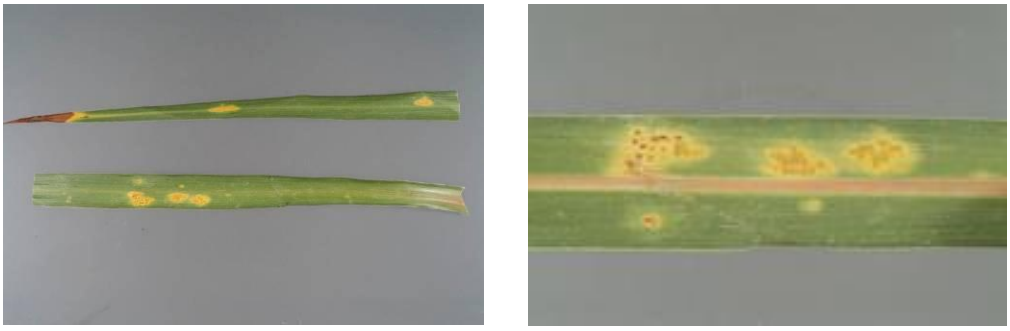

Figure 1. *Cordyline* leaf spot symptoms: raised pustules, initially chlorotic but becoming necrotic (Charles Lane, Fera).

In year 1, 33 *Cordyline* samples were screened for the presence of three viral pathogens (Cucumber mosaic virus, CMV; Tomato spotted wilt virus, TSWV; and *Impatiens* necrotic spot virus, INSV), all commonly found in a wide range of ornamental species and potentially linked to leaf spotting, and virus particles (Transmission Electron Microscope followed by inoculation onto a standard range of bio-indicator plants to assess whether any 'transmissible' pathogens were present). None of the viruses screened for, nor virus particles were detected in any of the samples tested, with or without symptoms. It was concluded that there was no commonly identified viral cause for leaf spotting in *Cordyline*.

A controlled environment study of *Cordyline* in year 1 aimed to reproduce oedema symptoms in leaf segments. A range of environmental conditions were investigated, but none of the combinations of light, temperature and humidity used reproduced the symptoms.

Summary of the project and main conclusions

Two areas of work were carried out during 2011/12:

- **Objective 1. Tip burn:** Investigate the involvement of nutrient imbalance and fluoride toxicity in tip burn through nutrient feeding trials.
- **Objective 2.** This section of work was completed in year 1.
- **Objective 3. *Cordyline yellow* leaf spot syndrome:** Monitor the environmental conditions under which *Cordyline* yellow leaf spot syndrome develops in commercially produced crops.

Objective 1. Tip burn (and yellow leaf spot) nutrition trial

The impact of calcium, potassium and fluoride on tip burn in *Cordyline* and *Phormium* were investigated via a nutrition trial. The trial was set up on 12 October 2011, sited within an unheated polytunnel at East Malling Research. Plants (*Cordyline australis* 'Red Star' and *Phormium* 'Yellow Wave') were potted into 3 L pots and irrigated via drip irrigation, and by hand watering as necessary during the winter. The nutrient feeding trial treatments, based on the results from year 1, previous research and best practice, were foliar and liquid feeds of calcium (applied as calcium nitrate, 1520 mg/L and 150 mg/L respectively), liquid feeds of potassium (applied as potassium nitrate, 200 mg/L and 50 mg/L; and potassium sulphate, 200 mg/L) and liquid feeds of fluoride (applied as sodium fluoride, 3.0 mg/L). Water only was applied as a control treatment throughout. The calcium and potassium treatments were applied weekly. Fluoride was applied at each irrigation. Following the interim assessment (4 July 2012) the fluoride dose rate was increased to 5.0 mg/L. The liquid feed treatments were applied via Dosatron D3 Greenline injectors governed by Galcon DC-4S controllers.

Tip burn was beginning to develop in the *Cordyline* by the planned final assessment (October 2012), although there were no visible differences between treatments, and no tip burn was found in the *Phormium*. However, as both tip burn and yellow leaf spot symptoms were developing on the *Cordyline*, the trial was extended until February 2013, with assessments at the end of November, January and February.

After 29 weeks of treatment, tip burn in *Cordyline* was significantly less in the calcium nitrate (liquid and foliar) and potassium nitrate (high dose rate) treatments than the untreated control and other treatments (Figure 2). The results at all three assessments generally followed the same trend, except that the level of tip burn measured in the control was reduced after 42 weeks, due to the breakdown and loss of dry necrotic tissue. The highest level of tip burn was recorded in all treatments at the week 29 assessment.

Plant quality was scored on a scale of 0-5 (0 = dead plants, 5 = no tip burn). Plant quality scores were greater in the potassium nitrate (high dose rate) and calcium liquid feed treatments, although all plots were given scores of 3 (over 50% of plants saleable) and above after 29 and 38 weeks of treatment, with no symptom-free plots. After 42 weeks of treatment the results generally followed the same trends, but plant quality appeared to have reduced in the potassium nitrate (low dose), potassium sulphate and fluoride treatments and the untreated control. Although the majority of plants in the trial were marketable, increased

levels of tip burn and leaf spot result in increased labour cost due to plant cleaning operations at dispatch.

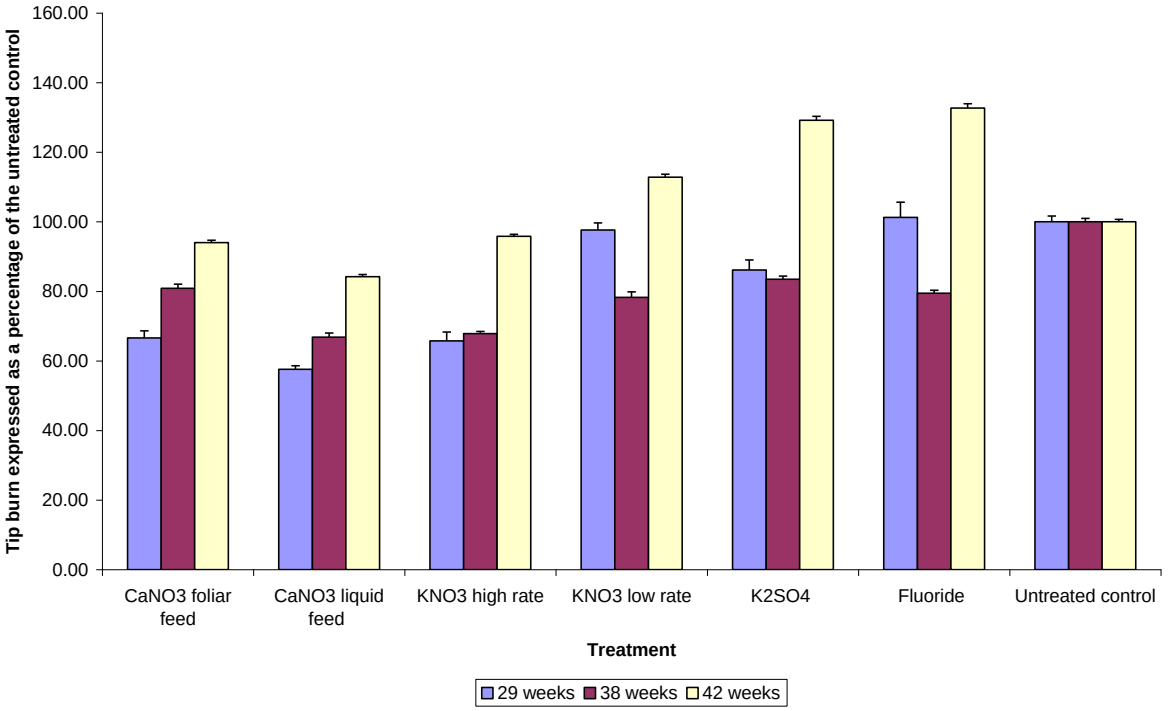

Figure 2. Tip burn, expressed as a percentage of the untreated control, in *Cordyline* 29, 38 and 42 weeks after treatments. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control.

Assessed after 38 and 42 weeks of treatment, the number of plants in each plot with yellow leaf spots followed the same general trend as seen with tip burn, with fewer plants with leaf spots in the calcium nitrate (foliar and liquid feeds) and potassium nitrate (high dose rate) treatments than the untreated control and other treatments. The same trend was found when yellow leaf spot symptoms were assessed using a system based on the NIAB scoring method for recording plant disease (0 = No leaf spot observable; 0.1 = Trace of leaf spot; 1= Leaves with one small lesion; plants with a few scattered lesions; 5 = Leaves appear 1/10 affected; affected leaves with a few lesions; 10 = Leaves appear 1/4 affected/ affected leaves with a few large or many small lesions) (Figure 3). Tissue samples were passed to Fera to investigate the cause of yellow leaf spot at each assessment, but no pest, pathogen or oedema was found on any of the samples.

Objective 3. Cordyline yellow leaf spot syndrome – environment monitoring

The environmental conditions of two *Cordyline australis* crops were monitored at Stoneyfield Nursery and Palmstead Nurseries. Watchdog 1000 Series Micro Station dataloggers with Lightscout 36681 PAR Light Sensors dataloggers were placed within the crop at plant height

(light sensor positioned above the crop) to record temperature, humidity and PAR (photosynthetically active radiation) light. Incidence of *Cordyline* yellow leaf spot syndrome was recorded, along with details of the production systems and infrastructure at each site.

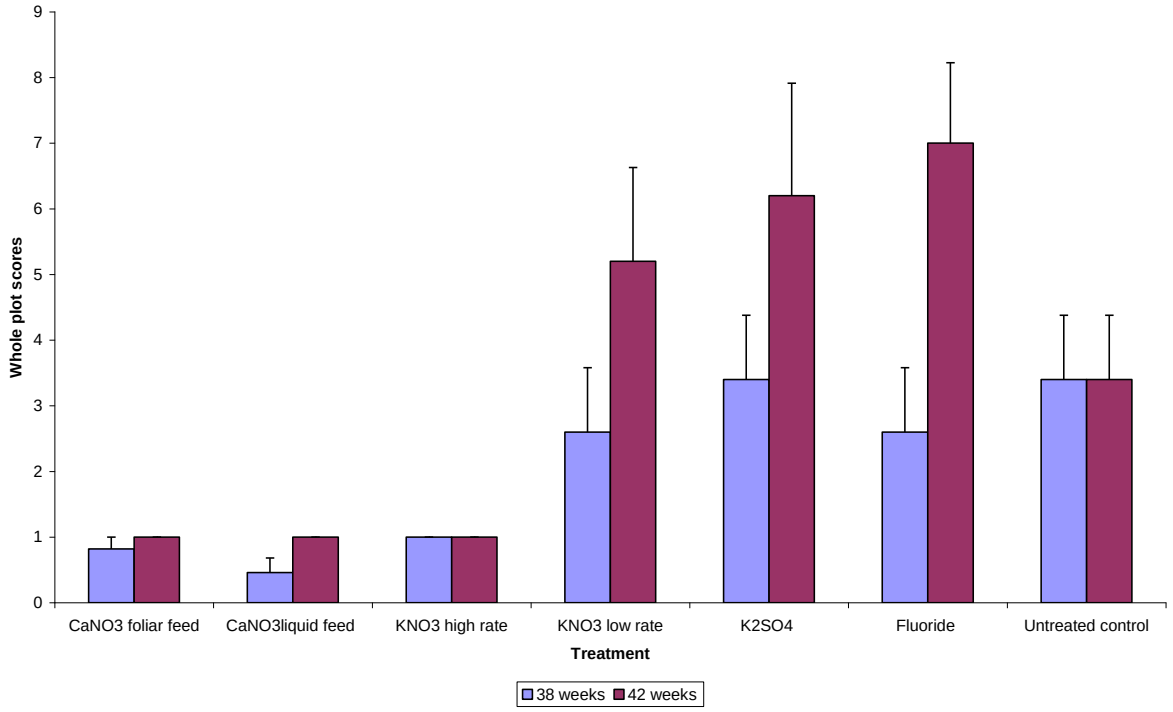

Figure 3. *Cordyline* yellow leaf spot syndrome symptoms, whole plot scores 38 and 42 weeks after treatments. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control.

