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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.

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GROWER SUMMARY

Headline

- Liquid feed applied weekly (0.5% and 1.0%) produced more marketable plants than higher dose rates for *Prunus lusitanica* 'Myrtifolia', *Spiraea arguta* and *Geranium* x *cantabrigiense* 'Westray'
- Liquid feed applied weekly (1.0%) was the most suitable feed for short term, vigorous crops such as *Tradescantia pallida* 'Purple Sabre'. Lower dose feeds can be used to restrict growth of this vigorous species.
- Liquid feed applied at every watering produced taller, less bushy plants. Lower dose rates could address this.
- Regular EC monitoring is useful for identifying excessive feed, particularly in shortening days and cooler temperatures, allowing growers to adjust feed rates. EC was generally more useful than SPAD for managing nutrient status.

Background

The majority of nursery stock growers currently use a base fertiliser with controlled release fertiliser (CRF), usually added by the growing media manufacturer to provide enough nutrition for the production phase. Some growers buy growing media with just base fertiliser added and then 'dibble' in the CRF at potting, which makes altering the rate used easier. There is increased interest in using lower CRF rates and supplementing with liquid feed to provide enough nutrition during key growth phases, to avoid excess fertiliser at other times and to reduce the potential for nutrient loss in run-off water. The combination of CRF and liquid feed can provide growers with greater control but still meet plant nutrient requirements. Crop safety can be improved by using a lower CRF rate for autumn potting under glass and topping up with liquid feed in the spring as appropriate. Growers could benefit from the associated nutrient cost savings, but with more control over plant growth, there is an opportunity to optimise productivity and improve quality while reducing crop waste and minimising the potential for point source nutrient pollution from grower holdings.

Year 1 of this work programme focused on obtaining separate baseline data for CRF and liquid feed uptake in nursery stock liners for a range of nursery stock subjects. Year 2 trials were based on the data obtained in year 1 and combined lower CRF rates with a range of liquid feeding regimes to develop 'feed to need' strategies. Year 3 trials in 2021 replicated those carried out in year 2 to confirm the reproducibility of the results and provide recommendations for growers.

Summary

The Year 3 HNS container trial took place at ADAS, Boxworth from May – October 2021 using four hardy nursery stock species (**Table 1**). Plants were supplied as 9 cm liners (*Prunus* and *Spiraea*) or 5 cm plugs (*Tradescantia* and *Geranium*) and transplanted into 3 L pots on 7 May 2021, (Week 20). SinclairPro (70% peat, 30% woodfibre) growing media was used, with no base fertiliser. Osmocote Exact 12-14 month CRF was dibbled into each pot at a single dose rate (1.5 g/L) at the time of transplant. For the 3L pots, 4.5 g of CRF was required per pot and the prills were measured out individually by weight for each plot. A 10:52:10 (ICL - Plant Starter) feed was used for four weeks from transplant, followed by a 3:1:3 (ICL – Grow Mix) feed until the end of the trial. All plants were irrigated by hand for the duration of the trial.

Table 1. Hardy Nursery Stock species

Species	Vigour	Term
Prunus lusitanica 'Myrtifolia'	vigorous	long
Spiraea arguta	moderate	long
Geranium x cantabrigiense 'Westray'	moderate	short
Tradescantia pallida 'Purple Sabre'	vigorous	short

There were 5 different feed treatment regimens (**Table 2**), including an untreated control, T1 (water only, no liquid feed), which were applied once per week from trial set-up, aside from T4 which received nutrients at every watering. Treatment T5 ('feed to need') was applied as required, according to weekly SPAD and EC measurements.

Table 2. Liquid feed treatments used in the container trial, 2021

Treatment No.	Treatment
1	No liquid feed
2	Liquid feed applied once per week (0.5%)
3	Liquid feed applied once per week (1.0%)
4	Low dose liquid feed (0.5%) at each watering
5	Feed to need applied weekly (0% / 1.0%). Timing based on EC/SPAD monitoring

The *Prunus* and *Spiraea* were grouped together as one trial. The *Geranium* and *Tradescantia* were grouped together as a second trial within the same polytunnel.

A pre-potting assessment was conducted for all species, including plant height, plant quality, and root coverage prior to any feed treatment applications to establish baselines for each ornamental species. Weekly assessments began one week after potting and lasted for the duration of the trial. They were completed on the same day each week, prior to irrigation: growing media electrical conductivity (EC, µS/cm), moisture content (%VMC), and leaf chlorophyll content (SPAD meter).

A mid-season assessment at week 13 (28 July 2021; *Prunus* and *Spiraea*) and week 12 (28 July 2021; *Geranium* and *Tradescantia*) assessed plant height, plant quality and root development. Final assessments were carried out in week 23 (5th October 2021; *Spiraea* and *Prunus*) and week 23 (11th October 2021; *Geranium* and *Tradescantia*). Plant height, quality, root coverage, and fresh and dry weights were assessed. Growing media and plant tissue samples were analysed (by Natural Resource Management, NRM) at the start of the trial, and then for each treatment and species at the final assessment. Tissue analysis results were compared with published standard figures (**Mills and Jones, 1996**).

***Prunus lusitanica* 'Myrtifolia' (Long term, vigorous crop)**

The most successful treatment in the *Prunus* trial was T3, producing taller plants with higher quality scores, and fresh and dry weights. The shortest plants were produced in treatments T1 and T5, which received no additional feed, and the highest root quality scores were produced by T1. Plants in all treatments were marketable, scoring above 3.T4 and T3 had the highest EC for most of the trial while leaf chlorophyll (SPAD) measurements were similar for all treatments until 16 weeks after potting, when measurements increased for T4 until the end of the trial. The high EC suggests that T3 and T4 were providing more nutrients than the plants were able to utilise. The growing media analysis of ground samples showed there were plentiful reserves of nutrients, except for T5 which had received no liquid feed. Reserves were particularly high in T4. Tissue analysis indicated that nutrient levels were within or above the standard range for T2, T3 and T4, but were below range for P and K in treatments T1 and T5. As plant quality scores were good for all treatments, this suggests that feed rates could potentially be reduced for this crop group without a negative impact on plant quality.

***Spiraea arguta* (Long term, moderate vigour crop)**

The *Spiraea* produced the tallest plants and highest plant quality scores in T2 and T3, although plants in all treatments were marketable. Root quality scores were similar in all treatments, although the lowest score was achieved in T4. Fresh and dry weights were highest in T3, but similar to T2 and T4. The lowest height, plant quality fresh and dry weight

scores were produced by T1 and T2 which did not receive additional feed. EC measurements were highest in T4 throughout most of the trial, while leaf chlorophyll (SPAD) measurements were tightly grouped for all treatments. Growing media analysis indicated that nutrient reserves were low in both ground and unground samples, except for T3 (P, K and Mg), T4 (nitrate-N, P, K and Mg). There was sufficient Mg in all treatments except for T5 (both ground and unground). Tissue analysis indicated that nutrient levels were within the standard range except for K, which was low in all treatments except for T4. While there were differences between the plants produced in each treatment, all treatments including the untreated controls produced good quality plants, indicating that additional liquid feed was beneficial but not essential in producing marketable plants.

***Geranium x cantabrigiense* 'Westray' (Short term, moderate vigour crop)**

The *Geraniums* that produced the best overall plants were from T3. They were taller, with the best foliage colour and plant and root quality scores, and higher fresh and dry weight. However, these measurements were not significantly different from the other treatments where nutrients were applied (T2, T3 and T4). EC measurements in T4 treatment were higher than other treatments, most notably for the first 13 weeks after potting, and after 22 weeks. Growing media analysis showed that by the end of the trial there were generally sufficient nutrients remaining, although ammonia-N reserves were low in all treatments except for T4, and EC and K were low in T5. Plant tissue analysis values were low in all treatments except for N and P in T4 compared with the standard range, and Mg levels were high for all treatments. This suggests that the although the *Geranium* have been termed 'moderately vigorous', they require less feed than the *Spiraea* (long term, moderate vigour). As plant quality scores were good for T2, T3 and T4, feed rates could potentially be reduced for this crop group without a negative impact on plant quality.

***Tradescantia pallida* 'Purple Sabre' (Short term, vigorous crop)**

At the end of the trial period and throughout, there was very little difference between treatments for plant quality and growth as all plants grew vigorously in all treatments. Plants grown in T3 were taller, with higher fresh and dry weights than other treatments and similar plant quality. T2 and T4 still produced marketable plants that were significantly different to the untreated plants (for plant and root quality), despite the various amounts of feed applied. Leaf chlorophyll (SPAD) measurements were variable, but were relatively tightly grouped for all treatments. EC was low throughout the trial except most notably at the beginning where it peaked before tailing off, for all treatments. This is a vigorous plant species and potentially lower feed rates could be used to manage growth of this plant. Growing media analysis

showed that N, P and K reserves were low for most treatments by the end of the trial. Tissue analysis also showed that N, P and K were low in all treatments; Mg was high.

Summary of findings

Many of the findings for all species from the 2020 trial were reflected in 2021, although weather conditions were cooler, and action points for growers remain unchanged.

From a grower perspective, shorter but bushier plants with more breaks / side shoots are usually more marketable for this sector. *Prunus*, *Spiraea* and *Geranium* plants produced under treatments T2 and T3 were considered more marketable due to their overall quality, height, and biomass. For the *Tradescantia*, all plants were marketable, but plants produced under T3 required less labour to produce plants of similar quality; low feed regimes could be used to restrict growth of these vigorous plants. This would also make the *Tradescantia* easier to handle without breakages.

T2 and T3, produced the most marketable plants with a bushier habit than other treatments, while T4 tended to produce taller, less bushy plants and appeared to provide excess nutrients. However, it may be that the habit of the plants in T4 (little and often) could be improved with lower dose rates.

T5 'feed to need' could be useful on nurseries producing a small range of species arranged in large blocks, but hardy nursery stock nurseries tend to have a wide range of species / cultivars; in the move away from peat based substrates plants may be held back by the time the need to feed is recognised, making this a more difficult option to manage. T3 is the more manageable treatment and produced good quality plants. No additional feed was applied to plants in T5 (no liquid feed).

The combination of SPAD and EC measurements allowed nutrient movements to be tracked. N uptake by the plants resulted in increased SPAD and lower EC readings; conversely where more liquid feed was provided than the plants required the salts remained within the growing media and the EC increased. For the *Tradescantia*, for example, the high SPAD and low growing media EC measurements indicated the plants were able to utilise the feed across all treatments.

The combination of EC and SPAD measurements is useful to identify trends. In this trial it was helpful to compare several treatments for specific species. In a nursery setting, however, growers will need to compare data for the same plant or plant group over multiple seasons to be able to make comparisons and put the data into context, for example if sufficient feed was applied in a hot season, and if it should then be reduced in a cooler season to produce marketable plants. This will also help growers to identify and rectify any issues sooner. It is

important to use the same piece of equipment throughout the season to gain the maximum benefit from the trends. Changing equipment can give variable results. It is also important with EC to take the readings at the same time each day to remove any variable moisture content that can alter the EC through the day.

High EC can be a cause for concern, particularly for sensitive plants, as it can result in root damage, and is usually addressed by irrigating to flush the salts out of the growing media. In this trial, plants were watered by hand with a measured amount of water so that treatments were standardised. The build-up of growing media EC, which could be interpreted as excess nutrient supply (given a high dose rate), could result in N or P in the run-off water, forming a potential environmental risk. The highest risk liquid feed regime would be 'little and often', where feed is applied at every irrigation (T4 in this trial). This could be mitigated by applying a lower dose feed with care to limit run-off (or capture / recycle run-off water).

There is currently a lack of tissue analysis data for specific species / cultivars, particularly for the herbaceous species. Growers will need to supplement and realign published data with their own data for tissue analysis to be used to greatest effect.

Categorising plants into long/short term and vigour groups will prove useful and will help growers to extrapolate data to a wider range of species, noting that woody and herbaceous plants are not directly comparable in terms of vigour. Grouping plants according to vigour category will make it easier to manage plant feed regimes.

In both years of this trial, the growing media used was SinclairPro 70% peat, 30% woodfibre. Growers are using more peat-free growing media, which can have higher conductivity (EC) and pH than peat-based media. Nutrients such as Mn, P and Fe can become unavailable as pH increases and this will need to be accounted for in fertigation regimes. Growers should also note that different substrates (e.g. bark) can provide a greater buffering effect which can help to protect plants against high salt levels. Substrate source and production method can also impact the way growing media materials perform in terms of water holding capacity (e.g. particle size, how fibrous the product is). Growers should trial new mixes before widespread use, with regular EC and nutrient monitoring to identify and address any deficiencies before they affect plant quality.

Treatment No.	Treatment	Outcome
2	Liquid feed applied once per week (0.5%)	Most marketable plants with bushier habit than T4, T1 and T5
3	Liquid feed applied once per week (1.0%)	Most marketable plants with bushier habit than T4, T1 and T5

4	Low dose liquid feed (0.5%) at each watering	Taller less bushy plants. Often provided excess nutrients. Dose rate could be adjusted. Risk of nutrient run-off where dose rate is too high.
5	Feed to need applied weekly (0% / 1.0%). Timing based on EC/SPAD monitoring	No liquid feed was applied for this treatment during the trial

Financial Benefits

Routine monitoring will identify low nutrient levels and allow corrective action to be taken before deficiency symptoms appear. A nutrient management regime could include regular on-site monitoring of EC and perhaps leaf chlorophyll, with laboratory irrigation water, substrate and leaf tissue analysis as appropriate.

While there are costs associated with purchasing monitoring equipment and submitting samples for laboratory analysis, there are some lower cost options, and these costs can be offset through reduced crop losses due nutrition problems. Regular on-site substrate EC measurements in this trial were carried out using a Terros 12 sensor with a ProCheck hand held reader (**Table 3**). Leaf chlorophyll was measured using a SPAD, but the AtLEAF is a useful, less expensive alternative that was tested in AHDB project HNS 193.

Presented in **Table 4** is an example costing of a laboratory analysis monitoring regime for irrigation water, substrate and leaf tissue samples on a medium sized, single site HNS nursery, extracted from Bragg and Holmes (**2016**).

Improving nutrient management practices can reduce plant waste and could save 1% - 3% of the crop. While crop value will vary depending on the species and market, assuming a farm gate value of 80p per plant for 9 cm liners, and an estimated 750,000 plants per hectare, this equates to between £6,000 and £18,000 per hectare per annum. For 3 L pots assuming a farm gate value of £3.00 per plant, with an estimated 187,500 pots per hectare, this equates to £5,625 and £16,875 per hectare per annum.

