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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

In Primula both Calcium and Boron nutrition can be improved by adjusting the growing media pH and by reducing humidity at crop height.

In bedding crops grown with overhead irrigation systems nutrient leaching and pH increases occur and can lead to loss of availability of key nutrients.

The delivery method for liquid fertilizer can have a greater impact on plant growth than the composition of the growing media, when using peat reduced mixes with coir, perlite or wood fibre.

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. In order to make nutritional recommendation for different crops 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 year one of this four-year project the target was to obtain data on the interactions between pot size, growing media, irrigation system, pH and environment by running experimental work on three key bedding species. The focus for the experiments was determined by the outcome of the scoping study in which we identified the most prevalent types of production setup and the problem crops for nutrition.

Three trials were undertaken in this year, one each on Petunia, Pansy and Primula.

The longer-term study on Nitrogen nutrition in field grown Narcissus was also established during this year the aim of which is to review the current advice available in RB209. Trials have been established in Cornwall and Lincolnshire and in year 1 base line observations have been taken. The first findings from these trials will be available in 2021 and be presented in the next annual report.

Summary

In order to investigate the different variables, a bespoke table system was set up in the glasshouses at the NIAB trial site in Cambridge to look at the impact of using different irrigation systems to delivery liquid feed to Petunia and Pansy plants. The Petunia trial was run during spring/summer of 2019, using F1 hybrid ‘Frenzy Blue Vein’ grown in 13cm 5deg 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. The trial was repeated in the autumn for Pansy using ‘Matrix® Blue Blotch’ 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. Two tables of each irrigation systems were used, and feed was introduced to only one of those.

Plants in each of the three different growing media mixes were put on each of the different set ups and grown to flowering stage.

Figure 1. Trial setup with Petunia in 13cm pots

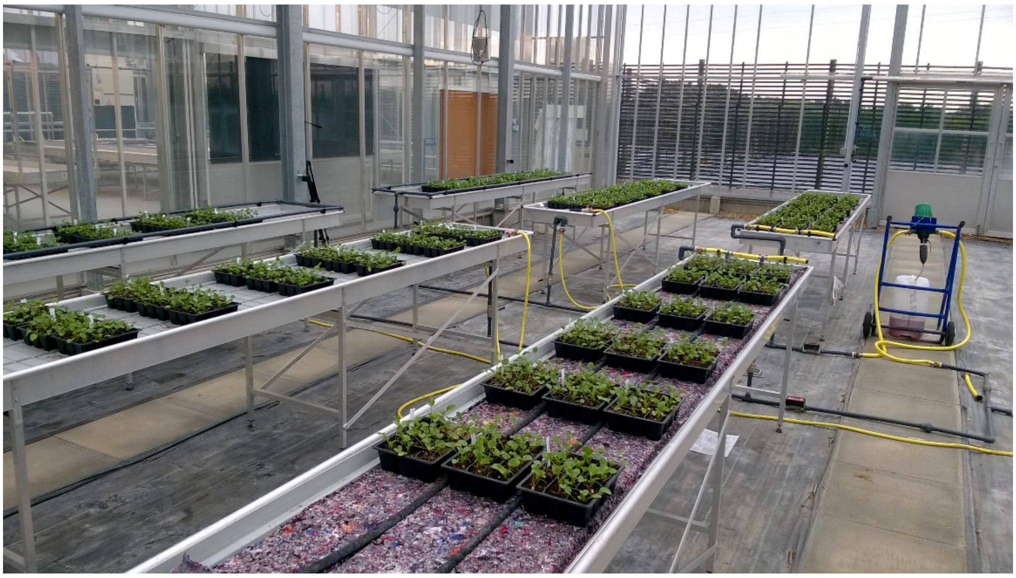


Figure 2: Trial setup with Pansy in 12-cell packs

To assess the performance of each combination of growing media x irrigation type x feed, observations on fresh weight were made. Weekly monitoring of growing media pH and EC was carried out, and laboratory testing of growing media and leaf tissue was done at the end of the trial.

In both trials good results were achieved from all growing media mixes when feed was applied via the overhead or ebb and flood irrigation. However, the peat and perlite and peat and coir mixes performed better than the peat and wood fibre mix, which showed early symptoms of Phosphorus deficiency which was confirmed by the tissue analysis.

In the summer trial the petunia plants grown on capillary matting were visually acceptable but had lower fresh weight than the other two systems. In the autumn pansy trial, the plants grown using capillary matting were very poor due to accumulation of salts in the growing media and a degree of waterlogging.

From our records on water usage it was possible to see that the capillary matting system had used most water, which resulted in overwatering at that period of the year. The lowest water input (and consequently lowest feed) was on the overhead irrigation system, and statistically these performed as well as the ebb and flood system which received more water and therefor more feed.

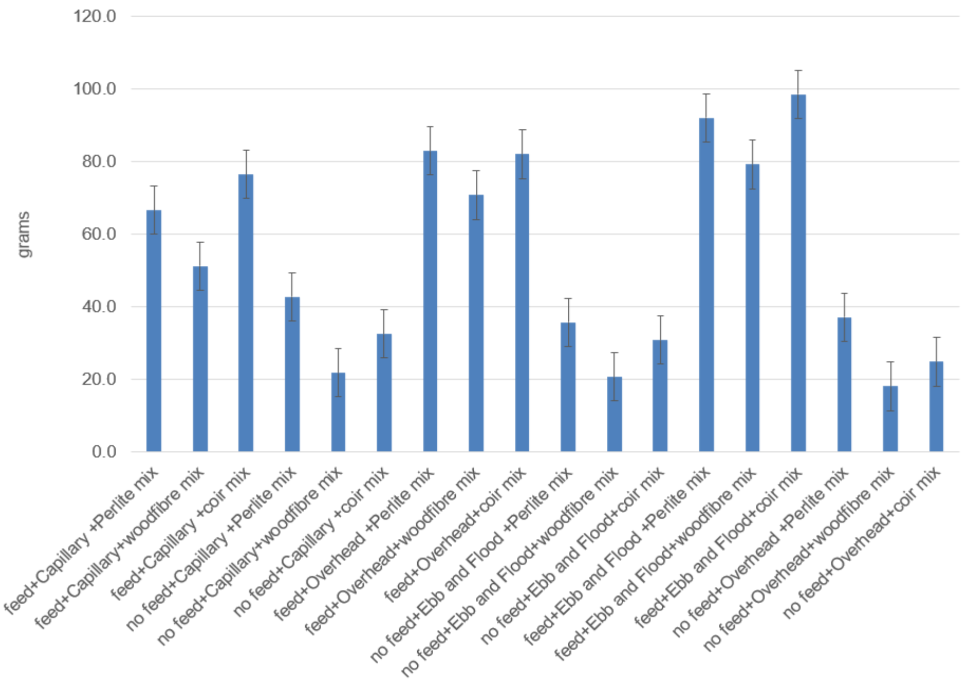


Figure 3: Fresh weight results for Petunia plants grown under the different irrigation x growing media x feed combinations. Bars represent least significant difference between treatments at a 95% confidence interval

