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Key staff:	Hilary Papworth Benjamin Tea
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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

Low calcium (Ca) in Primula is the likely cause of leaf-edge scorch and can be improved in spring and summer crops by reducing transpiration and not subjecting plants to water stress.

Although overhead irrigation can cause leaching of nutrients from growing media, plants benefit from the added foliar application of nutrients.

Delivery of nitrogen (N) in the form of ammonium (NH_4) up to 30% of total N, should not be detrimental to most bedding species in hard water areas.

Background

The target of this project is to make nutritional recommendations for key crops in the protected ornamental, bulb and outdoor cut flower industry which will form part of the guidance available in RB209. To make nutritional recommendations it is important to understand not only the nutritional requirements of the plants but also how the different variables in the production system will alter the availability of different nutrients.

In the second year of this four-year project the target was to:

- validate the data obtained in year 1 on the interactions between pot size, growing media and irrigation system, by repeating experimental work on Petunia and Pansy.
- To investigate how to avoid excessive EC levels when using capillary matting.
- To expand the work on the impact of pH and environment in Primula by carrying out two trials at different periods of the year, with the aim of reducing the incidence of leaf-edge scorch started in 2019.
- Look at the impact of NH_4 versus nitrate (NO_3) N fertiliser on bedding species, reviewing existing sources of experimental data and carrying out trials to gain first-hand experience of the issues.

The longer-term study on N nutrition in field-grown Narcissus continued this year at the trial sites in Cornwall and Lincolnshire, the aim of which is to review the current advice available in RB209. Application of treatments took place and data collection was underway at the time of writing the reports, findings from this year will be included in the next annual report.

A total of seven experimental trials were carried out in this year.

Summary

To confirm results from 2019 the same bespoke table system was used in the glasshouses at the NIAB trial site in Cambridge and again looked at the impact of using different irrigation systems to delivery liquid feed to Petunia and Pansy plants. The Petunia trial was run during summer of 2020, using F1 hybrid ‘Frenzy Blue Vein’ grown in 13 cm 5 deg pots using three different peat reduced growing media mixes. The mixes were 70:30 peat and perlite mix, 70:30 peat and wood fibre mix and 70:30 peat and coir mix, none had wetter or base feed incorporated. In the autumn Pansy ‘Matrix® White Blotch’ was grown using a 12-cell bedding pack and the same growing media mixes.

In the trial set up we compared irrigation delivered by overhead, ebb and flood and trickle tape onto capillary matting. Each trial had treatments which repeated the same combinations of feed vs irrigation vs growing media, but also included a feed that was reduced nutrient content compared with the previous year for the Petunia. For the Pansy, different strategies for avoiding accumulations of salt on capillary matting were investigated with different rates and feed sources, including a controlled release fertiliser (CRF) alternative.

The results for Petunia fresh weight showed plants grown under the ebb and flow regime with the standard feed product were larger than those in any other treatment, with coir based growing media producing the heaviest plants. The lowest fresh weights were observed in the treatments grown using the capillary irrigation systems or those with wood fibre growing media mixes.

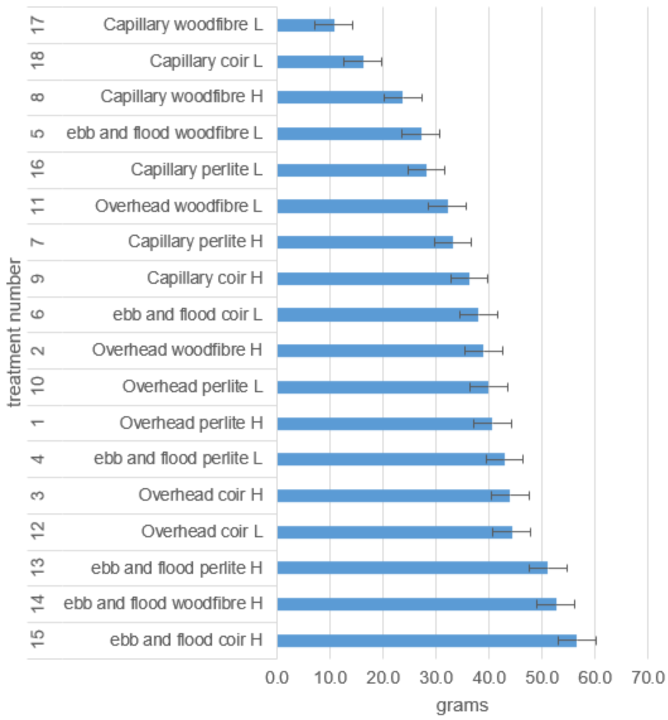


Figure 1. Average fresh weight for Petunia treatments ranked, observed 19/08/2020. H= high and L= low feed levels

The results indicate that with overhead irrigation with a perlite or coir mix growing media there is no impact from the reduction in nutrients between the feed regimes. This is not the case for the wood fibre mix; it has a significantly lower fresh weight with the tailored feed. It may be possible to adopt a lower feed regime and still achieve the same growth, but it is dependent on overhead irrigation and constituent parts of the growing media mix.

The results from the leaf tissue analysis for N show that N levels are linked to the irrigation method, with capillary matting delivering the lowest levels of N regardless of the feed regime. There appears to be a link between the irrigation system and the ratio of NH_4 to NO_3 in the leaf tissue which does not appear impacted by the type of growing media.

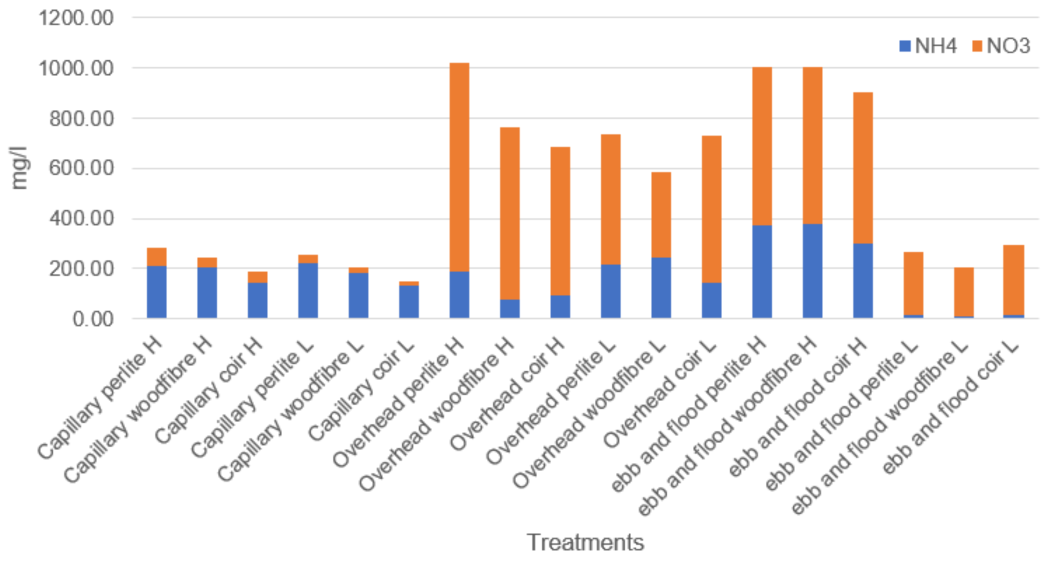


Figure 2. Results of leaf tissue analysis for total N content, samples 19/08/2020. H= high and L=low feed.

The Pansy trial shows the same link between overhead irrigation and greater efficiency of nutrient uptake. Use of a CRF in this trial was intended to disconnect the link between water application and nutrition, the results showed that this was successful under autumn growing conditions. These treatments had the highest plant fresh weight and most flowers in the trial,but increasing the feed/water ratio had a similar effect on plants, making it another successful strategy.

Three crops with different nutritional requirements were selected to illustrate the way species react to the NH_4 to NO_3 balance in feeds, these were Pansy 'Matrix® Blue Blotch', Geranium zonal 'Designer Scarlet Bright', Cyclamen F1 'Metis® White'.

Three feed treatments were applied to the trial each with NH_4 and NO_3 in the ratios 0:100, 20:80 and 30:70. However, all treatments provided 100 ppm N (NH_4/NO_3), 45 ppm phosphate (P),125 ppm potassium (K), 8 ppm magnesium (Mg) and trace elements.

Feeding was started one week after potting and then on a weekly basis. At each feeding event 10 ml of the diluted solutions were applied to individual pots.

The pH of the growing media initially declined, followed by a general increase. The highest pH values were observed in Pansy, followed by Geranium and lowest in Cyclamen, with no overlap in values for the species. Within each species there is no consistent trend linking the pH value to the N-form ratio, so final pH does not appear to be increasingly lower with increasing or decreasing amounts of NH_4 in the feed.

Table 1. Observation on growing media pH over duration of the trial for all treatments.

	Crop	Cyclamen			Geranium			Pansy		
	N form ratio NH_4:NO_3	0/100	20/80	30/70	0/100	20/80	30/70	0/100	20/80	30/70
Date	10/06/2020	6.14	6.16	6.05	6.43	6.43	6.29	6.25	6.28	6.25
	17/06/2020	6.15	6.11	6.04	6.18	6.17	6.17	6.12	6.14	6.17
	24/06/2020*	6.01	5.91	5.02	6.03	6.01	6.03	5.57	5.71	5.93
	01/07/2020	5.23	5.14	5.15	5.23	5.24	5.22	5.52	5.42	5.33
	08/07/2020	5.75	5.77	5.78	5.78	5.77	5.78	5.77	5.79	5.78
	15/07/2020	5.78	5.75	5.76	5.75	5.76	5.74	5.78	5.76	5.75
	23/07/2020	6.33	6.36	6.33	6.81	6.87	6.72	6.83	6.87	6.83
	30/07/2020	6.97	6.99	6.98	6.86	6.74	6.85	6.52	6.52	6.5
	05/08/2020	No observation in this week								
	13/08/2020*	6.31	6.36	6.13	7.12	6.86	7.34	7.48	7.37	7.55

*outdoor daytime temperature in excess of 30 ^{0}C during these weeks

There was little change in pH over the 9 weeks despite using different N-form ratios. Where changes occurred, the trend was the same in all treatments, and in all cases the growing media pH was higher at the end of the trial than at the start. From monitoring growing media pH in other trials, it appears likely that the upward trend in pH is from the use of overhead irrigation and the water, which is high in bicarbonate. It is also possible that the ratios are not high enough in NH_4 to cause a significant decline in pH under these conditions.

Previous work on Primula indicated a strong link between leaf-edge scorch, Ca, and environmental conditions. A trial was run during summer to see if the tissue death (necrosis) seen under high humidity conditions in spring were repeated, and to investigate if low growing media moisture content was a contributing factor in this problem.

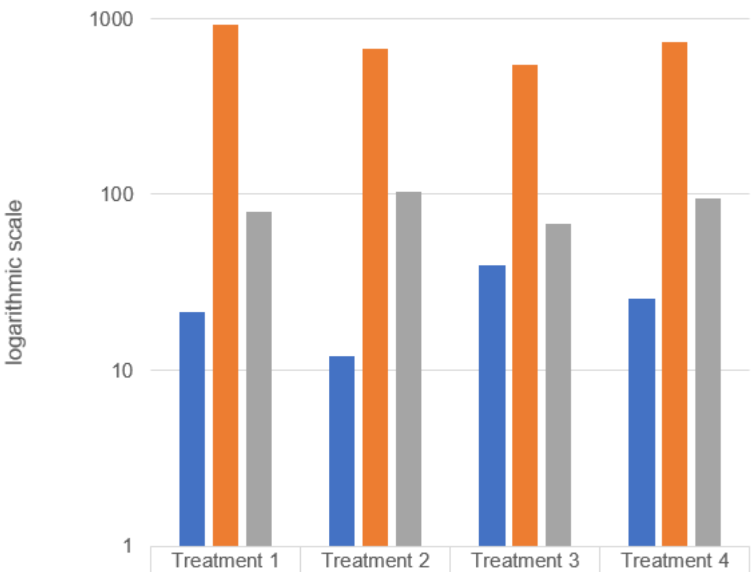
The investigation was untaken between May and August of 2020 using Primula 'Cresendo® Bright Red' and variation in plant spacing and watering levels were used to create four different treatments (Table 2).

Table 2. Treatment list for summer Primula trial.

Treatment code	1	2	3	4
Water rate	High	High	Low	Low
Humidity level	low	high	low	High

Plants were arranged in seven rows in a staggered arrangement, either at a spacing of around 10 cm between pot centres to create a lower humidity environment, or spaced pot-thick to increase the humidity. Watering was either applied as frequently as needed or limited to create a water deficit.

The results obtained for leaf tissue Ca show that the levels are highest in well-watered plants grown in lower humidity conditions. Increasing humidity or reducing irrigation levels were observed to reduce Ca in the leaf tissue by 20-40%.



	Treatment 1	Treatment 2	Treatment 3	Treatment 4
GM - mg/l	21.6	12	39.3	25.6
SAP - mg/l	916	671	546	732
Humidity - %	79.8	104.2	67.8	94.7

Figure 3. Results of growing media (GM) Calcium content, Leaf tissue (SAP) and average humidity at crop height from Blue Maestro™ disc monitors, figures are considered relative rather than exact as monitors do not have the high level of accuracy compared with glasshouse control systems but are accurate relative to one another.

In later stages of the trial, dying areas on the leaf margins were observed and these symptoms are recognisable as leaf-edge scorch. These were observed in treatments 2, 3 and 4 (see Table 2 for treatments), however the incidence in treatment 2 appeared most frequent.

Figure 4. Leaf edge scorch symptoms observed in the trial on treatments 2, 3 and 4, images dated 11/08/2020.

Results of growing media analysis show that sufficient Ca was present to avoid deficiency and the pH levels were suitable for its absorption.

Reducing humidity and improving the Ca in the leaf tissue, and apparently reducing the symptoms of leaf edge scorch, seemed to produce smaller plants over the same growing period.

The second investigation was done between September 2020 and January 2021 to see if the response to humidity and watering was the same during the autumn/winter growing period, and to see if applications of calcium nitrate ($Ca(NO_3)_2$) as a foliar feed can improve Ca nutrition under these conditions. Results are yet to be obtained for this trial.

Financial Benefits

In terms of fertiliser cost only, changing from a liquid feed regime to only using CRF could reduce costs, potentially to the point of being cost neutral. The level of cost depends on the efficiency of the irrigation system, and therefore the amount of liquid feed wasted. Using precision irrigation may reduce waste, making the use of liquid feed cheaper while achieving the same quality plants. However, CRF tends to have lower equipment costs and time input.

Action Points

- Regularly monitor the growing media EC to identify both inadequate and excessive levels, particularly in low water use periods, as trial results demonstrate that growing media EC can double in a week.
- Use CRF or increase the feed/water ratio for winter crops where irrigation can be low in response to weather conditions.
- In spring and summer Primula crops, reduce humidity in the glasshouse to improve Ca content in plants. This should reduce scorch symptoms.

SCIENCE SECTION

Introduction

This report describes the experimental work carried out in the second year of a four-year project which aims to make nutritional recommendations for key crops in the protected ornamental, bulb and outdoor cut flower industry. The output from this project will form part of the guidance available in the AHDB Nutrient Management Guide (RB209).

The work carried out in this year is a continuation from that described in the year 1 annual report dated March 2020. Experimental work was carried out on the variables affecting nutrient availability in peat-reduced growing media mixes in a range of bedding species, this was a repeat of the 2019 trials to examine if the results of these trials where repeatable and to investigate strategies to mitigate the nutritional issues observed. The first trial on Petunia repeated the standard feed regime used in 2019 and compared that with a feed designed around the results of the irrigation water, leaf tissue analysis (SAP) and growing media analysis in 2019. The aim was to see if a tailored feed with slightly lower nutrient levels could give the same quality of product. The second trial was on autumn grown pansy which repeated the feed, irrigation and growing media regime from 2019, but also looked at how delivery of nutrition could be adapted where capillary matting is used to avoid the build-up of ions causing excessive EC as observed in 2019. The guidance last included in RB209 on the use of capillary matting was to apply feed at 50% rate, the trial included this method as well as investigating controlled release fertilizer (CRF) and feeding in response to EC readings. To judge the effectiveness of these approaches they were compared with treatments where high EC was expected, and feed levels manipulated in order to achieve this.

In a continuation of the study of the cause of Primula leaf-edge scorch, results from the 2019/2020 winter trial were used to design new investigations into environmental factors effecting calcium (Ca) uptake. This resulted in two trials being carried out to investigate the incidence of this disorder under both summer and winter growing conditions and to look at potential management strategies for Ca deficiency. Both these trials aim to investigate the impact of crop height temperature, humidity, and root pressure. Ca uptake through the xylem is dependent on transpiration rates which can be stimulated by temperature, humidity, and the amount of available growing media water. During active growth when Ca is required at the furthest growing points, low transpiration rate and reduced root pressure leads to Ca not being available at the highest growing points (Marschner 1995).

New experimental work was started looking at nitrogen (N) nutrition and impact on the form N is supplied in. Assimilation of NO_3 into NH_4 has to take place in plants and the process has a high energy requirement, so it is considered most energy efficient to supply N to plants in a mix of both NO_3 and NH_4, The aim of the work in 2020 was to demonstrate the way pH changes in response to N when it is supplied as either NH_4 or NO_3 , and how the impact is different in different plant species. Detailed experimental work on N-form ratio with direct applicability has been carried out and reported (Johnson *et al* 2013). As has the fact that the way plants alter the rhizosphere pH varies at the cultivar level in some crops (Froehlich and Fehr, 1981; Saxena and Sheldrake, 1980).

The conclusion from the scoping study stated that it was unnecessary to carry out in depth investigations and unrealistic to develop detailed recommendations for N-form application, however the production of best practice advice backed by demonstration trials would be of benefit. The trial design took into consideration species which have differing imbalances in anion and cation uptake during growth and can subsequently suffer with different deficiencies due to changes in growing media pH, the current availability of commercial fertiliser formulations was also a consideration.

The longer-term study on N nutrition in field grown Narcissus was continued at the two trial sites in Cornwall and Lincolnshire, these trials aim to review the current advice available in RB209.

Materials and methods

During 2020 two glasshouse trials were undertaken to investigate the interaction between irrigation type, growing media type and pot size with relation to the delivery of liquid feed to different plant species (work package 2).

A single glasshouse trial was carried out to look at the impact of N-form ratio on different bedding species (work package 5).

Two trials were undertaken to look at how environment and growing practises affected Ca nutrition in Primula (work package 7).

And the two trials to investigate N application to field-grown narcissus in relation to stem length, base rot, and Nitrate Vulnerable Zone (NVZ) restrictions were continued (work package 6).

<u>Trial 1 (irrigation type, growing media and pot size)</u>

The investigation was untaken between June and August of 2020 and used the same methodology and principles as in 2019. The trial was grown in a glasshouse at NIAB's Cambridge trial site. The glasshouse was set to maintain a minimum temperature of 10 ^oC, no supplementary lighting was provided, and no shade screens were utilised. The trial was carried out on a bespoke six growing bench set up all fitted with Stal & Plast liners. Each table was L 383 cm x W 63 cm x H 75 cm with its own individual irrigation system.

The test plant was Petunia F1 hybrid ‘Frenzy Blue Vein’ which was raised at the trial facility from seed obtained from Ball Colegrave, the seed was sown on 15/06/2020 in a heated greenhouse direct in modules using Levington Advance Pot & Bedding M2 growing media. Five weeks after sowing the plants were transplanted into 13 cm 5 deg H SOPARCO Duo pot T/C, (D – 13.0 cm, H – 11.5 cm, V – 1.00 l) using three different peat-reduced growing media mixes. The mixes were 70:30 peat and perlite mix, 70:30 peat and wood fibre mix and 70:30 peat and coir mix.

No wetter or base feed was incorporated into the growing media, and the pH was adjusted to between 5.5 – 6. The peat used was the same for all mixes and was 0-10 mm grade, the perlite was 0-6 mm grade.

Figure 1. Overview of trial 1 set up, dated 12/08/2020.

The different growing media mixes were each grown under three different irrigation systems and a comparison between manual overhead irrigation, ebb and flood, and capillary matting (Growfelt Groundcloud purple, holding capacity 2.5 l/m^2) with water delivery by trickle tape was undertaken. Each of the three irrigation systems were set up on two of the table-top benches, with a fertigation system which delivered two different feed regimes to each of the irrigation methods.

The number of irrigation events and volume of water applied was based on the requirement of the plants. All systems were allowed to drain freely following irrigation events, with no water recycling.

The feed was applied via the irrigation system from one week after the potting date, and then at every subsequent irrigation event, up to a maximum of once per day. Where topping up of water was required for individual plants, or during hot weather, irrigation water without feed was used in all cases.

The two feed regimes used were as follows:

1) OMEX Adjust range, O-Mix 21-7-21 + 1.6 magnesium oxide plus trace elements (MgO + TE) which was made up to a stock solution of 1 kg/10 l that was diluted 1:200 using a Dosotron D3 Green Line injector. The resulting feed supplied 105ppm of N in the form of 1.6% NH_4 N, 3.4% NO_3 N, 16% Ureic N. (High)
2) Tailored feed prepared to supply 90 ppm N (20 ppm NH4+ - 80 ppm NO3-), 35 ppm phosphate (P), 125 ppm potassium (K) and 8 ppm magnesium (Mg), plus trace elements – boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) & zinc (Zn). This was made up to a stock solution and diluted 1:200 using a Dosotron D3 Green Line injector. (Low)

The tailored feed was calculated to give sufficient feed for the crop requirement when the nutrient available in the water source was taken into consideration, see Tables 1 and 2, Appendix 1 for water analysis and feed calculations.

Table 1. Treatment list for trial 1.

Table	Treatment	Feed	Irrigation System	Growing media mix
1	7	High	Capillary with trickle tape	Peat and perlite
1	8	High	Capillary with trickle tape	Peat and wood fibre
1	9	High	Capillary with trickle tape	Peat and coir
2	16	Low	Capillary with trickle tape	Peat and perlite
2	17	Low	Capillary with trickle tape	Peat and wood fibre
2	18	Low	Capillary with trickle tape	Peat and coir
3	1	High	Manual overhead	Peat and perlite
3	2	High	Manual overhead	Peat and wood fibre

3	3	High	Manual overhead	Peat and coir
4	10	Low	Manual overhead	Peat and perlite
4	11	Low	Manual overhead	Peat and wood fibre
4	12	Low	Manual overhead	Peat and coir
5	13	High	Ebb & Flood	Peat and perlite
5	14	High	Ebb & Flood	Peat and wood fibre
5	15	High	Ebb & Flood	Peat and coir
6	4	Low	Ebb & Flood	Peat and perlite
6	5	Low	Ebb & Flood	Peat and wood fibre
6	6	Low	Ebb & Flood	Peat and coir

For each of the 18 treatments 22 plants were grown, 66 plants arranged in a randomised layout on each table which resulted in a split-split plot design.

Observations were made throughout the trial on the incidence of deficiency symptoms, and those observed were noted and photographed.

Assessments were made 12 weeks after sowing, this consisted of plant height measured in millimetres (mm), a count of the number of flowers and fresh weight of the above ground growth in grams (g), along with photographs of plant and roots from each of the treatments.

The data from the trial was statistically analysed using analysis of variance (ANOVA) in order to determine the difference between treatments.

A sample of plant tissue and growing media from each treatment was also sent for laboratory analysis at the end of the trial. The material sent was a bulk sample taken from at least 10 randomly selected plants.

Trial 2 (irrigation type, growing media and pot size)

The second investigation took place between September and November of 2020 and was grown in a glasshouse at the Cambridge trial site, under the same conditions and table top set up as in 2019.

In trial 2 the test plant was Pansy 'Matrix® White Blotch', these were obtained from Ball Colegrave as plug plants and were received on 18/09/2020. Four days after receipt the plants were transplanted into H. Smith Plastic 12 cell bedding pack. (D – 23.0 cm, W – 17.5 cm, H

– 6.5 cm, Volume: 0.104 lt.) with the same three peat reduced growing media mixes as in trial 1.