Palmstead Nurseries. The *Cordyline* plants included in this trial were produced in an unheated, side-ventilated multi-span polytunnel, on drained beds covered with Mypex. Liners had been transplanted into 3 L pots (March 2011). Crops were irrigated with mains water during winter. Overhead irrigation (computer controlled, linked to a weather station, with some manual input) parameters were set to maintain a dry regime. Growing media consisted of coarse peat (100%) with nutrition provided by Osmocote Pro (16:11:10 @ 3.2 kg/m^3). The number of plants in the batch reduced throughout the monitoring as they were sold. Plants were initially placed pot thick but the distance between plants was increased to approximately 30 cm as space became available. At the start of the monitoring (12 December 2011) some leaf spotting was evident, affecting 1-2 leaves on less than 5% of the crop. By 16th March 2012 the majority of the older leaves of originally affected plants were heavily spotted (new leaves were not affected), and approximately 10% of the previously unaffected plants (9 plants/100) were now showing symptoms.

Stoneyfield Nursery. The *Cordyline* plants used in this trial were grown under glass. Plugs had been transplanted into 1 L pots and placed pot thick on the floor (Mypex over soil). The temperature was maintained above 1°C (diesel fuelled boilers, vented outside). A vent and fan system was used for ventilation above 12°C. The crop was hand watered during the winter (borehole water) maintaining 25% moisture in the growing media once the plants had rooted through. Growing media consisted of 75% peat, 25% wood fibre, pH 4.5-5.5. Nutrition was provided by a combination of fertilisers, Nutricote 140 Day (16-10-10 @1.5Kg/m³); Plantacote 12 month (18-6-12 @1.5 Kg/m³), fritted trace elements and liquid feed applied as necessary (Solufeed Vigil, 16:10:18). None of the plants were affected by leaf spots during most of the monitoring period. However, symptoms had appeared by the final assessment (4 May 2012) and batches of 20 plants from central rows of plants were sampled and an average of 10% were affected (Figure 13).

Temperature and humidity fluctuated more, and over a greater range, at Stoneyfield Nursery than Palmstead Nurseries. The greatest differences were seen in light level readings; at Palmstead Nurseries the light level exceeded 200 μM/m^2/s on one day only, however at Stoneyfield Nursery it was above this level for approximately 75% of period that data was collected. Whilst incidence of leaf spot was lower under the conditions at Stoneyfield Nursery compared with those experienced at Palmstead Nursery, it would be premature to conclude that this can be entirely attributed to the environmental conditions without comparing the incidence of symptoms on similar plant material under different controlled environmental conditions. It may also be significant that the plant material at Stoneyfield Nursery was younger than that at Palmstead Nursery.

Financial benefits

- Control of tip burn in *Cordyline and Phormium* could save the horticulture industry an estimated £1 million annually.
- Control of *Cordyline* yellow leaf spot syndrome could result in savings estimated at £120,000.

Action points for growers

The results from this trial need to be confirmed by further work in the final year of the project. However, application of calcium and potassium nitrate do appear to reduce incidence of tip burn and yellow leaf spot. Many growers do already apply foliar feeds of calcium nitrate to reduce tip burn.

SCIENCE SECTION

Introduction

The resurgence of interest in growing tropical plants including *Cordyline* and *Phormium* in recent years has resulted in an estimated 1 million and 1.24 million plants being grown each year respectively. Project HNS 171 identified *Cordyline* yellow leaf spot syndrome and tip burn in both *Cordyline* and *Phormium* as major problems to the horticulture industry, affecting production with no clearly established causes, leaving growers unable to take reliable practical courses of action to address them (England 2009).

Tip burn

Tip burn affects both *Cordyline* and *Phormium* and no clear cause has been established. Growers do not treat these symptoms as they have no diagnosis of the cause. In HNS 171, the value of *Cordyline* and *Phormium* crops affected by tip burn was estimated to be in excess of £1 million (England 2009).

Leaf margin and tip browning symptoms in plants can be caused by nutrient imbalance including calcium, potassium and boron deficiency, and boron and fluoride toxicity. Of these, only fluoride toxicity has been reported in *Cordyline* (Conover and Poole 1971), but not *Phormium*. Typical macroscopic symptoms of fluoride toxicity are tip and margin necrosis (tip burn) with a distinct reddish-brown line separating it from healthy tissue in both monocotyledons and broad leaved plants (Fornasiero 2001).

Conover and Poole (1971) recorded leaf necrosis due to fluoride toxicity in *Cordyline terminalis* 'Baby Doll' during propagation where fluoride levels exceeded 0.25 mg/L in the soil or water. Symptom severity increased with lower substrate pH and reduced light levels. Necrosis also occurred in misted cuttings in vermiculite, perlite and Terragreen, but not at significant levels in various barks and peats tested (Poole and Conover 1975).

The addition of superphosphate (3.80 kg m^3, 1.5% fluoride) has been found to increase necrosis and tissue fluoride content of cuttings of *Cordyline terminalis* 'Baby Doll' grown in German peat and Turface. Toxicity symptoms were reduced by increasing doses of calcium sulphate and magnesium sulphate (Poole & Conover 1975). Controlled release fertilisers are predominately used by growers today, and the consensus is that phosphate levels are higher than necessary for the production of hardy nursery stock in some formulations

(Holmes, personal communication). It has also been suggested that tip burn in very young leaves may be attributable to the application of fertilisers over the growing point of young leaves (Moorman 2009). Various sources recommend a growing media pH of 6.0 to 6.5 and irrigation water with fluoride levels below 0.25 mg/L (Bunt 1988) and 1.0 mg/L (Holmes and Adlam 2006) for ornamental crops. Fluoride levels are not generally included in standard irrigation water and growing media analyses and their concentration is rarely monitored.

Nutrient feeding trials carried out in year 1 of this project proved inconclusive. A large proportion of the *Cordyline* and *Phormium* plants were damaged during severe cold weather experienced during the winter. Plant tissue analysis revealed that fluoride accumulation in leaves increased with fluoride dose rate. Results also suggested that tip burn was associated with higher calcium levels, possibly through a reduction in potassium uptake, however no firm conclusions could be drawn.

Cordyline leaf spot syndrome

Cordyline yellow leaf spot syndrome is a condition of unknown aetiology that reduces the quality and profitability of these plants. The symptoms are unsightly yellow leaf spots. Initial small raised pustules are chlorotic, apparently water soaked and sometimes turn necrotic (Figure 4). Consultation with growers, consultants and plant pathologists across UK and Europe has revealed this to be an industry-wide problem, with no consistent cause as yet identified. Sales losses have been reported by nurseries throughout the UK, and a recent survey (HNS 171) estimated the loss across those *Cordyline* producers who responded to the survey at £119,437 each year. Additional losses are likely to be incurred once plants are distributed to retail nurseries and garden centres as larger plants appear to be affected more than plugs and liners (England, 2009).

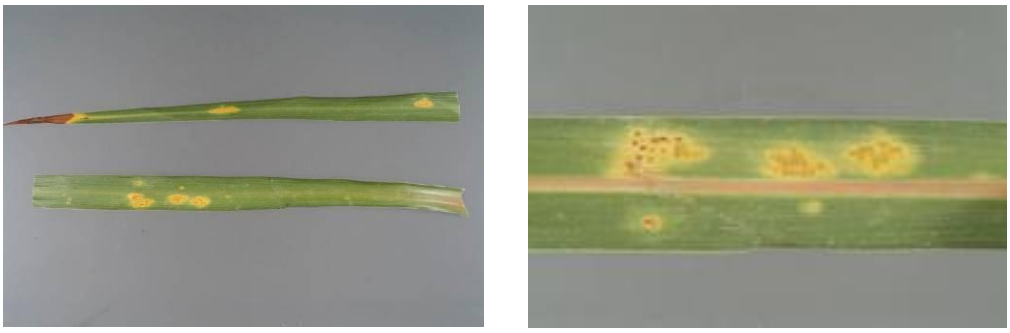

Figure 4. *Cordyline* leaf spot symptoms: raised pustules, initially chlorotic but becoming necrotic (Charles Lane, Fera).

Samples provided to Fera as part of HNS 171 were tested for a range of pests and diseases. Few pests (caterpillar and red spider mite, each on one sample) and no primary pathogenic bacteria or fungal species were associated with the samples. However, ultrastructure analysis identified swollen cells below the leaf epidermis of a number of leaf samples, typical of oedema. Oedema is a physiological condition attributed to an imbalance in water relations which commonly occurs during periods when high water availability coincides with high humidity. Roots then take up water faster than it is used or transpired through the leaves and the resultant build up of water pressure in leaf mesophyll cells causes them to enlarge and form swollen blister-like areas. Investigative work on oedema in other plant species susceptible to this condition (e.g. Eucalyptus, tomato, geranium) has previously enabled symptoms to be produced within a controlled environment (Morrow and Tibbetts, 1987).

A controlled environment study of *Cordyline* in year 1 aimed to reproduce oedema symptoms in leaf segments. A range of environmental conditions were investigated, but none of the combinations of light, temperature and humidity used reproduced the symptoms.

In year 1, 33 *Cordyline* samples were screened for the presence of three viral pathogens (Cucumber mosaic virus, CMV; Tomato spotted wilt virus, TSWV; and Impatiens necrotic spot virus, INSV), all commonly found in a wide range of ornamental species and potentially linked to leaf spotting, and virus particles (Transmission Electron Microscope followed by inoculation onto a standard range of bio-indicator plants to assess whether any 'transmissible' pathogens were present). None of the viruses screened for, nor virus particles were detected in any of the samples tested, with or without symptoms. It was concluded that there was no commonly identified viral cause for leaf spotting in *Cordyline*.

Objectives

Year 2

Objective 1. Tip burn: investigate the involvement of nutrient imbalance, and fluoride toxicity on incidence of tip burn in *Cordyline* and *Phormium* through nutrient feeding trials, refining treatments from year 1.

Objective 2. This section of work was completed in year 1.

Objective 3. *Cordyline yellow* leaf spot syndrome: Monitor the environmental conditions under which *Cordyline* yellow leaf spot syndrome develops in commercially produced crops.

Materials and methods

Objective 1: Tip burn

The trial was set up on 12 October 2011, sited within an unheated polytunnel at East Malling Research. The trial was set up and the plants established during the autumn of 2011, with nutrient feeding from spring to early 2013. Plugs of *Cordyline australis* 'Red Star' (Supplier: Kernock Park Plants) and *Phormium* 'Yellow Wave (Supplier: John Turner Phormium) were potted into 3 L pots; varieties were selected for their susceptibility to tip burn (England, 2009). Pots were placed on the ground and irrigated via drip irrigation, and by hand watering as necessary during the winter when automatic irrigation was not used. Drip irrigation recommenced once the risk of frost had passed. The trial was covered with fleece when the temperature was forecast to drop below 5°C. The potting mix used was Sinclair SHL Peat-Bark Growing Medium (pH 5.0, N 120 g/m^3, P_2O_5 140 g/m^3, K_2O 240 mg/L; peat: 0-10mm 40%, peat 3-15mm 45%, bark: 5-10mm 15%) with Osmocote Pro (12-14M, 3 kg/m^3) controlled release fertiliser. Growing media and irrigation water analyses were carried out prior to the trial, to establish a baseline for comparison with later analyses, and to determine intrinsic fluoride levels that may affect the results (Appendix 3).