Table 3. Crop monitoring equipment example costs. The AtLeaf sensor was not used in this trial but is included as an example. *Costs derived from 2019 quotations

Purpose	Device	Cost (+VAT)
Handheld reader for Terros 12 sensor	Decagon ProCheck *	£425
Substrate EC and moisture sensor	Terros 12*	£200

Chlorophyll sensor	Minolta SPAD 502 Plus	£2,680
	AtLEAF Standard version*	£268
	AtLEAF Standard version plus USB connection*	£339
	AtLEAF Standard version plus Bluetooth connection*	£372

Table 4. Analysis costs: growing media, water (including run-off), liquid feed and plant tissue, based on a medium sized, single site nursery. Extracted from Bragg and Holmes (2016); 2022 prices ex VAT

Analysis	No of analyses	Cost	Comments
Water	4 analyses per year	£100 - £150	Includes irrigation and run-off water.
Growing media	18 analyses over 18 months	£572	Analysis of three substrate batches or crops; four samples per batch analysed per year.
Leaf tissue	12 analyses over 18 months	£425	Three indicator crops in three substrate mixes, four samples per crop over 18 months.
Total		£1,097 - £1,147	

Action Points

- Improve understanding of crop vigour and nutrient requirements through planned monitoring and recording of growing media EC and pH, run-off water and submission of samples for laboratory analysis. This will be particularly useful to help build up the experience needed to manage crops grown in peat free growing media.
- Build up an on-nursery database of tissue, growing media and irrigation water analyses over several seasons, including samples from plants with potential nutrient problems and healthy plants, determining critical thresholds where possible.
- Group plants according to vigour groups, matching nutrient application to vigour group needs.
- Monitoring plant EC can be a useful tool to identify whether the nutrient feed thresholds are being surpassed or undercut for various ornamental species.
- Vigorous crops have higher nutrient requirements than other species and so can uptake more nutrients than the plant needs for it to be marketable.
- Combining leaf tissue and growing media analysis with weekly growing media electrical conductivity (EC) measurements will help give growers the confidence to use lower rates of CRF and liquid feed, with applications made in response to plant need.

SCIENCE SECTION

Introduction

The majority of nursery stock growers currently use a base fertiliser with controlled release fertiliser (CRF), usually added by the growing media manufacturer, to provide sufficient nutrition for the production phase. There is increased interest in using lower CRF rates and supplementing with liquid feed to provide sufficient nutrition during key growth phases, but not providing excess fertiliser at other times and increasing the potential for nutrient loss in run-off water, resulting in point source pollution.

Background

The combination of CRF and liquid feed provides growers with the greater control through reduced CRF application and with application of specific liquid or foliar feed formulations to meet plant requirements. Crop safety is improved by using a lower CRF rate for autumn potting under glass and topping up with liquid feed in the spring as appropriate. Growers will benefit from the associated nutrient cost savings, but with more control over growth there is an opportunity to optimise productivity and improve quality while reducing plant waste and minimising point source nutrient loss from grower holdings.

The last significant review of nutrient management in container grown nursery stock raised potential environmental and quality issues concerning total reliance on CRF (**Pennell, 2013**). Firstly, temperature extremes due to changing weather patterns can give rise to nutrient release when plants are unable to utilise it, particularly in plants grown under protection, with autumn potted plants under glass being particularly at risk, and this increases the potential for nutrient leaching or plant damage due to the build-up of nutrients in the substrate. In addition to this, increasing attention is being given to environmental pollution and the prevention of the excessive loss of nutrients, particularly nitrates and phosphates into the ground water. High fertiliser rates may contravene regulations such as Nitrate Vulnerable Zones (NVZ), potential Phosphate Vulnerable Zones and drinking water legislation. In future, growers could fall foul of any regulations that are brought in and be subject to regulatory penalties.

Whilst previous work has been carried out that investigated the use of CRFs under protection (**Scott et al., 1993**), formulations and coatings have since been further developed by the manufacturers. Early work to evaluate the use of computer simulation models generally gave good predictions but were not adopted for use in commercial practice to allow for leaching of nutrients (**Scott, 1996**). Recent work has contributed methodologies for sampling and

analysis interpretation by growers (**Bragg and Holmes, 2016**) and data on nutrient leaching (**Adlam, 2016**). This study also included a comparative study of optical sensing equipment for monitoring nutrient status (e.g. SPAD readings, AtLeaf and FieldScout GreenIndex Iphone app) and EC probes (e.g. ProCheck).

Independent laboratory analysis is underway to characterise nutrient release patterns of base fertilisers and CRFs using a range of products and formulations (coating and longevity) using the EN13266 method (**Terlingen et al., 2016**). Release patterns at different temperatures (50˚C vs 25˚C) indicate differences between products (**Personal communication, Neil Bragg, Ann McCann**). CRFs are sensitive to both substrate moisture and temperature; although excess water does not influence nutrient release, it is positively correlated with substrate temperature and therefore sensitive to prevailing environmental conditions. For non-urea containing CRFs, nutrient release in the field can be determined effectively (and non-destructively) by measurement of electrical conductivity (EC) using the 'pour through' method (**Hojjatie and Carney, 2014**).

There are currently no independent guidelines on the most appropriate CRF (formulation and rate) / liquid feed rates (individually or in combination) or application timings to optimise crop quality and reduce production time. Plant nutrient suppliers provide detailed guidance on the use of their products, with application rates categorised by plant groups based on low, medium, and high nutrient uptake rates.

This trial programme considers the practice of reducing CRF rates, which can then be supplemented with liquid feed as necessary to maintain plant growth and quality and will provide guidance on CRF / liquid feed combinations and delivery schedules. Combining leaf tissue and growing media analysis with weekly growing media electrical conductivity (EC) measurements will develop a practical methodology whereby growers can have confidence in using lower rates of CRF and liquid feed, with applications made in response to plant needs. The trials are being carried out during the summer and autumn, when the CRFs will release more nutrients in the higher temperatures, and the plants are in growth.

Year 1 of this work programme focussed on obtaining separate baseline data for CRF and liquid feed uptake in nursery stock liners for a range of nursery stock subjects. Year 2 trials were based on the data obtained in Year 1 and combined a single, lower CRF rate with a range of liquid feeding regimes and develop 'feed to need' strategies. Year 3 of the trial was based on the outcomes of Year 2 and was designed to confirm the reproducibility of the data.

This project is comprised of three work packages:

WP1. HNS (field and container) Literature review

WP2. Field tree production. To establish baseline information on nutrition for field-grown HNS trees by categorising the main plant families into vigour groups (e.g. Low; low – medium; medium - high), explore novel methods for applying fertilisers and determine the most suitable analyses (soil EC, tissue and/or leaf chlorophyll) to assess crop nutrient status (submitted as a separate report)

WP3. Container production. Optimisation of combined controlled release fertiliser (CRF) and liquid feed regimes for hardy nursery stock production under protection

This is the report for WP3.

WP3. Optimisation of combined controlled release fertiliser (CRF) and liquid feed regimes for hardy nursery stock production under protection

Aim

To develop a 'feed to need' methodology with baseline combined low rate CRF and liquid feed recommendations for application to hardy nursery stock under protection.

Objectives

Objective 1: To measure growth and quality of four nursery stock subjects grown in 70% peat growing media supplied with one low dose CRF rate, and five liquid feed treatments (including no liquid feed).

Materials and methods

This trial was carried out within a polytunnel at ADAS Boxworth from May – October 2021 using four hardy nursery stock species (**Table 5**). Plant species selection was based on plant vigour, as related to nutrient uptake, as more vigorous species require greater nutrient supply, and included both woody and herbaceous species. Plants were supplied as 9 cm liners (*Prunus* and *Spiraea*) or 5 cm plugs (*Tradescantia* and *Geranium*) and transplanted into 3 L pots on 7th May 2021 (both species). Growing media used was SinclairPro 70% peat, 30% woodfibre, with no base fertiliser. Osmocote Exact 12-14 month CRF was dibbled into each pot at a single dose rate (1.5 g/L) at the time of transplant. All plants were irrigated by hand for the duration of the trial.

Table 5. Hardy Nursery Stock species

Species	Vigour	Term
Prunus lusitanica 'Myrtifolia'	vigorous	long
Spiraea arguta	moderate	long
Geranium x cantabrigiense 'Westray'	moderate	short
Tradescantia pallida 'Purple Sabre'	vigorous	short

Experimental treatments

Osmocote Exact 12-14 month CRF was used in all pots at a rate of 1.5 g/L. There were five liquid feed treatments (**Table 6**), including two untreated controls, which were applied once per week from trial set-up, aside from T4 which was applied at every watering. A 10:52:10 (ICL - Plant Starter) feed was used for four weeks from transplant, followed by a 3:1:3 (ICL – Grow Mix) feed until the end of the trial. T5 was created so that we could continue to monitor those plants that did not receive feed, then if they started to indicate signs of deficiency through the EC and SPAD readings, they could be fed later in the trial. This did not occur however as the measurements from the weekly assessments did not indicate a "need to feed" by displaying deficiencies, and so T5 remained an untreated control throughout. For each liquid feed (10:52:10 and 3:1:3) a stock solution was made with 1 Kg fertiliser in 10 L water. The stock solution was then measured with a beaker and mixed with plain water in a watering can. Treatments were applied to plots using separate, labelled, 5 L watering cans. The amount of liquid fertiliser applied per plot remained consistent throughout the trial and did not change depending on weather or plant requirements. For T1 and T5 (no liquid feed), the same amount of plain water was applied to each plot using a separate, labelled can. Liquid feeds were applied on Fridays and no further irrigation was made to the plots on that day.

Table 6. Liquid feed treatments used in the container trial, 2021

Treatment No.	Treatment
1	No liquid feed
2	Liquid feed applied once per week (0.5%)
3	Liquid feed applied once per week (1.0%)
4	Low dose liquid feed (0.5%) at each watering
5	Feed to need applied weekly (1.0%). Timing based on EC/SPAD monitoring

Trial design and analysis

The *Prunus* and *Spiraea* were set-up first and therefore were grouped together as one trial. The *Geranium* and *Tradescantia* were grouped together as a second trial within the same polytunnel.

The *Prunus* and *Spiraea* were set-up and grouped together as a separate randomised trial to the *Geranium* and *Tradescantia*, but within the same polytunnel (**Figure 1**). For each species there were five treatments and four replications, resulting in 20 plots. Each plot contained two sub-plots, with nine plants within each sub-plot, resulting in 180 plants per species and 720 plants in total. Plants were placed directly on the mypex floor in a 3 x 3 formation (**Figure 2**). The layout being consistent for all four species. Data was analysed using ANOVA with Duncan's multiple range test.

Figure 1. *Prunus* and *Spiraea* (left) and *Geranium* and *Tradescantia* (right) plots set-out within the polytunnel, 14 May 2021

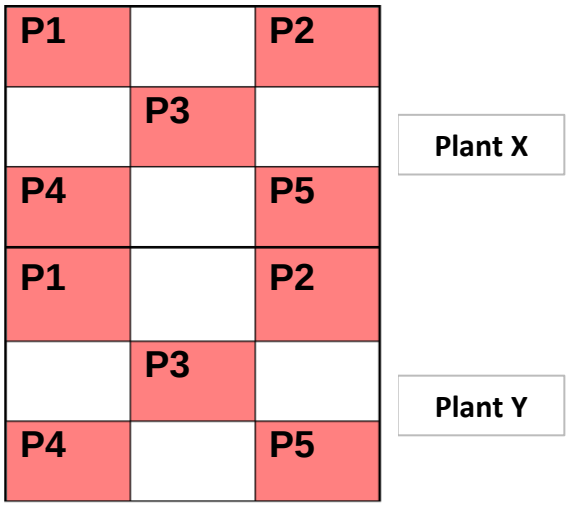

Figure 2. Layout of plants and formation of assessed plants


Figure 3. *Prunus* and *Spiraea* (left) and *Geranium* and *Tradescantia* (right) midway through trial, 27 July

Table 7. Summary of trial inspections and assessments, 2021

Date	Week No.	Action	Assessment
29.04.21	0	*Prunus* and *Spiraea* trial set-up	
04.05.21	0	*Geranium* and *Tradescantia* set-up	
07.05.21	0	Start of weekly treatments	
11.05.21	1	Weekly assessment 1 – All 4 species	EC, moisture, chlorophyll, photos of treatments
18.05.21	2	Weekly assessment 2 – All 4 species	EC, leaf chlorophyll
25.05.21	3	Weekly assessment 3 – All 4 species	EC, moisture, chlorophyll, photos of treatments
01.06.21	4	Weekly assessment 4 – All 4 species	EC, leaf chlorophyll, photos of treatments, moisture
08.06.21	5	Weekly assessment 5 – All 4 species	EC, leaf chlorophyll, photos of treatments, moisture
11.06.21	6	Weekly assessment 6 (all species)	EC, leaf chlorophyll photos of treatments, moisture
18.06.21	7	Weekly assessment 7 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
29.06.21	8	Weekly assessment 8 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
07.07.21	9	Weekly assessment 9 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
13.07.21	10	Weekly assessment 10 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
20.07.21	11	Weekly assessment 11 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
21.07.21	13	Weekly assessment 12 (all species)	EC, leaf chlorophyll, photos of treatments, moisture
27.07.21	14	Mid-season assessments 13	Plant height, quality, root quality
28.07.21	14	Mid-season assessment (P&S) (G&T)	Plant height, quality, root quality
06.08.21	15	Weekly assessment 14 (all species)	EC, moisture, chlorophyll, photos of treatments
13.08.21	16	Weekly assessment 15 (all species)	EC, moisture, chlorophyll, photos of treatments
20.08.21	17	Weekly assessment 16 (all species)	EC, moisture, chlorophyll, photos of treatments
27.08.21	18	Weekly assessment 17 (all species)	EC, moisture, chlorophyll, photos of treatments

03.09.21	19	Weekly assessment 18 (all species)	EC, moisture, chlorophyll, photos of treatments
08.09.21	20	Weekly assessment 19 (all species)	EC, moisture, chlorophyll, photos of treatments
13.09.21	21	Weekly assessment 20 (all species)	EC, moisture, chlorophyll, photos of treatments
22.09.21	22	Weekly assessment 21 (all species)	EC, moisture, chlorophyll, photos of treatments
28.09.21	22	Weekly assessment 22 (all species)	EC, moisture, chlorophyll, photos of treatments
04.10.21	23	Weekly assessment (P&S)	EC, moisture, chlorophyll, photos of treatments
05.10.21	22	Final assessments (P&S)	Plant height, quality, root quality, photos
06.10.21	22	Final assessments (P&S cont.)	Plant height, quality, root quality, photos
11.10.21	23	Final assessments (G&T)	Plant height, quality, root quality, photos

Assessments

Trial assessments that were carried out are summarised in **Table 7**.

Pre-potting

On the day of trial set-up, 20 plants per species were assessed for plant height (cm), plant quality (**Table 8**) and root development (**Table 9**). Photographs were also taken to track treatment progress of the foliage and roots. Plant tissue and growing media collected from the spare plants for each species and a sample of unused growing media for the trial were sent to Natural Resource Management (NRM) for analysis.

Table 8. Plant quality scores

Score	Definition
0	Dead
1	Very poor quality
2	Poor quality
3	Good quality, some damage visible
4	Very good quality, very little damage
5	Excellent quality, no damage visible

Table 9. Root development scores

Score	Definition
0	No root development
1	Rooting in up to 25% of plug/liner
2	Rooting in 26 - 50% of plug/liner
3	Rooting in 51 - 75% of plug/liner
4	Rooting in 76 - 100% of plug/liner

Weekly assessments

At the start of the trial, five plants per species per plot were labelled for weekly assessments. These assessments began one week after potting and lasted for the duration of the trial. They were completed on the same day each week (Tuesday), prior to irrigation. Weekly assessments covered:

- Growing media electrical conductivity, EC (µS/cm) using a Dragon ProCheck logger with a Terros 12 sensor
- Growing media moisture content (%VMC) using a Dragon ProCheck logger with a Terros 12 sensor
- Leaf chlorophyll content using a SPAD monitor, sampling the newest fully open leaves.
- Photographs of each species within each treatment (Block 1)

Mid-season assessment

A mid-season assessment was completed in week 14, 27 July 2021 on all four species on the same five assessment plants per plot for the following:

- Plant height (cm)
- Plant quality (scale of 0-5; **Table 8**)
- Root development (scale of 0-4; **Table 9**)
- Photographs of each species within each treatment

End of season assessment

A final assessment was completed in week 23 (5 October 2021; *Prunus* and *Spiraea*) and week 23 (11 October 2021; *Geranium* and *Tradescantia*) on the same five plants per plot for the following:

- Plant height (cm)

- Plant quality (scale of 0-5; **Table 8**, **Figure 9** to **Figure 11**)
- Root development (scale of 0-4; **Table 9**)
- Photographs of each species within each treatment
- Fresh and dry weight (g)
- Growing media analysis for each treatment per species (NRM)
- Plant tissue analysis for each treatment per species (using left-over plants from each plot) (NRM)
- For the growing media and plant tissue analysis, samples were collected separately from each plot, before being bulked together by treatment and then sub-sampled for analysis.