The irrigation and feed system for nine of the 18 treatments was the same as in 2019. The remaining nine treatments were all grown using trickle irrigation onto capillary matting with varying feed regimes designed to mitigate the build-up of salts in the capillary matting seen in 2019.

Irrigation events were determined by the requirements of the plants and all systems were allowed to drain freely following irrigation events, with no water recycling. The water run-off from the ebb and flood irrigation, and manual overhead irrigation benches was recorded in order to calculate the total water usage. The pH and EC of the irrigation and run-off from the treatments with added feed was also observed at each irrigation event; levels were measured using EXTECH ExStik II meter.

Figure 2. Overview of trial 2 set up, image dated 16/11/2020.

The feeds used in the different treatments were as follows:

1) A liquid feed from the OMEX Adjust range, O-Mix 21-7-21 + 1.6 MgO + TE which was made up to a stock solution of 1 kg/10 l which was diluted 1:200 using a Dosotron D3 Green Line injector. The resulting feed supplied 105 ppm of N in the form of 1.6% NH_4 N, 3.4% NO_3 N, 16% Ureic N.
2) A CRF with NPK ratio of 12-7-18 + TE, and a release time of 2 to 3 months (Osmocote Bloom). As no base feed is present in the growing media an initial liquid feed will be applied to provide nutrition while the product activated.

For treatments 1 to 9, feed was applied via the irrigation system from 10 days after potting, and then at every irrigation event (code L).

For treatments 10 to 12, feed was applied from 10 days after potting, and then every week to 10 days depending on the frequency of the irrigation events, records of dates of application and volume were made (code LW).

For treatments 13 to 15, feed was applied from 10 days after potting, and then based on EC levels from saturated media extraction testing (SME), records of dates of application and volume was made (code LEC).

For treatments 16 to 18 feed was provided by the CRF only (code CRF) (Table 2).

Where the results of the SME testing showed that EC remained low in capillary irrigation treatments where the levels were expected to increase, the dilution rate of liquid feed was increased to 1:100. This was in order to understand if the mitigation strategies were effective.

Where topping up of water was required for individual plants, irrigation water without feed was used in all cases.

Table 2. Treatment list for trial 2, with feed treatments standard liquid (L), low rate liquid (LW), liquid applied in response to EC monitoring (LEC) and controlled release fertilizer (CRF).

Table	Treatment	Feed	Irrigation System	Growing media mix
1	7	L	Capillary with trickle tape	Peat and perlite
1	8	L	Capillary with trickle tape	Peat and wood fibre
1	9	L	Capillary with trickle tape	Peat and coir
2	10	LW	Capillary with trickle tape	Peat and perlite
2	11	LW	Capillary with trickle tape	Peat and wood fibre
2	12	LW	Capillary with trickle tape	Peat and coir
3	1	L	Manual overhead	Peat and perlite
3	2	L	Manual overhead	Peat and wood fibre
3	3	L	Manual overhead	Peat and coir
4	13	LEC	Capillary with trickle tape	Peat and perlite
4	14	LEC	Capillary with trickle tape	Peat and wood fibre
4	15	LEC	Capillary with trickle tape	Peat and coir
5	4	L	Ebb & Flood	Peat and perlite

5	5	L	Ebb & Flood	Peat and wood fibre
5	6	L	Ebb & Flood	Peat and coir
6	16	CRF	Capillary with trickle tape	Peat and perlite
6	17	CRF	Capillary with trickle tape	Peat and wood fibre
6	18	CRF	Capillary with trickle tape	Peat and coir

Assessments were made 8 weeks after potting, this consisted of plant height measured in mm, a count of the number of flowers and the fresh weight of the above ground growth in g, along with photographs of plant and roots from each of the treatments.

The data from the trial was statistically analysed using analysis of variance (REML) in order to determine the difference between treatments. This method was used instead of ANOVA as it is more appropriate in an unbalanced trial design.

Weekly observations on growing media EC and pH were made from SME using EXTECH ExStik II meter.

A sample of plant tissue and growing media from each treatment was also sent for laboratory analysis at the end of the trial. The material sent was a bulk sample taken from at least 10 randomly selected plants.

Trial 3 (N-form ratio)

The investigation was untaken between May and August of 2020. The trial was grown in a glasshouse at NIAB's Cambridge trial site. The glasshouse was set to maintain a minimum temperature of 10 ^{o}C, no supplementary lighting was provided, and no shade screens were utilised. The trial was carried out on a tabletop bench fitted with Stal & Plast liners.

Crops with different nutritional requirements were selected in order to investigate the difference in response. Cyclamen has a lower nutrient requirement, pansy has a higher nutrient requirement and causes pH to increase over time, and geranium which drives pH down over time.

The test plants were as follows:

Pansy 'Matrix® Blue Blotch' – grown at the trial site from commercial supplied seed by Ball Colegrave

Geranium zonal 'Designer Scarlet Bright' – obtained as plug plants from Ball Colegrave during week 20.

Cyclamen F1 'Metis® White' – obtained as plug plants from Ball Colegrave during week 20.

Figure 3. Overview of trial 3 set up, dated 12/08/2020.

Plants were transplanted into Soparco Duo 13 cm 5 deg (1 l) pots using a standard peat based growing media mix, the specification of which can be found in Table 3.**Table 3.** Growing media specification.

Brand	ICL M2
pH range	5.3-6.0
Particle size	0-10 mm
Conductivity	228-414 µs
Nutrient added	192N 98P 319K

Irrigation to the trial was applied manually overhead using a lance. The water supply used was main supply for the area (hard water). Plants were irrigated according to need, with excess irrigation water freely draining to avoid cross contamination between treatments.

Three feed treatments were applied to the trial each with a different ratio of NH_4 and NO_3 (Table 4). However, all treatments provided 100 ppm N (NH_4/NO_3), 45 ppm P,125 ppm K, 8 ppm Mg and trace elements.

Table 4. treatment list – ratio of N components used to achieve 100 ppm of N in feed.

Feed Treatment no.	NH_4 (Ammonium)	NO_3 (Nitrate)
1	0	100
2	20	80
3	30	70

The details of the feed components can be found in Table 1, Appendix 9.

When fertiliser straights with sulphate (e.g. Magnesium Sulphate - MgS) are used to create the stock solutions, the potential for an increase of the media pH can be expected. To achieve the required Mg levels in all three stock feeds two forms of Mg (MgS & MgN) were used.

The three stock feeds were made up on 03/06/2020 and diluted at a rate of 5 ml to 1 l water (0.5% or 1:200).

Feeding started one week after potting and then on a weekly basis. At each feeding event 10 ml of the diluted solutions were applied manually by syringe to individual pots in the relevant treatments.

The trial consisted of 66 plants per species, 22 per feed treatment. They were arranged in replicated blocks to assist with application of feed and with sampling of growing media.

Observations were made throughout the trial on the incidence of deficiency symptoms, and those observed were noted and photographed.

Assessments were made on two occasions during the trial, this consisted of plant height or width (depending on species) measure in mm, a count of the number of leaves (cyclamen only), a count of the number of flowers and the fresh weight of the above ground growth in g

Weekly observations on growing media EC and pH (SME) were made using EXTECH ExStik II meter. In order to maintain consistency, the SME sample was taken before the feed was applied (same day).

A sample of growing media and plant tissue from each treatment was sent for laboratory analysis at the mid-point of the trial based on 10 randomly selected plants, final samples were taken from the remaining 12 plants.

<u>Trial 4 (Calcium in Primula)</u>

The investigation was untaken between May and August of 2020. The trial was grown in a glasshouse at NIAB's Cambridge trial site. The glasshouse was set to maintain a minimum temperature of 10 ^{o}C, no supplementary lighting was provided, and no shade screens were utilised. The trial was carried out on a tabletop bench fitted with Stal & Plast liners (Figure 4).

The test plant was Primula 'Cresendo® Bright Red' which was raised at the trial facility from seed obtained from Ball Colegrave, the seed was sown on 19/5/2020 in a heated greenhouse direct in modules using Levington Advance Pot & Bedding M2 growing media.

Plants were transplanted 15/06/20 into Aeroplas 9 cm Low 5 deg pots using a standard peat based growing media mix, the specification of which can be found in Table 3 (outlined in the previous trial).

Figure 4. Overview of trial 4 set up, dated 17/06/2020.

Ca was supplied from high levels in the irrigation water and from the liming material used in the growing media.

To maintain all other nutrients to an acceptable level all plants were fed once per week with Omex feed O-Mix 21-7-21 + 1.6 MgO + TE (diluted into stock then 1:200) 5 ml diluted feed once a week.

Irrigation to the trial was applied manually overhead using a lance. The water supply used was main supply for the area (hard water).

The volume and timing of the irrigation was varied in order to create differences between the treatments in plant root pressure. Water treatments consisted of two regimes, water for the high water regime was given on an 'as required' basis for the plants, with plants being watered generously at least once per day. In the low water regime, plants only received light irrigation in the morning and were intended to be somewhat wilted by the end of the day to ensure plants were under water deficit stress during the night.

All plants were allowed to drain freely following irrigation events, with no water recycling.

Spacing of the plants in the trial was varied to create differences between the treatments in crop height humidity. Humidity treatments consisted of two regimes, the lower humidity treatment plants were spaced with 2-3 cm between pot edges, and the higher humidity treatment plants were spaced pot thick.

The temperature and humidity were monitored at plant height using Blue Maestro Tempo Disc™ 3 in 1 Bluetooth environmental monitors.

Table 5. Treatment list for summer Primula trial.

Treatment code	1	2	3	4
Water rate	High	High	Low	Low
Humidity level	low	high	low	High

Twenty-four plants of each treatment were grown and arranged in single blocks, without any randomisation of the treatments. Plants were arranged in seven rows in a staggered arrangement, alternating three and four pots per row.

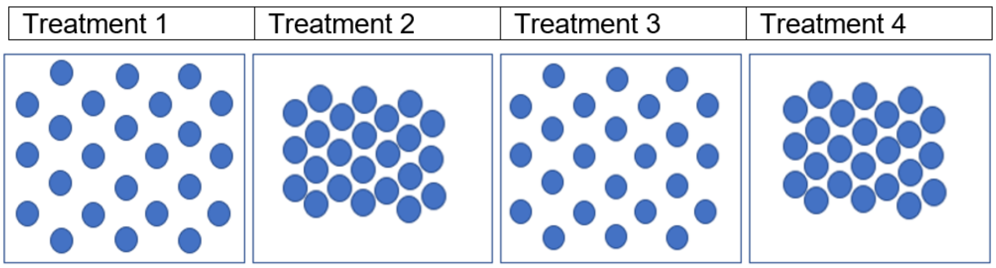


Figure 5. Layout of treatments in Primula trial (not to scale).

Observations were made throughout the trial on the incidence of deficiency symptoms, and those observed were noted and photographed.Assessments were made on two occasions during the trial, this consisted of plant width in mm, a count of the number of flowers, and fresh weight of the above ground growth in g.

A sample of growing media and plant tissue from each treatment was sent for laboratory analysis at the mid-point of the trial based on 10 randomly selected plants, final samples were taken from the remaining 12 plants.

Trial 5 (calcium in Primula)

The investigation was undertaken between September 2020 and January 2021. The trial was grown in a glasshouse at NIAB's Cambridge trial site. The glasshouse was set to maintain a minimum temperature of 10^{o}C, no supplementary lighting was provided, and no shade screens were utilised. The trial was carried out on a tabletop bench fitted with Stal & Plast liners.

The test plant was Primula 'Cresendo® Orange', these were obtained from Ball Colegrave as plug plants and were received on 18/09/2020. Four days after receipt the plants were transplanted into Aeroplas 9 cm Low 5 deg. pots using a standard peat based growing media mix, the specification of which can be found in Table 3.

Ca was supplied from high levels in the irrigation water and from the liming material used in the growing media. Additional Ca was added to four treatments in the form of foliar applications of $Ca(NO_3)_2$. A liquid formulation of the compound containing 22.5% Ca, 15% N with no other micro or macronutrients was used and applied as a foliar feed at weekly intervals from 28/10/2020 at two rates, 1:500 (0.2%) & 1:1000 (0.1%).

To maintain all other nutrients to an acceptable level all plants were fed once per week with Omex feed O-Mix 21-7-21 + 1.6 MgO + TE (diluted into stock then 1:200) 5 ml diluted feed once a week.

Additional applications of the product 'Maxicrop plus Iron' (seaweed extract base with 2% sequestered iron) to combat Iron deficiency were made following the development of deficiency symptoms early in the trial. These were applied weekly to all treatments, for four weeks from 30/10/2020 at 5 ml in 1 l water.

Irrigation to the trial was applied manually overhead using a lance. The water supply used was mains supply for the area (hard water). The two water regimes used in the summer trial were repeated as detailed in Table 6.

All plants were allowed to drain freely following irrigation events, with no water recycling.

The two humidity levels were also repeated using the different plant spacing regimes, these are detailed in Table 6.

The temperature and humidity were monitored at plant height using Blue Maestro Tempo Disc™ 3 in 1 Bluetooth environmental monitors.

Table 6. Treatment list for autumn/winter Primula trial.

Treatment code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Water rate	High	High	Low	Low	High	High	Low	Low	High	High	Low	Low
Humidity level	low	high	low	high	low	high	low	high	low	high	low	high
Calcium foliar feed	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Foliar feed rate	-	-	-	-	1:500	1:500	1:500	1:500	1:1000	1:1000	1:1000	1:1000

Figure 6. Overview of trial 5 set up, image dated 22/01/2021.

49 plants for each treatment were grown and arranged in single blocks, without any randomisation of the treatments. Plants were arranged in seven-by-seven row block (Figure 6), in a staggered arrangement, the edge plants of each block were excluded from the assessments.

Observations were made throughout the trial on the incidence of deficiency symptoms, and and where 'Leaf-edge scorch was observed the number of plants showing symptoms and the percentage of each plants affected were recorded and photographed. Assessments were made on two occasions during the trial, this consisted of plant width in mm, a count of the number of flowers, and fresh weight of the above ground growth in g..

A sample of plant tissue and growing media from each treatment was also sent for laboratory analysis at the end of the trial. The material sent was a bulk sample taken from at least 10 randomly selected plants.

Trial 6 and 7 (narcissus)

The trials investigating the application of N as a top dressing in field grown Narcissus, looking at the effect on yield, and on the incidence of basal rot caused by *Fusarium oxysporum* f.sp. *narcissi* (FON), continued this year with the same two sites.

Details of the two sites are as follows:

Lincolnshire trial host: Jack Buck Farms

Location: Moulton, Spalding, Lincolnshire (Figure 7)

Planting year: 2019

Variety: Tamsyn

Previous cropping: vining peas

Fertiliser: 0:100:300 kg/ha applied

Aspect: level

Soil: Loamy and clayey soils with naturally high groundwater

Figure 7. Lincolnshire trial site, image date 16/11/2020.

Cornwall trial host: Greenyard Flowers

Location: Trispen, Truro (Figure 8)

Planting year: 2019

Variety: Karenza

Previous cropping: Potatoes

Fertiliser: None applied

Aspect: gentle slope, north facing

Soil: Freely draining slightly acid loam

Figure 8. Cornwall trial site, dated 06/01/2021.

At each site, the trial consists of eight treatments replicated four times giving a total of 32 plots in randomised design which will remain consistent over the 3 years. The plot size is two rows x 12 m long with a buffer zone of two rows between plots to ensure that is no influence from the other plots.

In this second year of the trial N has been applied according to the following table.

Table 7. Treatment list with application rate and timing

Treatment	Application rate of N	Application timing	Application date Cornwall	Application date Lincolnshire
A	30 kg/ha	at leaf emergence	06/01/2021	16/11/2020
B	50 kg/ha	at leaf emergence	06/01/2021	16/11/2020
C	80 kg/ha	at leaf emergence	06/01/2021	16/11/2020
D	30 kg/ha	after 15th January	17/01/2021	18/01/2021
E	50 kg/ha	after 15th January	17/01/2021	18/01/2021
F	80 kg/ha	after 15th January	17/01/2021	18/01/2021
G	controlled release product *	Based on product recommendation	Delayed**	Delayed**
H	None (control)			

*composition to be defined in discussion with industry partners.

**appropriate product was not identified and sourced in time for application.

In all other respects the trial area will undergo the same agronomic practices as standard, including harvesting and application of sprays.

Observations will be made on 25 bulbs per plot on stem length (measured from the point of emergence to base of the flower bud, at the stage the spathe starts to split), number of flower stems per bulb and number of bulbs lost due to basal rot.

Results

Trial 1 (irrigation type, growing media and pot size)

For all treatments, observations on plant height, fresh weight and number of flowers were taken and statistically analysed (ANOVA), see Tables 1, 2 and 3, Appendix 2. In 2019 the results for fresh weight proved to be the most reliable indicator so these have been used again in 2020 to illustrate the outcome of the trial.

Based on 1 year only of data, the following have been seen at 95% confidence interval:

- a significant difference was seen between all irrigation types, with highest fresh weight in ebb and flood, followed by overhead and then capillary with trickle irrigation.
- a higher fresh weight was observed in the plants grown using the high feed regime irrespective of irrigation method.
- that plants grown in the wood fibre mix had the lowest fresh weight, irrespective of feed regime and irrigation type except with the high feed and overhead irrigation treatment where there was no significant difference between it and the perlite growing media mix.
- the highest fresh weight was observed in treatment 15, the coir growing media mix, with the high feed regime and ebb and flood irrigation.

Table 8. Abbreviation codes used in data collection and statistical analysis.

Variable	Code	Types
Feed	L	Tailored feed calculated from 2019 results
	H	Standard prepared feed (Omex Adjust range)
Irrigation type code	IA	Manual Overhead
	IB	Ebb & Flood
	IC	Capillary with trickle tape
Growing media type code	SA	Peat and perlite mix
	SB	Peat and wood fibre mix
	SC	Peat and coir mix

Figure 9. Images of trial 3 prior to final assessment, image dated 12/08/2020.

Visual differences were observed between treatments, but this was more pronounced in the later stages of the trial (Figure 9).

Table 9. Summary of results for treatments receiving high feed regime for plant fresh weight observed 19/08/2020. (See Table 8 for key to abbreviation codes.)

Treatment no.	**7**	**8**	**9**	**1**	**2**	**3**	**13**	**14**	**15**
Feed	H	H	H	H	H	H	H	H	H
Irrigation code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media code	SA	SB	SC	SA	SB	SC	SA	SB	SC
SE	4.25	6.25	8.20	7.92	5.92	7.60	5.84	6.61	5.84
Average fresh weight (g)	33.2	23.8	36.3	40.6	39.0	44.0	51.2	52.7	56.6

Table 10. Summary of results for treatments receiving low feed regime for plant fresh weight observed 19/08/2020. (See Table 8 for key to abbreviation codes.)

Treatment no.	**16**	**17**	**18**	**10**	**11**	**12**	**4**	**5**	**6**
Feed	L	L	L	L	L	L	L	L	L
Irrigation code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media code	SA	SB	SC	SA	SB	SC	SA	SB	SC
SE	3.69	3.39	2.56	7.51	6.76	5.81	4.53	5.06	5.32
Average fresh weight (g)	28.2	10.8	16.2	40.0	32.2	44.3	43.0	27.2	38.0

The visual observations are confirmed by the statistical analysed data for fresh weight in that all treatments under the ebb and flow regime with the standard feed product (code H) were larger than those under any other combination. Treatment 15 (the coir-based growing media) had the highest fresh weight.

The treatments with the next highest fresh weights are 12, 3 and 4 (see treatment details in Tables 9, 10); there was no significant difference in the plant weight between these treatments. Treatments 1 and 10 are next heaviest, but again these were not significantly different from one another. Treatment 3 and 12 both are the coir mix growing media with overhead irrigation, 1 and 10 are the perlite mix, and all are with overhead irrigation. However, treatments 1 and 3 are under the higher feed regime with the standard product and 12 and 10 are grown with the lower feed regime, using the tailored feed. This appears to indicate that with this delivery method and growing media mixes there is no impact from the change in feed regime. This is not the case for the wood fibre mix, it has a significantly lower fresh weight with the tailored feed.

The lowest weights were seen in the capillary irrigation systems, or any of the irrigation systems using the wood fibre mix, however in treatment 14 where ebb and flood irrigation is used there is no significant difference between the wood fibre and perlite mixes.

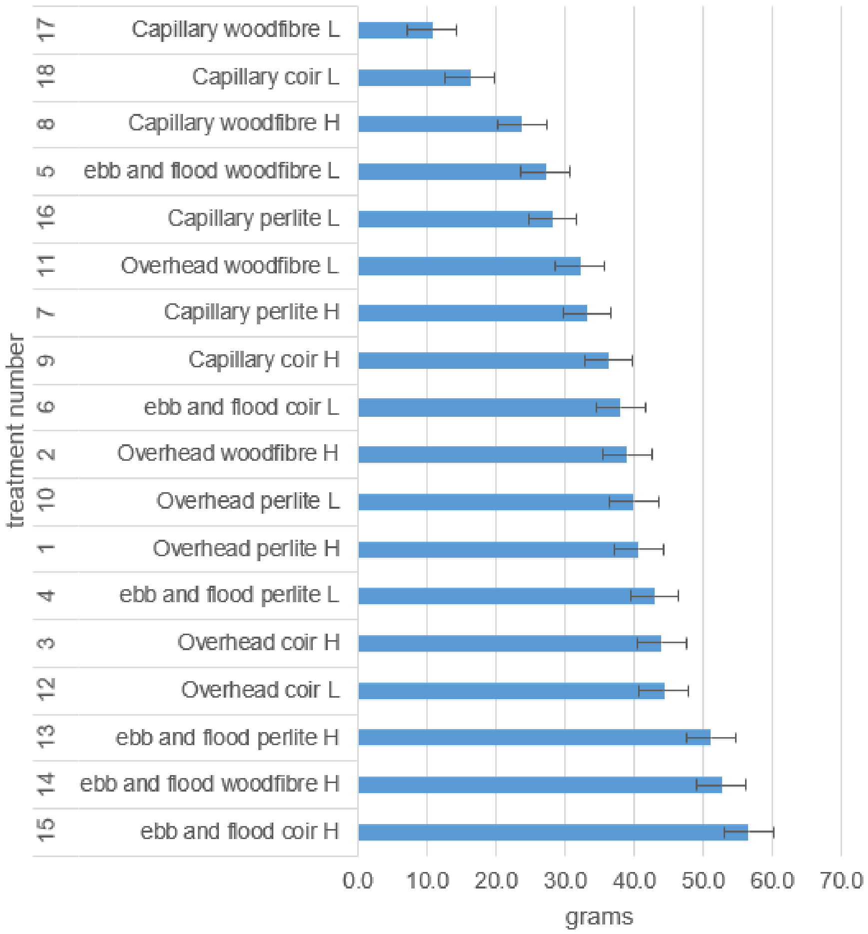


Figure 10. Average fresh weight ranked, observed 19/08/2020 (bars - LSD value of 3.54). H= high and L= low feed levels

The results obtained for flower number show a similar pattern to that for plant weight, with ebb and flow irrigation treatments giving the highest flower number, and generally the wood fibre growing media mixes have the lowest number. However, the results for capillary irrigation are much more mixed with respect to the flower number with treatment 9 (the high feed, capillary irrigation and coir mix growing media combination) showing no significant difference to treatments 14, 4 and 13 in this respect.