Treatments

Treatments (Table 1) based on the results from year 1, previous research and best practice, were applied from 9 May 2012.

Table 1. Nutrient feeding trial treatments

	Treatments
1	$Ca(NO_3)_2$ foliar application @ 1520 mg/L
2	$Ca(NO_3)_2$ liquid feed @ 150 mg/L
3	KNO_3 liquid feed, high rate @ 200 mg/L
4	KNO_3 liquid feed, lower rate @ 50 mg/L
5	K_2SO_4 liquid feed @ 200 mg/L
6	Fluoride @ 3.0 mg/L, increased to 5.0 mg/L
7	Control – water only

The nutrient feeding trial treatments were foliar and liquid feeds of calcium (applied as calcium nitrate), liquid feeds of potassium (applied as potassium nitrate and potassium

sulphate) and liquid feeds of fluoride (applied as sodium fluoride). Water only was applied as a control treatment throughout. The calcium and potassium liquid feeds treatments were applied weekly, and the calcium foliar feed was applied weekly, under dull conditions. Fluoride was applied at each irrigation. Following the interim assessment (4 July 2012) the fluoride dose rate was increased to 5.0 mg/L.

Experimental design

Treatments were evaluated in a randomised block experiment with 5-fold replication (Appendix 1), each plot containing 20 plants. Treatments were applied via Dosatron D3 Greenline injectors, fed from 20 L tanks of stock solution, and governed by Galcon DC-4S controllers.

Assessments

Inspections and assessments are summarised in (Table 2).

Samples for leaf tissue analysis (newest fully expanded leaf from each pot) were collected from each plot for nutrient analysis (Table 2); tissue samples from plots given the same treatment were pooled.

Table 2. Nutrient feeding trial inspections and assessments

Date	WOT*	Action	Data collection
12.10.11		Set up	Leaf tissue analysis Growing media analysis Irrigation water analysis
25.10.11		Inspection	
15.11.11		Inspection	
14.12.11		Inspection	
26.01.12		Inspection	
16.03.12		Inspection	
23.04.12		Inspection	
04.07.12	8	Interim assessment	Leaf tissue analysis
15.08.12	14	Inspection	
12.09.12	18	Assessment	Leaf tissue analysis Growing media analysis
30.10.12	25	Inspection	
29.11.12	29	Assessment	Leaf tissue analyses Growing media analysis
31.01.13	38	Assessment	Leaf tissue analyses Growing media analysis
28.02.13	42	Assessment	Leaf tissue analyses Growing media analysis

*WOT = weeks of treatment

Tip burn was assessed as follows:

1. The length of tip burn was measured from the tip of the leaf (mm), sampling 10 randomly selected, affected leaves per plot. Data was calculated and is presented in this report as a percentage of the control.
2. Quality score per plot which included both tip burn and yellow leaf spots (Table 3).

Table 3. Plant quality score grades

Score	Leaf appearance
5	No tip burn
4	All plants saleable (slight tip burn/leaf spots)
3	Plants mostly saleable (>50%)
2	Plants mostly unsaleable (>50%)
1	Plants all unsaleable
0	Dead plants

As yellow leaf spot was found within the tip burn trial, it was assessed as follows:

1. Number of plants per plot affected by leaf spot

2. Whole plot assessment of leaf spot, based on the NIAB method for recording plant disease (Table 4) (Anon, 2013).

Table 4. Score grades for NIAB method of recording plant disease (Anon, 2013)

Score	Leaf appearance
0	No leaf spot observable
0.1	Trace of leaf spot
1	Leaves with one small lesion; plants with a few scattered lesions
5	Leaves appear 1/10 affected; affected leaves with a few lesions
10	Leaves appear 1/4 affected/ affected leaves with a few large or many small lesions
25	Area appears half affected, half green (or normal colour for variety)
50	Leaf area appears more affected than green
75	Very little green tissue left
100	No green tissue left

Statistical analysis was carried out where appropriate using GenStat Release 12.1 (PC/Windows XP).

Objective 3: Cordyline yellow leaf spot syndrome

The environmental conditions of two *Cordyline australis* crops were monitored, at Stoneyfield Nursery and Palmstead Nurseries. Watchdog 1000 Series Micro Station dataloggers with Lightscout 36681 PAR Light Sensors were used to record temperature, humidity and PAR (photosynthetically active radiation) light. The dataloggers were placed within the crop at plant height, with the light sensor positioned above the crop. Incidence of *Cordyline* yellow leaf spot syndrome was recorded, along with details of the production systems and infrastructure at each site (Table 5).

Assessments

Table 5. *Cordyline* leaf spot trial inspections and assessments

Palmstead nursery	
	Action
12.12.11	Set up monitoring equipment.
26.01.12	Download data and inspection
28.02.12	Download data and inspection
16.03.12	Download data and inspection
04.05.12	Download data and inspection. Remove monitoring equipment
Stoneyfield Nursery	
	Action
02.12.11	Set up monitoring equipment
19.12.11	Inspection
16.01.12	Download data and inspection
02.02.12	Inspection
13.03.12	Inspection
20.04.12	Download data and inspection. Remove monitoring equipment

Results

Objective 1: Tip burn

Both the Cordyline and Phormium established well during autumn 2011, having rooted through by the November inspection (Figure 5). Plants were covered with fleece during cold spells and survived the winter without frost damage (Figure 6). However, due to the cold spring they were late into growth in spring 2012. Automatic irrigation and feeding was delayed until the risk of frost had past. The nutrient feeding trial was assessed mid-trial and

at the end of the trial. Leaf tissue nutrient analysis was completed at the start of the trial, mid-trial and final assessment (Appendix 3).

Figure 5. Nutrient trial at set up (left) and at the final assessment (right)

Figure 6. Nutrient feeding trial covered with fleece.

No tip burn was found on any plants at the mid-trial assessment (4 July 2012, after 8 weeks of treatment), therefore no assessment was made, however leaf tissue (newest fully expanded leaf from each pot) was collected for analysis. The analysis results indicated that fluoride levels were undetectable in all treatments therefore the tests were repeated. Following a review of the treatments, the fluoride dose rate was increased from 3.0 mg/L to 5.0 mg/L; the premise of this treatment was to induce fluoride toxicity which had been reported to cause tip burn in *Cordyline*. The aim of the calcium and potassium treatments was to prevent tip burn, but as no symptoms had developed the dose rates were not altered.

At the assessment on 12 September 2012 (after 18 weeks of treatment) there was no tip burn in the *Phormium*. Although there was some tip burn in the *Cordyline* (Figure 7) in all treatments, there were no visible differences in tip burn between treatments. For one plot of *Cordyline* treated with fluoride, the plants in the centre of the plot were smaller than the outer plants (Figure 8), which appeared more vigorous, and plant heights ranged between 69 and

77 cm. Investigation revealed that in general 5-20% of leaves per plant in all treatments had approximately 2 cm of tip burn (based on an average 57 leaves per plant). In consultation with the statistician it was decided not to collect any further data as no differences could be seen between treatments.

Figure 7. Detail of tip burn symptoms

Figure 8. Comparison of plants within one plot treated with fluoride

A grower review (eight growers) indicated that minimal tip burn had occurred on *Phormium*, and variable amounts had occurred on *Cordyline* during 2012; slight leaf spotting had occurred on *Cordyline.* As tip burn and leaf spot symptoms had started to appear on the *Cordyline* in the trial, it was extended until 28 February 2013, but only for *Cordyline*. Water only was applied during January, and liquid feed treatments were to be applied during February, however the cold temperatures meant that this was not possible. Observations made during the October inspection suggested that symptoms of yellow leaf spot syndrome were occurring with treatment effects visible, therefore data were collected during the January and February 2013 assessments.

Tip burn was significantly less in the calcium nitrate (liquid and foliar) and potassium nitrate (high dose rate) treatments than the untreated control, KNO_3 (low dose rate) and fluoride treatments after 29 weeks of treatment ($P<0.001$) (Appendix 4, Figure 9). After 38 weeks of treatment, tip burn was significantly less in all treatments than the control ($P = 0.004$) (Appendix 4). However, although there were significant differences between treatments ($P< 0.001$) after 42 weeks, tip burn was significantly less in the calcium nitrate (liquid and foliar), potassium nitrate (high and low dose rate) and control than the potassium sulphate and fluoride treatments (Appendix 4). At all three assessments there was less tip burn in the calcium nitrate (foliar and liquid feeds) and potassium nitrate (low dose rate) relative to the control.

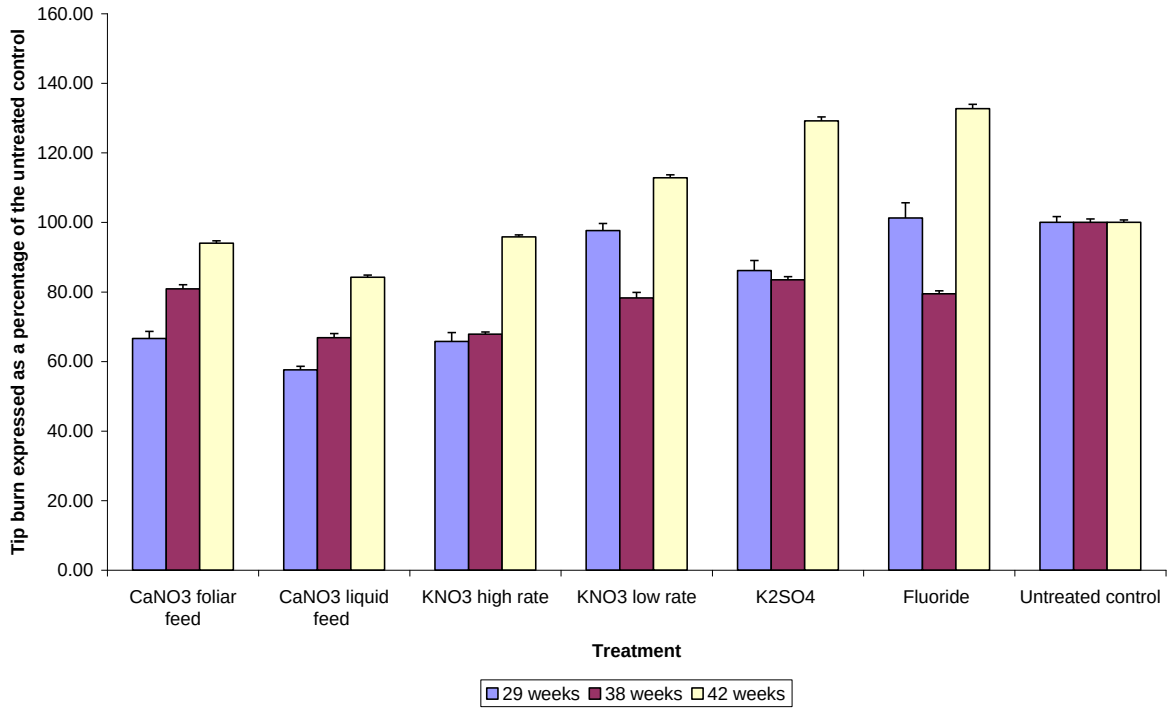

Figure 9. Tip burn 29, 38 and 42 weeks after treatments, expressed as a percentage of the untreated control. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control.