Figure 4. *Prunus* plant quality representative plants week 23, 5 October 2021 (L-R: score 2-5, end of season assessment)

Figure 5. *Spiraea* plant quality representative plants week 23, 5 October 2021 (L-R: score 3-5, end of season assessment)

Figure 6. *Geranium* plant quality representative plants week 23, 5 October 2021 (L-R: score 3-5, end of season assessment)

Figure 7. *Tradescantia* plant quality representative plants week 22, 5 October 2021 (L-R: Treatment 1-5, end of season assessment)

Crop husbandry

Temperature and humidity were recorded throughout the trial using two USB data loggers.

Aphid control:

- *Aphidius colemani* introductions every two weeks
- Gazelle (acetamiprid, 0.5 kg/ha in 500 L/ha water) applied to all *Spiraea* and *Prunus* plots on the 26 May 2021
- Hallmark with Zeon Technology (0.05 kg/ha in 500 L/ha water) applied to all plants on the 10 of June 2021

Two spotted mite control:

- *Amblyseius andersoni* introductions every two weeks

Results

The results for each species have been analysed and presented separately. Polytunnel temperature and humidity were monitored using two dataloggers located within the *Prunus* and *Spiraea* and the *Geranium* and *Tradescantia* (**Appendix 1**). Results of the growing media and nutrient analyses, and images of treatment effects are presented in **Appendices 2** to **13**.

***Prunus lusitanica* 'Myrtifolia'**

Quality and height

At the end of the trial period, there were no significant differences between treatments for plant height, plant quality, root quality and dry weight. The tallest plants were seen in T3 (1% applied once a week; 38.5 cm) and T2 (0.5% applied once a week; 36.0 cm) and the shortest plants were seen in T5 (no liquid feed; 31.7 cm, **Figure 4, Table 10**). There were slight differences in plant quality with T3 (1.0% 1/week) scoring higher than all other treatments, including T1 and T5, but all plants were marketable (score >3). Root development scores for plants in T1 (no liquid feed) was greater than the other treatments, but the differences were

not significant. T3 had significantly greater fresh weight (P=0.044) compared with all other treatments, while there were no significant differences in dry weight between treatments.

Table 10. Average scores for the final assessment on the *Prunus* trial, week 20, 5th October 2021. Figures in red are significantly different to T1 and T5 (no liquid feed). Ns = not significantly different

Treatment		Height (cm)	Quality	Root scores	Fresh weight (g)	Dry weight (g)
T1	None	32.9	3.5	1.7	42.9	17.4
T2	0.5% 1/wk	36.0	3.5	1.3	47.9	18.5
T3	1.0% 1/wk	38.5	3.7	1.5	51.7	19.4
T4	0.5% every watering	34.3	3.5	1.5	45.0	16.6
T5	1.0% feed to need	31.7	3.3	1.5	42.1	17.3
	F pr.	0.184 ns	0.102 ns	0.605 ns	0.044	0.337 ns
	l.s.d	6.045	0.2468	0.4613	6.58	3.060
	s.e.d	2.775	0.1133	0.2117	3.02	1.404

Electrical Conductivity

The weekly EC measurements are presented in **Figure 8**. Although there are some minor differences between treatments three weeks after potting, the treatments did not really start to separate out until five weeks after potting. From this point, although trends were similar, T4 (0.5% at every watering) and T3 began to diverge from the other treatments, showing a higher EC. From 12 weeks after potting, the EC in T4 and T3 (1.0% 1/wk) peaked (at 245.2 µS/cm and 230.1 µS/cm, respectively) before falling again in the following weeks. EC levels in T4 and T3 did begin to fall but were still greater than the other treatments. T1 (no liquid feed) and T5 (1% feed to need) did not receive any feed for the duration of the trial, however the EC levels remained very similar to T2 (0.5% 1/week) throughout.

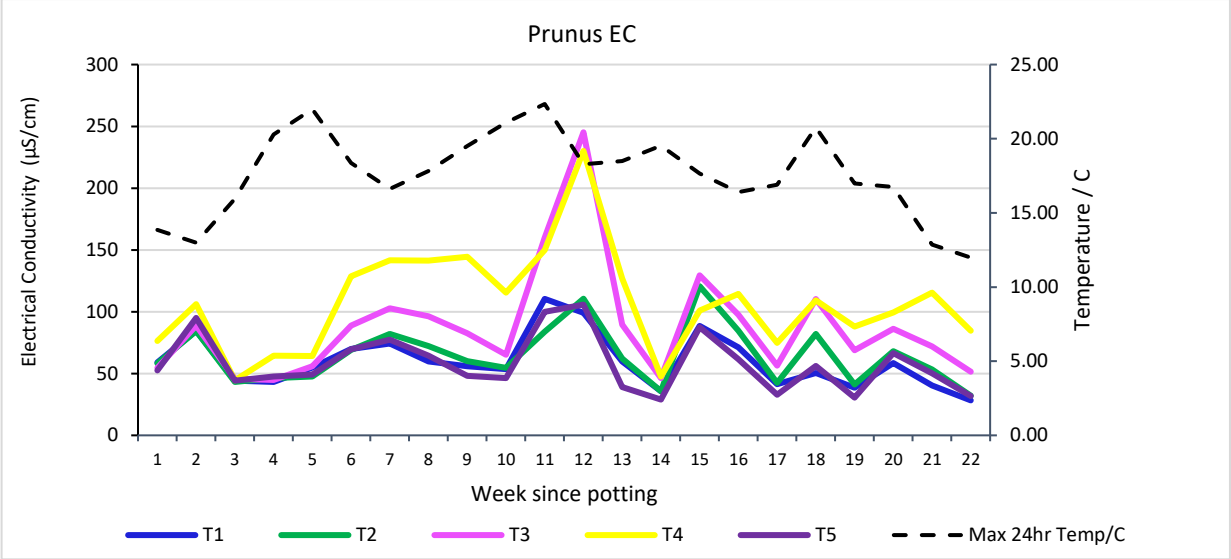

Figure 8. Weekly EC measurements for *Prunus*, with the average 24 hour temperature. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Leaf Chlorophyll (SPAD)

The results of the weekly leaf chlorophyll measurements are presented in **Figure 11**. There was a rapid decrease in leaf chlorophyll levels for all treatments during the first three weeks after potting. The levels then remained consistent for the remainder of the trial for all treatments, with slightly diverging peaks and troughs. This continued up until week 17 when T4 (0.5% at every watering) increased more than the other treatments until the end of the trial. Levels for T1 (no liquid feed) and T5 (1.0% feed to need) were very similar to T3 (1.0% 1/wk) and T2 (0.5% 1/week) throughout the trial.

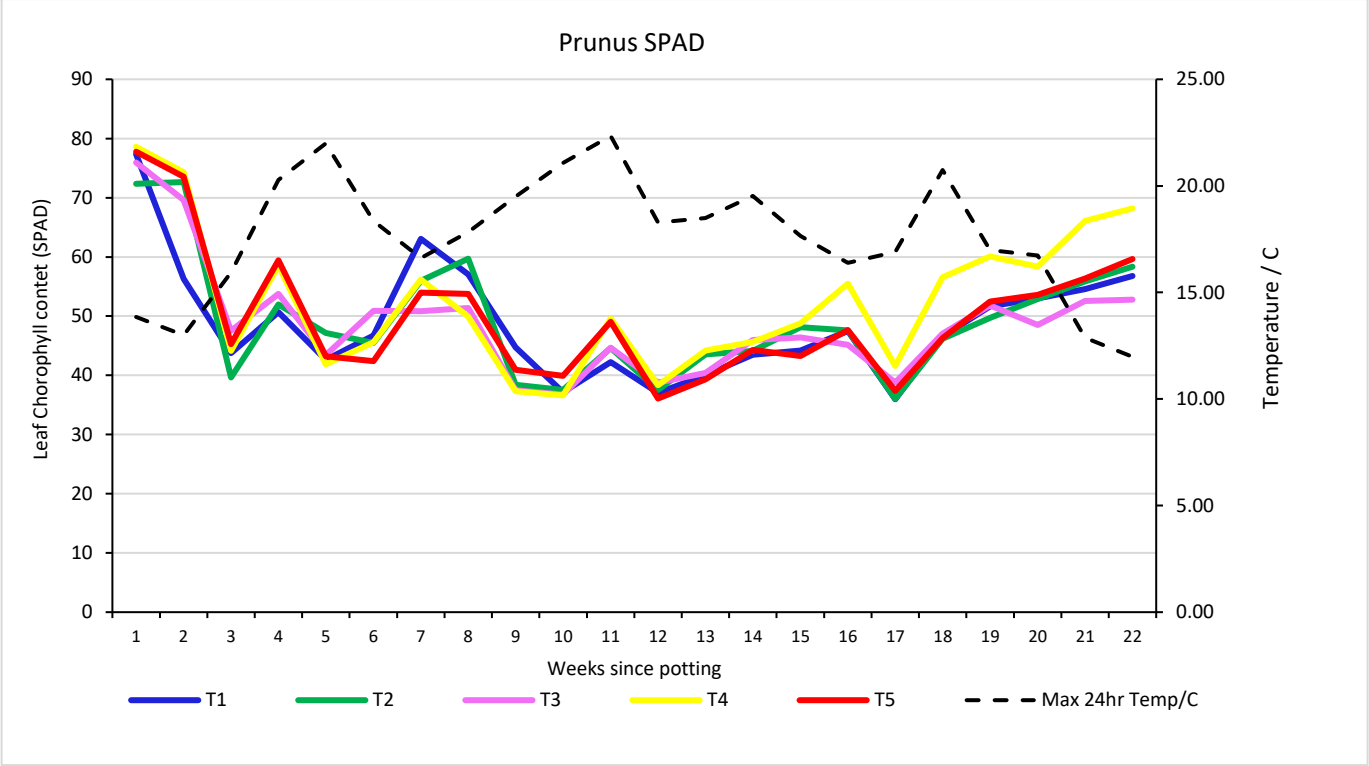

Figure 11. Weekly SPAD measurements for Prunus, with the average 24 hour temperature. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Growing media analysis

The end of trial growing media analyses show that for the *Prunus,* available levels of nutrients (N, P, K and Mg) were low in the unground samples from T1 (no liquid feed) and T5 (1.0% feed to need).

Table 11. Prunus: growing media analysis results for grower (that the plugs were supplied in) unused (May 2021), un-ground and ground samples (October 2021). T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Prunus			pH	EC	Ammonia-N	Nitrate-N	P	K	Mg
2021		T		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
11-May		Grower	6.1	62	<0.6	1.3	3.9	16.9	3.7
		Unused	6.2	227	53.9	106.3	<1	8.5	32.5
Unground	13-Oct	T1	5.6	159	3.0	5.3	0.15	<0.01	<0.01
		T2	5.5	236	7.0	20.2	6.9	41.8	51.8
		T3	5.9	444	29.8	99.6	27.3	126.7	84.7
		T4	5.2	378	10.9	123.2	22.4	139.6	82.8
		T5	6.3	83	<0.6	6.6	<1	3.8	15.6
Ground	13-Oct	T1	5.5	222	19.2	42.5	14.9	40.7	44.9
		T2	5.2	423	36.3	89.5	29.9	102.4	82.8
		T3	5.4	970	188.5	228.3	131.7	352.0	134.5
		T4	5.0	1540	377.2	446.7	216.8	588.6	204.7
		T5	5.7	140	8.4	25.4	6.9	17.5	28.1

Figures in red = Index 0 – deficiency. Figures in blue = >Index 6 (generally excessive). Figures in black = normal range

While levels of available Ammonia-N were low in unground samples from all treatments except for T3 (1.0% 1/wk), sufficient Ammonium-N remained within the CRF prills (other than in T5; **Table 11**, **Appendix 2**). There were sufficient levels of available N, P, K and Mg in ground samples from all treatments except for T5, and in T4 (0.5% every watering) these levels were excessive.

Tissue analysis

Plant tissue analysis at the end of the trial period showed that P and K were below the standard range for T1 (no liquid feed) and T5 (feed to need) at the end of the trial. The levels for N, P, K and Mg in T4 (0.5% every watering), and N and P in T3 (1% applied once a week) were higher than the standard range.

DATE	Tissue Analysis	Treatment	N	P	K	Mg
			%DM	%DM	%DM	%DM
	Standard leaf analysis (range)	From	1.53	0.2	0.93	0.4
		To	2.59	0.22	1.35	0.61
01/05/2021	Initial Leaf Analysis		1.29	0.21	0.57	0.13
01/10/2021	Foliage tissue	**T1**	2.268	0.1551	0.8177	0.512
	Foliage tissue	**T2**	2.35	0.2194	1.0236	0.5392
	Foliage tissue	**T3**	2.673	0.3687	1.2628	0.597
	Foliage tissue	**T4**	2.948	0.4735	1.549	0.6711
	Foliage tissue	**T5**	2.111	0.1501	0.7084	0.5266

Above Standard Range-	High
Within Standard Range-	OK
Below Standard Range-	Low

Table 12. Prunus: tissue analysis completed at the start (May 2021) and end of the trial (October 2021). Standard leaf analysis range sourced from Mills and Jones, 1996. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Spiraea arguta

Quality and height

For *Spiraea,* there were significant differences between T2 (0.5% 1/week), T3 (1.0% 1/week) and T4 (0.5% every watering) compared with T1 and T5 (both no liquid feed) for plant height ($P=0.004$), plant quality ($P<0.001$), fresh weight ($P<0.001$) and dry weight ($P<0.001$). Plants that received T2 and T3 were significantly taller than all other treatments (**Table 13, Figure 5Error! Reference source not found.**). Similarly, plants that received treatments T2 and T3

scored higher for quality than all other treatments, although plants in all treatments were marketable (scores >3). All the treatments that received feed (T2-T4) produced plants with a significantly higher fresh and dry weight compared with T1 and T5. None of the treatments significantly outperformed T1 or T5 in terms of root development.