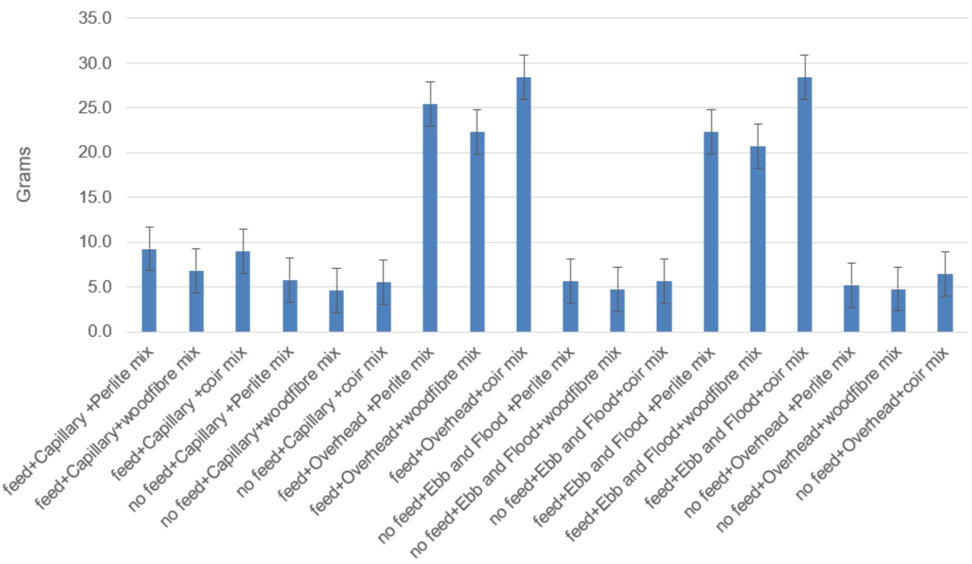


Figure 4: Fresh weight results for Pansy plants grown under the different irrigation x growing media x feed combinations. Bars represent least significant difference between treatments at a 95% confidence interval

By monitoring the pH of the growing media every week, we could see that pH altered with the different irrigation systems as the trial progressed, pH increased where overhead irrigation was used, and all the growing media mixes were affected in the same way.

We also monitored the pH of the run-off from the ebb and flood irrigation system and the overhead irrigation system.

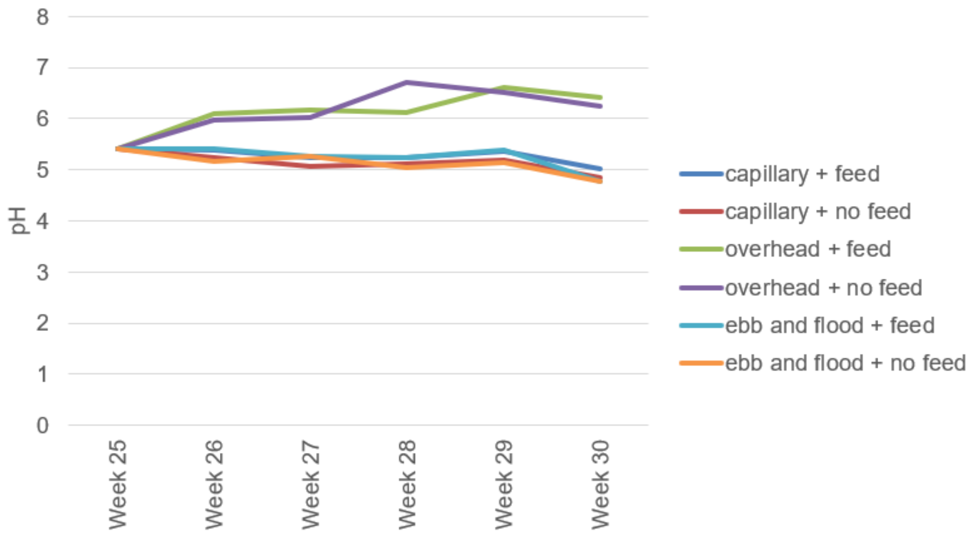


Figure 5. pH over duration of trial in peat and wood fibre mix growing media treatments

From the experimental work carried out we have seen a direct interaction between the irrigation water added through an overhead system and the amount of nutrients flushed out of the growing media (run-off). The high alkalinity of this irrigation water has raised the pH of the growing media through the life of the crop meaning elements such as P, Fe, Mn and Boron are less available. Acidifying the irrigation water to correct the high alkalinity will prevent pH movement and allow all nutrients to be available reducing the potential need to increase certain nutrients and use a more balanced (if not reduced) liquid feed.

The investigations into Primula focussed on the symptoms of 'leaf edge scorch' to see how the nutrition could be improved to reduce this problem. Deficiency symptoms for both Boron and Calcium can be seen as tissue necrosis, and work in other crops (Collier, G.F & Tibbitts, T.W. 1984) suggest this is made worse under conditions that reduce transpiration. Growing media pH is also a factor in the availability of the nutrients, with Boron and Calcium being more available in different parts of the pH scale.

The experimental work compared Primula plants grown under lower and higher humidity conditions in a range of growing media pH, in order to try and force the expression of tissue necrosis. Tissue and growing media analysis at the end of the trial was used to see what the impact of the different conditions had been.

Table 1. Treatments for Primula 'leaf edge scorch' investigation

Code	Description	Growing media spec.	Feed specification
A	'Optimal'*	Levington M2, pH 6.3	125ppm N plus TE
B	High EC	Peat reduced mix, pH 6.9	190ppm N plus TE
C	High pH	Peat reduced mix, pH 7.2	125ppm N plus TE
D	Low pH	Peat and coir mix, pH 6.3	125ppm N plus TE (and added Nitric Acid)

Figure 6. Marginal necrosis observed in high humidity conditions

Marginal necrosis was seen, but only where there was good growth and leaves were expanding rapidly.