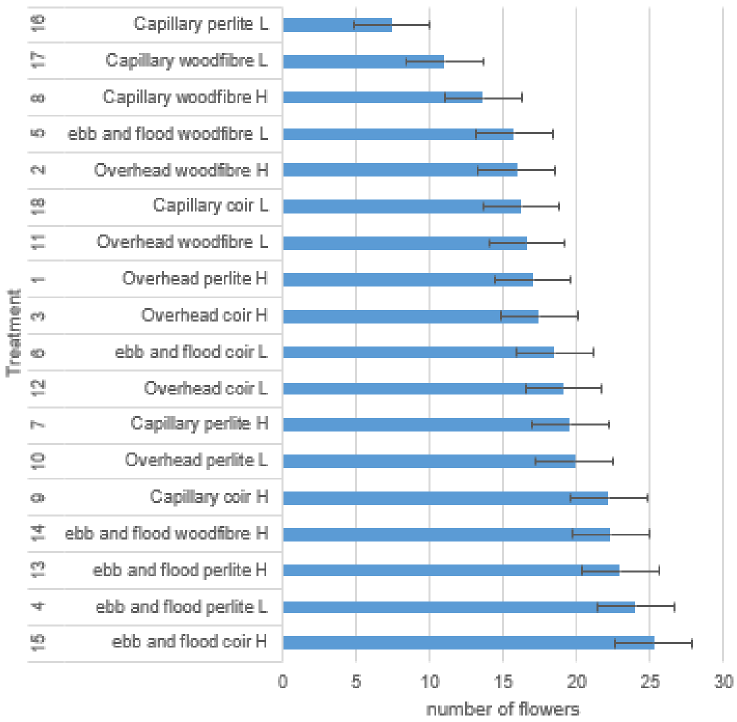


Figure 11. Average number of flowers ranked, observed 19/08/2020 (bars - LSD value of 2.16) . H= high and L= low feed levels

Bench 1 treatments 1,2,3
Capillary and Drip
Standard Feed

Bench 3 treatments 7,8,9
Overhead
Standard Feed

Bench 5 treatments 13,14,15
Ebb and Flood
Standard Feed

Bench 2 treatments 4,5,6
Capillary and Drip
Tailored Feed

Bench 4 treatments 10,11,12
Overhead
Tailored feed

Bench 6 treatments 16,17,18
Ebb and Flood
Tailored feed

Figure 12: representative plants of treatments at final assessment, images dated 19/08/2020.

See Figure 1, Appendix 4 for representative images of plant roots from each treatment.

Results from the leaf tissue SAP analysis for N show a pattern linked with the irrigation method. Where overhead irrigation is used, the N levels are all above 500 mg/l, with some further increase with increasing feed from the low to high treatments. However the difference is more marked in the ebb and flood irrigation treatments where N levels in the tissue are between 3 and 4 times higher in the high feed treatments. In the capillary irrigation treatments, the N levels have remained low even in the higher feed treatment.

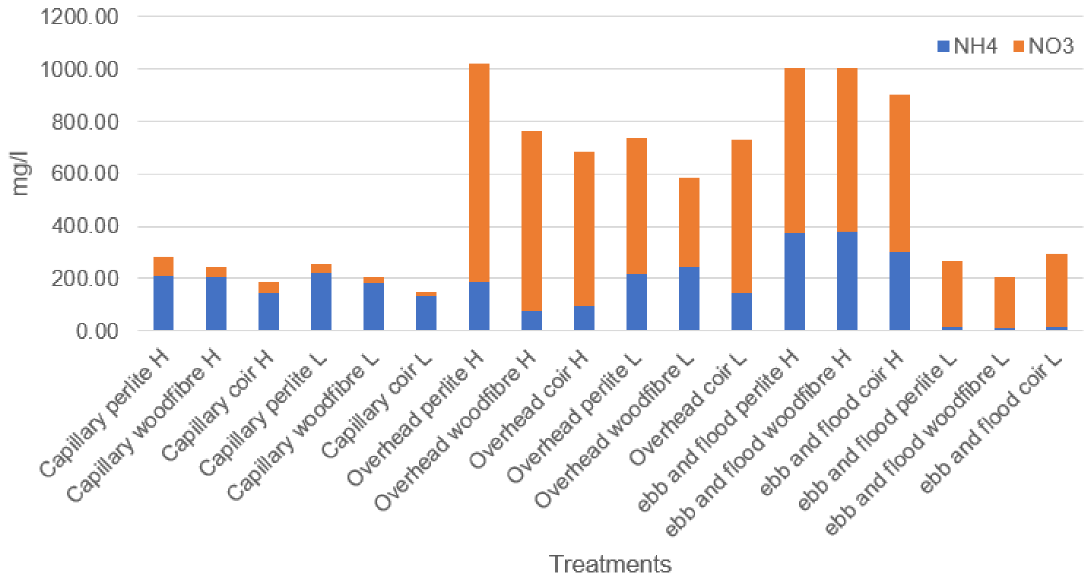


Figure 13. Results of leaf tissue analysis for total N content, samples 19/08/2020. H= high and L= low feed levels The irrigation and feed combinations that had the highest fresh weight of plant material overall also have the highest levels of N in the leaf samples, these are the ebb and flood treatments with high feed, and most of the overhead irrigated treatments.

Differences in the levels of NH_4 in the leaf tissue, and in the ratio of NH_4 to NO_3 between the different treatments appears to be correlated to the irrigation method, with capillary giving a very different ratio to the other methods. This does not appear to be impacted by the type of growing media used under the feed and irrigation regimes.

Table 11. Summary of results for treatments receiving high feed for plant fresh weight, number of flowers, growing media and SAP analysis -samples taken 19/08/2020. (See Table 8 for key to abbreviation codes.)

Table No.		1			3			5	
Treatment no.	**7**	**8**	**9**	**1**	**2**	**3**	**13**	**14**	**15**
Feed	H	H	H	H	H	H	H	H	H
Irrigation code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Substrate code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Plant assessment									
average fresh weight (g)	33.2	23.8	36.3	40.6	39.0	44.0	51.2	52.7	56.6
Plant Tissue analysis (mg/l)									
pH	4.51	4.64	4.36	6.23	6.11	6.2	5.05	4.43	4.33
NH4	212.52	202.5	140.94	190.26	75.66	95.58	373.74	377.7	297.36
NO3	70.5	40.98	45.48	829.38	687.24	587.04	628.8	623.22	606
K	1776.5	2267.09	3466.07	3247.98	2620.14	3762.09	2880.86	2932.74	3673.63
Mn	4.45	5.2	3.19	2.31	2.87	2.15	0.89	0.91	1.01
Fe	0.78	0.75	0.65	1.05	0.91	0.87	0.48	0.68	0.68
Growing media analysis (mg/l)									
pH	5.9	6.5	5.9	6.2	6.4	6.2	5.6	5.9	6
NH4	5.1	5.3	6	59.9	56.1	34.3	7	25.9	19.1
NO3	4.1	1.3	2.8	32.4	16.8	10	52.5	15	7
total sol N	9.2	6.6	8.8	92.3	72.9	44.3	59.5	40.9	26.1
K	<1	21.1	79.2	54.7	49.9	102.8	10	98.9	5.6
Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01
Fe	0.23	0.21	0.43	0.33	0.27	0.5	0.6	0.66	0.44

Full details of the growing media and leaf tissue analysis can be found in Tables 1 and 2, Appendix 3.

Similar growing media pH results are observed for all the treatments, where they are below 6.2 this is considered appropriate for the crop, this level is only exceeded by two of the wood fibre growing media mixes. The SAP pH results are less consistent, and show much lower values for the capillary, and the ebb and flood irrigated treatments.

Table 12. Summary of results for treatments receiving low feed for plant fresh weight, number of flowers, growing media and SAP analysis -samples taken 19/08/2020. (See Table 8 for key to abbreviation codes.)

Table No.		2			4			6	
Treatment no.	**16**	**17**	**18**	**10**	**11**	**12**	**4**	**5**	**6**
Feed	L	L	L	L	L	L	L	L	L
Irrigation code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Substrate code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Plant assessment									
average fresh weight (g)	28.2	10.8	16.2	40.0	32.2	44.3	43.0	27.2	38.0
Plant Tissue analysis (mg/l)									
pH	4.75	4.95	5.04	4.98	5.14	5.01	6.05	5.97	6.05
NH4	222.96	180.96	132.96	216.96	241.38	142.92	12.72	11.1	13.5
NO3	30.06	22.26	14.04	520.98	346.14	586.86	252.54	195.3	282.78
K	1577.43	3325.01	3671.27	2643.48	3893.08	4060.65	3547.14	4137.39	5007.9
Mn	5.28	6.63	4.72	2.72	2.74	2.25	2.72	3.02	1.77
Fe	0.58	0.74	0.62	0.76	0.83	0.74	0.66	0.66	0.76
Growing media analysis (mg/l)									
pH	6	6.1	6.4	6.3	6.9	6.8	5.9	6.4	6.6
NH4	4.1	4.1	4.3	4.2	1.2	2.6	3.8	3.3	5
NO3	5.1	<0.6	0.7	45.2	<0.6	3.8	11.3	<0.6	1.3
total sol N	9.2	4.7	4.9	49.3	1.2	6.3	15.1	3.9	6.3
K	1.4	3.6	51.1	97.3	101.5	106.2	8.8	28.3	69.4
Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	0.23	0.32	0.3	0.24	0.24	0.27	0.34	0.14	0.24

The growing media pH is slightly higher across the treatments with the tailored feed regime, with more above the 6.2 level.

Deficiency symptoms were observed across the trial (Figure 14), these were characterised by interveinal chlorosis in the new growth. Although specific leaf tissue analysis was not carried out to identify the deficiency it is most likely that this was Iron deficiency.

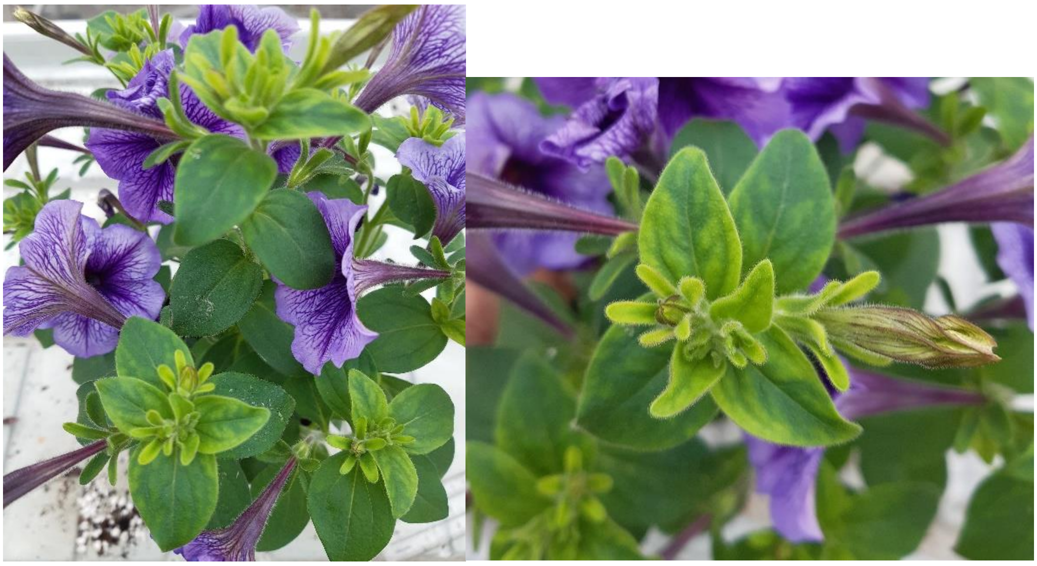


Figure 14. Deficiency symptoms observed August 2020, image of plants from treatment 6.

All treatments using coir mix growing media show the highest levels of K in the leaf tissue and growing media for each irrigation treatment, irrespective of the feed regime.

Phosphorus levels were lowest in the capillary irrigated treatments, but no consistent pattern was observed in which growing media mix this affected most. There were very minor deficiency symptoms observed, which appeared to relate to low P levels.

Figure 15. Deficiency symptoms observed July 2020, image of plants from treatment 5.

Trial 2 (irrigation type, growing media and pot size)

In 2019 the results for fresh weight proved to be the most reliable indicator so these have been used again in 2020 to illustrate the outcome of the trial. See Tables 1, 2 and 3, Appendix 5 for all plant observations and statistical analysis.

Based on 1 year only of data the following have been seen at 95% confidence interval:

- The plants grown in the growing media mix with 30% perlite had the highest fresh weight in all combinations of feed and irrigation.
- Where feed was applied only in liquid form, the plants grown using overhead irrigation had the highest fresh weights.
- The highest fresh weights for all growing media mixes were observed where CRF was used.
- The combination of CRF and 30% perlite growing media had the highest fresh weight of all treatments, but flower number was not significantly higher than other growing media mixes with the same fertiliser.

- In each irrigation and feed combination the 30% wood fibre growing media mix had the lowest fresh weights and flower numbers.
- The lowest fresh weight in the trial was observed in treatments 7, 8 and 9, the combination of capillary irrigation and the standard feed, with the plants grown in 30% wood fibre growing media mix having the lowest of all of these.

We observed no spike in growing media EC in treatments where capillary matting was used to deliver the irrigation, this resulted in treatments 7 to 15 receiving the same feed regime for the initial stages of the trial. At the half-way point of the trial it was decided to increase the feed rate on treatments 10 to 15 to 1:100, this was done on 14/10/2020 to see if the increase would cause a difference, however still no spike in EC was observed but an increase was seen on the final observations.

Table 1

Treatments 7,8,9

Table 3

Treatments 1,2,3

Table 5

Treatments 4,5,6

Table 2

Treatments 10,11,12

Table 4

Treatments 13,14,15

Table 6

Treatments 16,17,18

Figure 16. All trial treatments at flowering, image dated 16/11/2020.

Table 13. Abbreviation codes used in data collection and statistical analysis.

Variable	Code	Types
Feed	L	Standard prepared liquid feed (Omex Adjust range)
	LW	Low rate of the standard liquid feed
	LEC	Standard feed only applied when growing media EC is low
	CRF	Controlled release fertiliser
Irrigation type code	IA	Manual Overhead
	IB	Ebb & Flood
	IC	Capillary with trickle tape
Growing media type code	SA	Peat and perlite mix
	SB	Peat and wood fibre mix
	SC	Peat and coir mix

In the trial in 2019 we found fresh weight to be the most indicative of the assessments made on the trial, so this has been repeated in 2020. The other measures used in the trial produced similar rankings to the one observed for fresh weight.

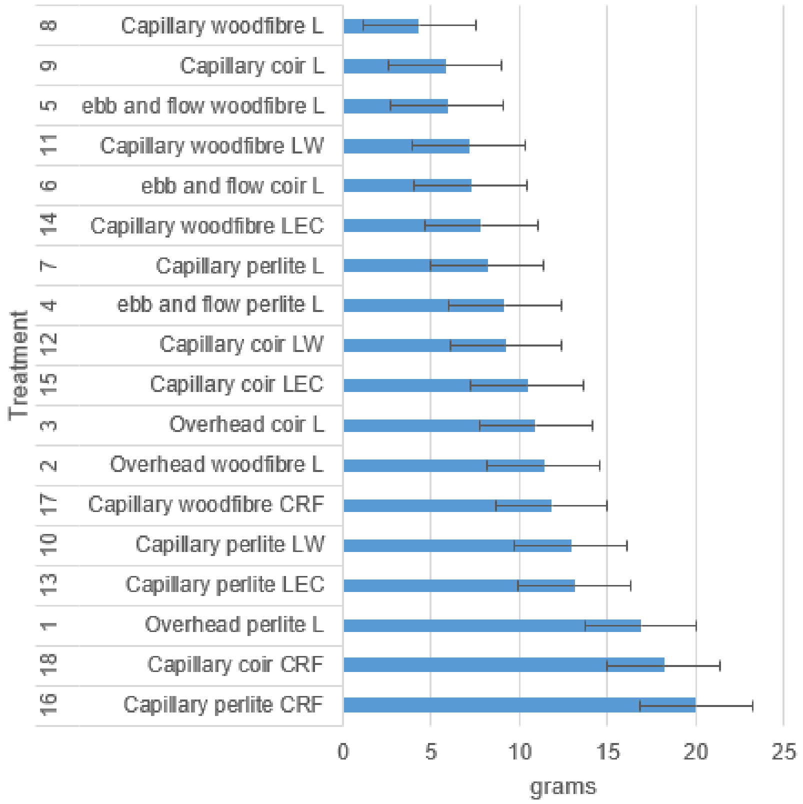


Figure 17. Average fresh weight of plants observed on (combined weight of 4 plants per treatment) ranked, with bar illustrating LSD between treatments. (See Table 13 for key to abbreviation codes)

In the treatments that were a direct repeat of the 2019 trial, fresh weight was highest in overhead irrigation, followed by ebb and flow and then capillary. The order is the same as in 2019 but the difference between fresh weight observed in plants grown under overhead irrigation compared with ebb and flood is greater in 2020 as the ebb and flood treatments performed poorly.

Plants grown in the perlite mix had the higher fresh weight for capillary and ebb and flood, followed by coir and then wood fibre. This appears not to be the case for the overhead irrigation where wood fibre has a higher average value for fresh weight than the coir, however statistical analysis shows no significant difference in the values obtained.

Treatment 1—Overhead
Peat and perlite mix
Feed - L

Treatment 2—Overhead
Peat and wood fibre mix
Feed - L

Treatment 3—Overhead
Peat and coir mix
Feed - L

Treatment 10 -Capillary
Peat and perlite mix
Feed - LW

Treatment 11—Capillary
Peat and wood fibre mix
Feed - LW

Treatment 12—Capillary
Peat and coir mix
Feed - LW

Treatment 4—Ebb and Flood
Peat and perlite mix
Feed - L

Treatment 5—Ebb and Flood
Peat and wood fibre mix
Feed - L

Treatment 6—Ebb and Flood
Peat and coir mix
Feed - L

Treatment 13—Capillary
Peat and perlite mix
Feed - LEC

Treatment 14—Capillary
Peat and wood fibre mix
Feed - LEC

Treatment 15—Capillary
Peat and coir mix
Feed - LEC

Treatment 7— Capillary
Peat and perlite mix
Feed - L

Treatment 8—Capillary
Peat and wood fibre mix
Feed - L

Treatment 9—Capillary
Peat and coir mix
Feed - L

Treatment 16—Capillary
Peat and perlite mix
Feed - CRF

Treatment 17—Capillary
Peat and wood fibre mix
Feed - CRF

Treatment 18—Capillary
Peat and coir mix
Feed - CRF

Figure 18. representative samples of each treatment at final assessment, images dated 18/11/2020. (See Table 13 for key to abbreviation codes)

Further trial images are in Figures 1 and 2, Appendix 8.

The treatments that included nutrition supplied via a CRF have the highest values using all measures, this appears not to be the case in the results for weight but treatments 10, 13 and 17 are not significantly different from one another.

Table 14: results summary for treatments repeated from 2019 (all irrigation types). (See Table 13 for key to abbreviation codes)

Table No.		**3**			**5**			**1**	
Treatment no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Feed	L	L	L	L	L	L	L	L	L
Irrigation code	IA	IA	IA	IB	IB	IB	IC	IC	IC
Substrate code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Plant assessment									
SE	5.31	3.28	4.12	3.39	2.56	2.68	1.01	0.63	0.65
average fresh weight (g)	16.89	11.36	10.94	9.19	5.91	7.23	8.2	4.33	5.79
Plant Tissue analysis (mg/l)									
pH	6.38	6.43	6.4	6.21	6.28	6.29	6.46	6.42	6.42
NH4	50.3	164.2	126.4	42.2	29.1	15.0	44.9	41.4	55.0
NO3	465	282	459	104	89	48	286	196	297
total sol N	515	446	585	146	119	63	331	237	352
P	439	295	620	215	238	212	135	122	186
K	3737	4225	4665	3578	4445	4615	3699	3287	3529
Growing media analysis (mg/l)									
pH	5.7	6.8	7	6	6.7	6.2	5.7	6.7	6.1
NH4	1.4	7	95.9	0	0.7	2	8.8	9	10.4
NO3	33.7	10.2	56.9	0	0	0	22.2	5.4	12
total sol N	35.1	17.2	152.8	0	0.7	2	31	14.4	22.4
P	0	2.1	27.6	0	0	0	0	0	0
K	23.4	62.5	178.7	7.7	9.9	44.7	58.8	62.7	109.6

Table 15: results summary for treatments using capillary matting and trickle irrigation. (See Table 13 for key to abbreviation codes)

Table No.		1			2			4			6	
Treatment no.	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Feed	L	L	L	LW	LW	LW	LEC	LEC	LEC	CRF	CRF	CRF
Irrigation code	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC
Substrate code	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC
Plant assessment												
SE	1.01	0.63	0.65	3.36	0.76	1.45	2.56	1.91	2.19	2.39	3.12	3.44
average fresh weight (g)	8.2	4.33	5.79	12.93	7.15	9.24	13.14	7.83	10.43	20.02	11.83	18.2
Plant Tissue analysis (mg/l)												
pH	6.46	6.42	6.42	6.32	6.35	6.29	6.3	6.29	6.28	6.34	6.31	6.3
NH4	44.9	41.4	55.0	24.1	35.2	23.0	24.1	52.5	32.9	16.6	17.0	18.3
NO3	286	196	297	471	248	426	479	439	517	435	342	457
total sol N	331	237	352	495	283	449	503	491	550	451	359	475
P	135	122	186	128	121	133	157	179	175	246	253	231
K	3699	3287	3529	4625	4036	4790	5085	5083	4907	5689	4964	5162
Growing media analysis (mg/l)												
pH	5.7	6.7	6.1	5.5	6.6	5.8	5.5	6.5	5.8	5.4	6.4	5.8
NH4	8.8	9	10.4	1	2.2	0.9	1.1	0.9	1	1.5	5.4	1.7
NO3	22.2	5.4	12	44.4	7.5	41.8	39.4	3.9	20.2	31.2	21.9	29.8
total sol N	31	14.4	22.4	45.4	9.7	42.6	40.5	4.8	21.2	32.7	27.3	31.5
P	0	0	0	0	0	0	0	0	0	2.9	4.6	2.5
K	58.8	62.7	109.6	87	90.2	169.1	85.1	46.7	108.1	49.2	97.3	103.6

Full results of the growing media and leaf tissue analysis can be found in Tables 1 and 2, Appendix 6.

When comparing the different measures observed, the ranking of treatments is not exactly the same, but the overall trend is. The only case where this is cannot not be said is in the number of flowers for treatment 5, which appears higher up the ranking than in the other scores, however statistical analysis shows no significant difference between treatments 4-9 for this measure. However, it should be noted that treatments 8 and 9 had no flowers observed so the visual appearance of these was different from 4 to 7.

In the treatments that were a repeat of the work carried out in 2019, we compared the observation of growing media EC with the 2020 trial. In 2020 these treatments (7,8 and 9) with capillary matting did not show the same increase in EC as observed in 2019, at the highest the coir mix (treatment 9) rose above 700 µS/m on one occasion whereas in 2019 highest observations were around 1300 µS/m.

As the work was carried out in the same weeks in both years and under similar weather conditions (cool with low light), we had anticipated that the 2 years results would be more similar than observed.

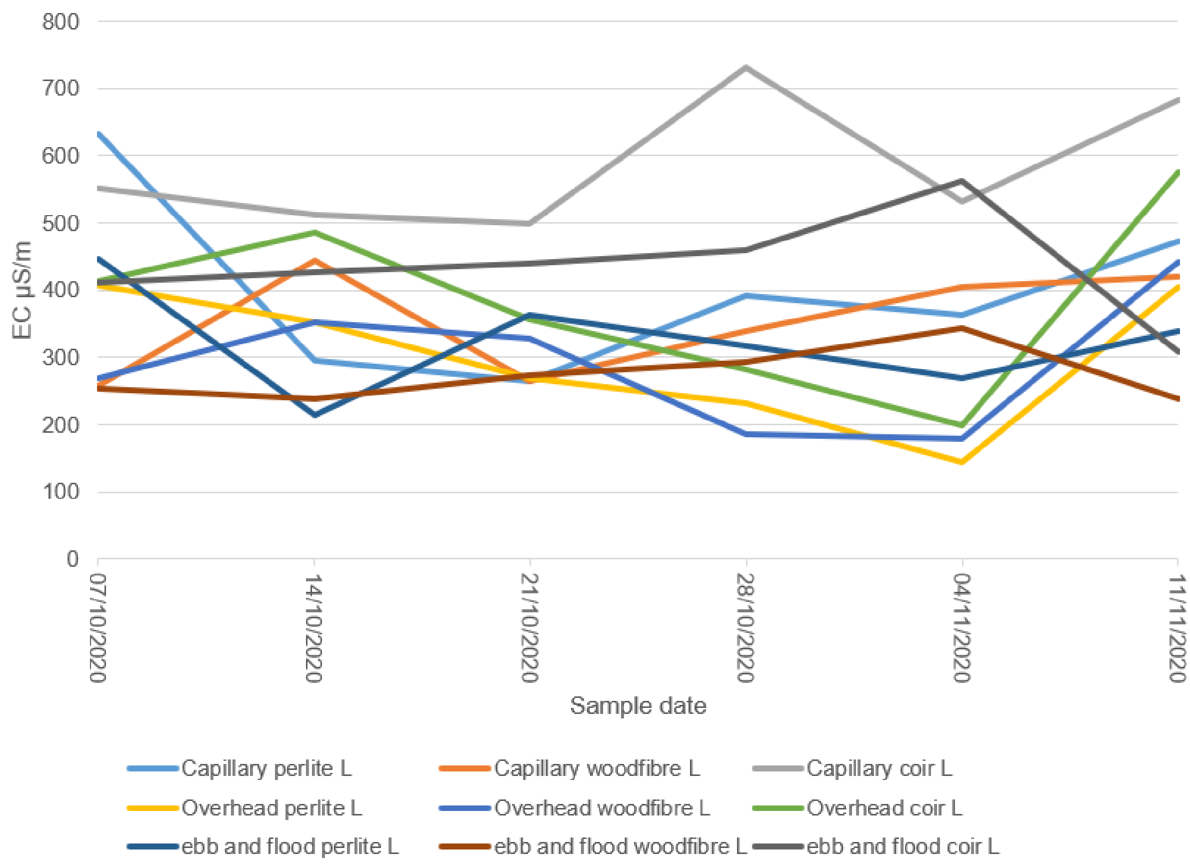


Figure 19. Growing media EC readings obtained by SME over duration of trial for treatments repeated from 2019 (L= standard liquid feed with all irrigation types).