Plant quality was scored on a scale of 0-5 (0 = dead plants, 5 = no tip burn, Table 3). Plant quality scores were greater in the KNO_3 (high dose rate) and calcium liquid feed than in the untreated control, calcium foliar feed, potassium sulphate, potassium nitrate (low dose rate) and fluoride treatments (Figure 10). All plots were given scores of 3 (over 50% of plants saleable) and above after 29 and 38 weeks of treatment, with no symptom-free plots. There appeared to be an improvement in plant quality after 38 weeks of treatment, with only the plants treated with potassium sulphate and fluoride scoring below 4. After 42 weeks of

treatment the results generally followed the same trends, although plant quality appeared to have reduced in the potassium nitrate (low dose), potassium sulphate and fluoride treatments and the untreated control. Plots treated with fluoride and potassium sulphate were noticeably shorter than other treatments. The plants were all running out of nutrients, but those in some of the control and potassium nitrate (low dose rate) treatments were noticeably paler than in other plots, whilst plants treated with calcium nitrate (foliar and liquid feed) tended to be darker coloured; this may be an effect of added nitrogen rather than the calcium alone.

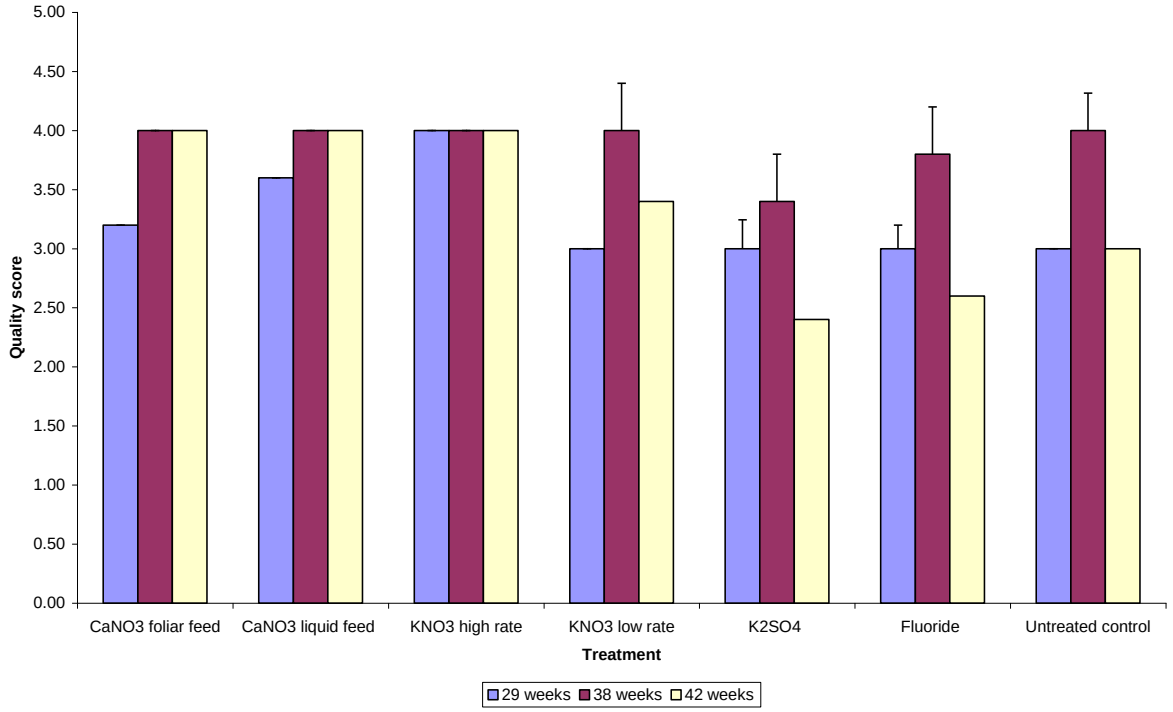

Figure 10. Quality scores 29, 38 and 42 weeks after treatments. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control.

The number of plants in each plot with yellow leaf spots was assessed after 38 and 42 weeks of treatment (Figure 11). There were no plots without any leaf spot. After 38 weeks, there were significantly fewer plants with leaf spot in the calcium nitrate (foliar and liquid feeds) than all other treatments ($P<0.001$) (Appendix 4). All plants treated with fluoride were affected to some degree by yellow leaf spot. After 42 weeks of treatment the results followed the same general trend with again significantly fewer plants with leaf spots in the calcium nitrate (foliar and liquid feeds) treatment and also the potassium nitrate (high dose rate) treatments compared with the untreated control and other treatments (Appendix 4). However, the number of plants with leaf spots was reduced across all treatments.

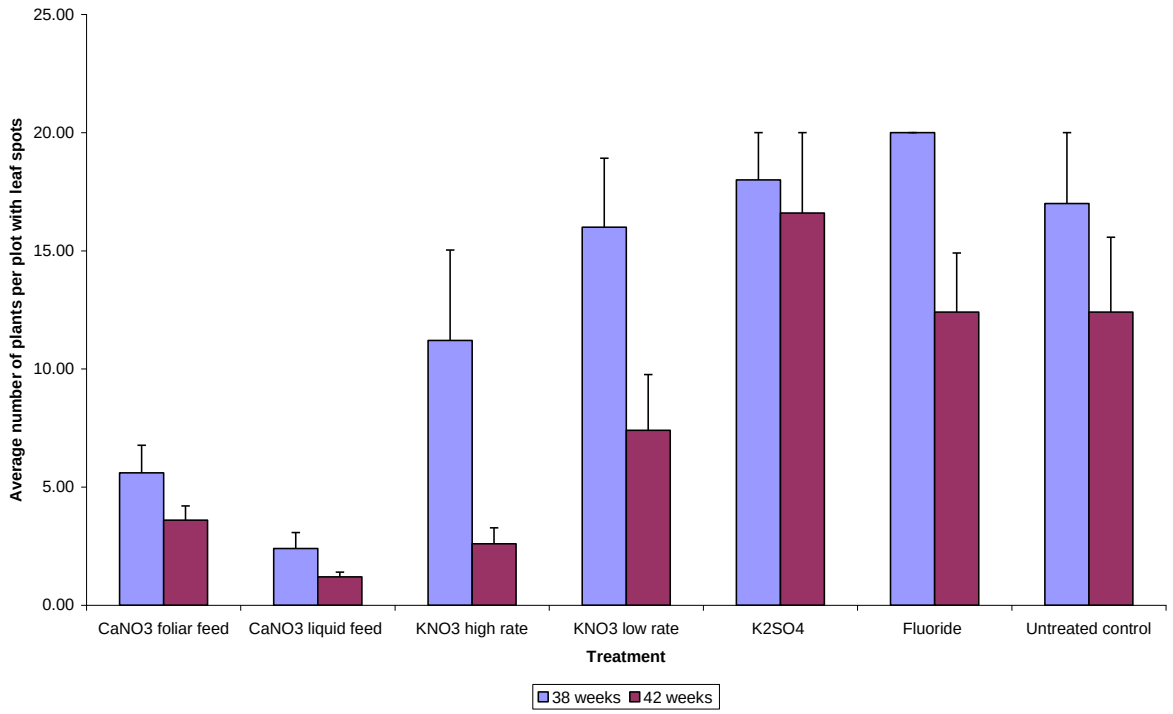

Figure 11. Number of plants per plot with *Cordyline* yellow leaf spot syndrome symptoms, 38 and 42 weeks after treatments. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control

Yellow leaf spot symptoms were assessed using a system based on the NIAB scoring method for recording plant disease (Table 4) after 38 and 42 weeks of treatment (Figure 12). There were significant differences between treatments after 38 weeks (P= 0.044) (Appendix 4). Further investigation using Duncan's multiple range test indicated that significantly less leaf spot appeared in the calcium nitrate (foliar and liquid feeds) than the control. After 42 weeks the results followed the same general trend with reduced incidence in the calcium nitrate and potassium nitrate treatments and again there were significant differences between treatments (P<0.001) (Appendix 4), however the calcium nitrate (foliar and liquid feed), potassium nitrate (high dose rate) and untreated control were not significantly different. Only the fluoride treatment was significantly different to the control.

Table 6 shows the distribution of yellow leaf spot scores recorded within the different treatments. The two calcium nitrate treatments and potassium nitrate (high dose rate) scored between 0.1 and 1, but the potassium nitrate (low dose rate), potassium sulphate and fluoride scores ranged between 1 and 10. The untreated control did not score above 5.

Tissue samples were passed to Fera to investigate the cause of yellow leaf spot at each assessment and no pest, pathogen or oedema was found on any of the samples.

Table 6. Distribution of yellow leaf spot whole plot scores. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control

	31-Jan-13				28-Feb-13			
	0.1	**1**	**5**	**10**	**0.1**	**1**	**5**	**10**
Ca foliar	1	4	0	0	0	5	0	0
Ca liquid feed	3	2	0	0	0	5	0	0
KNO_3 high dose	0	5	0	0	0	5	0	0
KNO_3 low dose	0	3	2	0	0	1	3	1
K_2SO_4	0	2	3	0	0	1	2	2
Fluoride	0	3	2	0	0	0	3	2
Control	0	2	3	0	0	2	3	0

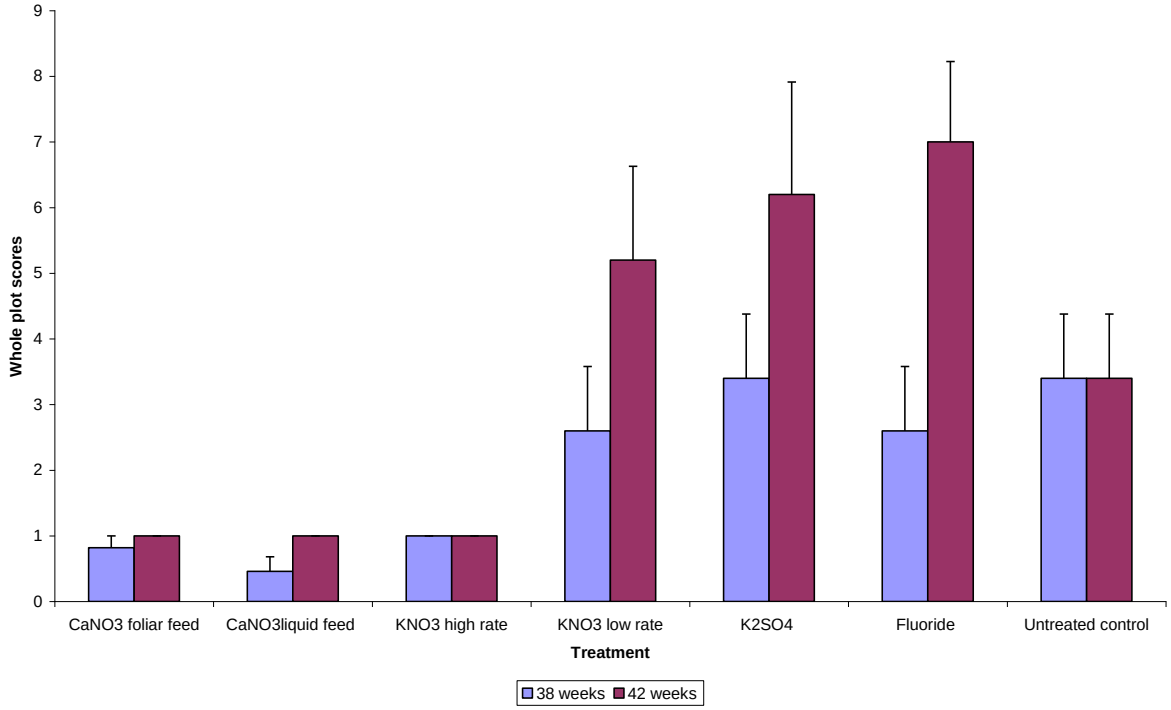

Figure 12. *Cordyline* yellow leaf spot syndrome symptoms, whole plot scores 38 and 42 weeks after treatments. Calcium nitrate foliar feed, calcium nitrate liquid feed, potassium nitrate high rate liquid feed, potassium nitrate low rate liquid feed, potassium sulphate liquid feed, fluoride liquid feed, untreated control.