The results of the analysis show that Calcium is present in the leaf tissue in higher amounts under the lower humidity conditions. For Boron the same is true for treatments A and B however, in D the 'low pH' treatment the opposite has been observed with higher levels of B in high humidity conditions and to a lesser extent the same is true for treatment C.

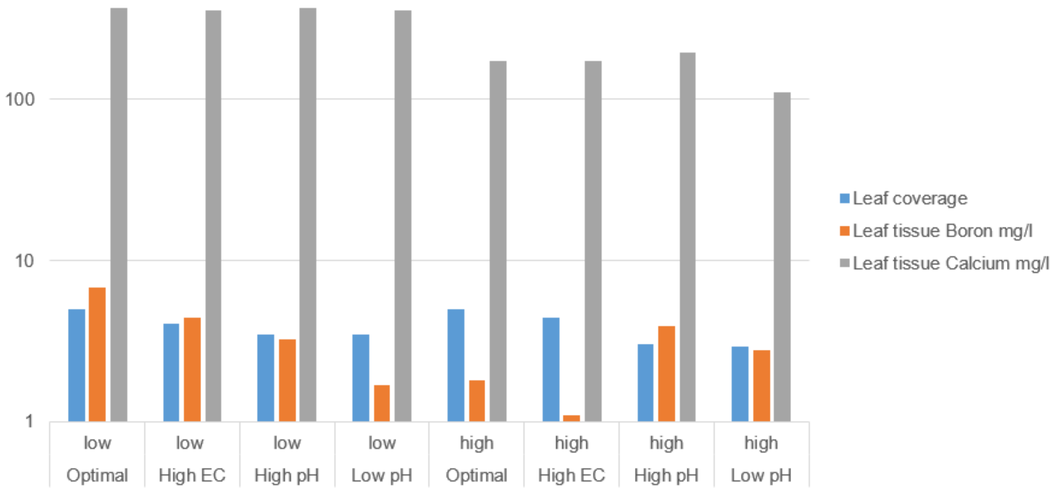


Figure 7. Comparison of observations for leaf coverage the tissue analysis results for Boron and Calcium

The environmental data obtained shows an average difference in humidity of around 10% between the high and low treatments, this reduction appears enough to improve Calcium and Boron content in the tissue.

Where Calcium levels were low in the leaf tissue under high humidity conditions, analysis shows that it was present in the growing media in significant quantities.

Financial Benefits

By adapting irrigation methods to time of year savings on water and fertilizer use can be made. Results indicate that during summer a reduction in water and fertilizer cost of 35% could be made using capillary matting.

Action Points

- In period of low transpiration be vigilant of overwatering and accumulation of salts (nutrients) in irrigations systems using capillary matting.
- Reduce humidity in the glasshouse to improve calcium and boron content in plants. This may reduce the risk of scorch symptoms
- EC is only a method for measuring total ions. Undertake sampling and laboratory testing of irrigation water to get a clear understanding of the amount and type of nutrient ions that are present in the water supply. This can prevent unnecessary fertilizer use and avoid potential nutrient toxicity.

SCIENCE SECTION

Introduction

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. In order to make nutritional recommendation for different crops 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.

The availability of nutrients in ornamental plant production can be affected by a number of factors: the delivery method for the fertilizer, the physical and chemical properties of the growing media, irrigation method, environmental conditions, and in containerised plants the pots size, shape and drainage design. The plants themselves have different requirements and also have the ability to impact the uptake by altering the root rhizosphere.

Less than optimum supply of nutrition can impact plants in terms of speed of growth, time to flowering, size and quality. In rapid growing crops such as the bedding sector, where production time can be as little as 10 weeks there is little time to rectify nutritional deficiencies, and less than high quality plants will impact saleability. Production schedules to meet key sale dates mean that knowledge of how growth can be manipulated by increasing or decreasing nutrition input is an important tool.

As identified in the scoping study, significant work has been carried out on some aspects of crop nutrition with direct relevance to the pot plants and bedding sector (Johnson *et al* 2013). Good understanding on the interaction between plants, substrate and composition of water-soluble fertilizer exists, including some tested models for prediction of effect on substrate pH (Fisher *et al* 2014b). However, much of this work relates to 100% peat based growing media and will have less relevance to peat reduced and peat free growing media mixes. Following the work done in the AHBD Defra funded project CP138, there is good understanding of the physical properties needed for growing media and how this can be achieved with responsibly sourced peat alternatives.

The work completed in year one of PO BOF 003 looked at the variables affecting nutrient availability using peat reduced mixes in conjunction with three bedding species.

The longer-term study on Nitrogen nutrition in field grown Narcissus was also established during this year the aim of which is to review the current advice available in RB209.

Materials and methods

During 2019 to 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 third trial was undertaken to look at how environment and growing media pH affected boron and calcium nutrition in Primula (work package 7).

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

Trial 1

The investigation was untaken between May and August of 2019 and was grown in a glasshouse at NIAB's Cambridge trial site. The glasshouse was set to maintain a minimum temperature of 10ºC, no supplementary lighting was provided, and no shade screens were utilised. The trial was carried out on a bespoke 6 growing bench set up all fitted with Stal & Plast liners. Each table was L 383cm x W 63cm x H 75cm with its own individual irrigation method incorporated.

Figure 1. Work package 2 trial set-up

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 10/05/2019 in a heated greenhouse direct in modules using Levington Advance Pot & Bedding M2 growing media. Five weeks after sowing the plants were transplanted into 13cm 5deg H SOPARCO Duo pot T/C, (D – 13.0cm, H – 11.5cm, V – 1.00lt) 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 substrate, and the pH was adjusted to between 5.5 – 6. The peat used was the same for all mixes and was 0-10mm grade, the perlite was 0-6mm grade.

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 2.5ltr/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 ensured only one set was provided with liquid feed (non-return valve fitted). In-line water meters were installed to the irrigation systems so that an accurate record of the volume of water applied at each irrigation event can be maintained. The target irrigation volume for each irrigation system is detailed in below.

Table 1: Water application for each irrigation system per table at each irrigation event

Irrigation system	litres
Ebb & Flood	77.3
Manual Overhead	18.2
Capillary with trickle tape	11.4

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

Where topping up of water was required for individual plants, or during the excessively hot weather experienced during July of 2019, irrigation water without feed was used in all cases.