Out of the growing media mixes, the perlite mix has the lowest EC of all treatments except where irrigation is applied overhead.

With these treatments all of the nutrition was provided as liquid feed, so the supply of nutrient is controlled by the requirement for water. Irrigation use followed the same trends as seen in 2019 – less water was used overall in the overhead irrigation treatments than in the ebb and flow, and the least amount of water used was in the capillary matting. When calculating the total amount of water retained on the bench the difference over the whole trial was minimal at around 21 L, but the increased volume of water and therefore feed did not result in a higher plant weight (see Table 2, Appendix 7 for full observation on irrigation frequency and volume).

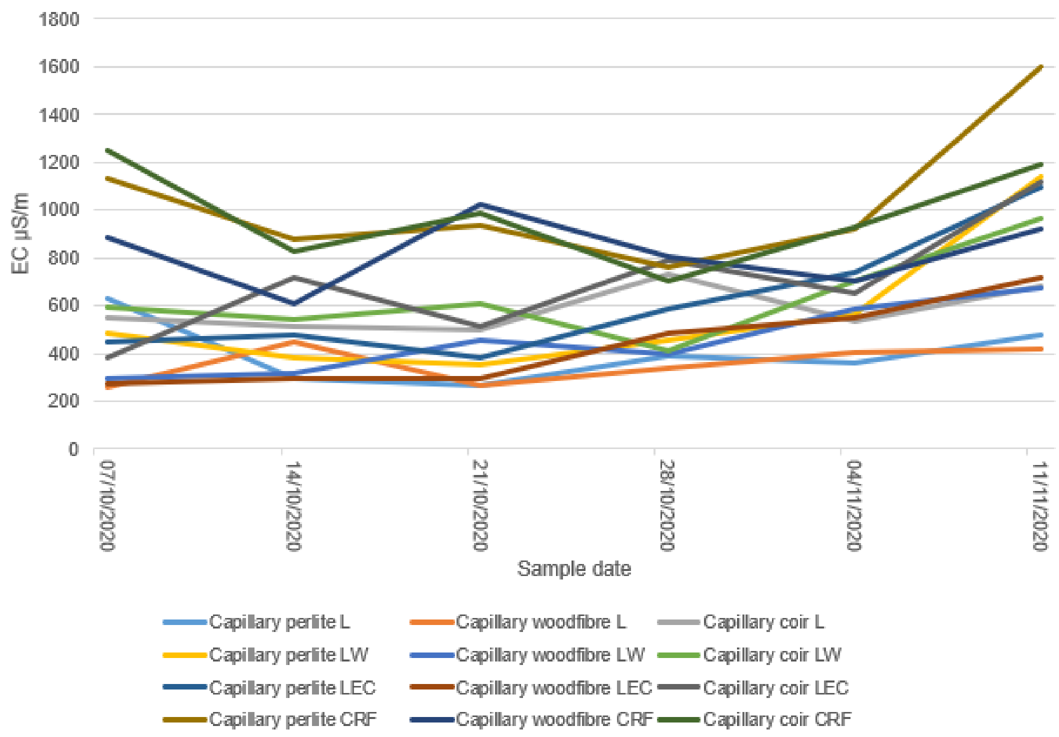


Figure 20. Growing media EC readings obtained by SME over the duration of the trial for all treatments using capillary matting and trickle irrigation. (See Table 13 for key to abbreviation codes).

Full observations on growing media EC are in Table 4, Appendix 6.

The difference between treatments receiving feed via irrigation and those with CRF can be seen in the capillary matting treatments. The trend is for those with CRF to maintain a higher EC for the duration of the trial, and the final observation for the perlite mix with CRF was 1600 µS/m. However as this was the final observation we do not know if this level would have been maintained, or if that would be to the detriment of the plants.

Due to the very low results for EC in the low standard (LW) and standard (low EC – LEC) feed treatments, we increased the feed rate in the second half of the trial to a 1:100 dilution. An uplift in values can be seen with most impact in the treatments with perlite, followed by coir and then wood fibre growing media mixes.

Sampling of growing media pH took place over the duration of the trial, there was a consistent pattern across all treatments of relatively stable pH levels with a drop at the final sampling. The trends in pH are consistent with those seen in 2019, except with the drop in pH at the end where in 2019 we observed a rise (Figure 21).

As in 2019 we observed the highest pH values in the treatments with overhead irrigation. The same trend could be seen in 2020 from 3 weeks after potting in the coir and wood fibre mixes, and 4 weeks in the perlite mixes. From then it continued to rise in coir and wood fibre mixes treatments until the final sampling took place.

The addition of CRF to the media mixes resulted in a lower pH; this was most obvious in perlite and wood fibre growing media mixes.

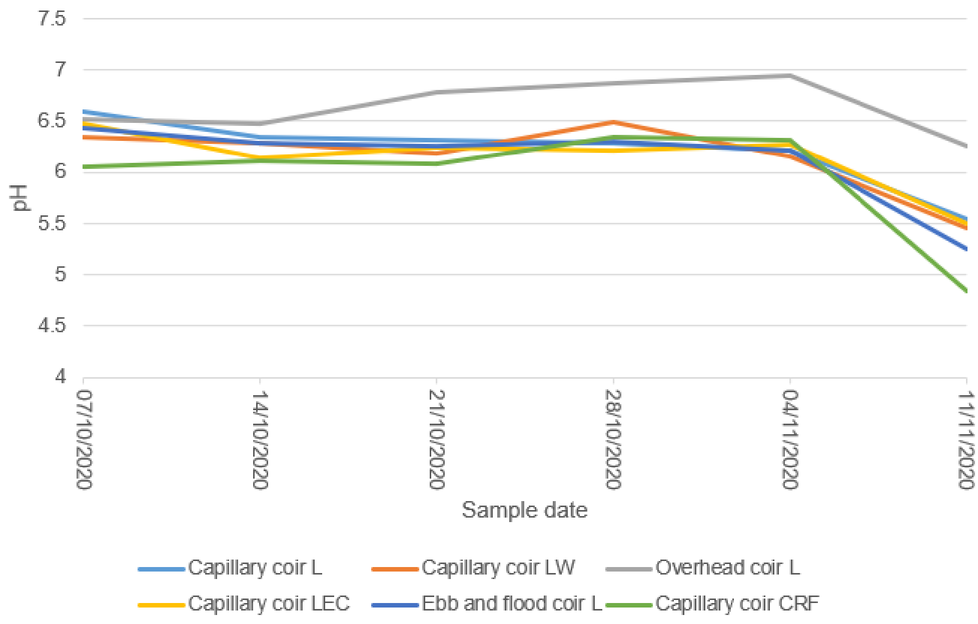


Figure 21. pH observations obtained by SME for treatments with 30% coir growing media mix.

Full observations on growing media pH are in Table 3, Appendix 6.

In a repeat of previous trials, K content of growing media was highest in the coir mixes. In the treatments with overhead or capillary irrigation these were the highest in the entire trial, ranging from 103 to 178 mg/l. For the ebb and flood irrigation the K levels in the coir were lower at 44.7 mg/l, but this was still higher than the perlite and wood fibre growing media mixes under the same irrigation system which were below 10 mg/l (Figure 22).

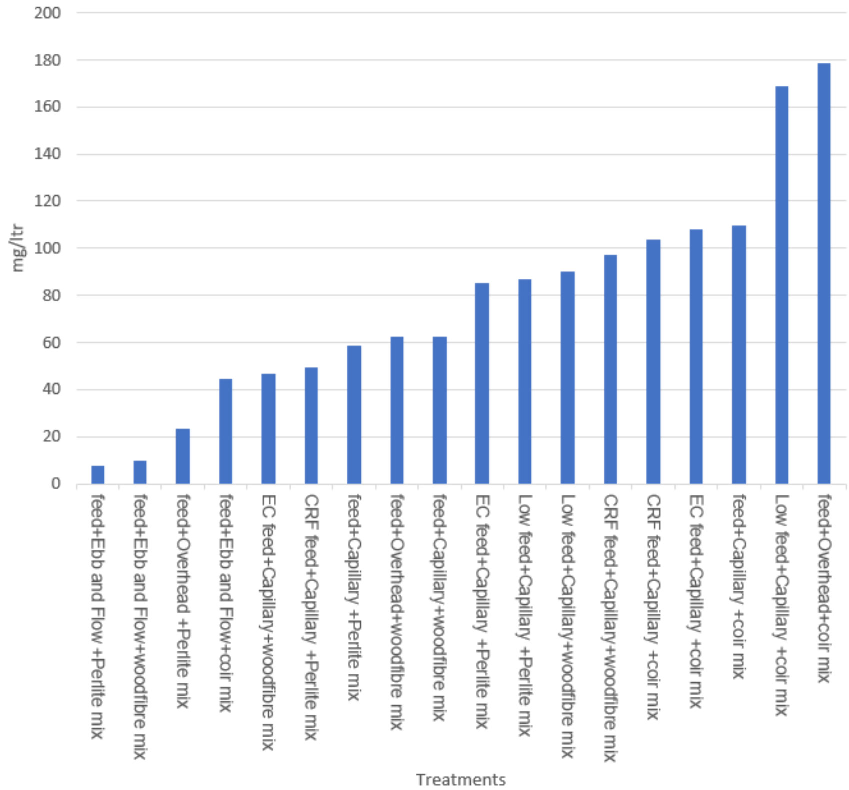


Figure 22. K content of growing media for each treatment.

<u>Trial 3 (N-form ratio)</u>

The trends resulting from the use of different N form ratios in this trial were not as clear as anticipated. Three crops with different nutritional requirements were selected to illustrate the way different species react, however the response was not as expected.

Weekly observations of growing media pH for all species show an initial decline in value, followed by a general increasing trend in the final six weeks of the trial. The highest values for pH were observed in Pansy, followed by Geranium and the lowest was in Cyclamen, with no overlap in values for the three different species. Within each species there is no consistent trend linking the pH value to the N-form ratio, so final pH does not appear to be lower with increasing or decreasing amounts of NH_4 in the feed (see tables 1, 2 and 3, Appendix 11 for all observations of growing media pH and EC).

Table 16. Results of observation on growing media pH over duration of the trial for all treatments.

	Crop	Cyclamen			Geranium			Pansy		
	N form ratio NH_4:NO_3	0/100	20/80	30/70	0/100	20/80	30/70	0/100	20/80	30/70
Date	10/06/2020	6.14	6.16	6.05	6.43	6.43	6.29	6.25	6.28	6.25
	17/06/2020	6.15	6.11	6.04	6.18	6.17	6.17	6.12	6.14	6.17
	24/06/2020*	6.01	5.91	5.02	6.03	6.01	6.03	5.57	5.71	5.93
	01/07/2020	5.23	5.14	5.15	5.23	5.24	5.22	5.52	5.42	5.33
	08/07/2020	5.75	5.77	5.78	5.78	5.77	5.78	5.77	5.79	5.78
	15/07/2020	5.78	5.75	5.76	5.75	5.76	5.74	5.78	5.76	5.75
	23/07/2020	6.33	6.36	6.33	6.81	6.87	6.72	6.83	6.87	6.83
	30/07/2020	6.97	6.99	6.98	6.86	6.74	6.85	6.52	6.52	6.5
	05/08/2020	No observation in this week								
	13/08/2020*	6.31	6.36	6.13	7.12	6.86	7.34	7.48	7.37	7.55

*outdoor daytime temperature in excess of 30 ⁰C during these weeks

The results of the leaf tissue analysis at the mid-point and the end of the trial show a greater difference between species in SAP pH than observed in the growing media analysis. As expected, Geranium has a low pH value, in this case below 4. For Pansy it was in the range of 5.4-6.0 and Cyclamen 5.1-5.2.

Table 17. Summary of results for all treatments for plant fresh weight, growing media and leaf tissue analysis - samples taken 17/07/2020 for mid-point, 18/08/2020 for final observations.

Species		**Cyclamen**			**Geranium**			**Pansy**		
Treatment		**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
N form ratio NH4:NO3		0/100	20/80	30/70	0/100	20/80	30/70	0/100	20/80	30/70
Plant assessment (average)										
	plant height/width (mm)	130.4	129.2	128.9	184.5	209.7	192.3	315.8	283.8	299.6
	Leaf number	11.1	13.5	16.1	-	-	-	-	-	-
	flower number	7.2	4.8	4.7	4.3	4.9	5.1	5.7	3.4	4.5
	fresh weight (g)	30.0	25.8	26.2	54.3	57.8	51.8	105.3	95.3	92.6
Plant Tissue analysis (mg/l)										
midpoint	pH	5.3	5.4	5.3	3.8	3.8	3.8	6.3	6.3	6.1
	NH4	49.3	59.3	49.7	140.0	136.1	153.9	43.7	29.1	22.7
	NO3	349.0	445.5	327.8	28.0	31.1	35.0	159.6	68.1	95.1
end point	pH	5.2	5.1	5.2	3.7	3.6	3.7	5.7	6.0	5.4
	NH4	27.2	29.1	31.0	38.5	42.2	36.0	10.3	14.9	14.0
	NO3	58.7	62.1	79.4	0.1	0.4	2.6	0.3	0.7	0.4
Growing media analysis (mg/l)										
midpoint	pH	5.9	5.7	5.6	5.8	5.8	5.9	6.1	6.2	6.1
	NH4	1.0	4.1	<0.6	0.8	0.9	2.0	<0.6	1.4	0.8
	NO3	137.5	153.0	193.3	87.2	61.8	54.0	19.1	21.1	29.7
	total sol N	138.5	157.2	193.3	88.0	62.7	56.0	19.6	22.5	30.5
end point	pH	6.1	6.1	5.9	6.3	6.4	6.5	6.4	6.4	6.6
	NH4	1.8	6.1	1.8	1.1	1.4	1.3	1.7	1.4	2.4
	NO3	24.6	50.3	46.5	<0.6	0.9	<0.6	2.7	2.0	3.7
	total sol N	26.4	56.3	48.3	1.1	2.3	1.5	4.4	3.4	6.1

Full results from the growing media and leaf tissue analysis are contained in Table 4 and 5, Appendix 11.

In all treatments the main (or only) form of N was NO_3, however in Figure 23, very different ratios for the forms of N in the plant were seen. We would expect to find NH_4 in all the leaf tissue of all treatments even where N is only supplied as NO_3 (NH_4 is present in the base feed) as reduction of NO_3 to NH_4 is an essential process.

At the mid-point of the trial, Pansy and Cyclamen both had more NO_3 than NH_4, and in Geranium the opposite was observed. At the end point of the trial the trend was the same in Cyclamen and Geranium, but in Pansy the values show virtually no NO_3.

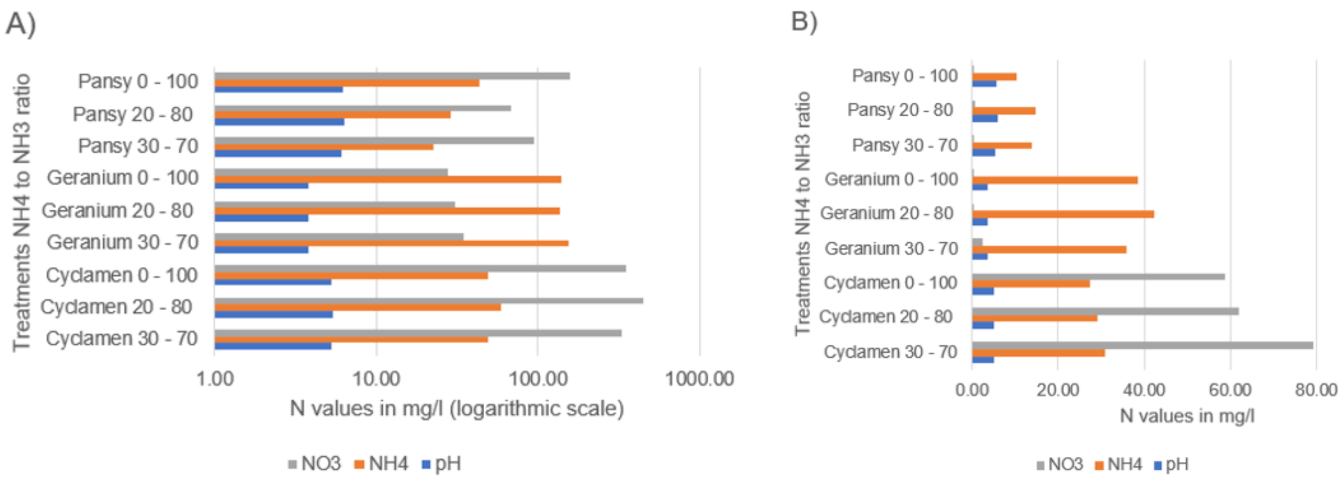
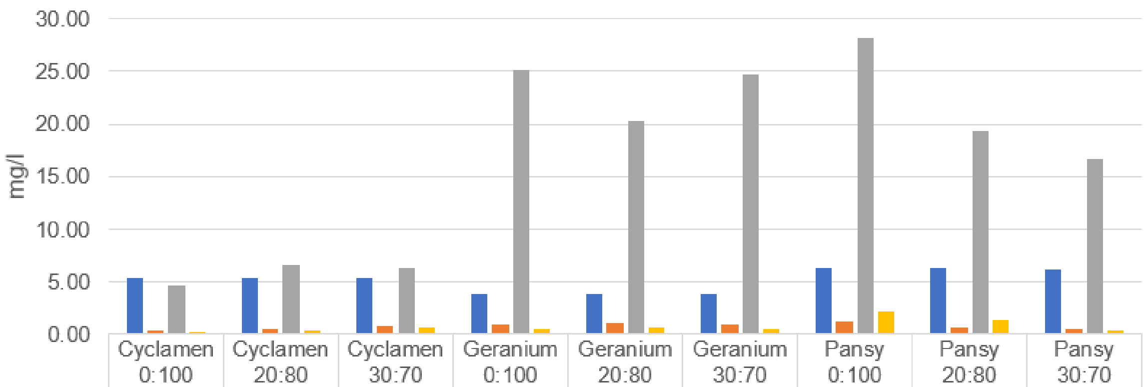


Figure 23. Results of leaf tissue analysis for NO_3, NH_4 and pH, samples from A) 17/07/2020 for mid-point observations, and B) 18/08/2020 for final observations.

The reduction of NO_3 to NH_4 produces positively charged hydrogen molecules which reduce cell pH, due to this we would anticipate the leaf tissue pH to be lowest where the results show the highest ratio of NH_4 to NO_3. The results from the trial confirm this trend.

The effect of pH on levels of micronutrient in the leaf tissue should show increased levels of Mowith increasing pH and increasing Fe and Mn with decreasing pH (Figure 24). The lower pH in Geranium does show generally higher Iron and Manganese, and Molybdenum is highest in Pansy with the highest pH. However, the trend is not an exact correlation as Pansy with the 100% NO_3 feed has the highest levels for all three nutrients and has the second highest pH.



	Cyclamen 0:100	Cyclamen 20:80	Cyclamen 30:70	Geranium 0:100	Geranium 20:80	Geranium 30:70	Pansy 0:100	Pansy 20:80	Pansy 30:70
pH	5.29	5.37	5.30	3.79	3.81	3.80	6.28	6.30	6.14
Fe	0.33	0.43	0.76	0.86	1.00	0.93	1.21	0.64	0.44
Mn	4.65	6.53	6.34	25.18	20.28	24.65	28.12	19.29	16.75
Mo	0.18	0.38	0.68	0.44	0.59	0.47	2.18	1.31	0.34

pH Fe Mn Mo

Figure 24. Leaf tissue analysis results for Fe, Mn and Mo in relation to pH, samples dated 17/07/2020.

Observations on plant size, number of flowers and fresh weight of above ground growth were taken during the trial. The data collected confirmed the visual conclusion (Figure 25) that there was little impact on growth between the different treatments for each species. In Geranium, slightly greater plant height and fresh weight were observed in the 20:80 treatment, but no difference observed in flower stem number. In the three Pansy treatments a slight increase in fresh weight was observed in the 0:100 treatment over the other two ratios, which was consistent with plant width observations at both the mid-point and end point of the trial (see Table 1, 2 and 3, Appendix 10 for full details of plant observations).

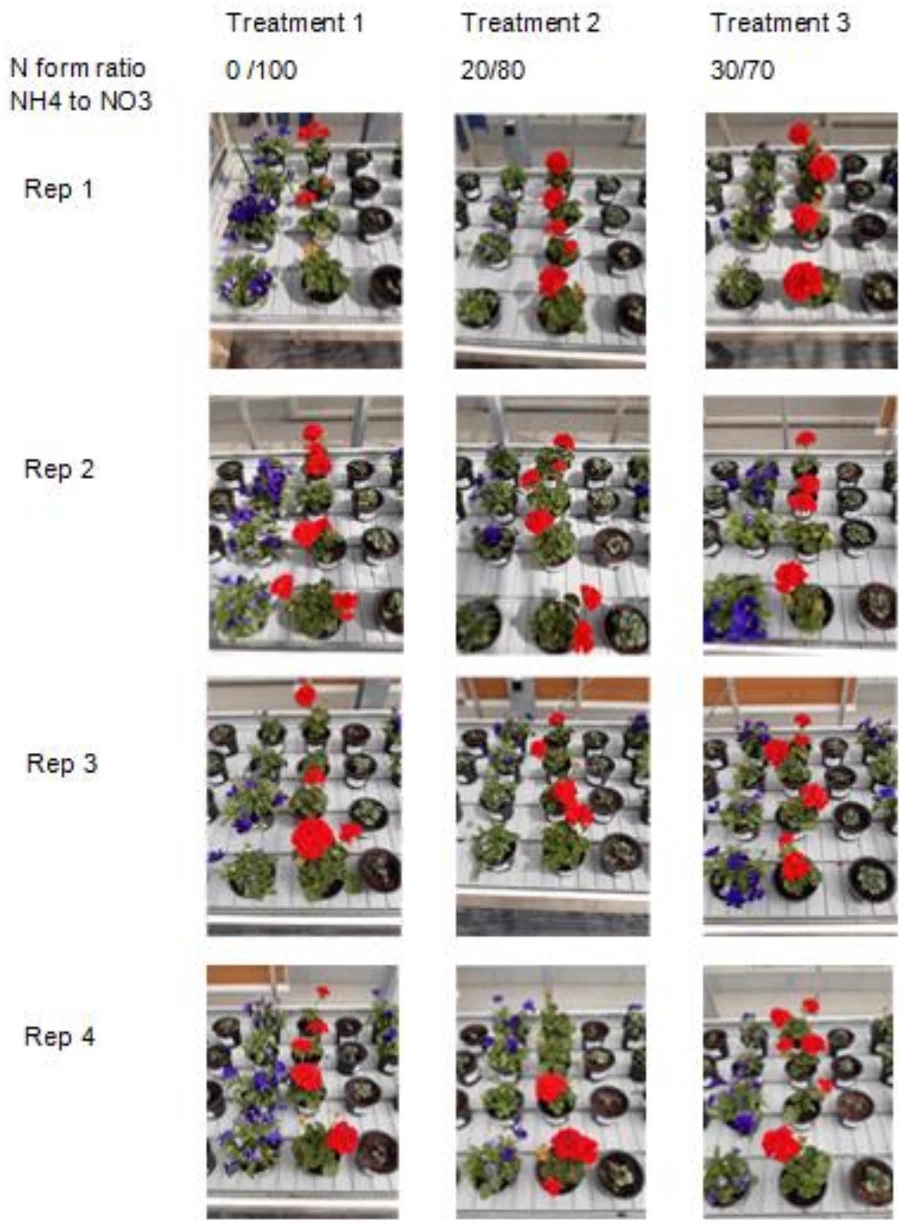


Figure 25. Trial images of all treatments, dated 03/07/2020.