Table 13. Average scores for the final assessment on the *Spiraea* trial, week 22, 11th October 2021. Figures in red are significantly different to T1 and T5 (no liquid feed)

	Treatment	Height (cm)	Quality	Root scores	Fresh weight (g)	Dry weight (g)
T1	None	60.2	3.2	3.0	29.1	16.0
T2	0.5% 1/wk	69.6	4.0	2.7	47.1	25.8
T3	1.0% 1/wk	70.2	4.1	3.0	52.4	28.3
T4	0.5% every watering	62.9	3.4	2.5	45.7	24.5
T5	1.0% feed to need	58.4	3.2	2.8	29.3	16.5
	F. pr	0.004	<.001	0.202 ns	<.001	<.001
	l.s.d	6.39	0.2990	0.4831	4.377	2.375
	s.e.d	2.933	0.1372	0.2217	2.009	1.090

Electrical Conductivity

Weekly EC recorded for *Spiraea* was similar for all treatments except for T4 (0.5% every watering), where EC was higher than in all other treatments for on most occasions (**Figure 93**). T4 had five notable peaks, with two larger peaks in weeks 16 and 20, which coincided with dips in temperature. EC for T1 (no liquid feed) and T5 (feed to need) were similar, although EC for T1 did increase in weeks 10 and 11, when only T4 recorded a higher EC.

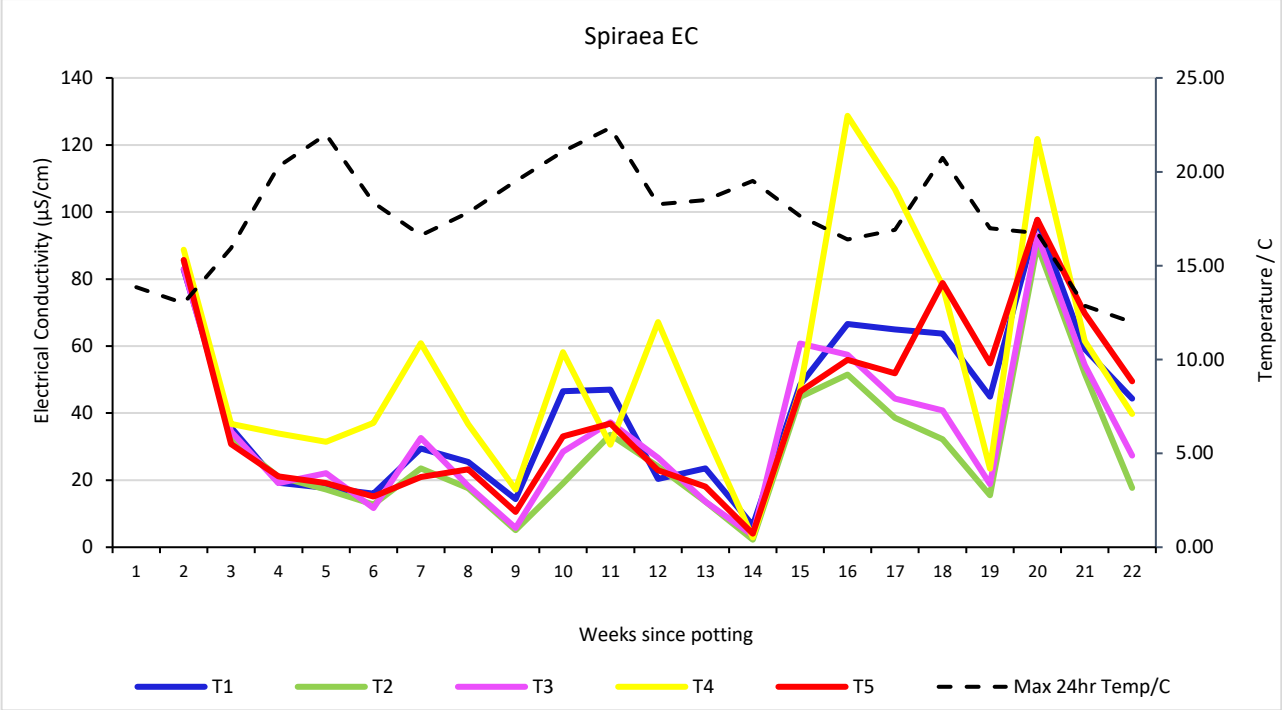

Figure 9. Weekly EC measurements for Spiraea, with the average 24 hour temperature. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Leaf Chlorophyll

Leaf chlorophyll measurements were very similar for all five treatments throughout the duration of the trial. (**Figure 104**). There were no clear differences for treatments that received no liquid feed (T1 and T5) or that received most liquid feed (T4, 0.5% every watering).

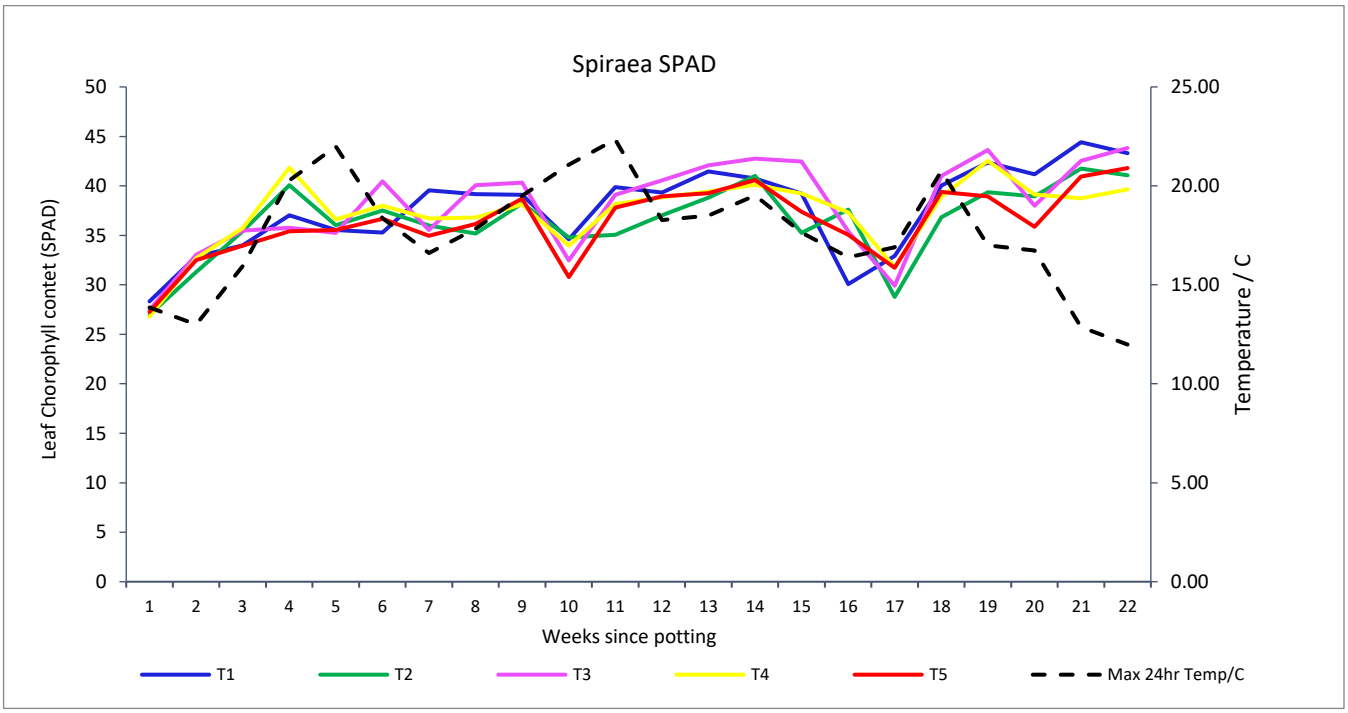

Figure 10. Weekly SPAD measurements for Spiraea, with the maximum 24 hour temperature. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Growing media analysis

Growing media analysis showed that by the end of the trial period values were low for the majority of nutrients (N, P and K) in both unground and ground samples except for Mg (**Table 14, Appendix 3**). Ammonia-N was deficient in all treatments (ground and un-ground), and Nitrate-N was deficient in all treatments apart from T4 (0.5% every watering). There was available N in ground and unground samples of T4 (0.5% every watering). T3 (1.0% 1/week) and T4 (0.5% feed to need) had available K in ground and unground samples (within standard range). Mg was available in all treatments, apart from T5 which was deficient in both ground and un-ground. T4 ground had a surplus of both Mg and P.

Table 14. Spiraea: growing media analysis results for grower (that the plugs were supplied in) unused (May 2021), un-ground and ground samples (October 2021). T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Spiraea			pH	EC	Ammonia-N	Nitrate-N	P	K	Mg
2021		T		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
11-May		Grower	7.5	108	<0.6	<0.6	5.1	11.6	9.7
		Unused	6.2	227	53.9	106.3	<1	8.5	32.5
Unground	13-Oct	T1	6.6	72	<0.6	2.4	<1	9.2	11
		T2	6.2	122	<0.6	1.0	1.4	19	20.1
		T3	6.2	139	<0.6	0.7	3.3	35.5	24
		T4	6.0	182	0.9	55.8	9.8	89.6	26.3
		T5	6.4	34	<0.6	1.3	<1	9.2	2.7
Ground	13-Oct	T1	5.9	124	4.7	11.7	5.3	21.4	19.3
		T2	6.0	98	<0.6	<0.6	3.1	19.1	13.4
		T3	5.8	187	1.6	3.5	12.9	57.0	30.0
		T4	5.7	362	3.0	87.8	44.5	154.7	62.6
		T5	6.4	61	<0.6	<0.6	4.7	10.6	5.0

*Figures in red = Index 0 – deficiency. *Figures in blue = >Index 6. Figures in black = normal range

Tissue analysis

Initial plant tissue analysis results were within or above the standard range for N, P and Mg, but below range for K (**Table 15**,

Appendix 7). Samples taken at the end of the trial showed that N and Mg were above the standard range for all treatments, as were P and K for T4 (0.5% every watering). Results for K were below the standard range in all treatments except for T4. P levels were within or above the standard range for all treatments.

Table 15. Spiraea: tissue analysis completed at the start (May 2021) and end of the trial (October 2021). Standard leaf analysis range sourced from Mills and Jones, 1996. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Date	Tissue Analysis	Treatment	N	P	K	Mg
			%DM	%DM	%DM	%DM
	Standard leaf analysis (range)	From	1.5	0.16	1.5	0.2
		To	2.16	0.31	1.6	0.29
01/05/2021	Initial Leaf Analysis		2.83	0.57	1.28	0.24
18/10/2021	Foliage tissue	**T1**	2.917	0.1896	0.677	0.66
	Foliage tissue	**T2**	2.906	0.2686	0.885	0.4473
	Foliage tissue	**T3**	3.078	0.3452	1.0053	0.422
	Foliage tissue	**T4**	3.418	0.4021	1.6584	0.3745
	Foliage tissue	**T5**	2.894	0.2036	0.855	0.5578

Above Standard Range-	High
Within Standard Range-	OK
Below Standard Range-	Low

Geranium x cantabrigiense 'Westray'

Quality and height

At the end of the trial period, there were significant differences between all treatments that received fertiliser (T2, T3, and T4) compared with those that did not (T1 & T5), for all parameters measured (height, plant quality, root quality, fresh and dry weights) (**Figure 6, Table 16**). In terms of **plant height**, plants that received T2, T3 and T4 were significantly taller than T1 and T5 ($P<0.001$). The tallest plants were recorded in T3 (1.0% 1/week, 22.7cm), and the shortest in T2 (0.5% 1/wk, 20.5 cm). Similarly the **quality** of plants that received T2, T3 and T4 was significantly greater than T1 and T5 ($P<0.001$), with the greatest quality score recorded for T3 (1.0% 1/week, score of 4.3). However, the greatest **root quality** was recorded for plants receiving T2 (0.5% 1/wk, score of 2.0). The heaviest weights were recorded in T3 (1.0% 1/week), with an average fresh weight of 101.3g and dry weight of 21.73g.

Table 16. Average scores for the final assessment on the *Geranium* trial, 11 October 2021. Figures in red are significantly different to T1 and T5 (no liquid feed)

Treatment		Av. height (cm)	Av. quality	Av. root scores	Av. fresh weight (g)	Av. dry weight (g)
T1	None	15.9	3.3	3.0	62.5	15.8
T2	0.5% 1/wk	20.5	3.9	2.0	87.0	20.4
T3	1.0% 1/wk	22.7	4.3	1.5	101.3	21.7
T4	0.5% every watering	21.6	4.0	1.4	84.8	19.1
T5	1.0% feed to need	15.9	3.4	2.8	64.2	16.3
	F.pr	<.001	<.001	<.001	<.001	0.002
	l.s.d	2.542	0.3387	0.2366	11.22	2.736
	s.e.d	1.167	0.1555	0.5156	5.15	1.256

Electrical Conductivity (EC)

EC remained very similar between most treatments for the first six weeks after potting (**Figure 11**), with T4 (0.5% every watering) peaking at 112.65 µS/cm, after two weeks. After that point EC levels in T4 remained slightly higher than the other treatments for the duration, peaking most notably at week 7 with 127.95 µS/cm and 109.8 µS/cm at 12 weeks in. These spikes in EC do similarly occur in the other treatments at the same time as the T4 spikes but to a lesser degree. Several of these spikes coincide with or closely follow temperature spikes during the same time, most obviously in week 12. Similarly, there was a spike in temperature at week 6 and large spike in EC for all treatments shortly after this occurred perhaps suggesting a linkage between the two.

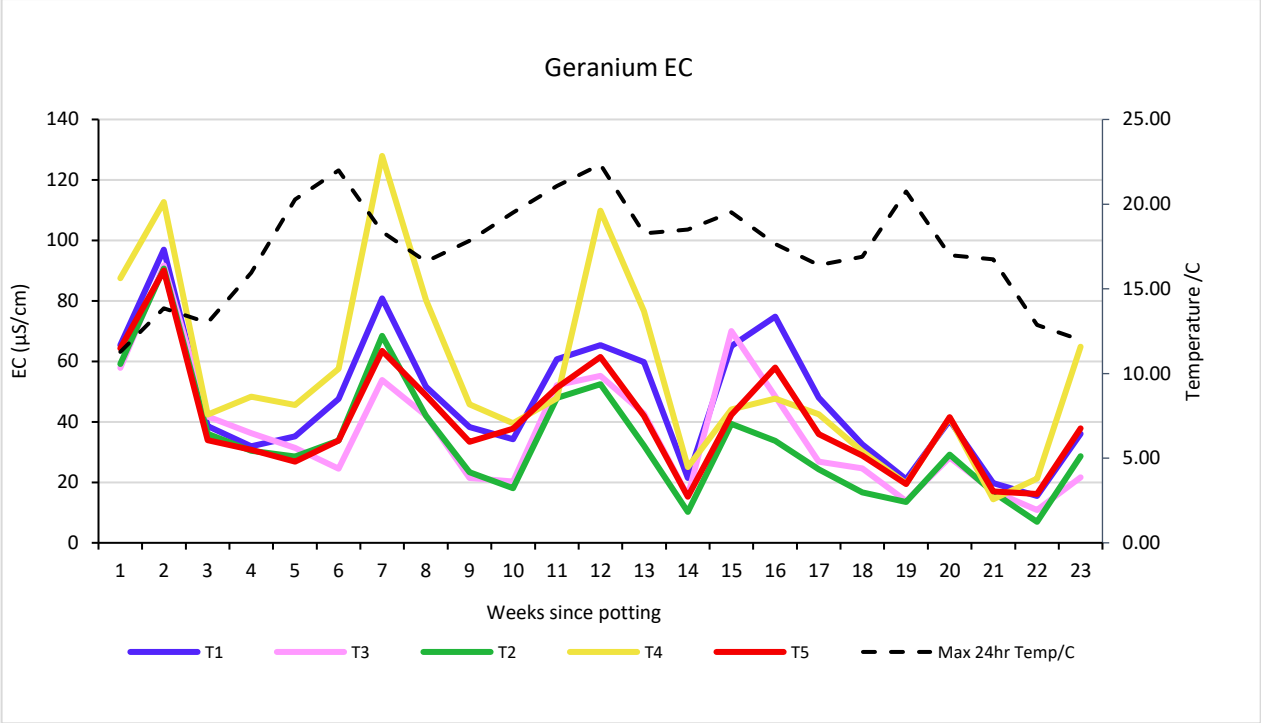

Figure 11. Weekly EC measurements for *Geranium*, with the average 24 hour temperature for reference. Treatments:T1 (no liquid feed); T2 (0.5% 1/wk); T3 (1.0% 1/week); T4 (0.5% at every watering) and T5 (no liquid feed)

Leaf Chlorophyll

Leaf chlorophyll measurements remained consistent for all treatments throughout the *Geranium* trial (**Figure 12**), ranging between 30 and 50 for most treatments, with no notable peaks and troughs, or differences between treatments. As there was no noticeable drop in leaf chlorophyll in T5 towards the latter end of the trial, fertiliser was never added to T5 (the "feed to need" treatment).