For the tables receiving feed this was applied via the irrigation system from one week after the potting date, and then at every subsequent irrigation event. The feed was from the OMEX Adjust range, O-Mix 21-7-21 + 1.6MgO+TE which was made up to a stock solution of 1kg/10ltr which was diluted 1:200 using a Dosotron D3 Green Line injector. The resulting feed supplied 105ppm of Nitrogen in the form of 1.6% Ammonium N, 3.4% Nitrate N, 16% Ureic N.

The resulting combination of growing media x irrigation system x feed regime resulted in 18 different treatments as detailed in the table below.

Table 2: Treatment list

Bench	Treatment	Feed	Irrigation System	Growing media mix
5	1	Yes	Ebb & Flood	Peat and perlite
5	2	Yes	Ebb & Flood	Peat and wood fibre
5	3	Yes	Ebb & Flood	Peat and coir
3	4	Yes	Manual overhead	Peat and perlite
3	5	Yes	Manual overhead	Peat and wood fibre
3	6	Yes	Manual overhead	Peat and coir
1	7	Yes	Capillary with trickle tape	Peat and perlite
1	8	Yes	Capillary with trickle tape	Peat and wood fibre
1	9	Yes	Capillary with trickle tape	Peat and coir

6	10	No	Ebb & Flood	Peat and perlite
6	11	No	Ebb & Flood	Peat and wood fibre
6	12	No	Ebb & Flood	Peat and coir
4	13	No	Manual overhead	Peat and perlite
4	14	No	Manual overhead	Peat and wood fibre
4	15	No	Manual overhead	Peat and coir
2	16	No	Capillary with trickle tape	Peat and perlite
2	17	No	Capillary with trickle tape	Peat and wood fibre
2	18	No	Capillary with trickle tape	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.

Weekly observation of growing media EC and pH, and irrigation water EC were made using an EXTECH ExStik II meter. Growing media EC & pH was observed using the SME technique.

Assessments were made 14 weeks after sowing, this consisted of plant height measured in mm, a count of the number of flowers and fresh weight of the plant top growth in grams, 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 (work package 2)

The second investigation took place between September and November of 2019 and was grown in a glasshouse at the Cambridge trial site, under the same conditions and tabletop set up as trial 1.

In trial 2 the test plant was Pansy ‘Matrix® Blue Blotch’, these were obtained from Ball Colegrave as plug plants and were received on 15/09/2019. Three days after receipt the plants were transplanted into H. Smith Plastic 12 cell bedding pack. (D – 23.0cm, W – 17.5cm, H – 6.5cm, Volume: 0.104lt.) using the same three peat reduced growing media mixes as in trial 1.

The plants were grown under the same irrigation and feed system as in trial 1 which resulted in the same 18 treatments – see table 2 for treatment list.

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 EC of the irrigation and run-off from the treatments with added feed was also observed at each irrigation event.

Table 3: Water application for each irrigation system per table at each irrigation event

Irrigation type	litres
Ebb & Flood	50
Manual Overhead	6
Capillary with trickle tape	9

For the tables receiving feed this was applied via the irrigation system from one week after the potting date, and then at every subsequent irrigation event. The feed was from the OMEX Adjust range, O-Mix 21-7-21 + 1.6MgO+TE which was made up to a stock solution of 0.95kg/10ltr which was diluted 1:200 using a Dosotron D3 Green Line injector. The resulting feed supplied 100ppm of Nitrogen in the form of 1.6% Ammonium N, 3.4% Nitrate N, 16% Ureic N.

For each of the 18 treatments 6 x 12 plant cell packs were grown, the cell packs were 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.

Weekly observation of growing media EC and pH, and irrigation water EC were made using EXTECH ExStik II meter.

Assessments were made 8 weeks after transplanting, this consisted of plant height measured in millimetres, a count of the number of flowers and fresh weight of the plant top growth in grams, 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.

In both trials no chemical pest and disease treatment was undertaken, control of pests was via a program of biological control agents. No plant growth regulator applications were made.

The irrigation water was mains water supply for the Cambridge area, with no onsite acidification. During the trials a chemical analysis of the irrigation water used was undertaken and the results are detailed below.

Table 4: Chemical analysis of irrigation water (sample dated 07/08/2019)

REF.	PH	EC @20c	Alkalinity as HCO3	Hardness as CaCO3	CL	P	K	Mg	Ca	Na
water untreated	7.50	602.00	272.00	309.50	32.40	1.00	2.80	3.60	118.00	12.00
	carbonate	NO_3	Sulphate as SO4	B	Cu	MN	Zn	Fe	Total particulates (mg/L)	
	<10	8.80	28.50	0.03	<0.01	<0.01	0.01	<0.01		788.64

It is recognised that irrigation water varies across the country, water can be extracted/collected by different methods and come from different geological regions, the alkalinity of 9 different combinations is considered by Bragg (1995). According to the analysis the water used in the trials can be considered very hard and will be the main source of Calcium and Magnesium ions.

<u>Trial 3 (work package 7)</u>

The third trial undertaken was to see under what conditions Primulas may express the symptoms of 'leaf edge scorch', and how that may be related to the availability of Calcium and Boron. The trial was a preliminary investigation to inform the trial design for year two and three of the project which will go on to look at optimum nutrition for this crop.

The investigation was undertaken between October 2019 and March 2020 and 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 an ebb and flood liner.

In trial 3 the test plant was Primula 'Cresendo® Bright Red' these were obtained from Ball Colegrave as plug plants and were transplanted on 25/10/2019 into 9cm 5degree pots using combinations of different growing media and feeds to create four different treatments. These were designed to vary the availability of the different key nutrients as the trial progressed, with the main emphasis on manipulating the growing media pH.

Table 5. Treatments for Primula 'leaf edge scorch' investigation

Code	Description	Growing media specification	Feed specification
A	'Optimal'*	Levington M2, pH 6.3	125ppm N plus TE
B	High EC	Peat reduced mix, pH 6.9	190ppm N plus TE
C	High pH	Peat reduced mix, pH 7.2	125ppm N plus TE
D	Low pH	Peat and coir mix, pH 6.3	125ppm N plus TE (and added Nitric Acid)

* based on guidance in Primula Culture and Production, M.G Karlson. (2001) HortTechnology, October-December 11(4) pg. 627 – 635

All plants were watered manually using an overhead lance; this was using untreated mains water.

Irrigation events were determined by the requirements of the plants and all treatments were allowed to drain freely following irrigation events, with no water recycling.