Trial 4 (Calcium in Primula)

Results obtained from leaf tissue SAP analysis show that where plants were watered with a high irrigation regime a difference in Ca content of 245 mg/l can be seen between the two humidity treatments, with the higher level of Ca being observed in the lower humidity treatment (Table 18). The difference in humidity between these two treatments was around 20% over the duration of the trial (see Table 1, Appendix 14 for environmental observations).

Table 18. Summary of results for all treatments for plant fresh weight, growing media and leaf tissue SAP analysis - samples taken 17/07/2020 for mid-point observations and 18/08/2020 for final observations, and average crop height humidity.

Treatment no.	**T1**	**T2**	**T3**	**T4**
Irrigation	high	high	low	low
Humidity	low	high	low	high
Plant observations				
Average fresh weight (g)	14.21	15.75	10.46	14.58
Tissue analysis (mg/l)				
mid- point pH	6.78	6.74	6.87	6.87
end pH	6.42	6.39	6.41	6.36
mid- point B	3.32	3.44	2.86	3.02
end B	3.30	2.82	3.03	3.44
mid- point Ca	334	279	244	200
end Ca	916	671	546	732
Growing media analysis (mg/l)				
pH	6.5	6.6	6.2	6.4
B	0.17	0.11	0.14	0.14
Ca	21.6	12	39.3	25.6
Average crop height humidity (%)				
	79.8	104.2	67.8	94.7

Full results for growing media and leaf tissue analysis can be found in Tables 1 and 2, Appendix 13.

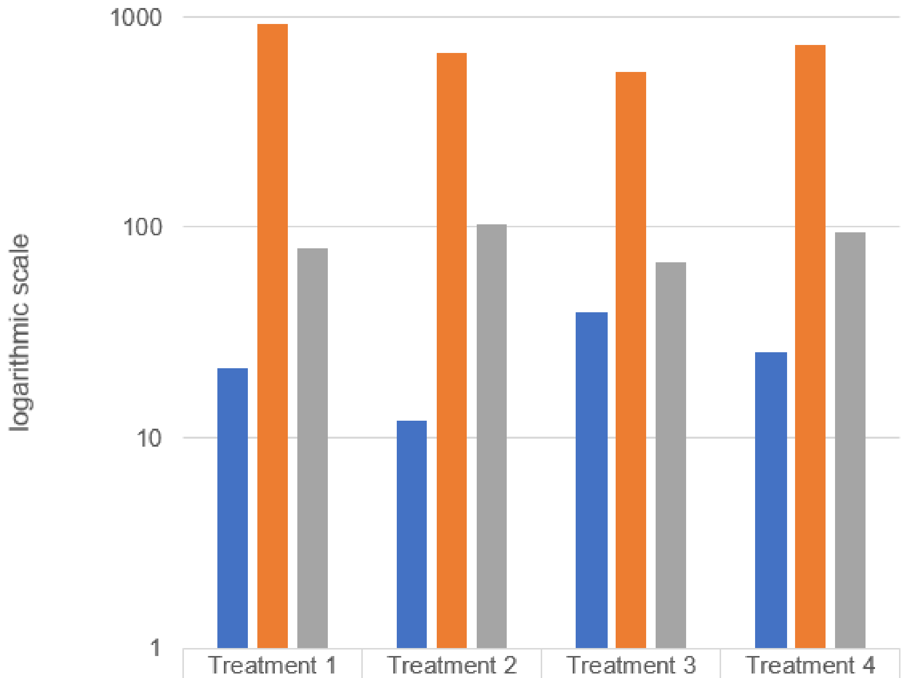
In the treatments where irrigation was kept low to reduce root zone osmotic pressure, both treatment 3 and 4 had lower leaf tissue Ca results than observed in the well-watered, low humidity treatment. This appears to confirm that multiple factors linked to transpiration will impact on the transport of Ca to the leaf tissue.

The leaf tissue analysis result for Ca level at the mid-point and end point of the trial change in their relative order, with treatment 4 being lowest at the mid-point and treatment 3 being lowest at the end (Figure 26). This appears to contradict our hypothesis that higher humidity conditions will reduce Ca uptake, however in this instance it is possible that the low humidity and low water regime caused sufficient stress to prompt stomatal closing which will stop transpiration and impact on the movement of Ca within the plant.

During the later stages of the trial, necrotic areas on the leaf margins were observed and these symptoms are recognisable as leaf-edge scorch (Figure 26). These were observed in treatments 2, 3 and 4, with the most frequent incidence in treatment 2. More extensive leaf necrosis was observed on mature fully expanded leaves, but this appears to be a result of the general stress imposed on the trial rather than as a symptom of nutritional deficiency.

Figure 26. Leaf edge scorch symptoms observed in the trial on treatments 2, 3 and 4, images dated 11/08/2020.

Results of growing media analysis show that sufficient Ca was present to avoid deficiency and the pH levels were suitable for its absorption (Figure 27).



	Treatment 1	Treatment 2	Treatment 3	Treatment 4
GM - mg/l	21.6	12	39.3	25.6
SAP - mg/l	916	671	546	732
Humidity - %	79.8	104.2	67.8	94.7

Figure 27. Comparison of the results of calcium content from growing media analysis (GM), Leaf tissue SAP analysis samples dated 18/08/2020 (SAP), and the average crop height humidity for each treatment (data collected by Blue Maestro™ disc monitors).

Plants from each treatment were assessed for size, number of flowers and fresh weight to quantify the impact of the different treatments (see Tables 1, 2 and 3, Appendix 12 for full plant observations and statistical analysis). Statistical analysis (ANOVA) shows a significant difference in fresh weight, at 95% confidence level, between treatment 1 and 2, 1 and 3, 2 and 3 and 3 and 4. So it can be concluded that the high and low water rate treatments, and the high and low humidity treatments have a significant impact on growth, but no significant difference was seen between treatment 1 and 4 in the fresh weight where the plants were grown under the combinations of high (1) versus low (4) irrigation, and low (1) versus high (4) humidity.

In reducing humidity and improving the Ca in the leaf tissue and apparently reducing the symptoms of leaf edge scorch, a smaller plant is produced over the same growing period.

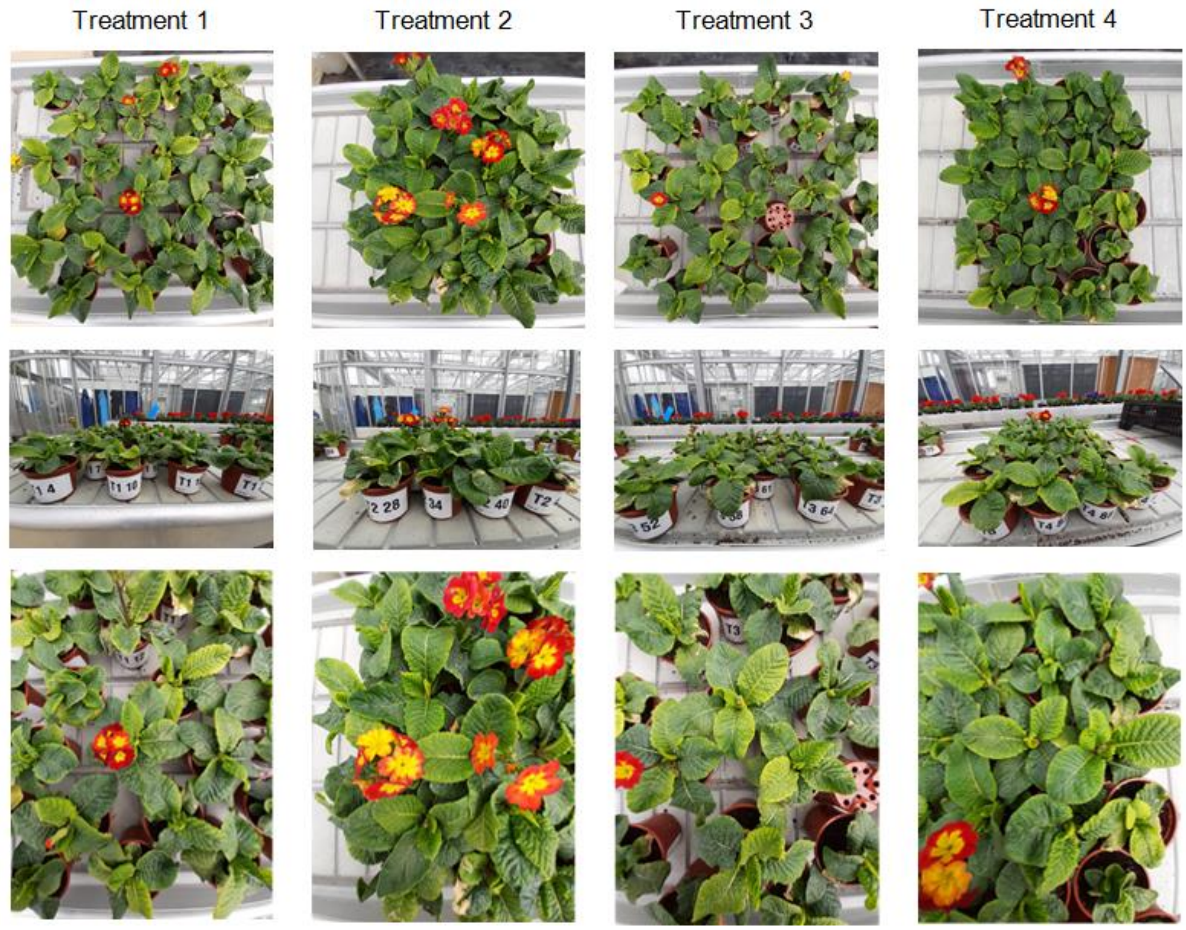


Figure 28. Images of each treatment prior to final assessment, dated 10/08/2020.

The results show a change in the level of Bin the leaf tissue over the life of the crop, and there was a difference of 0.62 mg/l between the highest and lowest treatments. However there does not appear to be the same link with environmental conditions as there is with Ca. The leaf tissue sample results show lowest B levels in the highest humidity plot at the mid-point, but at the end of the trial this treatment has the highest boron levels.

In addition to the leaf-edge scorch symptoms in the trial, we observed strong marginal chlorosis in the young growth (Figure 29). This was observed in some plants from all treatments and does not appear to be linked to availability of Ca, it is more likely to be another nutrient, possibly Fe and this will be followed up in the next trial.

Figure 29. Suspected Fe deficiency symptoms observed in early growth, image dated 27/10/2020.

Trial 5 (Calcium in Primula)

At time of writing this report this trial was underway as outlined in the method, but no results were available.

Trial 6 and 7 (Narcissus)

At time of writing this report these trials were underway as outlined in the method, but no results were available.

Discussion

Trials 1 and 2 (irrigation, growing media and pot size)

The results of the trial on Petunia indicate that it may be possible to adopt a lower feed regime and still achieve the same growth, but it is dependent on the method of irrigation and constituent parts of the growing media mix.

From the irrigation records we know that the plants grown under the overhead irrigation regime did not use more water, and therefore have access to more feed, than treatments with ebb and flood irrigation. The benches watered with ebb and flood irrigation used more water overall but in fewer irrigation events; this method of delivering water and feed seems less effective where the feed concentration was low even though with the higher feed it gave the highest overall fresh weights.

At this stage in the investigations it would appear that more frequent, smaller doses of overhead irrigation deliver lower concentrations of feed most effectively, and can give the same amount of growth as a higher amount of feed applied in the same way. In previous investigations we hypothesised that absorption of nutrient ions through foliar application could be increasing total nutrient uptake, this would still appear to be a valid conclusion to draw from the results obtained this year.

Petunias naturally increase the growing media pH over time (Johnson et al 2014), and research work has shown increasing growing media pH leading to a reduction in foliar N (Smith et al 2004). This correlation is not clear from our results, there are overlapping values for pH in the different treatments that have very different leaf N content. The link between irrigation type and leaf tissue N appears clearer than it does with pH, and the general trend is for it to mirror the results for fresh weight.

For capillary matting to function effectively as an irrigation method, the growing media always needs to be moist, this can lead to greater conversion of NO_3 into NH_4 in the media; the more acidic media pH of the low feed (tailored) supports this.

The trend for growing media to increase in pH will impact on the plants when the level is above 6.4. This pH is sufficient for the Fe in the growing media to be unavailable to the roots of Petunia which can be described as “Fe-inefficient” plants. This crop will often show Fe deficiency symptoms in the form of chlorotic new growth which was observed in the trial this year. To avoid Fe deficiency, a strategy is required where using irrigation that has the tendency to increase pH over time with this crop.

The aim in the experimental work on Pansy was to look at strategies for avoiding build-up of nutrient ions in the growing media when using capillary matting to delivery irrigation. The guidance given in the last version of RB209 to contain recommendations for these crop types was to give feed at 50% reduction when using capillary matting; we took this as one of the approaches used in the trial along with feeding on the basis of growing media EC results and changing the feed delivery method to a CRF instead of a liquid feed.

The trial results demonstrate the benefit of increasing the feed/water ratio for winter crops, where environmental conditions can lead to significantly reduced requirement for irrigation. This can result in higher fresh weight of plants and greater number of flowers but without causing an unwanted spike in EC, but regular monitoring of EC is important as the results show levels can double in a week.

The use of a CRF in the Pansy trial was intended to disconnect the link between water application and nutrition. The results showed that this was a successful strategy under autumn growing conditions.

The use of ebb and flood irrigation for delivery of the nutrients did not give any better results than the basic capillary matting treatments, again low demand for water due to the weather conditions are likely to be the cause and increasing the feed/water ratio would be a way of mitigating the problem.

The comparison of the different growing media mixes used in trials 1 and 2 reflect the current knowledge on K levels in coir. Higher levels of K were seen in the coir mix growing media under all of the combinations of feed and irrigation, this reflects the release of K from the coir over time.

Trials 3 and 4 (Calcium in Primula)

The results obtained in the summer Primula trial repeat the findings from the earlier trial in 2020 that Ca nutrition can be improved by altering environmental conditions. Ca is an immobile nutrient and can only move within the plant if it is actively transpiring. Where water is available and crop spacing increased, improved transpiration is seen and Ca levels will be higher in the leaf tissue, which is what was seen in the results. The converse of this was not seen, instead the lowest levels of Ca were observed in the low water and low humidity treatment. While it is possible to say that lower humidity will improve transpiration this is only true when sufficient water is available.

Transpiration cannot take place when the stomata are closed, this happens in response to external factors such as light and temperature and when the plant is under water stress as a water saving strategy. The plants in the trial in the low water treatments were deliberately subjected to water stress in order to look at the effect of reducing the root-zone pressure on the levels of Ca. Plants were allowed to wilt, and this may have been sufficient for the stomata to close in order to save water, stopping transpiration. This may explain why the lowest Ca levels were observed in the low water low humidity treatment, which will have been the plants under most water stress.

The trial was carried out during the summer, in a schedule that gave ‘finished’ plants in mid-August. These plants were grown in period of high temperature, high light levels and long days, where water stress was easily induced and glasshouse humidity naturally low. The aim of the later trial, which started in September, was to look at the same variables of humidity and root-zone water pressure but under different climatic conditions. Due to the time of year air temperature is lower, light levels lower and day length shorter. These factors will change the glasshouse environment and the speed of growth of the plants. The hypothesis is that although different levels of Ca are still expected to be observed in the different treatments, fewer symptoms of leaf-edge scorch are expected as growth is slow and Ca has more time to reach the margin as the leaf expands, If the results of the autumn/winter trial show the hypothesis to be correct it may be that different humidity conditions and watering regimes can be considered depending on the time of year.

Not all production systems will be suited to increasing spacing as a method for reducing humidity, but other methods can be adopted. The use of increased spacing will reduce production capacity which may offset any financial benefit in reducing leaf-edge scorch symptoms, and in the case of pack production it may not be achievable. In these cases, it is hoped that the investigations in trial 5 into use of $Ca(NO_3)_2$ as a foliar feed will prove a promising method for improving nutrition.

Trial 5 (N-form ratio)

The form that N is supplied to the plant in, either as a positively or negatively charged ion (NH_4^+ vs. NO_3^-), should influence the growing media pH as the plant exudes the oppositely charged ions during uptake. Feeds higher in positively charged NH_4 ions should see declining growing media pH and those higher in negatively charged NO_3 ions should see increasing pH.

In pansy the expected increase took place, but it was the same as in geranium, which was expected to have declining pH over the period of the trial. This should have been particularly obvious with the 30:70 treatment; the higher NH_4 content should give a greater decline in pH as the geraniums exude negatively charged ions as the NH_4 is taken in.

From monitoring growing media pH in trial 1, 2 and 3, it appears likely that the upward trend in growing media from the use of overhead irrigation and the water source (which is high in bicarbonate), has cancelled out the effect of the varying N-form ratios.

It is also possible that the ratios included in the trial are not sufficiently high in NH_4 to cause a significant decline in pH under the trial conditions. These ratios were selected as they are accessible to growers in the form of 'straights' or as part of prepared feeds; a higher NH_4 ratio may be detrimental in some crops but very unlikely to be used.

In contrast to the growing media, very different values for leaf tissue pH were observed. This was considered to be a reflection of the differences between species in the assimilation of NO_3 into NH_4 as part of normal metabolic processes. The low pH of the geranium leaf tissue correlates to the higher ratio of NH_4 to NO_3, and the opposite is true in cyclamen and pansy (Marschner 1994).

Conclusions

- Nutrition delivered via overhead irrigation can be as effective as doubling the feed concentration delivered by other methods of irrigation tested in this trial.
- Overhead irrigation delivery of liquid feed gives more consistent results over different seasons than feed delivered by other irrigation methods tested in this trial, but this can be mitigated in capillary irrigation systems by increases in feed/water ratios.
- In the conditions experienced in autumn 2020, the controlled release fertiliser delivered nutrition more successfully than liquid fertiliser in a period of low water use.
- Inconsistencies in ion build up in capillary matting irrigation systems highlight the need for constant monitoring
- Readily available (in trade) fertiliser ratios of NH_4 and NO_3 are unlikely to impact on growing media pH in hard water areas unless excessive quantities of feed are given.
- High alkaline irrigation water can eliminate the drop in pH that can occur through use of acidic feed, or when growing ‘acidifying’ plants (e.g. geranium).
- Accumulation of higher NH_4 levels when using capillary matting may make the use of high ratio NH_4 feeds undesirable where crops species are inclined to reduce pH e.g. Geranium.
- Results for pH in leaf tissue analysis and in the growing media of the same crop can be very different. It is important to understand both to identify the potential for deficiency and toxicity in different species.
- Results from the experimental work carried out and the study of relevant literature, clearly indicate that Ca deficiency is the cause of leaf-edge scorch in Primula.
- Water stress, or high humidity can decrease Ca levels in Primula leaves by between 20 and 40% during summer.
- Leaf tissue Ca is not solely dependent on what is available in the growing media and water; movement to the leaf and growing point is reliant on transpiration which is controlled by environmental conditions.

Knowledge and Technology Transfer

Glossary

Transpiration - the loss of water from a plant in the form of water vapour. Water is absorbed by roots from the soil and transported as a liquid to the leaves via xylem. In the leaves, stomata allow water to escape as a vapour.

Stomata - a pore in a leaf or leaf-like structure, that is surrounded by a pair of guard cells that regulate its opening and closure and serves as the site for gas exchange.

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Appendices

Appendix 1: Trial 1 feed calculations

Table 1. Analysis of trial site water supply

Water	Sample 1	Sample 2
	mg/l	mg/l
Nitrate	8.80	8.90
Phosphorous	1.00	0.90
Potassium	2.80	2.20
Calcium	118.0	122.9
Magnesium	3.60	3.85
Boron	0.03	0.01
Manganese	<0.01	<0.01
Copper	<0.01	<0.01
Zinc	0.01	<0.01
Iron	<0.01	<0.01
Sodium	12.00	14.70
Chloride	32.40	37.10
Sulphate	28.50	29.30
Alkalinity (HCO3)	272.0	274.0

Table 2. Calculations for tailored feed

Liquid Feed specification

Standard feed (1, 3 & 5)	OMEX Adjust range O-Mix 21-7-21 + 1.6MgO+TE (based on 105ppm N)				
Tailored (2, 4 & 6)	**Desired**	**Water**	**Feed**	**Feed Plus Wate ppm/mg/l (1:200 dilution)**	
	70ppm NO3-	8.5	73.1	81.6	99.7
	30ppm NH4+	N/A	18.1	18.1	
	35ppm P	1	34	35	35
	125ppm K	2	123	125	125
	8ppm Mg	3.6	4.4	8	8
	Hortifeeds TE BEMIX - 1.50% B, 2.93% EDTA-Cu, 5.78% EDTA-Fe, 2.93% EDTA-Mn, 0.04% Mo and 1.04% E				

Straight	**%N NH4+**	**NO3-**	**%P**	**%K**	**%Mg**
			Percentages of NPK,Mg		
PotNitrate (PotNit)	0	13.5	0	38.2	0
MonoPotassium Phosphate (MPP)	0	0	22.7	28.2	0
Magnesium Nitrate (MagNit)	0	11	0	0	9
MonoAmmonium Phosphate (MAP)	12	0	26.5	0	0

Calculated Feed

Stock Solution Contains:	g/l for stock	5ltr	10ltr
MAP	15.1	75.5	151
MPP	12.33	61.65	123.3
PotNit	46.18	230.9	461.8
MgN	9.78	48.9	97.8
TE BMIX	2	10	20

Table 3. Analysis of irrigation water with feed

	Irrigation water all benches			
	Standard Feed		Tailored Feed	
	EC	pH	EC	pH
22/07/2020	880	6.82	1149	6.86
23/07/2020	5.78	6.86	529	6.28
24/07/2020	1048	6.58	1040	6076
27/07/2020	889	6.69	1201	6.9
29/07/2020	746	6.76	1101	6.53
30/07/2020	953	7.18	1121	7.45
31/07/2020	1112	7.29	1038	7.31
03/08/2020	1021	7.36	1103	7.34
05/08/2020	1092	6.6	1094	6.91
07/08/2020	1099		1087	
09/08/2020	1191		1132	
10/08/2020	971		1103	
11/08/2020	1042		1064	
12/08/2020	1065		1144	
14/08/2020	1092	7.32	1057	7.24
18/08/2020	1101	7.29	1190	7.16

EC (in µS)