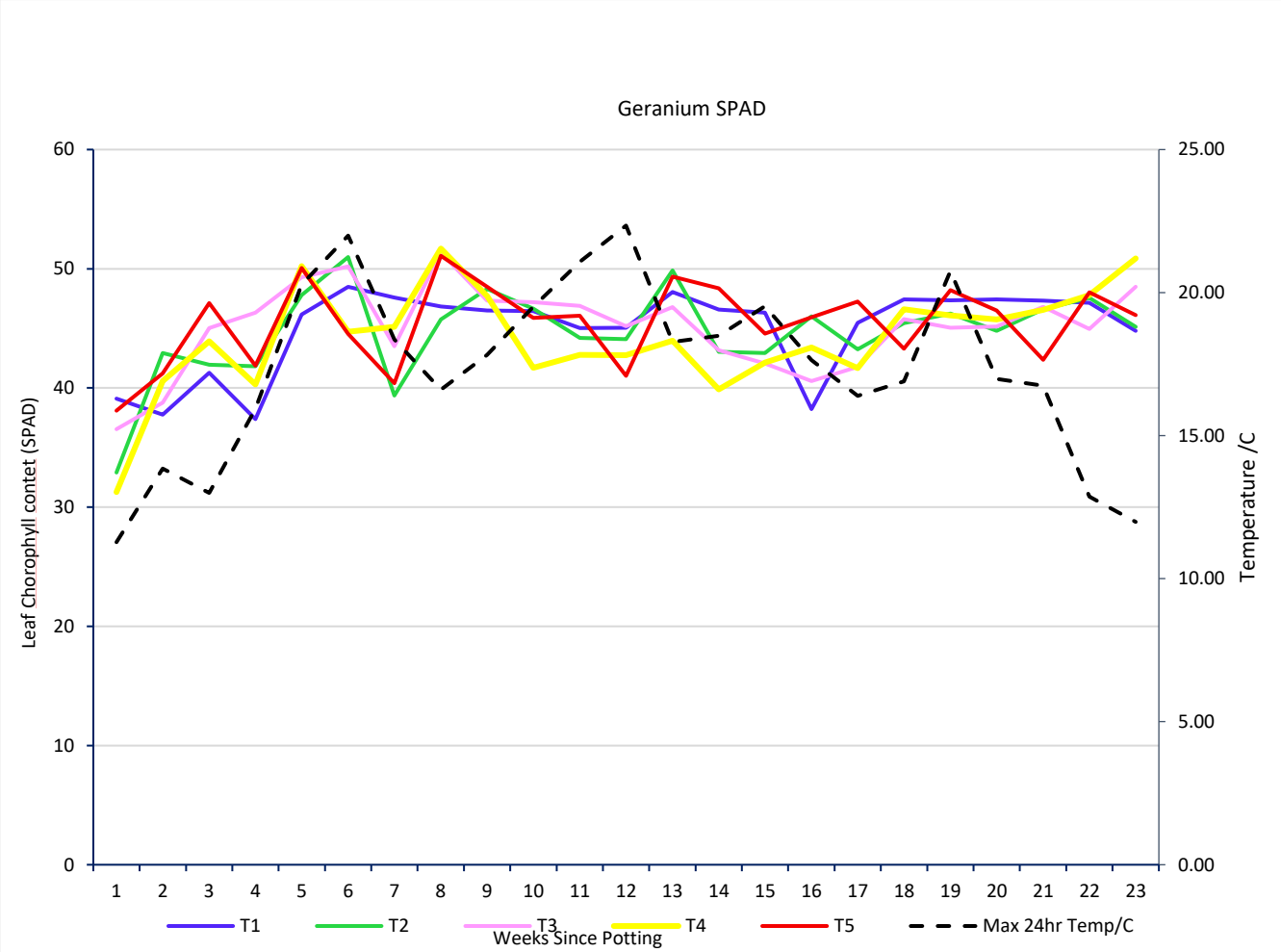

Figure 12. Weekly SPAD measurements for *Geranium*, with the average 24-hour temperature for reference. Treatments:T1 (no liquid feed); T2 (0.5% 1/wk); T3 (1.0% 1/week); T4 (0.5% at every watering) and T5 (no liquid feed)

Growing media analysis

The growing media analysis at the end of the *Geranium* trial showed that there was little available ammonia-N in most treatments, except for unground T1 (no liquid feed) and ground T4 (0.5% every watering). Mg was available in excess for ground sampled T3 and T4, as was P in T4. Analysis of ground samples from Treatments 2 (0.5% once a week) and T3 (1%, once a week) indicated that both had plentiful nitrate-N, P and K, but was deficient in Ammonia-N. T4 was the only treatment with sufficient or excess of N (nitrate and ammonia), P, K and Mg (**Table 17**, **Appendix 4**).

Table 17. Geranium: growing media analysis results for grower (that the plugs were supplied in) unused (May 2021), un-ground and ground samples (October 2021). T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

GERANIUM			pH	EC	Ammonia-N	Nitrate-N	P	K	Mg
2021		T		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
11-May		Grower	6.5	155	<0.6	29.8	10.0	108.1	13.3
		Unused	6.2	227	53.9	106.3	<1	8.5	32.5
Unground	11-Oct	T1	5.9	177	22.6	26.4	13.8	32.2	22.8
		T2	6.2	83	2.1	3.3	2.4	10.2	11.4
		T3	5.7	212	1.2	53.6	4.3	37.7	40.4
		T4	5.3	226	1.0	74.8	1.7	54.8	40.9
		T5	6.1	48	0.6	1.5	<1	6.2	6.2
Ground	11-Oct	T1	5.5	202	6.9	18.9	7.7	28.3	37.0
		T2	5.5	180	2.6	23.1	10.2	35.6	36.0
		T3	5.2	305	4.6	59.4	8.1	69.1	63.4
		T4	4.9	589	56.9	185.4	53.9	203.4	118.5
		T5	5.7	140	1.3	17.4	4.5	19.5	26.1

*Figures in red = Index 0 – deficiency. *Figures in blue = >Index 6. Figures in black = normal range

Tissue analysis

Plant tissue analysis showed that Mg levels were above the standard range, and K levels were below the standard range for all treatments (**Table 18**, **Appendix 8**). Levels of N and P were below the standard range for all treatments apart from T4 (0.5% every watering); for T4 N was within the standard range and P was above the standard range.

Table 18. Geranium: tissue analysis completed at the start (May 2021) and end of the trial (October 2021). Standard leaf analysis range sourced from Mills and Jones, 1996. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

			N	P	K	Mg
Date	Standard leaf analysis (range)	Treatment	%DM	%DM	%DM	%DM
		From	2.96	0.69	2.95	0.34
		To	2.96	0.69	2.95	0.34
18/05/2021	Initial Leaf Analysis		3.11	0.76	1.72	0.68
19/10/2021	Foliage tissue	T1	1.749	0.1478	0.96	0.6796
		T2	2.033	0.2571	1.6005	0.7131
		T3	2.673	0.4949	2.3818	0.7885
		T4	2.952	0.7425	2.7859	0.8667
		T5	1.795	0.176	1.1258	0.7389

*Figures in red = Below standard range. *Figures in blue = Above standard range. Figures in black = standard range

High	Above range
OK	In line range
Low	Below range

Tradescantia pallida 'Purple Sabre'

Quality and height

Tradescantia is a vigorous herbaceous perennial that produced the longest stems with the greatest fresh and dry weight in T3 (1.0% 1/wk) (**Figure 7**, **Table 19**). T2, T3 & T4 achieved significantly better quality scores (P<0.001) than T1 and T5, although all treatments were marketable, scoring above 3. Root quality scores for T2, T3 and T4 were significantly better than T1 and T5 (P=0.031). For height and fresh weight only T3 was significantly different to both T1 and T5 (p=0.031 and p<0.001, respectively).

Table 19. Average scores for the final assessment on the *Tradescantia* trial, week 23, 11 October 2021. Figures in red are significantly different to both T1 and T5 (no liquid feed)

	Treatment	Height (cm)	Quality	Root score	Fresh weight (g)	Dry weight (g)
T1	None	40.2	3.2	3.3	264.6	21.5
T2	0.5% 1/wk	42.7	3.7	2.9	317.6	24.0
T3	1.0% 1/wk	45.4	4.0	2.8	376.7	26.4
T4	0.5% every watering	41.2	4.0	2.9	317.2	23.0
T5	1.0% feed to need	39.9	3.3	3.3	284.0	22.7
	F pr.	0.031	<.001	0.031	0.015	0.162 ns
	l.s.d	3.536	0.3170	0.4027	59.62	4.111
	s.e.d	1.623	0.1455	0.1848	27.36	1.887

Electrical Conductivity

There were some differences between treatments for EC early on in the trial (**Figure 139**), with the highest EC levels in T4 (0.5% every watering) peaking at week 2 (111.85 µS/cm), before dropping back to between 0-50 µS/cm, in line with the other treatments, for the remainder of the trial. After the first spike in EC from T4, levels then fell sharply and remained low until the end of the trial. T5 and T1 followed a very similar trend throughout the trial, never reaching above 50 apart from the initial peak at week 2.

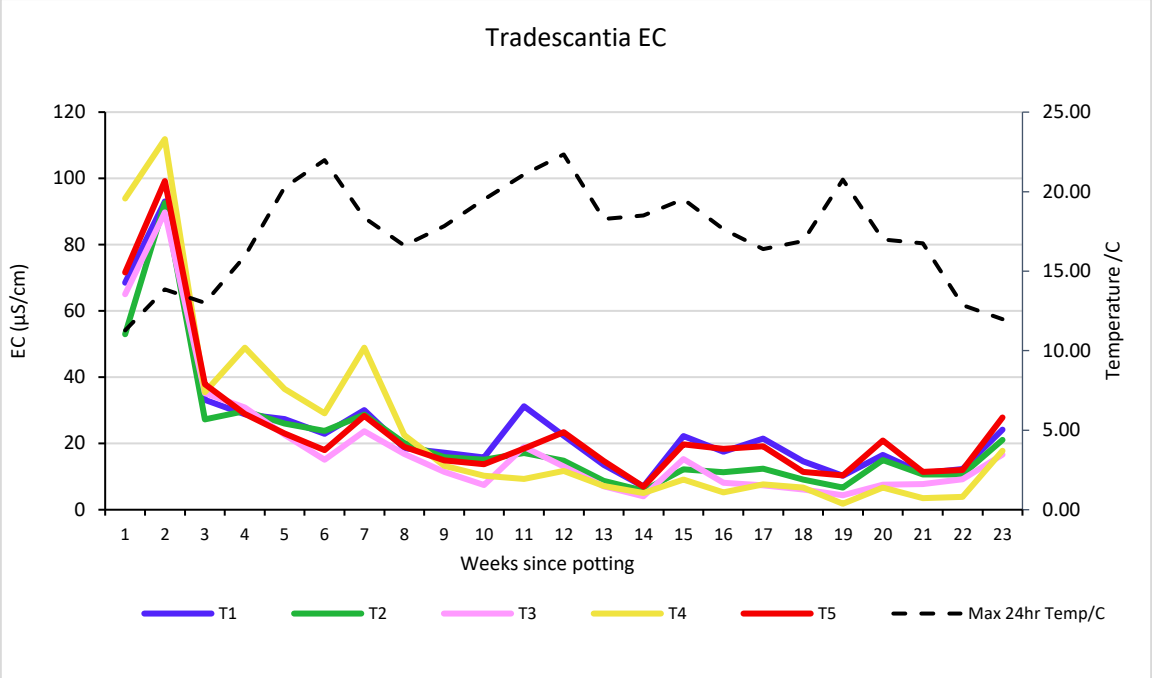

Figure 13. Weekly EC measurements for Tradescantia, with the maximum 24-hour temperature for reference. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Leaf Chlorophyll

Leaf chlorophyll measurements were relatively consistent throughout the trial (**Figure 14**), generally within the 30-50 range for all treatments. T3 (1% applied once a week) had the highest SPAD reading at week 15 of 56.7 and T5, the lowest at 35.9 at week 14. As leaf chlorophyll readings did not appear to decrease towards the end of the trial, T5 remained an untreated control as liquid feed was not required.

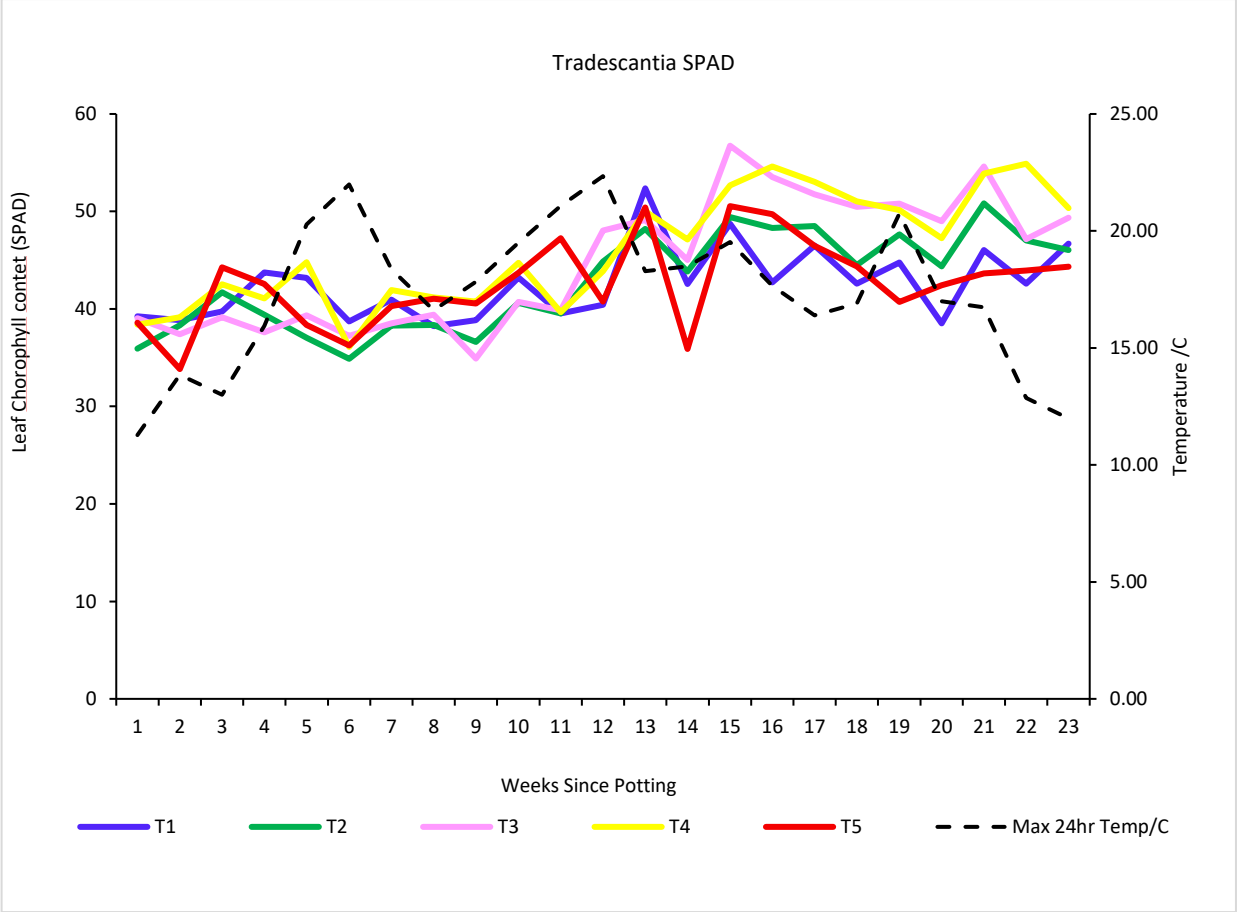

Figure 14. Weekly SPAD measurements for Tradescantia, with the maximum 24-hour temperature for reference. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

Growing media analysis

At the end of the trial period, growing media analysis in the *Tradescantia* trial showed that Ammonia-N was deficient in all treatments, in both ground and unground samples. K was deficient in all treatments, except for ground samples from T2 (0.5% once a week) and T4 (0.5% every watering) (**Table 20**, **Appendix 5**). No nutrients were available in excess. Levels of P and Mg were within range for all treatments (ground samples). EC was low for all treatments.