The feed treatments were applied as a liquid feed which was made up from a 1 litre stock solution containing Potassium nitrate 91.24 grams, mono Potassium phosphate 5.7 grams and trace elements from Hortifeeds TE Bmix 2 grams. The stock solution was diluted at two different rates, 1:100 to give treatments A, C and D, and 1:75 to give the high EC treatment B. The different treatments were applied using a syringe to the individual pots from one month after the potting date, and then weekly after that. At each feed event a 20ml dose was applied, supplying Nitrogen as detailed in table 5.

50 plants were grown for each of the four treatments; these were arranged in a randomised block layout on the table. After the first month, half of the plants from each treatment were taken and put under frames to create a higher humidity environment. The temperature and humidity were monitored at plant height using Blue Maestro Tempo Disc™ 3 in 1 Bluetooth environmental monitors.

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

Fortnightly observation of growing media EC and pH, and irrigation water EC were made.

Assessments were made at the end of the trial, this consisted of length of a fully expanded typical leaf, and coverage of the pot surface by the leaves on a 1 to 5 scale, with the following states: 1 – <10%, 2 – 25% , 3 – 50% , 4 – 75% , 5 – >90%

Data was not statistically analysed in this initial trial.

Photographs of plant and roots from each of the treatments were also taken.

A sample of plant tissue and growing media from each treatment was sent for laboratory analysis at the end of the trial. A bulk sample was taken for each treatment made up from 10 randomly selected plants.

No chemical pest or disease treatment was undertaken, control of pests was via a program of biological control agents.

No plant growth regulator applications were made during the trial.

Chemical analysis of the irrigation water used was undertaken and the results are detailed in table 6.

Table 6: Chemical analysis of irrigation water (sample dated 16/03/2020)

REF.	PH	EC @20c	Alkalinity as HCO3	Hardness as CaCO3	CL	P	K	Mg	Ca	Na
water untreated	7.5	609	274	322.8	37.1	0.9	2.2	3.85	122.9	14.7
	carbonate	NO_3	Sulphate as SO4	B	Cu	Mn	Zn	Fe	Total particulates (mg/L)	
	<10	8.9	29.3	0.01	<0.01	<0.01	<0.01	<0.01		426

Trial 4 and 5 (work package 6)

The trials are to investigate the application of Nitrogen as a top dressing in field grown Narcissus, taking the current guidance into consideration but also looking at the effect on yield versus incidence of basal rot caused by *Fusarium oxysporum* f.sp. *narcissi* (FON), as increased Nitrogen appears to give increased incidence of disease. The trial will also investigate if timing of applications can improve yield; currently the timing of application of Nitrogen for this crop is limited by NVZ restrictions.

Two sites were chosen from different growing areas to investigate application rates in different soil type, and different harvesting dates.

Sites were chosen in Cornwall and Lincolnshire where the trials will take place over 3 years on a single planting of bulbs at each site.

Details of the two sites are as follows:

Lincolnshire trial host: Jack Buck Farms

Location: Moulton, Spalding, Lincolnshire

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

Cornwall trial host: Greenyard Flowers

Location: Trispen, Truro

Planting year: 2019

Variety: Karenza

Previous cropping: Potatoes

Fertiliser: None applied

Aspect: gentle slope, north facing

Soil: Freely draining slightly acid loam

At each site the trial will consists of 8 treatments replicated 4 times giving a total of 32 plots in randomised design which will remain consistent over the 3 years. The plot size is 2 rows x 12m with a buffer zone of 2 rows between plots to ensure that is no influence from the other plots.

Prior to flowering in year 1, all treatment will be according to the host farmers normal agronomic practice. In year 2 and 3 the amount and timing of N application will be varied according to the following list. In all other respects the trial area will undergo the same agronomic practices as standard, including harvesting and application of sprays.

Table 7. Treatment list with application rate and timing

Treatment	Application rate of N	Application timing
A	30kg/ha	at leaf emergence
B	50kg/ha	at leaf emergence
C	80kg/ha	at leaf emergence
D	30kg/ha	after 15th January
E	50kg/ha	after 15th January
F	80kg/ha	after 15th January
G	controlled release product *	Based on product recommendation
H	None (control)	

*composition to be defined in discussion with industry partners

The timing of application at leaf emergence is expected to be at different times at the two sites, reflecting the difference in flowering period for the two areas. For both areas it is anticipated that in a normal flowering year this will fall within the NVZ closed period (1st September to 15th January).

All observations should be made at the time that picking would normally occur, but before picking commences. In year 1 base line observations will be taken with which to compare the data obtained in years 2 and 3. In years 1 and 2 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.

In addition to this in year 3, bulbs from a 2m section of a row will be lifted from each plot and scored for symptoms of basal rot on a 1 to 5 scale, from absent to very severe, plus measurement of dry weight.

Results

Trial 1

For all treatments observations on plant height, fresh weight and number of flowers were taken and statistically analysed (ANOVA). The outcome of the results showed the same pattern between the different treatment so fresh weight is used here to illustrate the outcome, as it is potentially the most useful measure.

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

- that a significant difference was seen between the fed and unfed treatment
- a significant difference was seen between all irrigation types, with highest fresh weight in ebb and flood, followed by overhead and then capillary
- that plants grown in the wood fibre mix had the lowest fresh weight, irrespective of irrigation type

Of the fed treatments it can be seen at the same level of confidence, that the combination of ebb and flood irrigation and either the perlite or coir mixes gave the highest fresh weight. However, we can say that all plants in the treatments with feed produced a visually acceptable product irrespective of combination of growing media and irrigation type.

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

Variable	Code	Types
Feed	N	No feed applied
	Y	Feed applied
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

Table 9. Summary of results for treatments receiving feed for plant fresh weight (grams) observed 07/08/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	7	8	9	1	2	3	4	5	6
SE	17.46	11.47	10.24	12.53	13.36	10.45	22.37	13.06	18.36
Average	66.6	51.3	76.5	92.1	79.2	98.5	83	70.8	82

Table 10. Summary of results for treatments with no feed for plant fresh weight (grams) observed 07/08/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	16	17	18	10	11	12	13	14	15
SE	9.18	5.21	6.35	7.19	2.78	4.11	4.42	3.59	2.24
Average	42.9	21.8	32.5	37.2	18.1	24.9	35.7	20.7	30.8

Full tables of results for all observations can be found in Appendix 1.