Table 4. Record of irrigation events

	Incidence of irrigation events						Irrigation volume (ltr)								EC (in µS) of irrigation run-off			
Bench no.	1	2	3	4	5	6	3		4		5		6		5	3	6	4
							In	Out	In	Out	In	Out	In	Out	Standard Feed		Tailored Feed	
17/07/2020	Y	Y	Y	Y	Y	Y												
18/07/2020	N	N	N	N	N	N												
19/07/2020	N	N	N	N	N	N												
20/07/2020	Y	Y	Y	Y	Y	Y												
21/07/2020	N	N	N	N	N	N												
22/07/2020	Y	Y	Y	Y	Y	Y	7.6	1.2	7.9	1.9	63.2	49.0	62.0	46.0	1063.0	880.0	1125.0	1112.0
23/07/2020	Y	Y	Y	Y	N	N	8.4	1.7	8.1	1.7						776.0		1881.0
24/07/2020	Y	Y	Y	Y	Y	Y	8.6	1.5	9.8	1.9	61.9	48.5	62.7	51.5	994.0	1840.0	1116.0	1833.0
25/07/2020	N	N	N	N	N	N												
26/07/2020	N	N	N	N	N	N												
27/07/2020	Y	Y	Y	Y	N	N	9.9	2.1	8.8	1.8						1569.0		1738.0
28/07/2020	N	N	N	N	N	N												
29/07/2020	Y	Y	Y	Y	Y	Y	10.0	2.5	9.7	2.2	65.8	50.0	65.7	51.0	1041.0	1303.0	12151.0	1546.0
30/07/2020	Y	Y	Y	Y	N	N	10.6	2.4	10.7	1.8						1198.0		NO
31/07/2020	Y	Y	Y	Y	Y	Y	19.1	4.3	23.0	6.7	64.6	51.5	64.4	44.5	1177.0	975.0	1079.0	1274.0
01/08/2020	N	N	N	N	N	N												
02/08/2020	N	N	N	N	N	N												
03/08/2020	Y	Y	Y	Y	Y	Y	13.2	4.4	19.9	5.1	64.2	46.0	64.5	48.5	1046.0	1232.0	1141.0	1334.0
04/08/2020	N	N	N	N	N	N												
05/08/2020	Y	Y	Y	Y	Y	Y	13.0	3.2	10.8	1.9	65.1	50.0	66.0	54.0	1084.0	1332.0	1084.0	1302.0
06/08/2020	N	N	N	N	N	N												
07/08/2020	Y	Y	Y	Y	Y	Y	20.5	7.1	22.5	5.9	65.6	47.0	65.2	50.0	1108.0	1372.0	1101.0	1293.0
08/08/2020	N	N	Y	N	N	Y												
09/08/2020	Y	Y	Y	Y	Y	Y	9.8	3.0	12.4	3.8	57.5	45.0	59.8	55.0	1102.0	1240.0	1102.0	1202.0
10/08/2020	Y	Y	Y	Y	Y	Y	10.8	2.2	13.6	2.8	63.2	45.0	62.8	48.0	1033.0	1275.0	1017.0	1282.0
11/08/2020	Y	Y	Y	Y	N	N	14.8	2.1	13.4	2.4						1451.0		1661.0
12/08/2020	Y	Y	Y	Y	Y	Y	17.0	3.7	16.0	3.9	63.5	43.0	63.5	46.0	1088.0	915.0	1087.0	1100.0
13/08/2020	N	N	N	N	N	N												
14/08/2020	N	N	Y	Y	Y	Y	8.4	1.9	8.0	1.6	64.8	51.0	65.1	54.0	1125.0	1358.0	1070.0	1186.0
15/08/2020	N	N	N	N	N	N												
16/08/2020	N	N	N	N	N	N												
17/08/2020	N	N	N	N	N	N												
18/08/2020	Y	Y	Y	Y	Y	Y	11.4	3.1	11.7	2.8	62.7	43.5	63.0	48.5	1115.0	1610.0	1179.0	1834.0
Total	16	16	18	17	13	14	193.2	46.3	206.5	48.2	762.2	569.5	764.6	597.0				

Appendix 2: Trial 1 data and statistical analysis

Table 1. Plant height observations (mm) and statistical analysis

Analysis of variance

Variate: Plant_Height

Source of v	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.		
Irrigation_c	2		341090	170545	111.58	<.001		***
Irrigation_code.feed_code								
		3		297457	99152	64.87	<.001	***
Irrigation_code.feed_code.Growing_media_code								
		12		161700	13475	8.82	<.001	***
Residual	368	-10	562496	1529				
Total	385	-10	1335145					

Tables of means

Variate: Plant_Height

Grand mean 307.4

Irrigation_co	IA	IB	IC		
	273.8	345.3	303	9.46	difference is significant @95% level

Irrigation_co'eed_code	H	L		
IA	286	261.7	13.38	difference is significant @95% level
IB	375.6	315		
IC	337.4	268.5		

Irrigation_co'eed_codeng_media_		SA	SB	SC		
IA	H	295.7	294.1	268.2	23.18	difference is significant @95% level
	L	289.8	254	241.1		
IB	H	376.6	376.8	373.4		
	L	340.7	293.6	310.7		
IC	H	359.8	312.7	339.8		
	L	315	238	252.5		

Observations 19/08/2020 - Plant height

feed code	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**
irrigation type code	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IA**	**IA**	**IA**	**IA**	**IA**	**IA**	**IB**	**IB**	**IB**	**IB**	**IB**	**IB**
Growing media type	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**
Treatment no	**7**	**8**	**9**	**16**	**17**	**18**	**1**	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**15**	**4**	**5**	**6**
Observations	330	260	310	250	250	205	250	280	260	320	245	250	345	345	340	325	333	331
	330	390	330	375	205	250	270	280	280	265	245	220	375	380	360	295	334	336
	320	210	360	375	200	230	305	290	225	310	315	230	280	400	490	410	339	338
	320	410	365	400	155	260	310	250	270	290	270	230	360	345	345	330	340	346
	365	280	315	340	260	260	265	330	290	310	230	240	370	410	380	330	341	347
	355	310	410	310	260	250	275	310	190	290	220	260	450	410	430	300	342	348
	410	280	380	290	260	320	310	330	260	270	240	225	390	410	380	315	351	349
	400	240	350	310	260	290	240	290	310	275	275	230	470	380	380	410	352	353
	450	315	350	320	320	240	290	265	250	300	230	230	390	380	400	370	356	355
	400	255	310	320	250	300	310	355	270	315	315	250	385	380	330	240	358	360
	210	340	310	400	220	190	270	355	245	260	310	260	380	285	410	280	361	365
	305	350	305	280	180	250	330	250	290	280	230	240	445	360	295	330	363	371
	300	320	330	260	210	280	320	325	360	310	240	225	390	380	405	390	366	372
	440	310	340	310	260	270	310	330	290	325	240	245	350	380	330	370	367	373
	435	310	380	260	240		350	290	280	300	220	220	355	400	390	370	377	374
	410	315	300	220		240	370	250	280	300	280	220	400	445	360	400	378	382
	310	330	330		290		260	330	310	320	260	280	360	355	355	340	379	383
	320	340	340	290			340	220	270	290	220	300	400	455	400	380	380	388
	325	320	300	330	300		250	250	220	220	380	280	340	330	345	385	381	389
	370	260	350		250	250	300	290	230	280	280	220	380	360	380	285	386	390
	300	400	340	330	200	220	300	310	260	280	245	230	370	410	360	310	392	391
	360	335	370	330	190	240	280	290	260	265	225	220	300	290	350	330	396	393
SE	57.91	50.59	29.58	48.59	42.16	32.19	34.27	36.92	35.64	25.00	40.63	22.62	43.57	42.27	40.87	46.09	19.37	19.83
Average	353.0	312.7	339.8	315.0	238.0	252.5	295.7	294.1	268.2	289.8	259.8	241.1	376.6	376.8	373.4	340.7	362.4	365.2

Table 2. Number of flowers observations and statistical analysis

Analysis of variance

Variate: Number_of_flowers

Source of v	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.	
Irrigation_c	2		2713.36	1356.68	69.87	<.001	***
Irrigation_code.feed_code							
	3		1761.24	587.08	30.23	<.001	***
Irrigation_code.feed_code.Growing_media_code							
	12		3260.03	271.67	13.99	<.001	***
Residual	369	-9	7165.27	19.42			
Total	386	-9	14447.6				

Tables of means

Variate: Number_of_flowers

Grand mean 18.24

Irrigation_co	IA	IB	IC		
	17.65	21.7	15.37	1.067	difference is significant @95% level

Irrigation_co'eed_code	H	L		
IA	16.79	18.52	1.508	difference is significant @95% level
IB	23.48	19.91		
IC	18.43	12.3		

Irrigation_co'eed_codeng_media_		SA	SB	SC		
IA	H	17	15.91	17.45	2.613	difference is significant @95% level
	L	19.86	16.59	19.09		
IB	H	22.95	22.27	25.23		
	L	24	15.73	20		
IC	H	19.52	13.64	22.14		
	L	18.5	7.4	11		

Observations 19/8/2020 - number of flowers

feed code	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**
irrigation type code	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IA**	**IA**	**IA**	**IA**	**IA**	**IA**	**IB**	**IB**	**IB**	**IB**	**IB**	**IB**
Growing media type	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**
Treatment no	**7**	**8**	**9**	**16**	**17**	**18**	**1**	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**15**	**4**	**5**	**6**
Observations	24	16	27	21	14	10	18	19	21	28	14	20	17	22	25	28	12	15
	21	14	38	21	4	11	16	16	20	16	20	17	27	23	31	19	23	20
	34	8	23	17	9	10	20	13	19	18	18	17	10	23	24	21	17	19
	22	13	19	29	3	9	21	18	14	15	19	23	32	25	25	21	15	21
	22	6	21	25	3	5	14	19	13	20	15	24	30	16	17	26	15	22
	17	15	29	15	16	13	28	16	20	29	16	15	24	25	29	24	15	15
	18	11	20	16	12	13	13	18	13	13	15	15	25	30	17	20	9	23
	14	6	28	17	4	17	12	13	13	18	14	20	14	21	30	31	12	12
	21	17	28	16	4	8	16	16	13	15	15	15	19	15	24	17	19	22
	14	14	17	22	8	11	17	20	16	16	22	19	22	24	22	28	15	21
	44	20	24	17	4	10	16	18	21	18	25	21	25	21	23	33	13	21
	19	16	19	17	6	16	19	13	14	24	7	17	20	31	26	23	16	19
	12	15	16	17	7	9	18	13	20	15	21	18	22	14	21	24	14	19
	18	16	17	24	9	9	19	23	18	22	16	11	14	16	25	21	13	20
	18	11	24	15	6		17	14	16	22	16	16	21	11	25	21	19	26
	17	10	21	17		8	14	11	20	24	19	24	27	19	27	32	19	24
	19	13	22		4		14	16	12	18	14	19	27	29	26	25	8	24
	19	16	21	12			11	11	23	23	21	21	26	27	26	19	8	19
	24	17	16	19	10		11	16	18	23	14	17	25	26	25	20	21	17
	21	12	21		8	11	13	14	16	13	17	17	27	26	22	20	23	26
	16	16	16	17	8	13	29	19	18	22	15	37	25	25	36	30	14	22
	20	18	20	16	9	15	18	14	26	25	12	17	26	21	29	25	26	13
SE	6.87	3.74	5.34	4.03	3.66	3.05	4.68	3.10	3.76	4.64	3.87	5.10	5.46	5.35	4.30	4.64	4.82	3.80
Average	20.6	13.6	22.1	18.5	7.4	11.0	17.0	15.9	17.5	19.9	16.6	19.1	23.0	22.3	25.2	24.0	15.7	20.0

Table 3. Plant fresh weight of above ground growth (g) observations and statistical analysis

Analysis of variance

Variate: Fresh_weight

Source of v	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Irrigation_c	2		29097.8	14548.9	408.06	<.001
Irrigation_code.feed_code	3		15445.5	5148.51	144.4	<.001
Irrigation_code.feed_code.Growing_media_code	12		10504.7	875.39	24.55	<.001
Residual	368	-10	13120.6	35.65		
Total	385	-10	64979.8			

Tables of means

Variate: Fresh_weight

Grand mean 36.50

Irrigation_co	IA	IB	IC		
	40.03	44.77	24.69	1.445	difference is significant @95% level

Irrigation_co'eed_code	H	L		
IA	41.24	38.82	2.044	difference is significant @95% level
IB	53.48	36.06		
IC	30.98	18.39		

Irrigation_co'eed_coder	ng_media_	SA	SB	SC		
IA	H	40.64	39.05	44.05	3.54	difference is significant @95% level
	L	39.95	32.18	44.32		
IB	H	51.18	52.68	56.59		
	L	42.95	27.18	38.05		
IC	H	32.9	23.77	36.27		
	L	28.2	10.75	16.22		

Observations 19/08/2020 - Fresh weight in grams

feed code	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**	**H**	**H**	**H**	**L**	**L**	**L**
irrigation type code	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IA**	**IA**	**IA**	**IA**	**IA**	**IA**	**IB**	**IB**	**IB**	**IB**	**IB**	**IB**
Growing media type	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**
Treatment no	**7**	**8**	**9**	**16**	**17**	**18**	**1**	**2**	**3**	**10**	**11**	**12**	**13**	**14**	**15**	**4**	**5**	**6**
Observations	35	23	37	28	5	18	47	46	41	56	27	43	44	57	53	45	24	48
	30	11	42	28	6	15	51	33	46	52	37	39	55	68	58	47	23	29
	37	31	25	32		20	44	36	37	37	26	42	51	53	54	39	30	45
	31	21	43	26	12		40	42	38	35	31	36	56	54	53	48	34	32
	24	32	32	32	13	17	46	39	39	34	33	41	51	53	48	47	29	44
	36	14	31	24	12		34	30	44	41	25	58	54	45	56	50	27	34
	41	15	34	38	10	19	49	34	42	30	28	38	55	49	54	45	21	38
	39	27	28	23	16	13	38	41	38	39	23	42	67	46	54	37	27	31
	33	23	28	25	9		44	55	39	30	33	45	42	59	63	49	21	45
	36	22	38	31	17	14	27	34	63	39	30	46	52	46	58	44	29	37
	25	22	51	26	12	18	52	34	36	37	49	42	50	49	56	37	26	39
	33	23	46		10	16	39	41	44	35	30	53	57	48	66	44	39	37
	32	24	23	26	6		37	40	44	42	32	39	47	53	59	44	22	45
	33	34	52	23	9	18	34	46	52	31	23	46	57	44	49	41	35	30
	34	23	38	29	14	19	29	40	39	34	31	51	56	61	65	41	27	32
	28	23	35	29	15	10	43	44	55	39	29	45	49	59	66	36	30	41
	30	33	29	29	13	16	58	43	34	41	40	43	45	44	57	49	23	40
	33	24	34			16	33	41	56	36	33	44	45	60	49	39	20	36
	31	18	45	32	7	17	36	41	47	36	26	45	51	51	64	37	34	37
	35	21	26	30	8	18	44	35	43	50	42	40	51	45	47	46	28	40
	39	34	41	25	11	15	37	32	38	55	42	57	43	56	62	43	23	37
	35	25	40	28	10	13	32	32	54	41	38	40	48	59	54	37	26	40
SE	4.25	6.25	8.20	3.69	3.39	2.56	7.92	5.92	7.60	7.51	6.76	5.81	5.84	6.61	5.84	4.53	5.06	5.32
Average	33.2	23.8	36.3	28.2	10.8	16.2	40.6	39.0	44.0	39.5	32.2	44.3	51.2	52.7	56.6	43.0	27.2	38.0

Appendix 3: Trial 1 tissue and growing media analysis

Table 1. Petunia leaf tissue SAP analysis results

RESULTS (are expressed as mg/l)

Treatment no.	Description	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
7	Capillary perlite H	4.51	212.52	70.50	0.15	2.12	1368	0.21	0.78	1777	974.12	4.45	0.01	649.74	62.39	149.28	3.10
8	Capillary woodfibre H	4.64	202.50	40.98	0.17	2.63	1374	0.18	0.75	2267	953.83	5.20	0.07	458.63	66.43	202.88	3.33
9	Capillary coir H	4.36	140.94	45.48	0.19	2.54	915	0.18	0.65	3466	544.74	3.19	0.02	231.44	54.13	192.39	3.33
16	Capillary perlite L	4.75	222.96	30.06	0.18	2.38	1579	0.21	0.58	1577	1224.52	5.28	0.01	618.91	104.22	176.39	2.91
17	Capillary woodfibre L	4.95	180.96	22.26	0.19	2.81	1829	0.28	0.74	3325	1142.88	6.63	0.01	274.51	159.34	292.67	3.56
18	Capillary coir L	5.04	132.96	14.04	0.18	2.83	1387	0.26	0.62	3671	899.07	4.72	0.00 u	278.97	138.92	228.74	3.14
1	Overhead perlite H	6.23	190.26	829.38	0.07	2.69	552	0.45	1.05	3248	470.30	2.31	0.03	407.74	553.95	241.90	2.84
2	Overhead woodfibre H	6.11	75.66	687.24	0.05	2.55	846	0.30	0.91	2620	699.68	2.87	0.04	333.73	447.47	218.54	2.43
3	Overhead coir H	6.20	95.58	587.04	0.05	2.82	491	0.35	0.87	3762	358.94	2.15	0.07	222.70	463.65	222.10	3.13
10	Overhead perlite L	4.98	216.96	520.98	0.19	2.48	860	0.36	0.76	2643	1065.30	2.72	0.00 u	446.48	357.09	133.43	3.19
11	Overhead woodfibre L	5.14	241.38	346.14	0.09	2.39	850	0.58	0.83	3893	666.09	2.74	0.00 u	198.19	293.28	139.27	3.56
12	Overhead coir L	5.01	142.92	586.86	0.11	2.37	665	0.54	0.74	4061	459.51	2.25	0.00 u	184.31	352.75	118.40	3.33
13	ebb and flood perlite H	5.05	373.74	628.80	0.08	2.52	246	0.45	0.48	2881	223.55	0.89	0.00 u	388.01	179.70	136.07	2.79
14	ebb and flood woodfibre H	4.43	377.70	623.22	0.11	2.40	334	0.51	0.68	2933	201.41	0.91	0.01	237.23	379.44	199.50	2.90
15	ebb and flood coir H	4.33	297.36	606.00	0.12	2.61	277	0.47	0.68	3674	166.06	1.01	0.00 u	186.12	392.98	197.07	3.00
4	ebb and flood perlite L	6.05	12.72	252.54	0.15	2.17	974	0.40	0.66	3547	710.12	2.72	0.01	340.82	415.79	111.32	1.98
5	ebb and flood woodfibre L	5.97	11.10	195.30	0.16	2.32	1243	0.45	0.66	4137	667.07	3.02	0.00	191.26	250.78	140.14	2.66
6	ebb and flood coir L	6.05	13.50	282.78	0.18	2.16	762	0.57	0.76	5008	405.79	1.77	0.00	161.51	391.30	111.82	2.44

Table 2. Growing media analysis results

RESULTS (are expressed as mg/l)

Treatment no.	Description	pH	EC @20c	density	dry matter	dry density	Cl	P	K	Mg	Ca	Na	NH4	NO3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
1	Overhead perlite H	6.2	283	448	33.1	148.3	33.9	9.4	54.7	22.7	17.5	56.2	59.9	32.4	92.3	381.9	0.17	0.01	<0.01	0.08	0.33
2	Overhead woodfibre H	6.4	247	450	31.4	141.3	28.3	10.2	49.9	14.7	12.4	45	56.1	16.8	72.9	349.1	0.18	0.01	<0.01	0.07	0.27
3	Overhead coir H	6.2	221	336	31.8	106.8	37.4	6.6	102.8	5.5	6.2	62.1	34.3	10	44.3	323.1	0.22	0.01	<0.01	0.08	0.5
4	ebb and flood perlite L	5.9	111	399	21.9	87.4	39.5	36.4	8.8	21.4	13.5	41.3	3.8	11.3	15.1	68.7	0.1	<0.01	<0.01	0.08	0.34
5	ebb and flood woodfibre L	6.4	93	410	20.5	84.1	44	25.4	28.3	9	7.1	31.2	3.3	<0.6	3.9	49.9	0.08	<0.01	<0.01	0.04	0.14
6	ebb and flood coir L	6.6	131	449	19.1	85.8	64	34.4	69.4	4.1	4.5	50.8	5	1.3	6.3	63.3	0.12	0.02	<0.01	0.04	0.24
7	Capillary perlite H	5.9	129	420	26.8	112.6	58.8	<1	<1	22.8	14.5	46.6	5.1	4.1	9.2	158.4	0.12	<0.01	<0.01	0.04	0.23
8	Capillary woodfibre H	6.5	112	410	27.5	112.8	66.5	4.6	21.1	14.3	9.9	38.1	5.3	1.3	6.6	83.1	0.09	0.01	<0.01	0.04	0.21
9	Capillary coir H	5.9	161	387	22.3	86.3	85.9	1.1	79.2	6.8	6.8	75.3	6	2.8	8.8	182.1	0.17	<0.01	<0.01	0.03	0.43
10	Overhead perlite L	6.3	229	399	28.6	114.1	58.9	75	97.3	36.7	27.6	54.7	4.2	45.2	49.3	96.1	0.11	0.03	<0.01	0.15	0.24
11	Overhead woodfibre L	6.9	167	379	25.8	97.8	55.3	61.4	101.5	15.1	14	34.1	1.2	<0.6	1.2	58.3	0.11	0.02	<0.01	0.12	0.24
12	Overhead coir L	6.8	168	432	25	108	68.2	52.1	106.2	8	6.5	59.4	2.6	3.8	6.3	73.2	0.1	0.02	<0.01	0.05	0.27
13	ebb and flood perlite H	5.6	228	399	27.2	108.5	35.1	4	10	63.6	37.9	54.1	7	52.5	59.5	258.3	0.12	0.02	0.03	0.18	0.6
14	ebb and flood woodfibre H	5.9	241	560	21.3	119.3	53.2	5	98.9	8.8	7.9	83.4	25.9	15	40.9	318.9	0.23	0.01	<0.01	0.08	0.66
15	ebb and flood coir H	6	221	560	23.7	132.7	41	2.7	5.6	43.9	26.3	65.3	19.1	7	26.1	371.9	0.15	0.01	<0.01	0.05	0.44
16	Capillary perlite L	6	114	435	25.4	110.5	66.8	2	1.4	18	11.9	50.2	4.1	5.1	9.2	106.5	0.1	0.01	<0.01	0.07	0.23
17	Capillary woodfibre L	6.1	151	388	24.6	95.4	62.4	<1	3.6	35.2	20.9	49.8	4.1	<0.6	4.7	214.8	0.11	<0.01	<0.01	0.04	0.32
18	Capillary coir L	6.4	108	420	22.2	93.2	75.2	2.3	51.1	2	3	42.9	4.3	0.7	4.9	61.9	0.15	<0.01	<0.01	0.03	0.3

The extraction is performed by adding a weight of sample equivalent to 60mls volume to 300mls of deionised water (ref BSEN 13652:2001).

Appendix 4: Trial 1 images

Treatment 1—Capillary
Peat and perlite mix
Standard feed

Treatment 2—Capillary
Peat and wood fibre mix
Standard feed

Treatment 3—Capillary
Peat and wood fibre mix
Standard feed

Treatment 4—Capillary
Peat and perlite mix
Tailored feed

Treatment 5—Capillary
Peat and wood fibre mix
Tailored feed

Treatment 6—Capillary
Peat and coir mix
Tailored feed

Treatment 7—Overhead
Peat and perlite mix
Standard feed

Treatment 8—Overhead
Peat and wood fibre mix
Standard feed

Treatment 9—Overhead
Peat and coir mix
Standard feed

Treatment 10—Overhead
Peat and perlite mix
Tailored feed

Treatment 11—Overhead
Peat and wood fibre mix
Tailored feed

Treatment 12—Overhead
Peat and coir mix
Tailored feed

Treatment 13—Ebb and Flood
Peat and perlite mix
Standard feed

Treatment 14—Ebb and Flood
Peat and wood fibre mix
Standard feed

Treatment 15—Ebb and Flood
Peat and coir mix
Standard feed

Treatment 16—Ebb and Flood
Peat and perlite mix
Tailored feed

Treatment 17—Ebb and Flood
Peat and wood fibre mix
Tailored feed

Treatment 18—Ebb and Flood
Peat and coir mix
Tailored feed

Figure 1. Image of representative plant from each treatment showing root development, images date 19/08/2020.