Tissue analyses

Leaf tissue analysis at the start of the trial (12 October 2011) indicated more fluoride in *Cordyline* leaves with tip burn than without (Appendix 5). There was less potassium in both *Cordyline* and *Phormium* tissue with tip burn than without. Lower levels of calcium were found in *Cordyline* leaves with tip burn, and higher levels in *Phormium* leaves with tip burn.

A further set of tissue analyses comparing leaves with and without leaf spots was carried out on 22 March 2013; samples were taken from the potassium nitrate (high dose rate) and the untreated control treatments, with and without yellow leaf spots (Appendix 5). Lower levels of potassium and phosphorus were found in *Cordyline* leaves with leaf spots than without in both the potassium nitrate treatment and the untreated control, in line with the analyses carried out on 12 October 2011. Nitrogen and calcium levels were not correlated with or without leaf spots across these samples. Higher manganese and magnesium levels were found in leaves with leaf spots and tip burn than without (i.e. in October 2011 and March 2013).

Tissue analyses (Appendix 5) confirmed that levels of calcium generally accumulated in line with treatments. Increased potassium in the feeds translated into increased potassium in leaf tissue of both *Cordyline* and *Phormium*, with levels in line with dose rate. Fluoride had not consistently accumulated in line with treatments in either *Cordyline* or *Phormium* tissue, when applied at 3.0 mg/L or 5.0 mg/L under the conditions of this trial. Tissue analysis also showed that total nitrogen was generally higher in the calcium nitrate and potassium nitrate treatments than the untreated control.

Growing media analyses

Growing media samples from each treatment were analysed at the start of the trial and during the autumn and winter 2012/13 assessments (Appendix 3, Appendix 6). Nutrient levels were generally depleting. The pH was below 5.0 in all but five samples; at this level calcium and magnesium are both less available to plants. Sulphate levels were high in a number of treatments, possibly due to build up over time due to drip irrigation and the salts not being flushed through the growing media, but not consistently in the same treatments. Sodium and magnesium levels were also high in some samples. Growing media potassium levels were low in a number of samples, including those where additional potassium was applied. Soluble nitrogen levels were generally higher in the calcium nitrate and potassium nitrate treatments, except for January 2013. In November 2012 soluble nitrogen levels were higher in the untreated control than all other treatments except for the potassium nitrate high dose rate treatment.

Objective 3: Cordyline yellow leaf spot

Palmstead Nurseries

The plants included in this trial were produced in an unheated, side-ventilated multi-span polytunnel, on drained beds covered with Mypex. Liners had been transplanted into 3 L pots (March 2011). Crops were irrigated with mains water during winter. Overhead irrigation

(computer controlled, linked to a weather station, with some manual input) parameters were set to maintain a dry regime. Growing media consisted of coarse peat (100%) with nutrition provided by Osmocote Pro (16:11:10, 3.2 kg/m^3). The number of plants in the batch reduced throughout the monitoring as they were sold. Plants were initially placed pot thick but the distance between plants was increased to approximately 30 cm as space became available.

At the start of the monitoring (12 December 2011) some leaf spotting was evident, affecting 1-2 leaves on less than 5% of the crop. By 16 March 2012 the majority of the older leaves of the originally affected plants were heavily spotted (new leaves were not affected), and approximately 10% of the previously unaffected plants (9 plants/100) were now showing symptoms.

Stoneyfield Nursery

The *Cordyline* plants used in this trial were grown under glass. Plugs had been transplanted into 1 L pots and placed pot thick on the floor (Mypex over soil). The temperature was maintained above 1°C(diesel fuelled boilers, vented outside). A vent and fan system was used for ventilation above 12°C. The crop was hand watered during the winter (borehole water), maintaining 25% moisture in the growing media once the plants had rooted through. Growing media consisted of 75% peat, 25% wood fibre, pH 4.5-5.5. Nutrition was provided by a combination of base fertiliser, (Nutricote 140 Day,16-10-10 @1.5Kg/m^3; and Plantacote 12 month (18-6-12 @1.5 Kg/m^3), fritted trace elements and liquid feed applied as necessary (Solufeed Vigil 16:10:18).

The batch of plants (>6,000) remained intact throughout the monitoring (from 2 December 2011). None of the plants were affected by leaf spots for the majority of the exercise. However, symptoms had appeared by the final assessment (20 April 2012) and batches of 20 plants from central rows of plants were sampled and an average of 10% were affected (Figure 13).


Figure 13. Stoneyfield Nursery *Cordyline* crop (left) and leaf spots (right)

Temperature, light levels and humidity were monitored at the two nurseries from December 2011 into spring 2012, data for December and January is presented (Table 7, Appendix 7). Data was not collected at Stoneyfield Nursery after 16 January 2012 due to damage to the datalogger caused by water ingress; leaf spot symptoms had not been observed in this crop before this time.

Table 7. Summary environmental data

		Maximum	Date	Minimum	Date
Palmstead Nurseries	**Temperature (°C)**	14.8	13.01.12	-3.5	19.12.11
Stoneyfield Nursery		22.6	13.12.11	-2.5	19.12.11
Palmstead Nurseries	**PAR light ($\mu M/m^2/s$)**	207	09.01.12		
Stoneyfield Nursery		513	10.01.12		
Palmstead Nurseries	**Humidity (%)**	83.9	13.12.11 & 22.12.11	39.6	16.01.12
Stoneyfield Nursery		94.9	7.01.12	42.2	06.01.12

Temperature and humidity fluctuated more, and over a greater range, at Stoneyfield Nursery than Palmstead Nurseries (Table 7). The greatest differences were seen in light level readings; at Palmstead Nurseries the light level exceeded 200 $\mu M/m^2/s$ on one day, however at Stoneyfield Nursery it was above this level for approximately 75% of period that data was collected. Whilst incidence of leaf spot was lower under the conditions at Stoneyfield Nursery compared with those experienced at Palmstead Nursery, it would be premature to conclude that this can be entirely attributed to the environmental conditions without comparing the incidence of symptoms on similar plant material under different controlled environmental conditions. It may also be significant that the plant material at Stoneyfield Nursery was younger than that at Palmstead Nursery.

Conclusions

There was a clear effect of the calcium nitrate foliar and liquid feeds, and the high dose rate of potassium nitrate, with lower levels of both tip burn and yellow leaf spots recorded in these treatments. Although higher in the calcium and potassium treatments than other treatments, plant quality was generally reduced towards the end of the trial as nutrients were becoming depleted. Whilst the majority of plants in the trial were marketable, increased levels of tip burn and leaf spot result in increased labour cost due to plant cleaning operations at dispatch.

Plant tissue analysis confirmed that both plant species accumulated nutrients broadly in line with the calcium and potassium nitrate treatments, but not the fluoride treatment. Nitrogen levels in plant tissue and soluble nitrogen in the growing media were also generally increased by the calcium and potassium nitrate treatments, resulting in improved leaf colour. Although there were increased levels of leaf spot and tip burn in plants treated with fluoride in some assessments, these results were not consistent, and toxicity did not appear to occur under the conditions of this trial.

It has been suggested that *Cordyline* yellow leaf spot syndrome is due to oedema, caused by environmental conditions. Different levels of leaf spot did occur at the nurseries monitored, and the environmental conditions were also different, however, this was a monitoring exercise rather than a planned trial and the plant material and treatment (age, growing media etc) were therefore not comparable.

Samples of *Cordyline* tissue with leaf spots were analysed by Fera, but no pest, pathogen or oedema were found. In previous years of this project, evidence of cell disruption due to oedema had been observed in some tissue samples.

During the final year of this project, a trial will be carried out to confirm the findings described in this report. Treatments will include different dose rates of calcium nitrate (applied as foliar and liquid feeds) and potassium nitrate, plus combinations of liquid feed treatments. Potassium sulphate and fluoride will not be included.

Technology transfer

- HDC News article December 2011/January 2012

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Appendix 1. Tip burn trial layout

BLOCK 1	P5	P4	C7	P1
	P7	C3	C5	P3
	P6	C2	C4	C6
	P2	C1	C6	C3
BLOCK 2	C4	P3	C7	P6
	P2	P1	P5	P7
	C1	P4	C2	C5
BLOCK 3	C4	P4	C2	C5
	P2	P6	C3	P3
	C7	P1	C1	C6
	P7	P5	P4	C3
BLOCK 4	P7	C2	C1	C4
	C7	P2	P3	C6
	P1	C5	P5	P6
BLOCK 5	C6	C7	P2	P3
	P7	C5	C1	C4
	P1	C2	P4	P5
	C3	P6		

Treatments

1	$Ca(NO_3)_2$ foliar application
2	$Ca(NO_3)_2$ liquid feed
3	KNO_3 high rate liquid feed
4	KNO_3 lower rate liquid feed
5	K_2SO_4 liquid feed
6	Fluoride liquid feed
7	Control – water only

C	*Cordyline*
P	*Phormium*

Appendix 2*. Cordyline* plots at final assessment

Treatment

$Ca(NO_3)_2$ foliar application

Treatment

$Ca(NO_3)_2$ liquid feed

Treatment

KNO_3 high rate liquid feed

Treatment

KNO_3 low rate liquid feed

Treatment

K_2SO_4 liquid feed

Treatment

Fluoride liquid feed

Treatment

Control – water only

Appendix 3. Pre-trial analyses

East Malling Research Water Analysis 20.09.11

pH	7.58	Conductivity	556 uS/cm
	mg/l		mg/l
Nitrate-N	4.6	Chloride	52.5
Sulphate	72.2	Phosphorus	1.3
Boron	0.08	Potassium	7.0
Copper	< 0.01	Magnesium	5.4
Manganese	< 0.01	Calcium	62.2
Zinc	0.12	Sodium	52.7
Iron	< 0.01	Carbonate	<0.1
Alkalinity as HCO_3	139.0	Fluoride	<0.1

Sinclair DHL Peat-Bark growing media 30.09.11

pH	4.84	Conductivity	248 uS/cm
Density	490 kg/m3	Ammonia-N	71.6 mg/l
Dry Matter	39.0%	Nitrate-N	86.0 mg/l
Dry Density	191.1 g/m^3	Total Soluble N	157.6 mg/l
Chloride	35.4 mg/l	Sulphate	221.4 mg/l
Phosphorus	52.2 mg/l	Boron	0.13 mg/l
Potassium	151.1 mg/l	Copper	< 0.06 mg/l
Magnesium	29.1 mg/l	Manganese	0.44 mg/l
Calcium	22.2 mg/l	Zinc	< 0.06 mg/l
Sodium	32.0 mg/l	Iron	0.99 mg/l

pH and conductivity measurements are made at 20°C

Appendix 4. Analysis of Variance (ANOVA) tables

Tip burn after 29 weeks of treatment

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	265.89	66.47	2.46	0.073
Treatment	6	1247.66	207.94	7.69	<0.001 ***
Residual	24	649.38	27.06		
Total	34	2162.93			

Tip burn after 38 weeks of treatment

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	54.836	13.709	2.85	0.046
Treatment	6	124.563	20.760	4.32	0.004 **
Residual	24	115.400	4.808		
Total	34	294.799			

Tip burn after 42 weeks of treatment

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	6.413	1.603	0.39	0.812
Treatment	6	210.038	35.006	8.58	<0.001***
Residual	24	97.899	4.079	24	97.899
Total	34	314.350			

Percentage of plants affected by yellow leaf spot after 38 weeks of treatment.