The pictures in figure 2 below show the plants in full flower from all treatments at nine weeks from sowing. From this it is possible to see that all plants are at similar stage of development irrespective of treatment.

Bench 5 treatments 1,2,3
Ebb and Flood
With feed

Bench 3 treatments 4,5,6
Manual over head
With feed

Bench 1 treatments 7,8,9
Capillary + drip
With feed

Bench 6 treatments 10,11,12
Ebb and Flood
No feed

Bench 4 treatments 13,14,15
Manual over head
No feed

Bench 2 treatments 16,17,18
Capillary + drip
No feed

Figure 2: Petunia ‘Frenzy Blue Vein’ in all treatments on 12/7/2019 - 9 weeks from sowing date.

During w/c 1st July 2019 symptoms of nutrient deficiency were first seen, this was purpling of mature leaf which indicated a lack of Phosphorus. This was seen in the wood fibre mix grown under ebb and flood irrigation where no feed was given. The same symptoms appeared within seven days on all unfed treatments grown in the wood fibre mix, and in the wood fibre mix grown under ebb and flood irrigation with feed.

Figure 3: Petunia 'Frenzy Blue Vein' treatment 2 on 1/7/2019 – 7.5 weeks from sowing date, show symptoms of P deficiency.

During the second half of July further deficiency symptoms appeared, all the unfed treatments had yellowing of the older leaves indicating Nitrogen deficiency, which would be anticipated.

Comparing the results of the fresh weight with the tissue and growing media analysis in table 9 it is possible to see that Phosphorus levels in the leaf tissue are lowest in each of the different irrigation systems for the wood fibre mix, apart from the ebb and flood where the coir mix is the lowest.

Leaf tissue Potassium levels are highest in the coir in each of the different irrigation systems.

The amount of Nitrogen in the leaf and the form varies between irrigation types, and between growing media mixes. There is not however a positive correlation between total Nitrogen in the leaf tissue and the fresh weight results, the treatments (1 and 3) with highest fresh weight having the highest total N and the second lowest total N respectively.

Table 11. Summary of results for treatments receiving feed for plant fresh weight (grams) and growing media and SAP analysis -samples taken 7/8/2019

Irrigation type	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment no.	7	8	9	1	2	3	4	5	6
SE	17.46	11.47	10.24	12.53	13.36	10.45	22.37	13.06	18.36
Average	66.6	51.3	76.5	92.1	79.2	98.5	83	70.8	82
Leaf tissue SAP results									
NH_4	90	120	48	160.00	100.00	38.00	42	40.00	30
NO_3	188	186	120	430	260.00	165.00	348	260.00	276
total N	278	306	168	590	360	203	390	300	306
K	2738	2413	4269	3327	2527	4405	2103	2550	6040
P	78.78	54.53	57.05	200.7	132.90	90.50	199.70	119	136.10
Growing media analysis									
pH	5.50	5.70	4.50	5.70	5.70	4.40	6.50	6.60	5.90
EC @ 20c	338	363	319	510	325	303	142	149	112

The treatments without feed show similar trends for levels of Phosphorus in the leaf tissue, with the lowest in wood fibre mixes across all irrigation types.

Table 12. Summary of results for treatments with no feed for plant fresh weight (grams) and growing media and SAP analysis -samples taken 7/8/2019

Irrigation type	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment no.	16	17	18	10	11	12	13	14	15
SE	9.18	5.21	6.35	7.19	2.78	4.11	4.42	3.59	2.24
Average	42.9	21.8	32.5	37.2	18.1	24.9	35.7	20.7	30.8
Leaf tissue SAP results									
NH_4	78	128	30	30.00	15.00	6.00	20.00	0.00	24.00
NO_3	0	0	12	0.00	8.00	6.00	0.00	15.00	0.00
total N	78	128	42	30.00	23.00	12	20.00	15	24
K	599.4	481.7	3607	645	462	2998	473	584	3513
P	49.33	25.33	38.06	97.98	27.02	32.90	65.57	40.96	45.51
Growing media analysis									
pH	5.60	5.50	4.60	6.70	6.70	6.00	5.70	5.60	4.50
EC @ 20c	560.00	533.00	436.00	75.00	80.00	73.00	333.00	342.00	378.00

Full tissue and growing media analysis can be found in appendix 2.

The results from weekly observation on growing media pH show similar trends in all three growing media mixes. In the treatments where overhead irrigation is used there is an increase in growing media pH for all mixes, and it remains higher throughout the trial than any treatment grown using ebb and flood, or capillary irrigation. The graph in figure 4 shows the pH over the duration of the trial for peat and wood fibre mix treatments, for the different irrigation systems with and without feed. There is no observable difference between the treatments with and without feed, but it is possible to see the pH under the overhead irrigation increases overtime.

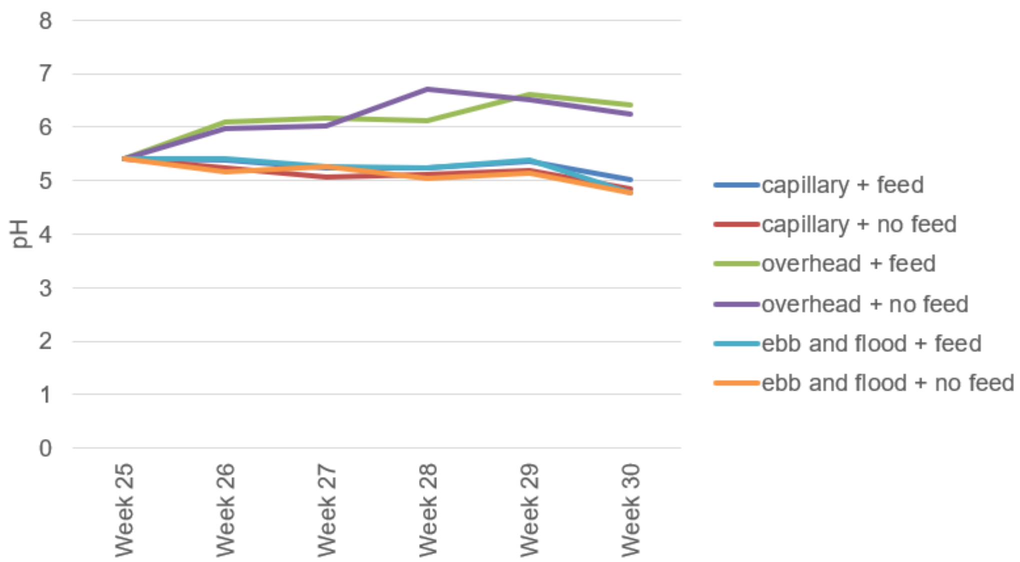


Figure 4. pH over duration of trial in peat and wood fibre mix growing media treatments

The results in the peat and coir mix show the same pattern but the results diverge more, giving a greater diffference in pH between the irrigation types by the end of the trial.