Appendix 5: Trial 2 data and statistical analysis

Table 1. Plant height observations (mm) and statistical analysis

REML variance components analysis

Respons‹ **height**
Fixed mo‹ Constant + Treatment_number
Number c 108 (1 units excluded due to zero weights or missing values)

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed terr	Wald stat	n.d.f.	F statistic	d.d.f.	F pr	Sig
Treatmen	147.12	17	8.65	90	<0.001	***

Table of predicted means for Treatment_number

Treatmen	1	2	3	4	5	6	7
	112.17	85.83	81.83	81	56.17	71.17	68.17

Treatmen	8	9	10	11	12	13	14
	51.33	57.33	110.83	88.83	99	119.83	95.17

Treatmen	15	16	17	18
	103.67	134.83	121.83	120

LSD 23.91 differences between treatment codes of more than 23.91 are significant

Observations 18/11/2020 - Plant height in mm

feed code	L	L	L	L	L	L	L	L	L	LW	LW	LW	LEC	LEC	LEC	CRF	CRF	CRF
irrigation type code	IA	IA	IA	IB	IB	IB	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC
Growing media type cod	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Observations	125	98	120	102	25	72	56	54	65	118	110	110	120	102	61	138	128	135
	115	109	44	123	61	43	54	43	64	105	95	110	141	124	118	136	112	111
	118	96	108	40	45	70	92	55	65	117	114	105	122	102	96	124	137	108
	110	83	83	58	111	48	55	57	48	138	88	92	101	104	98	140	96	124
	90	85	85	115	48	92	92	55	55	61	70	95	120	64	125	136	147	118
	115	44	51	48	47	102	60	44	47	126	56	82	115	75	124	135	111	124
SE	11.92	22.57	30.12	36.50	29.25	23.31	18.57	6.15	8.50	26.74	22.60	11.24	12.89	21.82	24.43	5.60	18.88	9.86
Average	112.2	85.8	81.8	81.0	56.2	71.2	68.2	51.3	57.3	110.8	88.8	99.0	119.8	95.2	103.7	134.8	121.8	120.0

Table 2. Number of flowers and statistical analysis

REML variance components analysis

Respons number_of_flowers
Fixed mo Constant + Treatment_number
Number c 108 (1 units excluded due to zero weights or missing values)

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed terr	Wald stat	n.d.f.	F statistic	d.d.f.	F pr	sig
Treatmen	220.94	17	13	90	<0.001	***

Table of predicted means for Treatment_number

Treatmen	1	2	3	4	5	6	7
	6.5	2.833	4.5	2.667	1.333	0.5	0.667

Treatmen	8	9	10	11	12	13	14
	0	0	5.667	1.667	3.5	7	1.667

Treatmen	15	16	17	18
	4.667	11.333	8.333	11.167

LSD **2.798** differences between treatment codes of more than 2.798 are significant

Observations 18/11/2020 - number of flowers

feed code	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**LW**	**LW**	**LW**	**LEC**	**LEC**	**LEC**	**CRF**	**CRF**	**CRF**
irrigation type code	**IA**	**IA**	**IA**	**IB**	**IB**	**IB**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**	**IC**
Growing media type c	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**	**SA**	**SB**	**SC**
Treatment no	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Observations	11	1	10	1	0	0	0	0	0	10	1	3	4	2	1	12	7	11
	8	3	0	11	1	0	0	0	0	5	2	3	7	1	10	10	9	10
	8	1	5	0	0	1	2	0	0	4	2	3	6	1	5	13	8	12
	6	3	10	0	7	0	1	0	0	7	3	3	5	4	6	15	7	13
	2	9	2	2	0	1	1	0	0	2	2	4	10	1	4	7	10	9
	4	0	0	2	0	1	0	0	0	6	0	5	10	1	2	11	9	12
SE	3.21	3.25	4.64	4.18	2.80	0.55	0.82	0.00	0.00	2.73	1.03	0.84	2.53	1.21	3.20	2.73	1.21	1.47
Average	6.5	2.8	4.5	2.7	1.3	0.5	0.7	0.0	0.0	5.7	1.7	3.5	7.0	1.7	4.7	11.3	8.3	11.2

Table 3. Plant fresh weight of above ground growth observations (g) and statistical analysis

REML variance components analysis

Respons **weight_in_grams**
Fixed mo Constant + Treatment_number
Number c 108

Tests for fixed effects

Sequentially adding terms to fixed model

Fixed terr	Wald stat	n.d.f.	F statistic	d.d.f.	F pr	sig
Treatmen	252.57	17	14.86	90	<0.001	***

Table of predicted means for Treatment_number

Treatmen	1	2	3	4	5	6	7
weight	16.89	11.36	10.94	9.19	5.91	7.23	8.2

Treatmen	8	9	10	11	12	13	14
	4.33	5.79	12.93	7.15	9.24	13.14	7.83

Treatmen	15	16	17	18
	10.43	20.02	11.83	18.2

LSD 3.190 differences between treatment codes of more than 3.190 are significant

Observations 18/11/2020 - Plant fresh weight in grams

feed code	L	L	L	L	L	L	L	L	L	LW	LW	LW	LEC	LEC	LEC	CRF	CRF	CRF
irrigation type code	IA	IA	IA	IB	IB	IB	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC	IC
Growing media type	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Observations	26.45	10.63	17.71	9.83	4.48	8.12	6.21	4.74	5.52	19	7.93	9.37	10.15	7.96	9.46	20.82	10.73	19.97
	14.9	13.4	6.28	15.57	7.79	4.88	8.63	4.78	5.1	9	7.47	9.24	13.84	4.66	13.08	21.13	14.11	18.43
	19.49	8.53	12.85	5.71	5.14	7.64	8.52	4.45	6.88	12.18	7.85	9.05	14.22	6.94	12.5	17.37	17.06	18.66
	15.04	14.34	11.33	7.96	10.21	3.77	8.57	3.34	5.35	13.37	7.14	8.5	10	7.89	11.22	16.7	9.15	23.29
	12	14.55	10.07	7.68	4	7.55	9.03	4.89	6.21	11.09	6.52	7.47	14.14	9.76	8.76	21.73	10.64	15.29
	13.49	6.68	7.38	8.41	3.81	11.39	8.24	3.75	5.66	12.96	6	11.83	16.51	9.76	7.56	22.4	9.31	13.58
SE	5.31	3.28	4.12	3.39	2.56	2.68	1.01	0.63	0.65	3.36	0.76	1.45	2.56	1.91	2.19	2.39	3.12	3.44
Average	16.9	11.4	10.9	9.2	5.9	7.2	8.2	4.3	5.8	12.9	7.2	9.2	13.1	7.8	10.4	20.0	11.8	18.2

Appendix 6: Trial 2 tissue and growing media analysis

Table 1. Pansy leaf tissue SAP analysis results, sampled 18/11/2020.

RESULTS (are expressed as mg/l)

Treatment no.	Description	pH	EC @20c	density	dry matter	dry density	Cl	P	K	Mg	Ca	Na	NH4	NO3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
1	Overhead perlite L	5.7	147	430	24.4	104.9	20.1	<1	23.4	28.2	24	34.1	1.4	33.7	35.1	144.2	0.13	0	<0.01	0.07	0.2
2	Overhead woodfibre L	6.8	162	624	18	112.3	24.6	2.1	62.5	20.3	17	36.1	7	10.2	17.2	183.7	0.14	0.1	<0.01	0.09	0.2
3	Overhead coir L	7	398	555	16.7	92.7	40.6	27.6	178.7	7.1	8.9	51.1	95.9	56.9	152.8	333.3	0.19	0	0.02	0.09	0.5
4	ebb and flow perlite L	6	68	495	22.9	113.4	20.1	<1	7.7	10	8.4	26.5	<0.6	<0.6	0.6	96.8	0.08	0	<0.01	<0.02	0.2
5	ebb and flow woodfibre L	6.7	79	549	20.8	114.2	37.7	<1	9.9	10.5	8.3	26.7	0.7	<0.6	0.7	66.4	0.08	0	<0.01	<0.02	0.2
6	ebb and flow coir L	6.2	119	589	17.2	101.3	43.4	<1	44.7	9.6	10.8	52.9	2	<0.6	2	123.3	0.13	0	<0.01	<0.02	0.5
7	Capillary perlite L	5.7	190	475	19.1	90.7	54.6	<1	58.8	23.3	16.8	41.3	8.8	22.2	31	202.2	0.09	0	0.01	<0.02	0.2
8	Capillary woodfibre L	6.7	160	503	19.1	96.1	60.9	<1	62.7	14.7	10.6	34.9	9	5.4	14.4	168.3	0.08	0	<0.01	<0.02	0.2
9	Capillary coir L	6.1	217	519	18.8	97.6	87.1	<1	109.6	18.4	14.6	56.8	10.4	12	22.4	218.9	0.13	0	<0.01	0.02	0.5
10	Capillary perlite LW	5.5	282	446	24.9	111.1	80	<1	87	47.3	39.6	59.3	1	44.4	45.4	304.1	0.13	0	0.03	0.02	0.3
11	Capillary woodfibre LW	6.6	195	430	20.9	89.9	66.5	<1	90.2	24.1	19.1	43.4	2.2	7.5	9.7	238.5	0.14	0	<0.01	<0.02	0.2
12	Capillary coir LW	5.8	308	458	19.6	89.8	97.3	<2	169.1	38.4	28.6	71.8	0.9	41.8	42.6	319.1	0.18	0	0.02	0.03	0.4
13	Capillary perlite LEC	5.5	295	459	22.1	101.4	83.6	<1	85.1	51.7	41.9	66.6	1.1	39.4	40.5	337.3	0.11	0	0.04	0.02	0.3
14	Capillary woodfibre LEC	6.5	170	431	21.6	93.1	41.3	<1	46.7	28.7	18.7	44	0.9	3.9	4.8	244.7	0.08	0	<0.01	<0.02	0.2
15	Capillary coir LEC	5.8	239	464	20.2	93.7	59.8	<1	108.1	30	21.4	66.6	1	20.2	21.2	287.8	0.13	0	0.01	<0.02	0.5
16	Capillary perlite CRF	5.4	273	438	22.9	100.3	50.1	2.9	49.2	54.6	57.7	62.3	1.5	31.2	32.7	366.4	0.19	0	0.02	0.05	0.7
17	Capillary woodfibre CRF	6.4	264	409	23	94.1	49.2	4.6	97.3	47.6	42.6	49.6	5.4	21.9	27.3	377.7	0.19	0	<0.01	0.24	0.3
18	Capillary coir CRF	5.8	268	428	22.7	97.2	67.3	2.5	103.6	44.3	39.1	72.6	1.7	29.8	31.5	335.3	0.21	0	<0.01	0.15	0.9

Table 2. Growing media analysis results, sampled 18/11/2020.

RESULTS (are expressed as mg/l)

Treatment no.	Description	PH	NH_4	NO_3	Total N	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
1	Overhead perlite L	6.38	50.29	465.09	515.38	0.08	3.12	608	0.60	1.02	3737	914.47	7.61	0.24	41.49	438.98	226.14	6.31
2	Overhead woodfibre L	6.43	164.21	282.15	446.36	0.11	2.81	511	0.53	0.99	4225	747.52	4.55	0.29	39.98	294.65	382.04	7.18
3	Overhead coir L	6.40	126.38	458.71	585.09	0.09	3.82	378	0.56	0.90	4665	615.28	7.21	0.18	51.58	620.12	354.69	6.30
4	ebb and flow perlite L	6.21	42.24	104.02	146.26	0.14	2.99	862	0.51	1.35	3578	1386.24	17.59	0.05	54.24	215.09	235.68	10.16
5	ebb and flow woodfibre L	6.28	29.09	89.46	118.55	0.25	3.16	730	0.48	1.53	4445	1136.03	10.01	0.14	44.20	238.41	252.29	9.91
6	ebb and flow coir L	6.29	14.99	47.99	62.98	0.22	3.20	564	0.46	1.46	4615	853.45	16.18	0.03	40.32	212.19	221.64	8.88
7	Capillary perlite L	6.46	44.93	285.87	330.80	0.18	3.34	888	0.39	0.89	3699	1214.24	17.61	-0.04	86.02	134.85	320.07	9.39
8	Capillary woodfibre L	6.42	41.41	195.75	237.16	0.18	2.65	717	0.33	0.90	3287	849.15	12.67	0.22	59.08	122.06	272.43	8.00
9	Capillary coir L	6.42	55.03	296.70	351.73	0.16	3.08	503	0.44	1.00	3529	659.83	14.88	0.14	57.62	185.55	246.37	7.80
10	Capillary perlite LW	6.32	24.08	471.12	495.20	0.14	3.13	791	0.47	1.59	4625	1068.34	16.36	0.14	59.19	128.26	262.81	9.54
11	Capillary woodfibre LW	6.35	35.23	248.06	283.29	0.14	3.17	560	0.39	1.02	4036	738.76	8.65	0.24	45.16	120.65	267.98	8.77
12	Capillary coir LW	6.29	22.99	426.20	449.19	0.23	2.87	557	0.43	1.18	4790	752.95	15.82	0.08	50.05	132.92	280.84	9.13
13	Capillary perlite LEC	6.30	24.08	479.34	503.42	0.17	2.80	797	0.50	3.00	5085	1042.29	16.31	0.23	63.81	157.14	275.57	8.56
14	Capillary woodfibre LEC	6.29	52.47	438.78	491.25	0.22	2.94	673	0.43	1.44	5083	886.58	10.56	0.41	36.95	179.21	287.14	9.99
15	Capillary coir LEC	6.28	32.88	517.01	549.89	0.16	3.23	531	0.48	1.53	4907	725.19	14.08	0.69	53.11	174.76	267.17	8.42
16	Capillary perlite CRF	6.34	16.55	434.81	451.36	0.15	3.87	623	0.49	1.85	5689	956.31	12.87	-0.10	45.42	246.34	236.90	8.65
17	Capillary woodfibre CRF	6.31	17.03	342.02	359.05	0.10	3.30	560	0.41	1.12	4964	776.83	8.82	-0.08	39.74	253.38	242.59	8.52
18	Capillary coir CRF	6.30	18.34	457.05	475.39	0.14	2.93	415	0.37	1.33	5162	659.70	9.59	-0.13	38.66	231.45	201.58	6.31

The extraction is performed by adding a weight of sample equivalent to 60mls volume to 300mls of deionised water (ref BSEN 13652:2001).

Table 3. Trial 2 observations on growing media pH obtained from bulk samples from each treatment using SME.

	Observation date					
Treatment	07/10/2020	14/10/2020	21/10/2020	28/10/2020	04/11/2020	11/11/2020
1	6.55	6.39	6.63	6.74	6.64	5.98
2	6.93	7.03	7.15	7.22	7.35	6.52
3	6.52	6.47	6.79	6.87	6.94	6.26
4	6.27	6.34	6.25	6.37	6.3	5.69
5	6.92	6.88	6.88	6.85	6.86	5.66
6	6.43	6.28	6.25	6.3	6.21	5.25
7	6.9	6.79	6.17	6.52	6.4	5.58
8	7.33	6.88	6.74	6.91	6.86	5.86
9	6.59	6.35	6.32	6.28	6.21	5.55
10	6.46	6.25	6.27	6.33	5.95	5.78
11	6.79	6.87	6.76	6.88	6.78	5.84
12	6.35	6.29	6.19	6.49	6.15	5.45
13	6.51	6.25	6.21	6.19	6.08	5.53
14	6.92	6.87	6.92	6.89	6.88	5.9
15	6.48	6.14	6.24	6.22	6.27	5.5
16	6.03	5.95	5.75	6.01	5.85	4.61
17	6.51	6.62	6.41	6.54	6.69	5.3
18	6.05	6.11	6.08	6.35	6.31	4.84

Table 4. Trial 2 observations on growing media EC (µS) obtained from bulk samples from each treatment using SME.

Treatment	Observation date 07/10/2020	14/10/2020	21/10/2020	28/10/2020	04/11/2020	11/11/2020
1	406	351	268	231	144	405
2	269	353	328	186	179	441
3	414	485	356	283	198	575
4	446	215	363	317	268	339
5	253	238	274	293	344	238
6	411	426	440	460	563	308
7	633	295	265	391	362	473
8	257	445	265	339	405	421
9	551	511	499	731	532	682
10	484	382	355	456	563	1143
11	291	315	453	398	584	675
12	592	543	610	409	701	966
13	445	477	379	586	740	1098
14	271	293	293	484	548	718
15	379	717	512	791	654	1115
16	1134	879	936	763	920	1602
17	886	611	1021	807	703	920
18	1246	827	990	703	927	1193

Appendix 7: Trial 2 Irrigation records

Table 1. Analysis of irrigation water with feed

Irrigation water and standard feed		
	EC	pH
29/09/2012	N/A	N/A
02/10/2020	1068	7.39
09/10/2020	1026	7.32
14/10/2020	1385	7.35
16/10/2020	1304	7.38
22/10/2020	1116	7.33
23/10/2020	1099	7.50
28/10/2020	688	7.86
30/10/2020	1184	7.61
04/11/2020	1154	7.47
06/11/2020	1189	7.36
11/11/2020	1263	5.72*
13/11/2020	1164	7.44

EC (in µS)

Table 2. Record of irrigation events

	incidence of irrigation events						Irrigation volume (Ltr)				EC (in µS) of irrigation run-off	
Bench no.	1	2	3	4	5	6	3		5		3	5
							In	Out	In	Out		
29/09/2012	Y	Y	Y	Y	Y	Y	N/A	N/A	N/A	N/A	N/A	N/A
02/10/2020	Y	Y	Y	Y	Y	Y	6.36	2.60	52.99	42.00	933	706
09/10/2020	Y	Y	Y	Y	N	Y	6.21	1.20	N/A	N/A	1275	N/A
14/10/2020	Y	Y	Y	Y	Y	Y	8.78	3.40	65.06	50.00	778	947
16/10/2020	Y	Y	Y	Y	N	Y	3.86	0.62	N/A	N/A	2090	N/A
22/10/2020	Y	Y	Y	Y	N	Y	7.27	1.34	N/A	N/A	1320	N/A
23/10/2020	Y	Y	Y	Y	Y	Y	4.43	1.10	62.57	46.00	821	1174
28/10/2020	Y	Y	Y	Y	N	Y	5.34	1.19	0.00	0.00	745	N/A
30/10/2020	Y	Y	N	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A
04/11/2020	Y	Y	Y	Y	Y	Y	7.23	1.95	62.15	44.00	1133	868
06/11/2020	Y	Y	Y	Y	Y	Y	6.62	1.60	62.57	54.00	875	3860
11/11/2020	Y	Y	Y	Y	N	Y	9.46	2.30	0.00	0.00	1743	N/A
13/11/2020	Y	Y	Y	Y	Y	Y	7.27	2.60	62.11	53.00	1907	946
Total	13	13	12	13	7	13	72.82	19.90	367.45	289.00		

Appendix 8. Trial 2 images

Table 1

Treatments 7,8,9

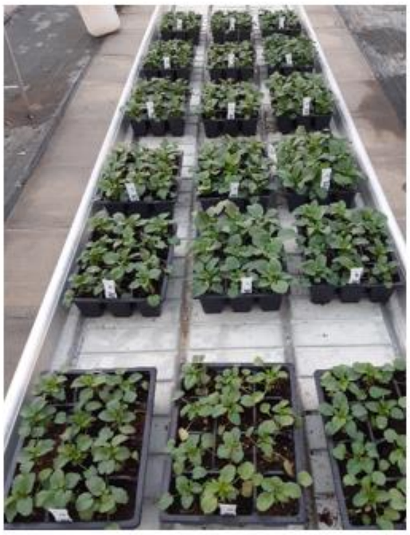


Table 3

Treatments 1,2,3

Table 5

Treatments 4,5,6

Table 2

Treatments 10,11,12

Table 4

Treatments 13,14,15

Table 6

Treatments 16,17,18

Figure 1. Treatment photographs, images dated 27/10/2021

Treatment 1—Overhead

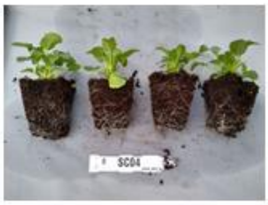
Peat and perlite mix

Feed - L

Treatment 2—Overhead

Peat and wood fibre mix

Feed - L



Treatment 3—Overhead

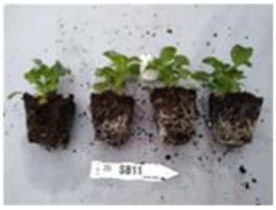
Peat and coir mix

Feed - L

Treatment 10 — Capillary

Peat and perlite mix

Feed - LW



Treatment 11- Capillary

Peat and wood fibre mix

Feed - LW

Treatment 12—Capillary

Peat and coir mix

Feed - LW

Treatment 4—Ebb and Flood

Peat and perlite mix

Feed - L

Treatment 5—Ebb and Flood

Peat and wood fibre mix

Feed - L

Treatment 6—Ebb and Flood

Peat and coir mix

Feed - L

Treatment 13—Capillary
Peat and perlite mix
Feed - LEC

Treatment 14—Capillary
Peat and wood fibre mix
Feed - LEC

Treatment 15—Capillary
Peat and coir mix
Feed - LEC

Treatment 7—Capillary
Peat and perlite mix
Feed - L

Treatment 8—Capillary
Peat and wood fibre mix
Feed - L

Treatment 9—Capillary
Peat and coir mix
Feed - L

Treatment 16—Capillary
Peat and perlite mix
Feed - CRF

Treatment 17—Capillary
Peat and wood fibre mix
Feed - CRF

Treatment 18—Capillary
Peat and coir mix
Feed - CRF

Figure 2. Treatment photographs from final assessment on 18/11/2020 with feed treatments standard liquid (L), low rate liquid (LW), liquid applied in response to EC monitoring (LEC) and controlled release fertilizer (CRF).

Appendix 9: Trial 3 Feed

Table 1. Feed calculations

Liquid Feed specification 0:100				
Target	**Water**	**Feed**	**Feed & Water**	**ppm/mg/l (1:200 dilution)**
70ppm NO3-	8.5	92.04	100.54	100.54
30ppm NH4+	N/A	0	0	
45ppm P	1	44	45	45
125ppm K	2	115	117	117
8ppm Mg	3.6	4.4		8

Hortifeeds TE BEMIX - 1.50% B, 2.93% EDTA-Cu, 5.78% EDTA-Fe, 2.93% EDTA-Mn, 0.04% Mo and 1.04% EDTA-Zn.

Liquid Feed specification 20:80				
Target	**Water**	**Feed**	**Feed & Water**	**ppm/mg/l (1:200 dilution)**
80ppm NO3-	8.5	73.1	81.6	99.7
20ppm NH4+	N/A	18.1	18.1	
45ppm P	1	44	45	45
125ppm K	2	123	125	125
8ppm Mg	3.6	4.4	8	8

Hortifeeds TE BEMIX - 1.50% B, 2.93% EDTA-Cu, 5.78% EDTA-Fe, 2.93% EDTA-Mn, 0.04% Mo and 1.04% EDTA-Zn.

Liquid Feed specification 30:70				
Target	**Water**	**Feed**	**Feed & Water**	**ppm/mg/l , (1:200 dilution)**
70ppm NO3-	8.5	67.83	76.33	106.22
30ppm NH4+	N/A	29.89	29.89	
45ppm P	1	44	45	45
125ppm K	2	121.85	123.85	123.85
8ppm Mg	3.6	4.4	8	8

Hortifeeds TE BEMIX - 1.50% B, 2.93% EDTA-Cu, 5.78% EDTA-Fe, 2.93% EDTA-Mn, 0.04% Mo and 1.04% EDTA-Zn.

Appendix 10: Trial 3 observations and data

Table 1. Observations on Geranium.