Table 20. Tradescantia: growing media analysis results for grower (that the plugs were supplied in) unused (May 2021), un-ground and ground samples (October 2021). T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

TRADESCANTIA			pH	EC	Ammonia-N	Nitrate-N	P	K	Mg
2021		T		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l
11-May		Grower	6.6	59	<0.6	3.9	3.6	7.4	3.0
		Unused	6.2	227	53.9	106.3	<1	8.5	32.5
Unground	11-Oct	T1	6.0	36	1.8	1.9	2.1	7.2	1.0
		T2	5.4	66	8.4	12.2	8.2	14.1	4.0
		T3	5.6	54	3.2	6.9	5.7	7.9	3.5
		T4	5.8	38	1.4	3.0	11	5.5	2.3
		T5	5.8	26	1.1	1.5	<1	3.0	1.0
Ground	11-Oct	T1	5.3	126	13.1	18.6	12.4	24.9	7.3
		T2	4.9	132	19.5	23.5	18.7	32.0	7.7
		T3	5.3	81	7.3	10.9	13.5	21.0	5.6
		T4	5.4	150	18.6	26.7	37.4	41.8	18.4
		T5	5.4	86	7.9	11.4	8.2	18.2	5.9

*Figures in red = Index 0 – deficiency. Figures in black = normal range

Tissue analysis

Plant tissue analysis at the end of the trial period showed that N, P and K were below the standard range for all treatments, with T4 (0.5% every watering) having the highest N, P and K levels out of all the treatments. (**Table 21**,

Appendix 9). Conversely, levels of Mg were above the standard range for all treatments, with T2 (0.5% once a week) having the highest levels.

Table 21. Tradescantia: tissue analysis completed at the start (May 2021) and end of the trial (October 2021). Standard leaf analysis range sourced from Mills and Jones, 1996. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

			N	P	K	Mg
Date	Standard leaf analysis (range)	Treatment	%DM	%DM	%DM	%DM
		From	4.84	0.52	5.41	0.36
		To	4.84	0.52	5.41	0.36
18/05/2021	Initial Leaf Analysis		2.460	0.4000	2.6500	1.680
19/10/2021	Foliage tissue	T1	1.714	0.2111	1.4394	1.662
	Foliage tissue	T2	1.877	0.2238	0.9616	2.111
	Foliage tissue	T3	2.328	0.3268	1.2816	1.854
	Foliage tissue	T4	3.033	0.4459	1.8692	1.737
	Foliage tissue	T5	2.140	0.2539	1.0748	2.056

*Figures in red = Below standard range. *Figures in blue = Above standard range. Figures in black = standard range

High	Above range
OK	In line range
Low	Below range

Discussion

Prunus lusitanica 'Myrtifolia' - Long term, vigorous

The most successful treatment in the *Prunus* trial was T3 (1% applied once a week), with taller, better quality plants with greater fresh and dry weight compared with all other treatments. However, other than fresh weight, none of these differences were significant, and greater root development was achieved in T1 (no liquid feed).

Higher EC measurements were recorded for T4 (0.5% every watering) and T3 than other treatments for most of the trial, with higher SPAD measurements for T4 from week 16. The high SPAD measurements and tissue analysis for T4 suggest that additional nutrients provided by this treatment were taken up by the plants, but the high growing media EC indicates that excess nutrients were available that the plants were not able to utilise, particularly in unground samples. A lower dose rate would be more appropriate for *Prunus*, and would produce plants of similar quality.

The raised EC measurements for T4 from 18 weeks after potting indicates that less feed was required as days shortened and temperatures reduced. This is similar to findings in 2020, although the difference in EC between treatments was less pronounced.

The growing media analyses indicated there was available Nitrate-N, P, K and Mg in both ground and unground samples from T3 and T4 (other than ammonia-N in T4), and generally more than for other treatments, suggesting that liquid feed rates could be reduced.

Spiraea arguta – long term, moderate vigour

For the *Spiraea,* plant height and quality were significantly greater in T2 (0.5% 1/week) and T3 (1.0% 1/week) than other treatments, while fresh and dry weights were significantly greater in T2, T3 and T4 (0.5% every watering). Greatest root development was recorded in T1 (no liquid feed) and T3, but differences between treatments were not significant.

EC was higher in T4 than the other treatments, suggesting that this treatment provided more nutrients than the plants could utilise, similar to the *Prunus.* As for the *Prunus,* the raised EC from 18 weeks after potting suggests less feed was required as the season progressed, days shortened, and temperature reduced. For *Spiraea,* SPAD readings were closely aligned for all treatments throughout the trial, including from week 16, although in general the *Prunus* maintained higher leaf chlorophyll levels than the *Spiraea* (ranging between around 35-60 for *Prunus* compared with 27-45 for *Spiraea*).

The growing media analyses indicate that nutrient reserves were running low in both ground and unground samples, while the tissue analyses suggest a high level of utilisation of the

nutrients, in that N, P, K and Mg levels were higher than the standard range in T4 and T3 (except for K where levels were lower than the standard for T3).

For the *Spiraea*, growing media analysis indicated that generally there was less nutrient availability compared with the *Prunus*, which suggests greater uptake by the plants. Despite higher nutrient levels remaining in the growing media (both ground and unground) for T4, the tissue analysis indicated that quantities taken up by the plants were above the standard range, but this may be an indication that the standard range used may not be suitable for *Spiraea arguta.*

***Geranium x cantabrigiense* 'Westray' – short term, moderate vigour**

The *Geranium* trial showed that plants from T2 (0.5% 1/week), T3 (1.0% 1/week) and T4 (0.5% every watering) were significantly taller, with significantly higher quality scores, greater fresh and dry weight than treatments T1 (no liquid feed) and T5 (feed to need).

However, EC measurements were generally higher than in other treatments in the earlier weeks of the trial (up to around week 14) while SPAD measurements were very closely aligned throughout across all treatments. Growing media analyses indicated that supplies of available nutrients were present within the CRFs. Tissue analyses suggest that nutrient uptake was generally above the standard range, other than for Mg which was below the standard data for all treatments. Only a single value is available for the standard tissue analysis rather than a range (for the *Spiraea* and *Tradescantia)*, which has the immediate effect of making it look as if plant tissue analyses are high or low, when in fact a nutrient range is not provided.

In 2020, *for Geranium* and *Tradescantia*,T5 (1% feed to need, no liquid feed applied) was split into two, to form the additional treatment T6. Feed was applied to T5 (1.0% feed to need) from 13 weeks after potting) to explore if this change would be evident in the EC and SPAD measurements. As for the *Prunus* and *Spiraea*, *Geranium* plants in T2 and T3 were considered more marketable than those in T4. EC and SPAD measurements for T5 (1.0% feed to need) fluctuated through the season, so while it may appear that there was a response to the liquid feed application provided to plants in T5, this was not clear or consistent across the *Geranium* and *Tradescantia.* Growing media analysis showed that generally there were plentiful nutrients remaining in all treatments apart from T1 (no liquid feed) and T6. This suggests that the although the *Geranium* have been termed 'moderately vigorous', they require less feed than the *Spiraea* (long term, moderate vigour) and feed rates could potentially be reduced for this crop group without a negative impact on plant quality.

Tradescantia pallida 'Purple Sabre' – short term, vigorous

At the end of the trial period, plant height was significantly greater in T3 (1.0% 1/week) than T1 (no liquid feed) and T5 (feed to need). While treatments that delivered more nutrients to the plants (e.g. T4, 0.5% every watering) may be thought the most appropriate treatment for this vigorous plant, overall plant marketability may be improved by applying less feed (e.g. T3 or T2) to restrict growth, producing smaller plants that may be less prone to breakage.

Growing media EC fell sharply and, very different from all other species, by week 3 was below 40 for all treatments except for T4, and remained around or below 20 for much of the trial. Leaf chlorophyll (SPAD) measurements were fairly tightly grouped. Growing media analysis indicated that EC was low in all treatments, both ground and unground samples, by the end of the trial, with N, K and Mg generally deficient to low (Indexes 0 to 1). Similarly, tissue analysis indicated that N, P and K were below the standard 'range'. More available N, P, K and Mg remained in T4 than all other treatments, but the plants had not utilised all of these nutrients. Similar to the trial in 2020, there was little difference between treatments for plant and root quality suggesting that *Tradescantia* does not need the tissue nutrient levels suggested by the standard tissue analysis for the plant to be of marketable quality.

While both *Prunus* (long term vigorous) and *Tradescantia* (short term vigorous) are both categorised as vigorous plants, the growing media analyses indicate that while the *Tradescantia* utilised most of the feed applied, the *Prunus* utilised least (compared with all species) in all treatments. These results are similar to those from 2020, and they suggest that the *Tradescantia* and *Prunus* have different nutrient requirements; the *Tradescantia* may be more vigorous in terms of the amount of nutrients required to produce a marketable plant. This is converse to *Spiraea* vs *Geranium* (both denoted as moderately vigorous), the herbaceous *Geranium* (short term, moderate vigour) was less vigorous than the woody *Spiraea* (long term, moderate vigour) in terms on nutrient requirements. Comparing the two woody species, the *Spiraea* had a greater requirement for nutrients over the timeframe of this trial than the *Prunus.*

General discussion

For this trial, the results reflect and confirm those from the 2020 trial, which produced similar results under different growing conditions, although temperatures in 2020 were warmer and less consistent than in 2021 (**Appendix 1b**).

In both 2020 and 2021, although significant differences between treatments were considered in terms of plant height, from a grower perspective shorter but bushier plants with more breaks / side shoots are usually more marketable for this sector. Notably, in 2021, significant differences were most often between the two treatments that didn't receive additional nutrition

(T1 and T5), and treatments T2, T3 and T4. In both 2020 and 2021, *Prunus*, *Spiraea* and *Geranium* plants produced under treatments T2 and T3 were considered more marketable than those produced under treatment T4, which tended to produce taller plants with fewer breaks. T2 and T3 were easier to manage than T4 as the plants were fed weekly (not daily as in T4) and had a lower labour requirement. For the *Tradescantia* in particular, there was little difference in the effect of the treatments on plant quality, but plants produced under T3 required less labour to produce plants of similar quality, and low feed regimes could be used to restrict growth of these vigorous plants. Similarly, T5 required weekly monitoring and a decision whether to apply liquid feed each week. This would be more difficult to implement nursery wide where many species or cultivars are grown, and perhaps in small numbers.

The combination of SPAD and EC measurements was useful as it allowed nutrient movements to be tracked. N uptake by the plants resulted in increased SPAD and lower EC readings; conversely where more liquid feed was provided than the plants required the salts remained within the growing media and the EC increased. For the *Tradescantia*, for example, the high SPAD and low growing media EC measurements indicated the feed was taken up across all treatments.

For treatment 4 (2020 and 2021), EC measurements were often high compared with other treatments, because more nutrients were supplied (at every irrigation). While the plants were often able to utilise more of the nutrients, as seen in the SPAD measurements, there was still excess and this was seen in the higher growing media EC. This was most clear for *Prunus*, *Spiraea* and *Geranium*.

High EC can be a cause for concern, particularly for sensitive plants, as it can result in root damage, and is usually addressed by irrigating to flush the salts out of the growing media. Incorporating a lower rate of CRF in the growing media helps to reduce the risk of flash release of excessive nutrients in high temperatures. In this trial, plants were watered by hand with a measured amount of water so that treatments were standardised. The build-up of growing media EC, which could be interpreted as excess nutrient supply (given a high dose rate), could result in increased N or P in the run-off water, forming a potential environmental risk. The highest risk liquid feed regime would be ‘little and often’, where feed is applied at every irrigation (T4 in this trial). This could be mitigated by applying a lower dose feed with care to limit run-off (or capture and recycle run-off water).

The relationship between EC and SPAD measurements provided a useful indication of when the plants required less feed as the season progressed into shorter days and cooler temperatures and nutrients accumulated in the growing media, with less uptake by the plants. This is a good example of when the general approach of providing low dose CRF

supplemented with liquid feed can provide a level of flexibility that allows the grower to match nutrient supply with plant need.

Weekly measurement of EC and leaf chlorophyll (SPAD) proved useful tools to monitor nutrient uptake in this trial, particularly as plant nutrient requirements diminished towards the end of the season, or where differences between treatments became more extreme. However, while such EC measurements show changes in salt level (i.e. relating to total nutrient level) within the growing media this is a broad measurement that does not identify which nutrients contributed to a high EC or which may be deficient or excessive; growing media analysis provides more detailed information on individual nutrient levels. All of these measurements (EC, leaf chlorophyll, growing media analysis) are most useful if carried out regularly so that trends can be identified, ideally over multiple seasons, then signs of deficiency can be identified early and adjustments can be made to the feed regime before symptoms become visible and affect the marketability of the plants. Similarly, if excessive salts build up in the growing media liquid feed applications can be reduced.

In 2020, P was generally high in the growing media and tissue analyses, particularly for the *Geranium*. P levels can be high in proprietary fertilisers and was more apparent in these results for the moderately vigorous *Geranium* which utilised less P than other species, and in T4 (Prunus and Spiraea), where more P was supplied than was taken up by the plants. Similarly, in 2021 values for P were higher where less was utilised by the plants, but the differences were less apparent than in 2020.

Considering tissue analyses, values obtained, particularly for P, were often outside the published standard ranges for all species in this trial (**Mills and Jones, 1996**), with no visible deficiency symptoms. These standard ranges should be viewed with caution as they are historical, specific for variety/cultivar and are means of data. For example, there are ten standard values for *Spiraea*, but no specific ranges for *Spiraea arguta.* Where standard nutrient analysis values are not available / published for all cultivars, it is important that growers keep records for the specific important cultivars that they grow, alongside commentary on plant quality and any visual symptoms of nutrient imbalance.