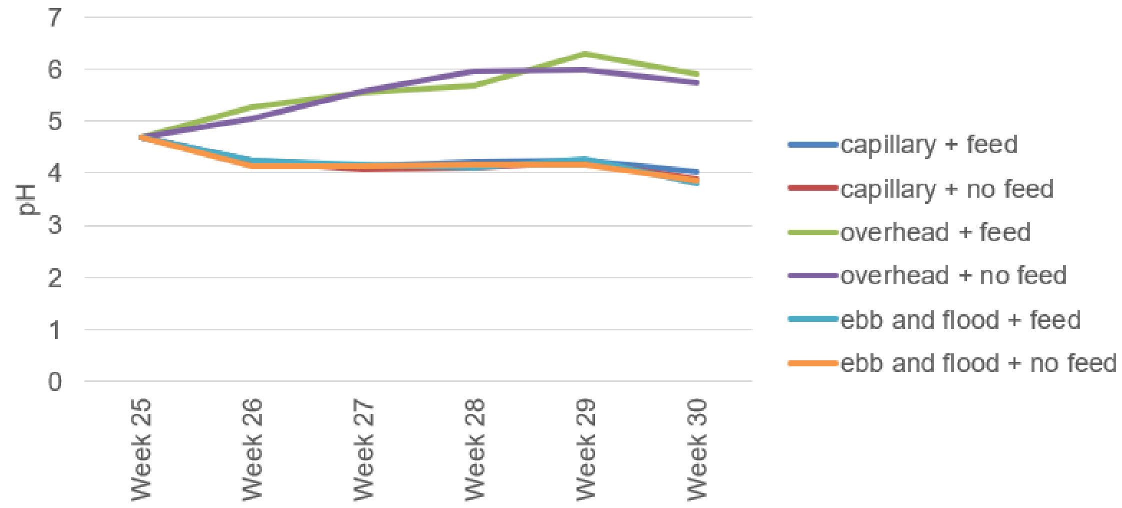


Figure 5. pH over duration of trial in peat and coir mix growing media treatments

The full results of the weekly pH and EC reading can be found in appendix 2.

The weekly EC readings taken for growing media show more variability than those for the pH readings, however it is possible to see trends which are roughly the inverse of those seen with pH. Figure 6 shows the EC reading taken from the six coir mix treatments grown under the different irrigation methods and feed regimes. The EC seen from these reading is lowest in treatments using overhead irrigation, with little difference between fed and unfed treatments in the later week of the trial.

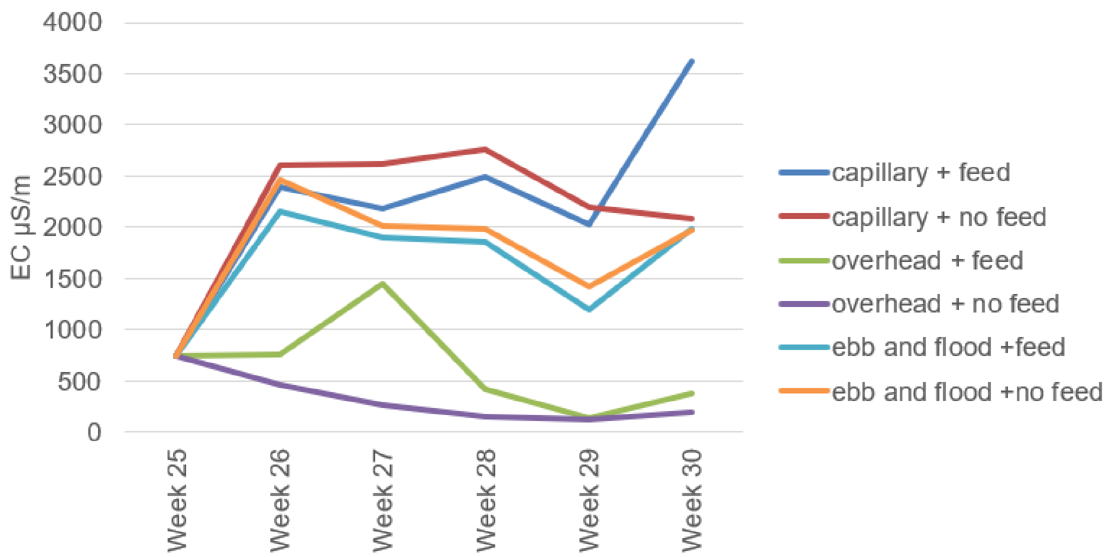


Figure 6. EC over duration of trial in peat and coir mix growing media treatments

Treatments grown with irrigation delivered via capillary matting had the highest EC, with the results for ebb and flood between the other two systems. The trends here appear to be irrespective of the fed regime and are not reflected in the statistical analysis of fresh weight. The highest fresh weight was observed under ebb and flood irrigation, with no statistical difference between the plants grown in the coir, or perlite mixes. The coir mix grown under overhead irrigation was the next highest, which statistically performed the same as the wood fibre mix under ebb and flood irrigation. However, the EC readings at the end of the trial were very different, as all growing media followed the same trends as seen in coir in figure 6.

The growing media analysis taken from the end of the trial sampled 10 days later does show higher EC in the unfed overhead irrigation than we had observed. This may have been a result of increased irrigation events at this time due to the exceptionally hot weather experience at the end of July 2019.

Results from the growing media analysis also showed relatively high levels on Potassium in the coir mix treatments, in the case of the capillary irrigation treatments this was irrespective of the feed regime. Coir mixes showed low levels of Magnesium and Calcium and higher levels of Boron relative to the wood fibre and perlite mixes, and this was the case under all irrigation systems.

Trial 2

For all treatments observations on plant height, fresh weight and number of flowers were taken and statistically analysed (ANOVA). The outcome of the results showed the same pattern between the different treatment so fresh weight is used here to illustrate the outcome.