Geranium plant height observations in mm 03/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	170	145	170
	95	130	130
	130	130	175
	160	175	175
	165	160	140
	160	165	145
	170	160	140
	175	130	175
	180	160	165
	160	160	140
	140	170	155
	190	130	165
	160	150	185
	140	150	155
	130	190	155
	145	175	160
	160	170	150
	140	210	180
	135	150	120
	165	160	150
	130	150	155
	150	150	160
SE	21.3	19.9	16.6
Average	152.3	157.7	156.6

Geranium plant height observations in mm 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	172	205	175
	175	255	203
	245	221	150
	228	229	235
	190	255	205
	170	130	165
	195	175	190
	145	225	245
	150	240	180
	180	185	220
	180	196	155
		200	185
SE	29.9	36.0	30.3
Average	184.5	209.7	192.3

Geranium number of flower observations, 03/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	3	2	3
	3	4	2
	4	2	5
	3	2	3
	2	3	2
	2	3	2
	3	4	2
	3	1	2
	2	2	4
	1	3	2
	2	2	2
	4	1	2
	2	5	3
	2	2	2
	3	2	2
	4	2	3
	4	2	2
	1	3	3
	2	2	2
	1	3	2
	3	3	2
		1	3
SE	1.0	1.0	0.8
Average	2.6	2.5	2.5

Geranium number of flower observations, 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	3	4	5
	3	7	4
	5	4	3
	7	6	7
	3	4	3
	5	3	4
	5	4	9
	4	8	7
	4	4	6
	3	6	3
	3	5	5
	6	4	
SE	1.4	1.5	2.0
Average	4.3	4.9	5.1

Geranium fresh weight observations in grams, 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	48	58	58
	64	83	57
	67	50	44
	69	64	67
	46	37	55
	49	49	36
	61	33	62
	43	81	58
	54	71	39
	54	58	51
	47	59	41
	50	50	54
SE	8.8	15.5	9.7
Average	54.3	57.8	51.8

Table 2. Observations on Cyclamen.

Cyclamen plant width observations in mm 03/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	60	65	80
	75	65	70
	50	111	75
	72	96	83
	71	91	79
	91	80	90
	95	100	95
	90	87	73
	60	78	83
	100	70	67
	96	75	74
	67	83	76
	70	76	76
	74	80	69
	60	80	74
	80	66	76
	82	45	100
	80	62	80
	102	80	76
	81	82	60
	66	70	93
			72
SE	14.5	14.4	9.5
Average	77.2	78.2	78.2

Cyclamen plant width observations in mm 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	88	80	140
	131	76	130
	172	170	160
	135	163	160
	95	140	118
	160	125	100
	130	150	147
	155	138	120
	132	114	142
	106	136	126
			132
			72
SE	27.7	31.6	24.9
Average	130.4	129.2	128.9

Cyclamen leaf number observations 03/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	3	9	20
	4	4	4
	2	21	17
	9	19	24
	20	25	14
	5	15	27
	19	24	32
	22	13	15
	4	16	21
	21	12	18
	16	17	12
	3	15	16
	14	8	15
	17	7	11
	3	13	10
	15	4	20
	10	16	22
	10	8	16
	15	12	11
	6	12	7
	14		17
	12		5
SE	6.6	5.9	6.9
Average	11.1	13.5	16.1

Cyclamen fresh weight observations in grams, 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	10	5	29
	31	7	25
	41	56	44
	35	48	45
	14	27	21
	46	19	17
	35	34	24
	29	28	17
	26	24	35
	33	10	25
			24
			8
SE	11.1	16.9	10.9
Average	30.0	25.8	26.2

Cyclamen number of flower observations, 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	9	0	3
	0	0	0
	5	9	0
	1	9	10
	13	1	0
	0	0	3
	9	0	7
	0	1	0
	6	4	0
	0	5	7
			1
			2
SE	4.8	3.8	3.4
Average	4.3	3.6	2.8

Table 3. Observations on Pansy.

Pansy plant width observations in mm 03/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	200	160	180
	220	180	165
	250	160	180
	220	185	160
	170	145	230
	225	170	200
	230	210	210
	140	180	140
	200	150	200
	225	180	190
	170	190	190
	150	210	195
	190	165	140
	220	135	260
	165	190	130
	210	185	155
	205	210	165
	185	130	185
	185	170	180
	170	140	190
	170	195	190
	140	145	150
SE	30.8	24.4	30.3
Average	192.7	172.0	181.1

Pansy plant width observations in mm 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	330	245	320
	320	210	375
	365	325	310
	315	240	365
	330	350	300
	340	345	320
	320	320	240
	300	355	300
	290	320	230
	300	200	330
	280	300	300
	300	195	205
SE	22.0	61.5	51.5
Average	321.0	283.8	299.6

Pansy flower number observations 3/07/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	5	3	5
	5	4	2
	6	0	5
	0	2	8
	7	2	11
	9	3	3
	10	5	7
	1	3	0
	2	2	5
	7	4	4
	2	5	3
	1	6	7
	9	4	2
	8	1	6
	2	6	2
	8	6	5
	10	8	2
	4	4	4
	8	2	6
	8	0	4
	11	4	3
	3	1	4
SE	3.4	2.1	2.4
Average	5.7	3.4	4.5

Pansy fresh weight observations in grams, 03/08/2020

	Treatment 1	Treatment 2	Treatment 3
N form ratio NH4:NO3	0 - 100	20 - 80	30 - 70
Observations	121	122	116
	87	87	114
	133	90	101
	106	102	111
	116	91	115
	73	110	78
	111	99	67
	121	115	83
	96	89	94
	111	63	77
	109	90	83
	80	85	72
SE	18.0	15.7	18.2
Average	105.3	95.3	92.6

Appendix 11. Trial 3 Growing Media analysis results

Table 1. Observations on growing media pH and EC (SME) in Cyclamen treatments.

pH level in growing media in Cyclamen treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	6.14	6.16	6.05
17/06/2020	6.15	6.11	6.04
24/06/2020	6	5.9	5
01/07/2020	5.23	5.14	5.15
15/07/2020	5.76	5.75	5.78
23/07/2020	6.33	6.36	6.33
30/07/2020	6.97	6.99	6.98
13/08/2020	6.31	6.34	6.13

EC (in µS) level in growing media in Cyclamen treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	1163	1244	1351
17/06/2020	1088	1621	1590
24/06/2020	1083	1938	1301
01/07/2020	1734	2850	2780
15/07/2020	1318	1361	1389
23/07/2020	690	670	656
30/07/2020	996	1154	1212
06/08/2020	758	1615	1968
13/08/2020	896	761	1253

Table 2. Observations on growing media pH and EC (SME) in Geranium treatments.

pH level in growing media in Geranium treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	6.43	6.43	6.29
17/06/2020	6.18	6.17	6.17
24/06/2020	6	6	6
01/07/2020	5.23	5.24	5.22
15/07/2020	5.75	5.76	5.74
23/07/2020	6.81	6.87	6.72
30/07/2020	6.86	6.74	6.85
13/08/2020	7.12	6.86	7.34

EC (in µS) level in growing media in Geranium treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	1042	806	663
17/06/2020	546	1007	949
24/06/2020	488	636	464
01/07/2020	1276	896	1125
15/07/2020	362	268	312
23/07/2020	429	434	441
30/07/2020	639	521	439
06/08/2020	445	259	381
13/08/2020	218	344	220

Table 3. Observations on growing media pH and EC (SME) in Pansy treatments.

pH level in growing media in Pansy treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	6.25	6.28	6.25
17/06/2020	6.12	6.14	6.17
24/06/2020	5.5	5.7	5.9
01/07/2020	5.52	5.42	5.33
15/07/2020	5.78	5.76	5.75
23/07/2020	6.81	6.87	6.72
30/07/2020	6.52	6.52	6.5
13/08/2020	7.48	7.37	7.55

EC (in µS) level in growing media in Pansy treatments			
Treatment	1	2	3
NH4:NO3 ratio	0-100	20-80	30-70
10/06/2020	1148	1692	1121
17/06/2020	873	956	775
24/06/2020	393	584	533
01/07/2020	989	1128	1578
15/07/2020	231	200	221
23/07/2020	250	224	237
30/07/2020	325	205	203
06/08/2020	205	212	262
13/08/2020	212	195	229

Table 4. Laboratory analysis of growing media.

Observations on Growing media analysis, sampled 03/07/2020

RESULTS (are expressed as mg/l)

Treatment name	NH4:NO3	pH	EC @20c	density	dry matter	dry density	Cl	P	K	Mg	Ca	Na	NH4	NO3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
Cyclamen 3	30:70	5.6	616	602	25.1	151.1	132.5	84.3	255.4	159.4	116.6	73	<0.6	193.3	193.3	396.8	0.25	0.03	0.79	0.1	0.79
Cyclamen 2	20:80	5.7	575	632	23	145.4	150	77.4	248.9	141.4	102.3	77.3	4.1	153	157.2	376.1	0.26	0.04	0.61	0.1	0.56
Cyclamen 1	0:100	5.9	581	667	24.5	163.4	157.8	93.6	266.8	143	102.4	81.8	1	137.5	138.5	451.1	0.28	0.04	0.51	0.13	0.55
Geranium 3	30:70	5.9	390	639	23.5	150.2	114.9	49.3	114.9	93.8	70	75.4	2	54	56	474.3	0.33	0.04	0.33	0.27	0.71
Geranium 2	20:80	5.8	355	589	22.6	133.1	119	38.7	97.3	90.5	68.2	69.7	0.9	61.8	62.7	399.2	0.19	0.03	0.32	0.05	0.72
Geranium 1	0:100	5.8	409	612	22.1	135.3	133.6	43.1	114.7	106.8	83.5	74.5	0.8	87.2	88	416.8	0.21	0.02	0.39	0.11	0.65
Pansy 3	30:70	6.1	266	669	20.9	139.8	90.6	27.7	75.5	53.4	45.5	59.3	0.8	29.7	30.5	295.8	0.18	0.03	0.22	0.08	0.6
Pansy 2	20:80	6.2	186	688	20.2	139	82.7	26.7	65.6	46.5	43.9	60.3	1.4	21.1	22.5	298.5	0.17	0.02	0.18	0.04	0.55
Pansy 1	0:100	6.1	213	659	18.1	119.3	56.2	20.7	51.9	38.7	32.7	45.4	<0.6	19.1	19.6	231.8	0.15	0.03	0.16	0.06	0.45

Observations on Growing media analysis, sampled 03/07/2020

RESULTS (are expressed as mg/l)

Treatment name	NH4:NO3	pH	EC @20c	density	dry matter	dry density	Cl	P	K	Mg	Ca	Na	NH4	NO3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
Cyclamen 3	30:70	5.9	301	412	31.1	128.1	92.5	43	66.7	65.3	62.3	50.6	1.8	46.5	48.3	266.4	0.19	0.02	0.07	<0.02	0.19
Cyclamen 2	20:80	6.1	313	445	26.6	118.4	113.3	46.1	91	62.7	58.9	59.6	6.1	50.3	56.3	260.6	0.22	0.02	0.02	0.03	0.15
Cyclamen 1	0:100	6.1	262	466	27.4	127.7	101.7	40.3	64.6	50.4	45.3	54.6	1.8	24.6	26.4	242.3	0.2	0.01	<0.01	<0.02	0.16
Geranium 3	30:70	6.5	142	545	24.7	134.6	65.6	7.2	6.1	18.8	22	41.2	1.3	<0.6	1.5	122.9	0.16	0.01	<0.01	<0.02	0.18
Geranium 2	20:80	6.4	128	450	24.6	110.7	59	5.1	7	15.7	19.6	32.7	1.4	0.9	2.3	115	0.13	0.02	<0.01	<0.02	0.17
Geranium 1	0:100	6.3	116	450	23	103.5	56.5	2.4	3.2	16	17.3	36.4	1.1	<0.6	1.1	108.5	0.11	<0.01	<0.01	<0.02	0.14
Pansy 3	30:70	6.6	96	450	28.2	126.9	29.6	2.8	7	7.3	10.4	35.6	2.4	3.7	6.1	84.5	0.1	0.02	<0.01	<0.02	0.23
Pansy 2	20:80	6.4	112	420	31.3	131.5	31.5	4.1	6.4	11.7	13.8	43.2	1.4	2	3.4	130.8	0.12	0.01	<0.01	<0.02	0.24
Pansy 1	0:100	6.4	140	444	28.9	128.3	43.4	6.1	9.3	16.9	21.5	50.7	1.7	2.7	4.4	164	0.1	0.01	<0.01	0.02	0.18

The extraction is performed by adding a weight of sample equivalent to 60mls volume to 300mls of deionised water (ref BSEN 13652:2001).

Table 5. Laboratory analysis of leaf tissue (SAP).

Observations on leaf tissue analysis, sampled 03/07/2020

RESULTS (are expressed as mg/l)

Treatment name	NH4:NO3	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
Cyclamen 3	30:70	5.30	49.68	327.78	0.26	3.33	696	0.56	0.76	5046	353.11	6.34	0.68	558.33	275.45	568.01	3.22
Cyclamen 2	20:80	5.37	59.28	445.50	0.24	3.87	737	0.23	0.43	5695	514.47	6.53	0.38	744.69	213.57	721.38	3.09
Cyclamen 1	0:100	5.29	49.26	349.02	0.27	3.82	513	0.18	0.33	4922	323.54	4.65	0.18	633.46	266.94	663.65	2.99
Geranium 3	30:70	3.80	153.90	34.98	0.31	4.38	73	0.42	0.93	2637	803.15	24.65	0.47	228.47	640.73	78.52	5.58
Geranium 2	20:80	3.81	136.14	31.08	0.41	4.15	148	0.45	1.00	2588	646.95	20.28	0.59	218.98	541.41	75.74	5.60
Geranium 1	0:100	3.79	139.98	28.02	0.39	4.26	200	0.30	0.86	3089	706.20	25.18	0.44	254.01	629.02	88.75	6.14
Pansy 3	30:70	6.14	22.68	95.10	0.17	2.61	947	0.28	0.44	2566	1284.09	16.75	0.34	77.11	875.67	382.99	2.30
Pansy 2	20:80	6.30	29.10	68.10	0.32	4.21	1064	0.43	0.64	2723	1382.82	19.29	1.31	109.91	822.10	399.03	3.50
Pansy 1	0:100	6.28	43.70	159.60	0.45	4.36	1498	0.96	1.21	3329	2038.50	28.12	2.18	114.83	1173.44	535.83	3.95

Observations on leaf tissue analysis, sampled 03/08/2020

RESULTS (are expressed as mg/l)

Treatment name	NH4:NO3	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
Cyclamen 3	30:70	5.23	30.96	79.37	0.22	4.16	688	0.08	0.34	6037	403.95	5.74	0.01	774.91	219.76	757.85	3.26
Cyclamen 2	20:80	5.12	29.10	62.09	0.16	3.83	509	0.07	0.28	5735	361.76	5.26	0.01	739.92	194.73	751.89	3.02
Cyclamen 1	0:100	5.24	27.24	58.67	0.17	3.84	476	0.08	0.25	5915	300.47	4.65	0.01	749.37	194.85	848.53	2.97
Geranium 3	30:70	3.73	36.00	2.57	0.36	4.99	548	0.15	0.87	2008	878.77	34.29	0.01	371.85	525.25	80.13	6.16
Geranium 2	20:80	3.57	42.24	0.37	0.34	4.96	580	0.14	0.88	1717	968.06	36.21	0.01	434.17	544.45	84.35	5.25
Geranium 1	0:100	3.66	38.52	0.14	0.27	4.35	240	0.09	0.55	1575	807.94	28.60	0.01	357.40	477.42	66.97	4.80
Pansy 3	30:70	5.43	13.98	0.43	0.10	2.27	1060	0.29	0.35	1350	1070.35	15.56	0.12	91.35	446.45	173.82	2.45
Pansy 2	20:80	5.97	14.88	0.72	0.14	2.37	1056	0.41	0.48	1416	1052.61	17.20	0.30	105.88	407.30	134.76	2.68
Pansy 1	0:100	5.74	10.26	0.34	0.13	2.18	881	0.24	0.32	799	862.37	14.16	0.19	79.82	322.53	120.91	2.36

Appendix 12. Trial 4 data and statistical analysis

Table 1. Plant width observations (mm) and statistical analysis

Analysis of variance

Variate: PLTWDT_14_07_2020

Source of	d.f.	s.s.	m.s.	v.r.	F pr.	
Treatment	3	12898.9	4299.6	11.25	<.001	***
Residual	92	35156	382.1			
Total	95	48055				

Tables of means

Grand mean 138.0

Treatment	T1	T2	T3	T4
	137	156.8	133	125.4

s.e.d.	5.64
l.s.d.	11.21
cv%	14.2

Sig diff
T1 & T2
T1 & T4
T2 & T3
T2 & T4

Analysis of variance

Variate: PLTWDT_18_08_2020

Source of	d.f.	s.s.	m.s.	v.r.	F pr.	
Treatment	3	16655	5551.7	12.84	<.001	***
Residual	92	39791.5	432.5			
Total	95	56446.5				

Tables of means

Grand mean 168.9

Treatment	T1	T2	T3	T4
	156.6	190.2	159.5	169.2

s.e.d.	6
l.s.d.	11.92
cv%	12.3

Sig diff
T1 & T2
T1 & T4
T2 & T3
T2 & T4

Plant width observations in mm, 14/07/2020

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Irrigation	high	high	low	low
Crop height humidity	low	high	low	high
Observations	123	162	130	121
	156	130	120	142
	121	138	127	124
	126	142	131	109
	132	181	146	152
	135	147	127	167
	113	183	179	118
	149	187	151	154
	114	175	125	115
	147	142	119	113
	127	181	135	153
	135	157	123	157
	160	181	114	110
	167	181	132	126
	148	170	142	118
	148	155	128	127
	147	153	142	135
	133	141	127	113
	100	96	144	76
	150	180	130	141
	146	172	161	137
	128	140	114	105
	136	125	118	85
	146	143	126	111
SE	16.1	23.1	15.3	22.4
Average	137.0	156.8	133.0	125.4

Plant width observations in mm, 18/08/2020

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Irrigation	high	high	low	low
Crop height humidity	low	high	low	high
Observations	172	150	162	140
	165	187	180	156
	150	185	157	195
	131	163	140	167
	160	191	168	183
	154	200	180	230
	152	196	175	165
	148	231	155	190
	173	221	132	176
	160	187	129	166
	172	223	153	180
	171	210	167	196
	186	213	152	167
	182	217	172	149
	153	201	170	182
	152	173	158	157
	146	201	172	200
	174	195	160	155
	112	147	176	102
	170	182	165	191
	151	197	153	147
	130	160	152	143
	125	163	153	162
	170	172	146	162
SE	18.5	23.2	13.9	25.6
Average	156.6	190.2	159.5	169.2

Table 2. Number of flower stem observations and statistical analysis.

Analysis of variance

Variate: log_flowers data transformed for analysis

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Treatment	3	0.22611	0.07537	1.63	0.187	N.S.
Residual	92	4.24565	0.04615			
Total	95	4.47176				

Tables of means

Grand mean 0.09

Treatment	T1	T2	T3	T4	Sig diff
	0.12	0.15	0.03	0.06	none

s.e.d.	0.062
l.s.d.	0.123
cv%	241.4

Plant number of flower stems, 18/08/2020

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Irrigation	high	high	low	low
Crop height humidity	low	high	low	high
Observations	0	0	0	0
	3	0	0	0
	0	0	0	0
	0	0	0	0
	0	6	1	0
	1	1	0	0
	1	0	0	0
	0	0	0	0
	0	2	0	4
	0	0	0	0
	5	2	0	0
	1	4	0	5
	0	0	0	0
	0	5	0	0
	3	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	1	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
SE	1.3	1.7	0.3	1.3
Average	0.6	0.8	0.1	0.4

Table 3. Fresh weight of above ground growth observations (g) and statistical analysis

Analysis of variance

Variate: weight_in_grams

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
Treatment	3	377.75	125.92	12.24	<.001	***
Residual	92	946.25	10.29			
Total	95	1324				

Tables of means

Grand mean 13.75

	Treatment	T1	T2	T3	T4	Sig diff
		14.21	15.75	10.46	14.58	T1 & T3
			13.911			T2 & T3
s.e.d.	0.926					T3 & T4
l.s.d.	1.839					
cv%	23.3					

Plant fresh weight of above ground growth in grams, 18/08/2020

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Irrigation	high	high	low	low
Crop height humidity	low	high	low	high
Observations	12	13	7	13
	14	16	9	13
	15	14	10	18
	12	12	4	11
	15	19	12	17
	12	18	13	19
	19	16	14	14
	18	18	18	20
	18	21	10	18
	9	16	6	9
	15	20	9	17
	11	15	13	17
	12	16	12	19
	17	18	11	15
	17	19	12	17
	11	14	9	9
	15	15	13	17
	15	15	10	15
	15	6	12	12
	17	16	14	16
	17	21	7	13
	12	13	8	7
	12	11	8	10
	11	16	10	14
SE	2.8	3.4	3.1	3.6
Average	14.2	15.8	10.5	14.6

Appendix 13. Trial 4 Leaf tissue SAP and Growing Media analysis results

Table 1. Laboratory analysis of leaf tissue (SAP).

Observations on leaf tissue SAP analysis, sampled 14/07/2020

RESULTS (are expressed as mg/l)

Treatment	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
Primrose T1	6.78	32.70	129.78	0.24	3.32	334	0.55	0.73	3758	405.62	2.83	1.49	173.95	411.56	317.43	2.87
Primrose T2	6.74	28.74	98.58	0.17	3.44	279	0.49	0.55	3588	322.80	2.61	0.87	79.96	468.74	223.07	3.25
Primrose T3	6.87	28.14	149.70	0.12	2.86	244	0.18	0.28	3617	381.36	2.27	0.40	131.51	381.68	238.95	2.18
Primrose T4	6.87	41.52	305.22	0.15	3.02	200	0.34	0.61	4851	405.27	2.95	0.40	164.78	491.49	287.20	2.73

Observations on leaf tissue SAP analysis, sampled 18/08/2020

RESULTS (are expressed as mg/l)

Treatment	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
Primrose T1	6.42	31.56	7.92	0.09	3.30	916	0.16	0.17	4389	797.79	4.63	0.01	345.71	363.40	558.37	3.60
Primrose T2	6.39	28.50	6.60	0.10	2.82	671	0.14	0.14	3793	590.42	3.51	0.01	134.93	316.94	337.86	3.28
Primrose T3	6.41	30.84	14.40	0.07	3.03	546	0.21	0.23	4139	574.34	3.56	0.01	262.99	409.92	424.10	3.28
Primrose T4	6.36	38.22	13.80	0.10	3.44	732	0.16	0.20	4975	852.82	4.57	0.01	391.79	473.12	658.94	3.50

Table 2. Laboratory analysis of growing media.

Growing media analysis, sampled 18/08/2020

RESULTS (are expressed as mg/l)

Treatment	pH	EC @20c	density	dry matter	dry density	Cl	P	K	Mg	Ca	Na	NH4	NO3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
Primrose T1	6.5	145	530	21.9	116.1	70.4	9.9	5.2	15.5	21.6	58.2	6.5	3	9.4	138.1	0.17	0.02	<0.01	0.04	0.16
Primrose T2	6.6	100	466	23.1	107.6	48.1	4	2.9	7.5	12	35.3	1.2	<0.6	1.2	66.6	0.11	0.01	<0.01	<0.02	0.13
Primrose T3	6.2	212	472	25.4	119.9	95.1	16.3	14	33.3	39.3	74.6	1.8	4.6	6.4	236.3	0.14	0.02	0.07	0.04	0.16
Primrose T4	6.4	159	530	27.6	146.6	73.9	9.4	5.8	20.8	25.6	55.7	1.1	1.3	2.4	154.7	0.14	0.02	0.01	<0.02	0.23

The extraction is performed by adding a weight of sample equivalent to 60mls volume to 300mls of deionised water (ref BSEN 13652:2001).

Appendix 14. Trial 4 Environmental observations

Table 1. Average observations of crop heigh humidity from data collected by Blue Maestro™ disc monitors

	Treatment 1			Treatment 2			Treatment 3			Treatment 4		
Irrigation	high			high			low			low		
crop height humidity	low			high			low			high		
Observations	average	max	min	average	max	min	average	max	min	average	max	min
temperature (°C)	24.2	52.5	12.0	21.3	39.3	16.2	25.4	59.3	11.6	21.3	35.6	12.0
humidity (%)	79.8	113.8	11.6	104.2	118.9	80.0	67.8	110.2	10.5	94.7	118.9	44.5
dewpoint (°C)	19.3	43.7	6.4	23.2	36.1	18.7	17.2	41.9	6.1	20.6	34.8	11.8

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