Conclusions

T2 and T3, produced marketable plants with a bushier habit than other treatments, while T4 produced taller less bushy plants and appeared to provide excess nutrients. However, it may be that the habit of the plants in T4 could be improved with lower dose rates.

T5 ‘feed to need’ could be useful on nurseries producing a small range of species arranged in large blocks, but HNS nurseries tend to have a wide range of species / cultivars; in the

move away from peat based substrates plants may be held back by the time the need to feed is recognised, making this a more difficult option to manage. T3 is the more manageable treatment and produced good quality plants.

The combination of EC and SPAD measurements is useful to identify trends. In this trial it was helpful to compare several treatments for specific species. In a nursery setting, however, growers will need to compare data for the same plant or plant group over multiple seasons to be able to make comparisons and put the data into context, for example if sufficient feed was applied in a hot season, and if it should be reduced in a cooler season to produce marketable plants. This will also help growers to identify and rectify any issues sooner.

Growing media moisture can affect EC measurements, therefore measurements should be made prior to the plants being irrigated to minimise distorted readings, ideally at the same time of day on each occasion. EC will be affected not only by the liquid feed, but also the CRF, which is released in response to high temperature and requires moisture for nutrient release, and this can cause spikes in EC.

There is currently a lack of tissue analysis data for specific species / cultivars, particularly for the herbaceous species. Growers will need to supplement and realign published data with their own data for tissue analysis to be used to greatest effect.

Categorising plants into long/short term and vigour groups will prove useful and will help growers to extrapolate data to a wider range of species, noting that woody and herbaceous plants are not directly comparable in terms of vigour. Grouping plants according to vigour category will make it easier to manage plant feed regimes.

RB209 recommendations for container grown nursery stock

Combined controlled release fertiliser and liquid feeding

Lower CRF rates can be combined with top up liquid feed. This can enable nutrition supply to be more closely matched with plant needs, both in terms of the nutrient balance and the dose rate of nutrients applied. However, this system does require regular monitoring to reduce the potential for nutrient deficiencies or toxicities to develop. Over application may result in nutrients being lost if the run-off from watering/feeding is not collected and could cause pollution. Use of such combinations ensures that any initial immobilisation of 'N' is offset. It also allows for the steady build up and release from the CRF granules.

CRF and liquid feed rate selection will depend on crop vigour group and crop longevity, examples in **Table 1**. The following CRF / liquid feed combinations have proven successful over two seasons:

Recommendation 1 – Low CRF, low weekly liquid feed

CRF: 12-14 month, 1.5 g/L mixed or dibbled at potting

Liquid feed applied once per week at 0.5%:

- 10:52:10 (N:P:K) for four weeks from transplant
- 3:1:3 (N:P:K) from 5 weeks after transplant

Suitable for *Prunus lusitanica* 'Myrtifolia', *Spiraea arguta* and *Geranium x cantabrigiense* 'Westray' were produced under this regime.

This option provides less nutrients than Recommendations 2 and 3, and requires less labour input than Recommendation 3.

Recommendation 2 – Low CRF, higher weekly liquid feed

CRF: 12-14 month, 1.5 g/L mixed or dibbled at potting

Liquid feed applied once per week at 1.0%:

- 10:52:10 (N:P:K) for four weeks from transplant
- 3:1:3 (N:P:K) from 5 weeks after transplant

This option uses less liquid feed than Recommendation 3, and the lower nutrient content may help to restrict the growth of vigorous species such as Tradescantia and there is less risk of excess nutrients being applied.

Suitable for *Spiraea arguta*, *Geranium x cantabrigiense* 'Westray' and *Tradescantia pallida* 'Purple Sabre'.

Recommendation 3 – Low CRF, low liquid feed at every irrigation

CRF: 12-14 month, 1.5 g/L mixed or dibbled at potting

Liquid feed: applied at each irrigation at 0.5%

- 10:52:10 (N:P:K) for four weeks from transplant
- 3:1:3 (N:P:K) from 5 weeks after transplant

The liquid feed rate should be adjusted to meet the needs of the crop to prevent excessive application and nutrient loss in run-off water. Lower feed rates could be used to manage growth of vigorous species such as *Tradescantia pallida* 'Purple Sabre'. However, this option requires more labour input to produce plants of similar quality.

Suitable for *Tradescantia pallida* 'Purple Sabre'. To select the most effective recommendation for your crop you will need to consider your plant nutrient needs and monitor nutrient supply.

Regular EC monitoring is useful for identifying excessive liquid feed, particularly in shortening days and cooler temperatures, allowing growers to adjust feed rates. With EC monitoring,

devices can show readings that can be different to laboratory data, so aim to follow the trend in readings, rather than the reading itself, noting a rise or fall in the data shown week by week on your measuring device and responding with feeding accordingly.

Knowledge Exchange

- Trial open day. Field and container trials. Coles Nurseries. 12 September 2019
- Presentation. Container trial. Herbaceous perennials discussion group. 19 February 2020
- Presentation / stand. Field and container trials. ICL Hort Science Live. October 2020

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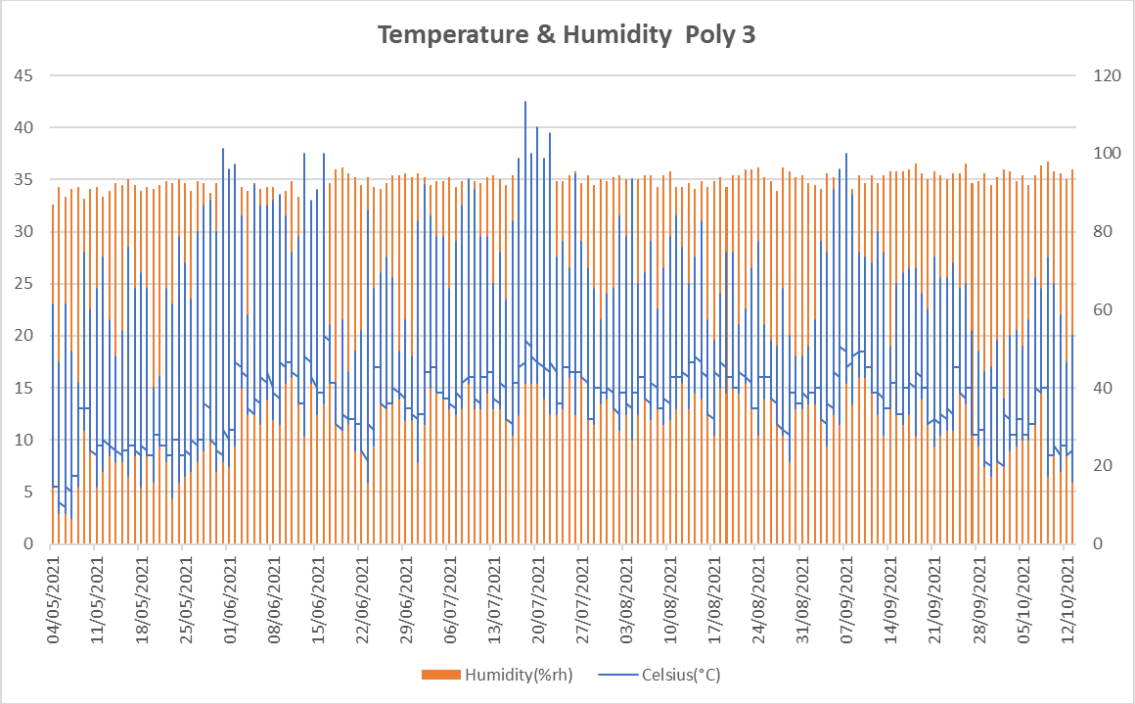
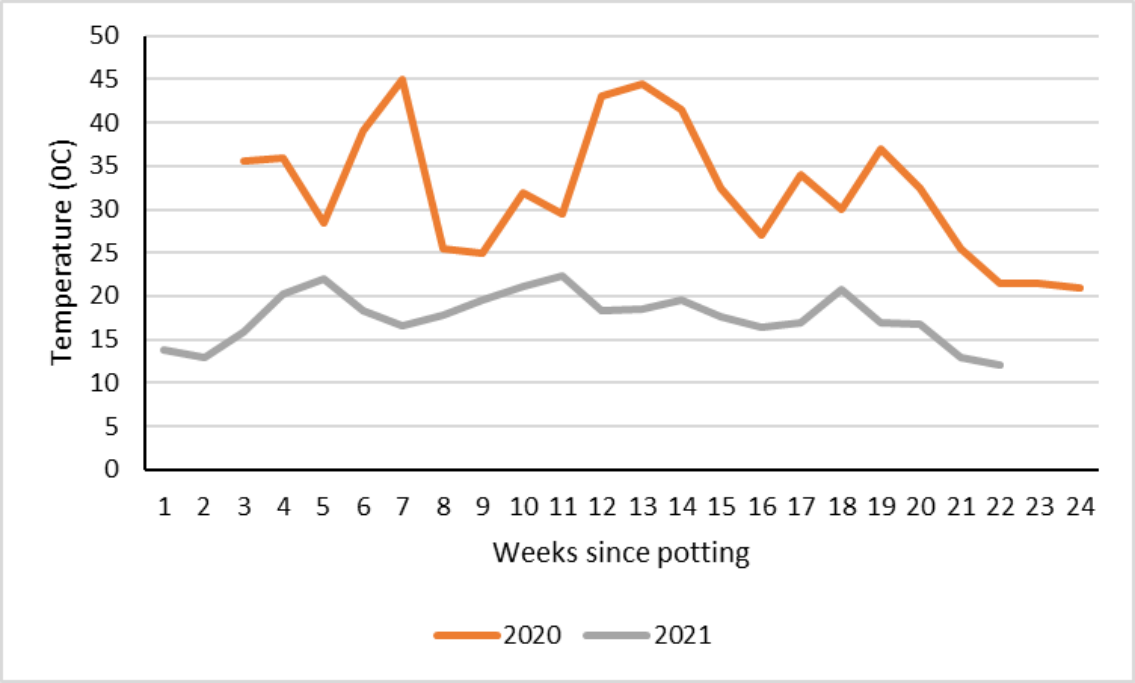
Appendices

Appendix 1a. Polytunnel temperature and humidity



Appendix 1b. Polytunnel temperature 2020 vs 2021. Week 1 is the date of the first inspection in 2020; the trial started and finished two weeks later in 2021.



Appendix 2. Growing media analyses. *Prunus lusitanica* 'Myrtifolia'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need. U = unground and G = ground

Treatment		Date	pH	EC	NH_4^-	NO_3^-	N	P	K	Mg	Ca	Fe	Cu	Mn	Zn	Na	B	SO_4	Cl	Density	Dry matter	Dry density
		2021		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	kg/m^3	%	kg/m^3
Unground	Grower	11-May	6.1	62	<0.6	1.3	1.9	3.9	16.9	3.7	14	0.2	<0.01	<0.01	0.09	27.6	0.15	64.5	44.3	356	24.3	86.5
	Unused		6.2	227	53.9	106.3	160.1	<1	8.5	32.5	22.5	0.9	<0.01	0.09	<0.02	28.0	0.13	33.1	26.2	334.0	45.6	152.3
	T1	13-Oct	5.6	159	3.0	5.3	8.3	0.15	<0.01	<0.01	0.09	0.38	0.03	0.04	0.02	43.8	<0.05	186	102.9	216	43.5	94
	T2		5.5	236	7.0	20.2	27.2	6.9	41.8	51.8	35	<0.01	0.11	0.04	0.76	56.5	0.06	242	138.4	335	39.6	132.7
	T3		5.9	444	29.8	99.6	129	27.3	127	84.7	72	0.86	0.1	0.09	0.19	71.3	0.11	317	161.3	333	43.1	143.5
	T4		5.2	378	10.9	123.2	134	22.4	140	82.8	58.5	0.93	0.02	0.28	0.13	48.0	0.08	208	93.3	276	51.1	141
	T5		6.3	83	<0.6	6.6	6.8	<1	3.8	15.6	18	0.21	<0.01	0.02	<0.02	25.4	<0.05	64.2	58.9	215	53.2	114.4
Ground	T1	11-Oct	5.5	222	19.2	42.5	61.7	14.9	40.7	44.9	32.5	0.45	0.02	0.1	0.12	42.9	0.14	177	87.1	216	43.5	94
	T2		5.2	423	36.3	89.5	126	29.9	102	82.8	65.9	1.38	0.03	0.22	0.13	70.8	0.13	322	161.4	335	39.6	132.7
	T3		5.4	970	188.5	228.3	417	131.7	352	135	128	3.81	0.37	0.63	0.86	75.4	0.57	915	148.9	333	43.1	143.5
	T4		5.0	1540	377.2	446.7	824	216.8	589	205	158	6.94	0.37	1.47	1.18	66.5	0.85	1468	106	276	51.1	141
	T5		5.7	140	8.4	25.4	33.9	6.9	17.5	28.1	21.9	0.24	<0.01	0.03	0.05	27.3	0.05	111	51.6	215	53.2	114.4

Appendix 3. Growing media analyses. *Spiraea arguta*. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need.

Treatment		Date	pH	EC	NH_4^-	NO_3^-	N	P	K	Mg	Ca	Fe	Cu	Mn	Zn	Na	B	SO_4	Cl	Density	Dry matter	Dry density
		2021		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	kg/m^3	%	kg/m^3
Unground	Grower	11-May	7.5	108	<0.6	<0.6	< 0.6	5.1	11.6	9.7	24.9	0.15	<0.01	<0.01	<0.02	52.6	0.18	83.7	68.2	450	21.1	95
	Unused		6.2	227	53.9	106.3	160.1	<1	8.5	32.5	22.5	0.9	<0.01	0.09	<0.02	28.0	0.13	33.1	26.2	334	45.6	152.0
	T1	11-Oct	6.6	72	<0.6	2.4	2.9	<1	9.2	11.0	10.7	0.43	<0.01	0.02	<0.02	26.5	<0.05	56	46.7	305	45.7	139
	T2		6.2	122	<0.6	1.0	1.4	1.4	19.0	20.1	18.9	0.31	<0.01	0.01	<0.02	43.8	<0.05	101.1	102.6	273	49.8	136
	T3		6.2	139	<0.6	0.7	1.0	3.3	35.5	24.0	22.1	0.44	<0.01	0.02	0.03	44.2	<0.05	147.1	100.9	244	49.5	121
	T4		6.0	182	0.9	55.8	56.7	9.8	89.6	26.3	36.8	0.35	<0.01	<0.01	0.05	28.9	0.1	91.9	55.8	263	40.3	106
	T5		6.4	34	<0.6	1.3	1.6	<1	9.2	2.7	3.6	0.25	<0.01	<0.01	<0.02	13.7	<0.05	19.8	22.2	372	33.4	124
Ground	T1	11-Oct	5.9	124	4.7	11.7	16.4	5.3	21.4	19.3	18.8	<0.01	0.02	0.04	0.34	36.4	<0.05	104.8	68.1	305	45.7	139
	T2		6.0	98	<0.6	<0.6	< 0.6	3.1	19.1	13.4	11.9	0.25	<0.01	<0.01	<0.02	35.9	<0.05	68.7	82.8	273	49.8	136
	T3		5.8	187	1.6	3.5	5.1	12.9	57.0	30.0	30.3	0.37	0.02	0.02	0.05	50.4	<0.05	156.4	123	244	49.5	120
	T4		5.7	362	3.0	87.8	90.9	44.5	154.7	62.6	68.2	0.51	0.02	0.05	0.11	59.9	0.1	196.3	126.6	263	40.3	106
	T5		6.4	61	<0.6	<0.6	< 0.6	4.7	10.6	5.0	6.4	0.25	0.01	<0.01	<0.02	19.5	0.05	29.4	41.6	372	33.4	124

Appendix 4. Growing media analyses. *Geranium* x *cantabrigiense* 'Westray'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need.