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	9410.0	2352.5	5.90	0.002
Treatment	6	33658.6	5609.8	14.07	<0.001 ***
Residual	24	9570.0	398.8		
Total	34	52638.6			

Percentage of plants affected by yellow leaf spot after 42 weeks of treatment.

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	3602.9	900.7	1.60	0.208
Treatment	6	25974.3	4329.0	7.67	<0.001***
Residual	24	13547.1	564.5		
Total	34	43124.3			

Whole plot assessment of yellow leaf spot after 38 weeks of treatment.

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	5.924	1.481	0.49	0.743
Treatment	6	46.964	7.827	2.59	0.044 *
Residual	24	72.496	3.021		
Total	34	125.384			

Whole plot assessment of yellow leaf spot after 42 weeks of treatment.

Source of variation	d.f.	s.s.	m.s	v.r.	F pr.
Block	4	36.971	9.243	1.98	0.129
Treatment	6	205.886	34.314	7.36	<0.001***
Residual	24	111.829	4.660	24	
Total	34	354.686			

Appendix 5. Plant tissue analyses

Leaf tissue analysis 12.10.11

Cordyline	**Total N DUMAS**	**Total P**	**Total K**	**Total Ca**	**Total Mg**	**Total S**	**Total Mn**	**Total Cu**	**Total Zn**	**Total Fe**	**Total B**	**Fl**	**K:Mg**	**K:Ca**	**Ca:Mg**
	% w/w	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**			
No tip burn	1.732	2442	18489	9342	2767	1894	162.0	3.9	36.6	413	24.2	<0.5	6.7	2.0	3.4
With tip burn	1.593	1655	14128	8708	3184	1522	379.0	2.0	47.2	150	16.5	1.1	4.4	1.6	2.7
Phormium	**Total N DUMAS**	**Total P**	**Total K**	**Total Ca**	**Total Mg**	**Total S**	**Total Mn**	**Total Cu**	**Total Zn**	**Total Fe**	**Total B**	**Fl**	**K:Mg**	**K:Ca**	**Ca:Mg**
	% w/w	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**			
No tip burn	2.200	2459	20142	6390	2777	159	56.5	2.0	21.9	159	15.2	<0.5	7.3	3.2	2.3
With tip burn	1.646	1626	16342	10481	3819	1512	158.0	2.0	24.7	444	13.7	I.S.	4.3	1.6	2.7

I.S. = Insufficient Sample. Results are reported on a 100% Dry Matter Basis. pH and conductivity measurements are made at 20°C

Leaf tissue analyses 4.07.12

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	2.04	3555	22615	5124	2461	986	191	6.0	26.7	115	14.7	<0.5	9.2	4.4	2.1
$Ca(NO_3)_2$	2.48	3433	21800	4683	2269	927	149	4.6	25.7	58.1	13.4	<0.5	9.6	4.7	2.1
KNO_3 (high rate)	2.19	3384	23946	4017	2138	903	128	4.2	26.9	53.6	12.2	<0.5	11.2	6.0	1.9
KNO_3 (low rate)	2.13	3413	22762	4963	2346	992	172	4.1	26.2	58.4	13.1	<0.5	9.7	4.6	2.1
K_2SO_4	2.19	3393	25503	4198	2307	911	168	4.0	27.5	68.3	13.5	<0.5	11.1	6.1	1.8
Fluoride	2.18	3475	22585	4846	2478	940	165	4.0	27.2	45.1	13.4	<0.5	9.1	4.7	2.0
UC*	2.20	3016	20528	5386	2164	848	151	4.6	26.3	221	14.9	<0.5	9.5	3.8	2.5
Phormium	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	2.22	2884	21384	4243	1658	526	169	2.3	16.8	94.9	22.7	<0.5	12.9	5.0	2.6
$Ca(NO_3)_2$	2.27	2894	22068	3476	1636	428	136	1.8	16.6	66.2	22.7	<0.5	13.5	6.3	2.1
KNO_3 (high rate)	2.29	2958	23893	3005	1649	466	136	2.0	15.6	46.9	21.3	<0.5	14.5	8.0	1.8
KNO_3 (low rate)	2.37	2985	21564	3154	1607	446	143	2.2	18.1	110	23.9	<0.5	13.4	6.8	2.0
K_2SO_4	2.21	3036	23385	3374	1644	452	152	2.0	18.1	52.9	23.3	<0.5	14.2	6.9	2.1
Fluoride	2.24	2966	21904	3272	1674	431	153	1.9	17.2	45.8	21.6	<0.5	13.1	6.7	2.0
UC*	2.23	2997	21821	3019	1676	430	127	1.9	16.8	37.5	20.9	<0.5	13.0	7.2	1.8

* Untreated control. Results are reported on a 100% Dry Matter Basis. pH and conductivity measurements are made at 20°C

Leaf tissue analyses 12.09.12

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	1.5	1970	13315	9631	2812	1358	136.0	3.5	21.6	104.0	37.6	2.0	4.7	1.4	3.4
$Ca(NO_3)_2$	1.5	1766	11883	8410	2367	1383	94.2	2.5	15.5	1121.0	20.5	4.4	5.0	1.4	3.6
KNO_3 (high rate)	1.9	1861	17480	8215	2606	1712	107.0	2.9	17.3	299.0	23.2	2.2	6.7	2.1	3.2
KNO_3 (low rate)	1.3	1845	14835	6993	2530	1361	94.7	2.5	15.3	189.0	18.5	1.7	5.9	2.1	2.8
K_2SO_4	1.3	1888	18405	7235	2535	1415	115.0	2.3	17.7	80.4	18.0	0.9	7.3	2.5	2.9
Fluoride	1.5	1975	13897	9246	2988	1605	142.0	2.8	20.9	94.5	27.2	4.2	4.7	1.5	3.1
UC*	1.3	1865	13219	8194	2726	1360	123.0	2.5	17.8	62.5	25.0	0.8	4.8	1.6	3.0
Phormium	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	2.3	2484	17113	5525	1660	1584	104.0	1.9	18.3	168.0	26.8	1.9	10.3	3.1	3.3
$Ca(NO_3)_2$	2.1	2627	17976	4077	1556	1535	90.4	1.5	18.1	56.8	28.0	<0.5	11.6	4.4	2.6
KNO_3 (high rate)	2.6	2507	20047	3983	1633	1802	101.0	1.5	16.7	52.2	25.9	<0.5	12.3	5.0	2.4
KNO_3 (low rate)	2.1	2779	19337	5396	1868	1531	112.0	1.9	19.8	88.4	30.6	<0.5	10.4	3.6	2.9
K_2SO_4	2.0	2505	21564	4974	1768	1447	143.0	1.7	19.8	65.7	27.1	<0.5	12.2	4.3	2.8
Fluoride	1.9	2377	16548	4050	1642	1430	99.1	1.5	18.9	56.6	25.6	0.6	10.1	4.1	2.5
UC*	2.2	2794	18362	4341	1765	1478	110.0	1.6	19.2	85.0	27.8	<0.5	10.4	4.2	2.5

* Untreated control. Results are reported on a 100% Dry Matter Basis. pH and conductivity measurements are made at 20°C

Leaf tissue analysis 29.11.12

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	1.73	2502	18443	13365	2681	1025	122	6.7	33.1	918	19.3	4.1	6.9	1.4	5.0
$Ca(NO_3)_2$	2.37	2505	17531	13594	2199	971	92	4.4	28.0	364	20.8	1.4	8.0	1.3	6.2
KNO_3 (high rate)	2.45	2702	24822	12501	2439	887	98.5	7.8	30.4	300	18.9	1.1	10.2	2.0	5.1
KNO_3 (low rate)	2.20	2337	20430	13751	2459	705	103	4.6	27.4	271	18.7	1.3	8.3	1.5	5.6
K_2SO_4	1.84	2400	23814	11016	2527	952	109	4.4	28.4	118	16.2	0.7	9.4	2.2	4.4
Fluoride	1.58	2354	18244	11746	2585	744	115	3.9	28.7	121	17.4	2.6	7.1	1.6	4.5
UC*	1.78	2603	17741	13141	2848	685	124	4.3	29.0	151	19.4	0.9	6.2	1.4	4.6

* Untreated control. Results are reported on a 100% Dry Matter Basis. pH and conductivity measurements are made at 20 °C

Leaf tissue analysis 31.01.13

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	1.75	2601	15420	21268	2636	1556	167	16.0	56.3	4374	15.9	13.2	5.8	0.7	8.1
$Ca(NO_3)_2$	2.28	2946	18025	13546	1710	1446	87.9	5.1	29	748	15.8	2.9	10.5	1.3	7.9
KNO_3 (high rate)	2.07	2780	22756	8863	1770	1370	62.5	3.3	24.1	239	12.8	1.4	12.9	2.6	5.0
KNO_3 (low rate)	2.12	2776	21082	9432	1794	1464	75.9	4.2	25.6	322	12.0	1.5	11.8	2.2	5.3
K_2SO_4	1.66	2551	20971	8025	1694	1278	73.6	3.4	23	154	11.1	0.8	12.4	2.6	4.7
Fluoride	1.71	2747	18305	10815	1771	1182	82.1	4.0	24.9	152	12.4	0.9	10.3	1.7	6.1
UC*	1.61	2466	17261	8781	1723	1167	73.9	3.3	21.3	122	10.7	0.7	10.0	2.0	5.1

* Untreated control

Leaf tissue analysis 28.02.13

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	Fl	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
$Ca(NO_3)_2$ (foliar feed)	1.61	2471	15068	12371	2061	1375	106.0	3.5	22.4	181.0	24.2	1.3	7.3	1.2	6.0
$Ca(NO_3)_2$	1.99	2449	14729	11222	1670	1409	79.1	3.8	21.3	93.6	24.3	0.7	8.8	1.3	6.7
KNO_3 (high rate)	1.80	2377	18470	9657	1851	1265	64.7	2.6	19.9	74.8	21.8	<0.5	10.0	1.9	5.2
KNO_3 (low rate)	1.52	2168	16099	9563	2012	1487	91.8	3.0	20.2	54.8	22.8	<0.5	8.0	1.7	4.8
K_2SO_4	1.34	2072	17321	8815	1975	1048	96.9	2.5	19.6	71.2	18.7	<0.5	8.8	2.0	4.5
Fluoride	1.43	2240	15028	8968	1726	1151	79.1	2.7	19.6	51.6	19.5	1.8	8.7	1.7	5.2
UC*	1.31	2128	13831	8913	1847	1192	87.8	2.6	19.6	57.0	20.2	1.0	7.5	1.6	4.8

* **Untreated control**

Leaf tissue analysis 22.03.13

Cordyline	Total N DUMAS	Total P	Total K	Total Ca	Total Mg	Total S	Total Mn	Total Cu	Total Zn	Total Fe	Total B	K:Mg	K:Ca	Ca:Mg
	% w/w	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg			
KNO_3 (high rate) with leaf spots	1.44	1546	15496	9676	2666	1134	182	2.8	27.5	172	17.0	5.8	1.6	3.6
KNO_3 (high rate) with no leaf spots	1.66	1896	17736	13042	2323	1192	109	3.0	25.1	149	20.0	7.6	1.4	5.6
UC* with leaf spots	1.21	1749	11953	11754	2871	1111	162	2.4	25.2	115	20.8	4.2	1.0	4.1
UC* with no leaf spots	1.10	1939	12319	11509	2601	1027	133	2.6	24.3	79	17.3	4.7	1.1	4.4

*** Untreated control.**

Appendix 6. Growing media analyses
Growing media analysis 12.10.12

Cordyline		$Ca(NO_3)_2$ (foliar feed)	$Ca(NO_3)_2$ (liquid feed)	KNO_3 (high rate)	KNO_3 (low rate)	K_2SO_4	Fluoride	UC*
pH		4.45	5.26	4.40	4.97	4.79	5.74	4.66
Cond. at 20°C	**uS/cm**	1055	229	534	309	175	376	407
Density	**kg/m3**	545	665	526	611	591	578	594
Ammonia-N	**mg/l**	115.8	22.1	20.1	19.0	12.9	17.9	15.4
Dry Matter	**%**	35.1	27.9	32.0	27.3	27.8	34.8	29.3
Nitrate-N	**mg/l**	311.3	19.3	20.1	21.1	10.2	10.3	7.7
Dry Density	**kg/m3**	191.3	185.5	168.3	166.8	164.3	201.1	174.0
Total Soluble N	**mg/l**	427.1	41.4	40.2	40.1	23.1	28.2	23.1
Cl	**mg/l**	174.9	35.9	46.3	42.9	24.4	96.5	44.6
Sulphate	**mg/l**	1250.4	407.2	1283.9	599.2	279.7	673.3	890.5
P	**mg/l**	167.8	23.7	41.4	33.5	18.2	31.2	37.1
B	**mg/l**	0.21	0.21	0.17	0.15	0.17	0.19	0.22
K	**mg/l**	467.60	21.10	49.10	31.30	103.80	26.00	23.70
Cu	**mg/l**	0.15	0.08	0.15	0.14	0.06	0.16	0.10
Mg	**mg/l**	233.80	15.70	84.00	41.40	11.40	37.50	63.00
Mn	**mg/l**	3.85	0.10	0.74	0.20	0.09	0.14	0.45
Ca	**mg/l**	230.30	52.50	131.30	97.10	22.50	145.80	149.70
Zn	**mg/l**	0.30	0.08	0.15	0.11	<0.06	0.45	0.15
Na	**mg/l**	216.00	153.00	332.10	153.80	80.40	200.60	201.80
Fe	**mg/l**	5.76	0.81	1.84	1.29	0.37	1.05	1.41
K:Mg		2.0	1.3	0.6	0.8	9.1	0.7	0.4
K:Ca		2.0	0.4	0.4	0.3	4.6	0.2	0.2
Ca:Mg		1.0	3.3	1.6	2.3	2.0	3.9	2.4

* Untreated control.

Growing media analysis 29.11.12

Cordyline		$Ca(NO_3)_2$ (foliar feed)	$Ca(NO_3)_2$ (liquid feed)	KNO3 (high rate)	KNO3 (low rate)	K2SO4	Fluoride	UC*
pH		4.46	5.02	4.20	4.35	4.21	4.60	4.09
Cond. at 20°C	**uS/cm**	493	380	742	326	574	222	572
Density	**kg/m3**	734	729	584	732	663	593	564
Ammonia-N	**mg/l**	22.8	26.7	31.3	27.3	22.4	17.3	33.9
Dry Matter	**%**	29.6	28.7	33.4	26.2	31.9	28.2	31.4
Nitrate-N	**mg/l**	12.5	11.1	30.2	9.2	19.4	<0.6	18.6
Dry Density	**kg/m3**	217.3	209.2	195.1	191.8	211.5	167.2	177.1
Total Soluble N	**mg/l**	35.3	37.8	61.5	36.5	41.8	17.3	52.5
Cl	**mg/l**	34.0	30.5	70.1	34.7	87.3	41.9	55.9
Sulphate	**mg/l**	1312.2	957.5	2006.6	764.1	1527.2	495.4	1586.8
P	**mg/l**	44.8	31.8	93.0	29.5	45.1	20.7	67.9
B	**mg/l**	0.21	0.18	0.20	0.18	0.19	0.18	0.18
K	**mg/l**	29.2	14.2	98.3	33.3	107.0	11.8	48.9
Cu	**mg/l**	0.18	0.14	0.21	<0.06	0.11	0.09	0.13
Mg	**mg/l**	104.4	58.5	163.6	56.7	107.1	33.7	153.6
Mn	**mg/l**	0.60	0.29	1.58	0.23	0.81	0.24	1.63
Ca	**mg/l**	222.7	173.4	258.5	89.4	194.1	81.6	189.8
Zn	**mg/l**	0.30	0.23	0.28	0.17	0.27	0.14	0.33
Na	**mg/l**	233.8	201.3	430.6	186.0	335.3	131.2	302.2
Fe	**mg/l**	3.21	1.81	2.63	1.35	1.34	1.79	3.48
F	**mg/l**	<1.0	<1.0	<1.0	<1.0	<1.0	5.0	<1.0
K:Mg		0.3	0.2	0.6	0.6	1.0	0.4	0.3
K:Ca		0.1	0.1	0.4	0.4	0.6	0.1	0.3
Ca:Mg		2.1	3.0	1.6	1.6	1.8	2.4	1.2

* Untreated control.

Growing media analysis 31.01.13

Cordyline		$Ca(NO_3)_2$ (foliar feed)	$Ca(NO_3)_2$ (liquid feed)	KNO3 (high rate)	KNO3 (low rate)	K2SO4	Fluoride	UC*
pH		3.94	4.32	4.28	3.93	4.16	4.24	4.35
Cond. at 20°C	**uS/cm**	313	517	451	584	433	339	498
Density	**kg/m3**	495	458	442	440	452	516	440
Ammonia-N	**mg/l**	29.2	37.6	39.9	27.4	31.4	39.4	40.5
Dry Matter	**%**	40.8	42.2	45.4	46.5	35.9	32.7	41.7
Nitrate-N	**mg/l**	2.0	7.1	6.1	5.0	<0.6	0.7	7.9
Dry Density	**kg/m3**	202.0	193.3	200.7	204.6	162.3	168.7	183.5
Total Soluble N	**mg/l**	31.2	44.7	46.0	32.4	31.9	40.1	48.4
Cl	**mg/l**	54.9	26.2	29.3	24.4	52.6	46.4	23.6
Sulphate	**mg/l**	693.9	1500.1	1250.6	1659	1196.2	877.1	1451
P	**mg/l**	31.2	42.5	41.8	52.9	35.6	19.7	61.6
B	**mg/l**	0.15	0.16	0.14	0.18	0.16	0.14	0.16
K	**mg/l**	20.1	23.1	49.4	25.2	23.6	8.8	41.3
Cu	**mg/l**	0.10	0.15	0.14	0.13	0.12	0.10	0.12
Mg	**mg/l**	57.7	114.2	97.5	175.1	111.2	60.3	124
Mn	**mg/l**	0.41	0.75	0.58	1.34	0.54	0.30	0.85
Ca	**mg/l**	74.8	207.5	151.7	229.7	158.6	115.4	204
Zn	**mg/l**	0.43	0.48	0.49	1.17	0.50	0.25	0.39
Na	**mg/l**	203.2	326.7	278.8	291.9	235.9	204.7	257
Fe	**mg/l**	1.82	2.70	2.75	3.63	1.97	1.02	2.92
F	**mg/l**	<5.0	<5.0	<5.0	<5.0	<5.0	7.5	<5.0
K:Mg		0.3	0.2	0.5	0.1	0.2	0.1	0.3
K:Ca		0.3	0.1	0.3	0.1	0.1	0.1	0.2
Ca:Mg		1.3	1.8	1.6	1.3	1.4	1.9	1.6

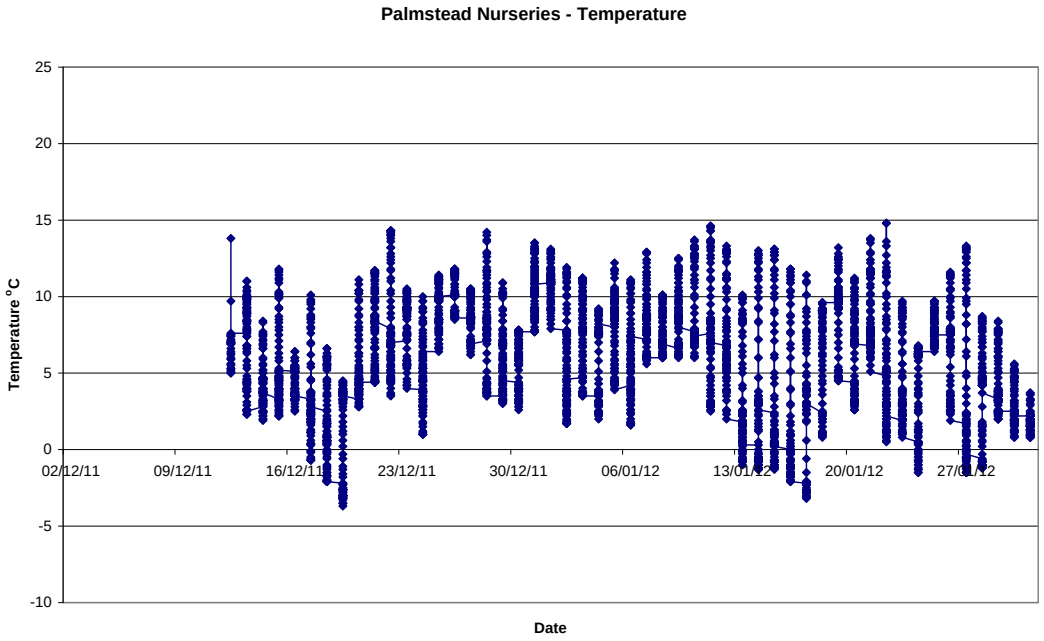
* Untreated control.