Treatment		Date	pH	EC	NH_4^-	NO_3^-	N	P	K	Mg	Ca	Fe	Cu	Mn	Zn	Na	B	SO_4	Cl	Density	Dry matter	Dry density
		2021		uS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	kg/m^3	%	kg/m^3
Unground	Grower	11-May	6.5	155	<0.6	29.8	30.3	10.0	108.1	13.3	13.4	0.53	<0.01	<0.01	<0.02	52.1	0.31	120.6	58.3	544	19.1	103.9
	Unused		6.2	227	53.9	106.3	160.1	<1	8.5	32.5	22.5	0.9	<0.01	0.09	<0.02	28.0	0.13	33.1	26.2	334.0	45.6	152.3
	T1	11-Oct	5.9	177	22.6	26.4	49	13.8	32.2	22.8	22.7	1.94	<0.01	0.05	0.11	36.5	0.09	168.9	59.5	411	34.4	141.4
	T2		6.2	83	2.1	3.3	5.4	2.4	10.2	11.4	10.5	0.41	<0.01	<0.01	<0.02	34.8	<0.05	98.5	36.8	251	41.3	103.7
	T3		5.7	212	1.2	53.6	54.9	4.3	37.7	40.4	31.1	0.86	<0.01	0.06	0.03	138	0.05	58.2	80.0	297	51.6	153.3
	T4		5.3	226	1	74.8	75.9	1.7	54.8	40.9	36.3	0.46	<0.01	0.04	<0.02	53.6	<0.05	94.9	66.8	238	43.4	103.3
	T5		6.1	48	0.6	1.5	2.1	<1	6.2	6.2	6.1	0.45	<0.01	<0.01	<0.02	19	<0.05	38.7	39.2	331	43.3	143.3
Ground	T1	11-Oct	5.5	202	6.9	18.9	25.8	7.7	28.3	37	32.7	0.84	0.02	0.14	0.08	58.5	0.08	216.6	95.6	411	34.4	141.4
	T2		5.5	180	2.6	23.1	25.7	10.2	35.6	36	30.1	0.4	0.04	0.1	0.06	51.1	<0.05	162.4	73.3	251	41.3	103.7
	T3		5.2	305	4.6	59.4	64	8.1	69.1	63.4	48.7	82.5	0.02	0.15	0.09	0.91	0.06	250.1	110	297	51.6	153.3
	T4		4.9	589	56.9	185	242	53.9	203.4	119	104	2.53	0.16	0.57	0.27	62.4	0.37	476.4	72.3	238	43.4	103.3
	T5		5.7	140	1.3	17.4	18.7	4.5	19.5	26.1	24.9	0.32	0.03	0.08	0.03	40.4	0.05	124.5	63.8	331	43.3	143.3

Appendix 5. Growing media analyses. *Tradescantia pallida* 'Purple Sabre'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need. U = unground and G = ground

Treatment		Date 2021	pH	EC uS/cm	NH_4^- mg/l	NO_3^- mg/l	N mg/l	P mg/l	K mg/l	Mg mg/l	Ca mg/l	Fe mg/l	Cu mg/l	Mn mg/l	Zn mg/l	Na mg/l	B mg/l	SO_4 mg/l	Cl mg/l	Density kg/m^3	Dry matter %	Dry density kg/m^3
Unground	Grower	11-May	6.6	59	<0.6	3.9	4.4	3.6	7.4	3	5.5	0.47	<0.01	<0.01	<0.02	47.3	0.33	72.9	20.2	473	23.3	110.2
	Unused		6.2	227	53.9	106.3	160.1	<1	8.5	32.5	22.5	0.9	<0.01	0.09	<0.02	28.0	0.13	33.1	26.2	334	45.6	152.3
	T1	15-Oct	6	36	1.8	1.9	3.7	2.1	7.2	1.0	3.3	0.95	<0.01	<0.01	<0.02	18.5	<0.05	34.8	14.3	392	31.2	122.3
	T2		5.4	66	8.4	12.2	20.6	8.2	14.1	4.0	4.9	0.97	<0.01	<0.01	0.02	24.9	0.05	61.2	10.2	235	36.9	86.7
	T3		5.6	54	3.2	6.9	10.1	5.7	7.9	3.5	4.0	1.32	0.01	<0.01	<0.02	29.3	<0.05	57.9	14.8	218	35.1	76.5
	T4		5.8	38	1.4	3.0	4.4	11	5.5	2.3	3.5	0.77	<0.01	<0.01	0.02	23.5	0.06	35.8	10.6	191	58.2	111.2
	T5		5.8	26	1.1	1.5	2.6	<1	3.0	1.0	2.3	<0.01	<0.01	<0.02	0.78	16.5	<0.05	29.6	11.7	267	38.1	101.7
Ground	T1	23-Oct	5.3	126	13.1	18.6	31.7	12.4	24.9	7.3	9.1	1.13	0.03	0.03	0.03	39.5	0.11	124.6	13.6	392	31.2	122.3
	T2		4.9	132	19.5	23.5	43.0	18.7	32.0	7.7	8.8	1.20	0.02	0.03	0.02	43.0	0.07	122.7	12.9	235	36.9	86.7
	T3		5.3	81	7.3	10.9	18.2	13.5	21.0	5.6	5.9	1.06	0.09	0.03	0.04	29.7	0.07	68.5	13.6	218	35.1	76.5
	T4		5.4	150	18.6	26.7	45.3	37.4	41.8	18.4	16.6	0.13	0.08	0.12	1.14	37.3	0.11	126.6	17.9	191	58.2	111.2
	T5		5.4	86	7.9	11.4	19.4	8.2	18.2	5.9	7.2	0.68	0.03	0.03	0.04	32.7	0.05	88.1	14.5	267	38.1	101.7

Appendix 6. Tissue analyses. *Prunus lusitanica* 'Myrtifolia'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need. Standard range extracted from Mills and Jones,1996

		High																
		OK	N		P		K		Ca		Mg		S	Mn	Cu	Zn	Fe	B
Date	Sample	Low	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	ppm	ppm	ppm	ppm
Standard leaf analysis (range)		From	1.53	-	0.2	-	0.93	-	1.18	-	0.4	-	0.09	409	6	22	31	26
		To	2.59	-	0.22	-	1.35	-	2.24	-	0.61	-	0.11	643	11	35	97	34
10-May-21	Initial leaf analysis		1.29		0.21		0.57		1.1		0.13		842	24.2	4.1	10.9	56.7	15.9
Oct-21	T1		2.350	2194	0.2194	10236	1.0236	14155	1.4155	5392	0.5392	1372	1.372	58.9	1.6	13.4	67.6	22.5
	T2		2.673	3687	0.3687	12628	1.2628	16530	1.6530	5970	0.5970	1438	1.438	74.9	1.8	14.4	81.4	24.4
	T3		2.948	4735	0.4735	15490	1.5490	18299	1.8299	6711	0.6711	1534	1.534	94.5	1.8	15.5	87.7	24.5
	T4		2.111	1501	0.1501	7084	0.7084	13693	1.3693	5266	0.5266	1234	1.234	49.1	2.3	12.7	52.7	21.2
	T5		2.202	2444	0.2444	8275	0.8275	12380	1.2380	4242	0.4242	1515	1.515	43.1	1.5	16.3	57.5	21.0

Appendix 7. Tissue analyses. *Spiraea arguta*. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need. Standard range extracted from Mills and Jones,1996

		High																
		OK	N		P		K		Ca		Mg		S	Mn	Cu	Zn	Fe	B
Date		Low	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	ppm	ppm	ppm	ppm
Standard leaf analysis (range)		From	1.5	-	0.16	-	1.5	-	0.69	-	0.2	-	0.12	103	3	18	75	36
		To	2.16	-	0.31	-	1.6	-	1.18	-	0.29	-	0.16	189	6	32	84	44
10-May-21	Initial leaf analysis		2.83		0.57		1.28		0.7		0.24		3191	31.7	5.7	45.8	49.7	20.1
Oct-21	T1		2.917	1896	0.1896	6770	0.6770	11387	1.1387	6600	0.6600	1785	0.179	340	5.6	19.7	102	19.4
	T2		2.906	2686	0.2686	8850	0.8850	9024	0.9024	4473	0.4473	1839	0.184	253	1.6	23.8	111	20.2
	T3		3.078	3452	0.3452	10053	1.0053	8802	0.8802	4220	0.4220	1825	0.183	232	1.1	24.5	120	18.3
	T4		3.418	4021	0.4021	16584	1.6584	8372	0.8372	3745	0.3745	1938	0.194	256	0.8	29.2	76.1	14.8
	T5		2.894	2036	0.2036	8550	0.8550	9764	0.9764	5578	0.5578	1773	0.177	284	6.4	23.4	106	20.1

Appendix 8. Tissue analyses. *Geranium* x *cantabrigiense* 'Westray'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need; T6 = 1.0% feed to need from week 13 (after potting), *Geranium* and *Tradescantia* only. Standard range extracted from Mills and Jones,1996. Note: for *Geranium* and *Tradescantia* there is no lower standard range.

		High																	
		OK	N		P		K		Ca		Mg		S		Mn	Cu	Zn	Fe	B
Date		Low	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	ppm	ppm	ppm	ppm	ppm
	Standard	From	2.96		0.69		2.95		1.33		0.34		0.29		55	8	55	51	25
	leaf	To	2.96		0.69		2.95		1.33		0.34		0.29		55	8	55	51	25
10-May-21	Initial leaf analysis		3.11		0.76		1.72		1.03		0.68		2520		50.1	7.7	38.7	135	60.4
	T1		1.749	1478	0.1478	9600	0.96	17328	1.7328	6796	0.6796	1835	0.1835		69.2	4.3	18.7	138	25.2
	T2		2.033	2571	0.2571	16005	1.6005	16709	1.6709	7131	0.7131	1947	0.1947		57.3	2	14.3	50.3	20.8
Oct-21	T3		2.673	4949	0.4949	23818	2.3818	18030	1.803	7885	0.7885	2595	0.2595		81.4	2.4	17.4	59	28.4
	T4		2.952	7425	0.7425	27859	2.7859	20041	2.0041	8667	0.8667	2813	0.2813		91.8	2.7	15.9	62.5	30.5
	T5		1.795	1760	0.176	11258	1.1258	18621	1.8621	7389	0.7389	1920	0.192		71.5	2	15.4	40.9	25.4

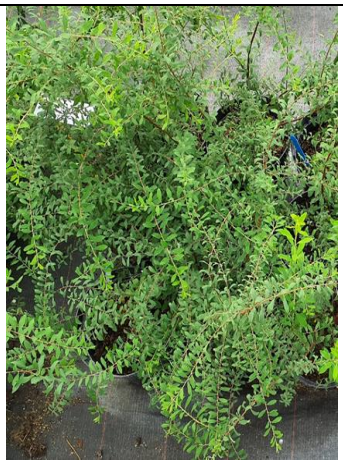
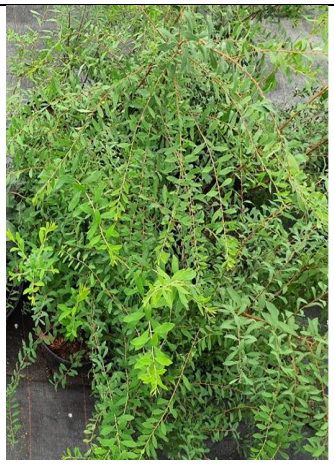
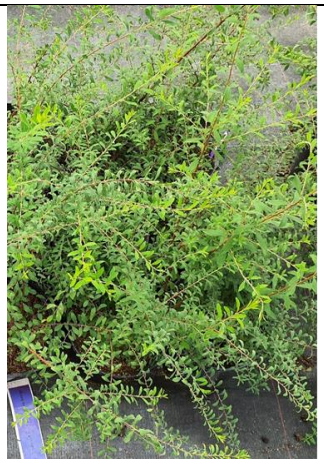
Appendix 9. Tissue analyses. *Tradescantia pallida* 'Purple Sabre'. Liquid feed treatments: T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need; T6 = 1.0% feed to need from week 13 (after potting), *Geranium* and *Tradescantia* only. Standard range extracted from Mills and Jones,1996. Note: for *Geranium* and *Tradescantia* there is no lower standard range.

		High																	
		OK	N		P		K		Ca		Mg		S		Mn	Cu	Zn	Fe	B
Date		Low	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	%DM	ppm	ppm	ppm	ppm	ppm	ppm
	Standard	From	4.84		0.52		5.41		2.07		0.36		0.31	1069		10	63	127	20
	leaf	To	4.84		0.52		5.41		2.07		0.36		0.31	1069		10	63	127	20
10-May-21	Initial leaf analysis		2.46		0.4		2.65		2.09		1.68		6587	124		13.4	73.8	151	21.1
	T1		1.714	2111	0.2111	14394	1.4394	34609	3.4609	16620	1.662	4109	0.4109	79		7.1	28.4	351	19.4
	T2		1.877	2238	0.2238	9616	0.9616	38756	3.8756	21110	2.111	4835	0.4835	131		5.9	30.6	375	22.5
Oct-21	T3		2.328	3268	0.3268	12816	1.2816	35469	3.5469	18540	1.854	5112	0.5112	139		6.5	28.9	257	27.7
	T4		3.033	4459	0.4459	18692	1.8692	41138	4.1138	17370	1.737	5905	0.5905	152		6.1	27.8	157	27.4
	T5		2.14	2539	0.2539	10748	1.0748	40428	4.0428	20560	2.056	4918	0.4918	132		6.1	30.7	325	23.7

Appendix 10. Prunus lusitanica ‘Myrtifolia’. Treatment effects. Final assessment, week 23, 05 October 2021. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

	
T1 – No liquid feed	T2 – 0.5% once per week
	
T3 – 1.0% once per week	T4 – 0.5% every watering
	
T5 – 1.0% feed to need	

Appendix 11. Spiraea arguta. Treatment effects. Week 22 04.10.2021. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

T1 – No liquid feed	T2 – 0.5% once per week
	
T3 – 1.0% once per week	T4 – 0.5% every watering
	
	
T5 – 1.0% feed to need	

Appendix 12. Geranium x cantabrigiense ‘Westray’. Treatment effects. Final assessment, week 23, 11 October 2021. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

	
T1 – No liquid feed	T2 – 0.5% once per week
	
T3 – 1.0% once per week	T4 – 0.5% every watering
	
T5 – 1.0% feed to need	

Appendix 13. Tradescantia pallida ‘Purple Sabre’. Final assessment, week 23, 11 October 2021. T1 = no liquid feed; T2 = 0.5% 1/week; T3 = 1.0% 1/week; T4 = 0.5% every watering; T5 = 1.0% feed to need

	
T1 – No liquid feed	T2 – 0.5% once per week
	
T3 – 1.0% once per week	T4 – 0.5% every watering
	
T5 – 1.0% feed to need	