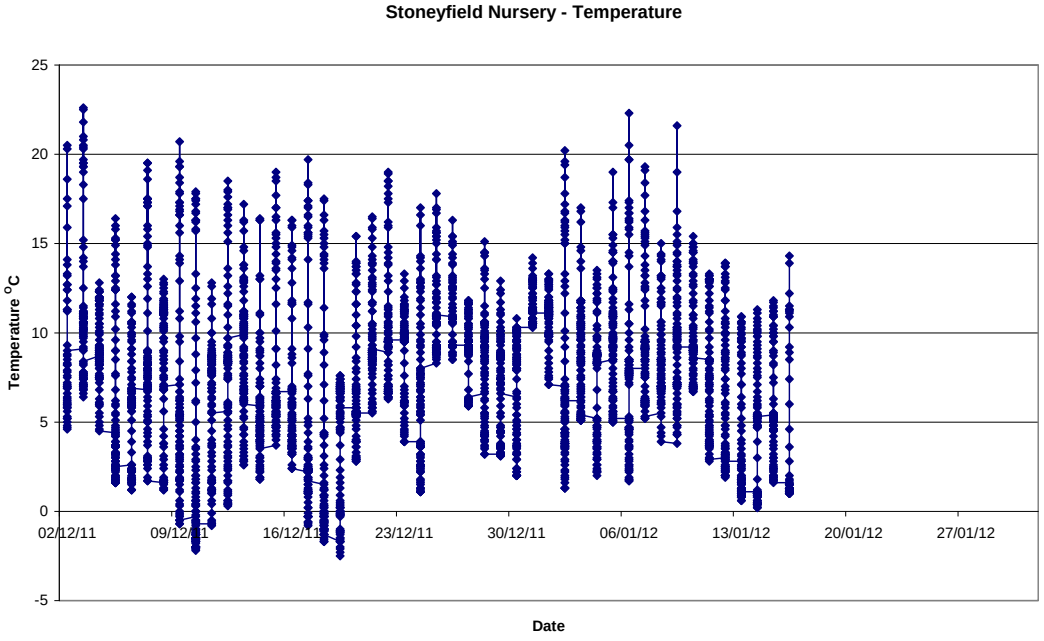
Growing media analysis 28.02.13

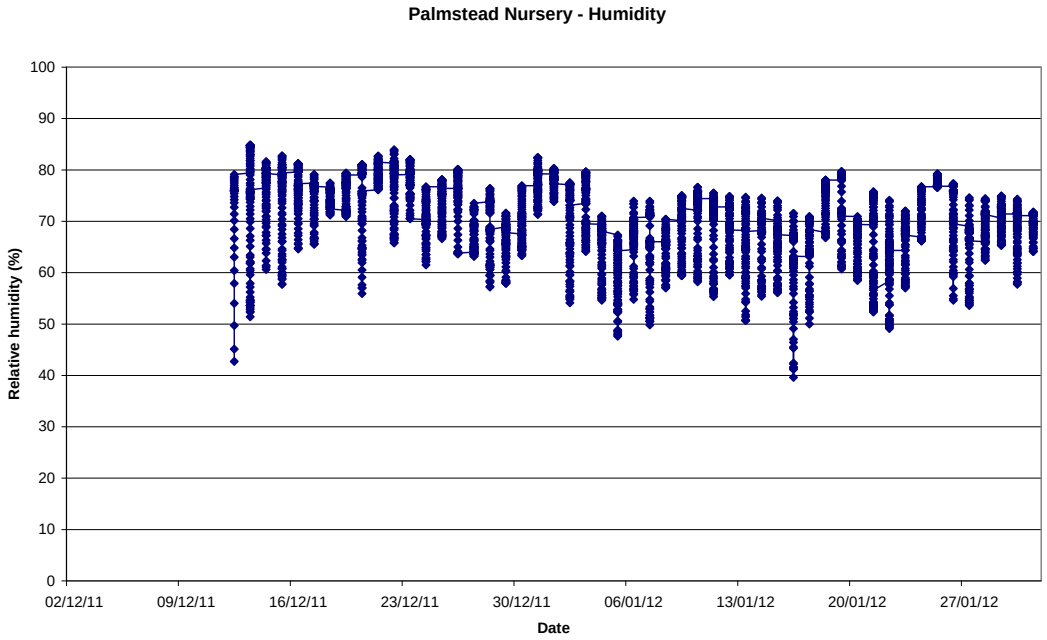
Cordyline		$Ca(NO_3)_2$ (foliar feed)	$Ca(NO_3)_2$ (liquid feed)	KNO3 (high rate)	KNO3 (low rate)	K2SO4	Fluoride	UC*
pH		4.40	4.96	4.38	4.30	4.36	4.44	4.88
Cond. at 20°C	**uS/cm**	361	183	315	543	484	348	240
Density	**kg/m3**	477	430	384	400	394	365	410
Ammonia-N	**mg/l**	31.00	25.70	25.30	24.20	22.80	20.00	21.60
Dry Matter	**%**	35.0	44.9	46.3	50.3	32.4	37.5	55.1
Nitrate-N	**mg/l**	2.4	5.9	2.7	1.2	1.3	<0.6	1.9
Dry Density	**kg/m3**	166.9	193.1	177.8	201.2	127.7	136.9	225.9
Total Soluble N	**mg/l**	33.4	31.6	28.0	25.4	24.1	20.5	23.5
Cl	**mg/l**	51.7	12.4	17.6	39.9	58.4	56.6	41.3
Sulphate	**mg/l**	827.9	429.4	739.8	1387.8	1214.3	815.5	527.1
P	**mg/l**	30.9	16.8	27.0	51.7	35.9	36.8	20.4
B	**mg/l**	0.13	0.25	0.10	0.16	0.15	0.12	0.24
K	**mg/l**	32.40	10.30	22.60	22.70	102.90	14.00	12.80
Cu	**mg/l**	0.07	<0.06	0.06	0.10	0.08	0.06	<0.06
Mg	**mg/l**	70.20	24.80	58.90	150.20	103.80	82.90	33.40
Mn	**mg/l**	0.44	0.10	0.26	1.09	0.79	0.55	0.14
Ca	**mg/l**	103.50	60.50	64.90	187.50	211.60	97.90	75.20
Zn	**mg/l**	0.13	0.10	0.08	0.18	0.14	0.11	0.13
Na	**mg/l**	199.70	100.50	211.90	281.10	178.40	219.20	145.10
Fe	**mg/l**	2.37	1.99	1.88	2.79	2.06	1.78	1.59
F	**mg/l**	0.67	<0.60	0.67	0.67	<0.60	6.00	0.90
K:Mg		0.5	0.4	0.4	0.2	1.0	0.2	0.4
K:Ca		0.3	0.2	0.3	0.1	0.5	0.1	0.2
Ca:Mg		1.5	2.4	1.1	1.2	2.0	1.2	2.3

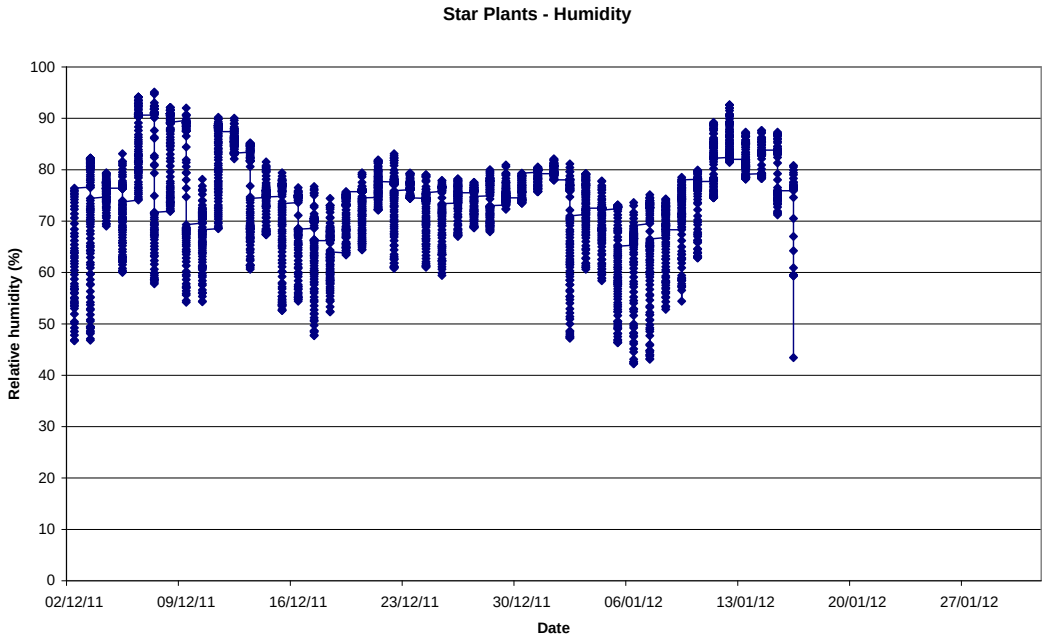
* Untreated control.

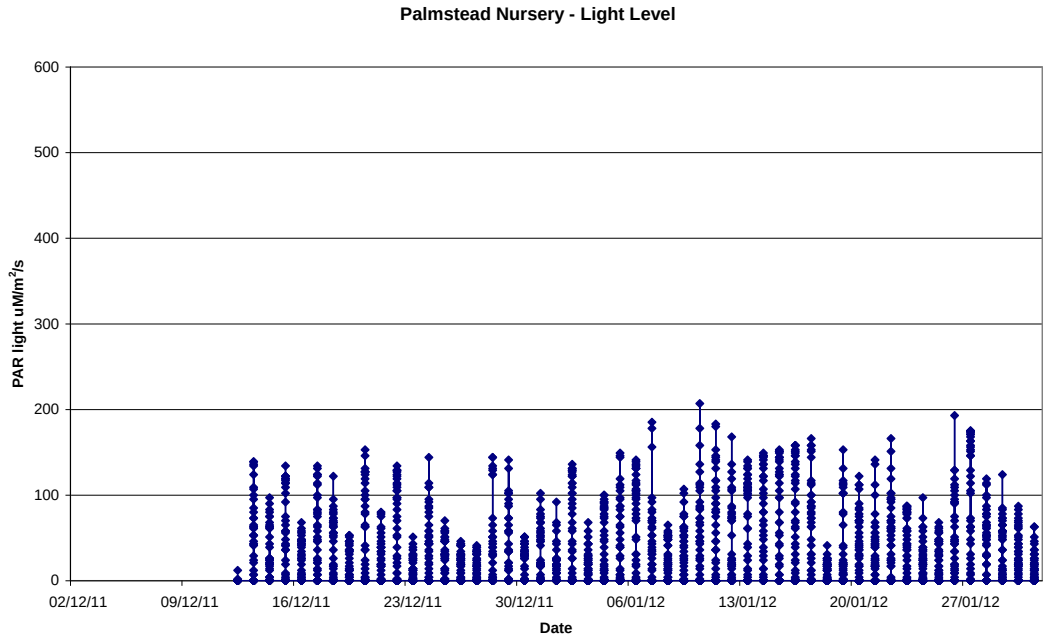
Appendix 7. Environmental data. December 2011 and January 2012, Palmstead Nurseries and Stoneyfield Nursery

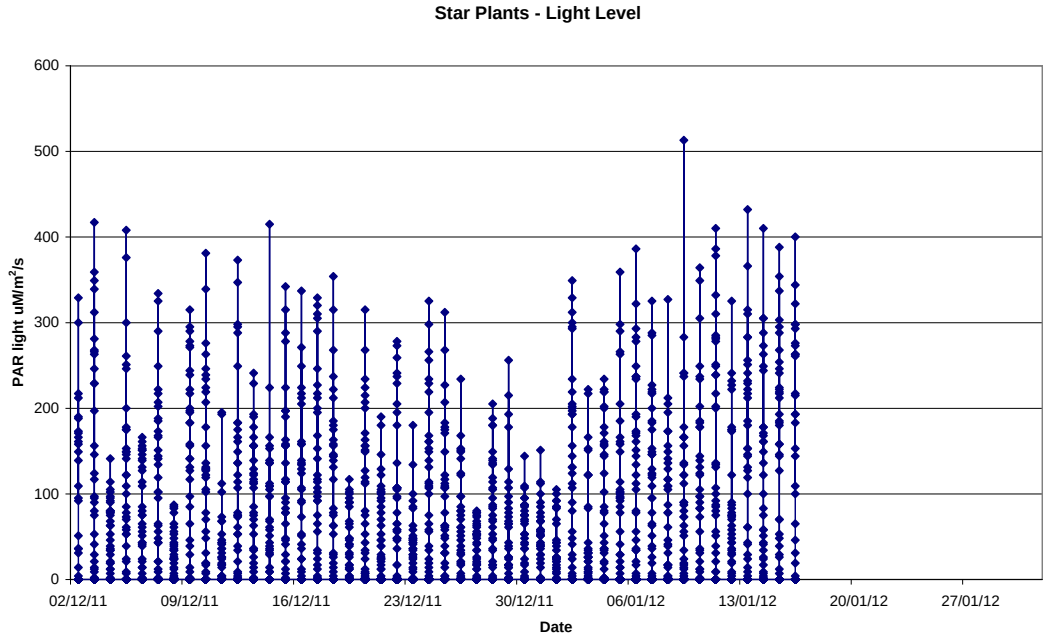












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