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

The highest fresh weight was observed in the fed treatments of plants grown in coir mix growing media under the ebb and flood and overhead irrigation systems. No statistical difference was seen between these two treatments

Of the fed treatments, the lowest fresh weights were seen where irrigation was delivered via capillary matting, with the wood fibre mix having the lowest overall. Based on the statistical analysis there was no significance between this treatment and any of the unfed treatments irrespective of the combination of growing media mix and irrigation system.

Of the growing media mixes the wood fibre mix produced lower fresh weights in all irrigation systems.

Table 13. Summary of results for treatments receiving feed for plant fresh weight (grams) observations made 11/11/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	7	8	9	1	2	3	4	5	6
SE	0.7	0.9	0.6	5.1	3.6	3.7	1.8	2.5	3.5
Average	9.3	6.8	9.0	25.5	22.3	28.4	22.3	20.7	28.4

Raw data and statistical analysis can be found in appendix 4

Table 14. Summary of results for treatments with no feed for plant fresh weight (grams) observations made 11/11/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	16	17	18	10	11	12	13	14	15
SE	0.7	1.0	0.6	0.3	0.3	0.5	0.6	0.4	0.2
Average	5.8	4.6	5.5	5.7	4.8	5.6	5.2	4.8	6.4

Only plants in the treatments with feed grown with ebb and flood and overhead irrigation produced a visually acceptable product, irrespective of the growing media.

1 Peat and perlite
Ebb & Flood
Feed

2 Peat and wood fibre
Ebb & Flood
Feed

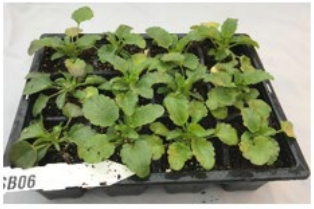

3 Peat and coir
Ebb & Flood
Feed

4 Peat and perlite
Manual overhead
Feed


5 Peat and wood fibre
Manual overhead
Feed

6 Peat and coir
Manual overhead
Feed

7 Peat and perlite
Capillary and trickle tape
Feed


8 Peat and wood fibre
Capillary and trickle tape
Feed


9 Peat and coir
Capillary and trickle tape
Feed

Figure 7. Pansy plant images from fed treatments 1-9 – images taken 11/11/2019

10 Peat and perlite
Ebb & Flood
No feed

11 Peat and wood fibre
Ebb & Flood
No feed

12 Peat and coir
Ebb & Flood
No feed

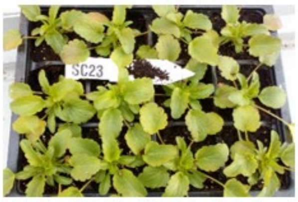
13 Peat and perlite
Manual overhead
No feed

14 Peat and wood fibre
Manual overhead
No feed

15 Peat and coir
Manual overhead
No feed

16 Peat and perlite
Capillary and trickle tape
No feed

17 Peat and wood fibre
Capillary and trickle tape
No feed



18 Peat and coir
Capillary and trickle tape
No feed

Figure 8. Pansy plant images from unfed treatments 10-17 – images taken 11/11/2019

Although there is no significant difference at a 95% confidence interval, between the fresh weight of the plants grown on capillary matting with feed than those grown with no feed under any irrigation system, it was observed that the plants produced flowers which were nearly absent in the unfed treatments.

Observation on 24/10/2019 show a visual difference in plant size, and apparent early stages of deficiency were visible, plants in treatments 7 to 18. All plants in these treatments were paler and slightly yellowing compared with 1 to 6. In the following two weeks purpling of mature leaves was observed in the wood fibre mix in all unfed treatments. In the final observations on 11/11/2019 treatments 7 to 18 all plants were stunted, pale and had significant yellowing of the mature leaves suggesting Nitrogen deficiency; as well as purpling suggesting Phosphorus deficiency.

No deficiency symptoms were seen in treatments 1 to 6 for the duration of the trial.

The growing media analysis results showed very mixed results for different nutrient content, and a much higher EC result for the wood fibre mix on overhead irrigation than observed in our own testing. This appeared to be due to high levels of Zinc, Calcium, Magnesium and Sulphur ions present in the sample, which was not seen in the previous trial.

The results from analysis shows higher Potassium content in the coir mix under all the different irrigation methods, which may in part explain its better performance. This was seen in the previous trial but not in all treatments.

The results for Magnesium and Calcium also show similar pattern to the first trial, however the difference between wood fibre and the other growing media mixes is not a pronounced.

Table 15. Summary of results for treatments receiving feed for plant fresh weight (grams) and growing media analysis - records and samples taken 11/11/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	7	8	9	1	2	3	4	5	6
SE	0.7	0.9	0.6	5.1	3.6	3.7	1.8	2.5	3.5
Average	9.3	6.8	9.0	25.5	22.3	28.4	22.3	20.7	28.4
Growing media analysis									
pH	6.2	5.8	6.0	5.9	6.0	5.9	5.9	5.9	6.2
EC @ 20c	97	102	114	74	73	49	72	131	79
P	1.5	1.0	1.2	1.3	1.6	1.5	1.2	1.4	2.2
K	12.9	7.3	45.5	3.4	4.2	8.5	2.9	3.5	24.2

Table 16. Summary of results for treatments with no feed for plant fresh weight (grams) and growing media analysis - records and samples taken 11/11/2019

Irrigation type code	IC	IC	IC	IA	IA	IA	IB	IB	IB
Growing media type code	SA	SB	SC	SA	SB	SC	SA	SB	SC
Treatment number	16	17	18	10	11	12	13	14	15
SE	0.7	1.0	0.6	0.3	0.3	0.5	0.6	0.4	0.2
Average	5.8	4.6	5.5	5.7	4.8	5.6	5.2	4.8	6.4
Growing media analysis									
pH	6.0	6.2	6.2	6.1	6.1	6.2	6.4	6.2	6.1
EC @ 20c	77	79	81	56	76	89	47	54	59
P	<1	<1	1.1	1.2	1.5	1.6	1.1	1.2	1.1
K	3.1	2.9	33.6	1.7	4.3	31.4	2.3	3.6	22.7

Full details of the growing media analysis can be found in appendix 5.

The results for the weekly analysis of growing media for pH show similar change over time as in the Petunia experiment, with overhead irrigation increasing in pH. However, in the pansy trial the starting pH was higher and resulted in a pH of around 7 for the last three to four weeks of the growing period for all growing media mixes under the overhead irrigation system. Figure 9 shows the pH trend in wood fibre, which is also seen in the other two growing media mixes.

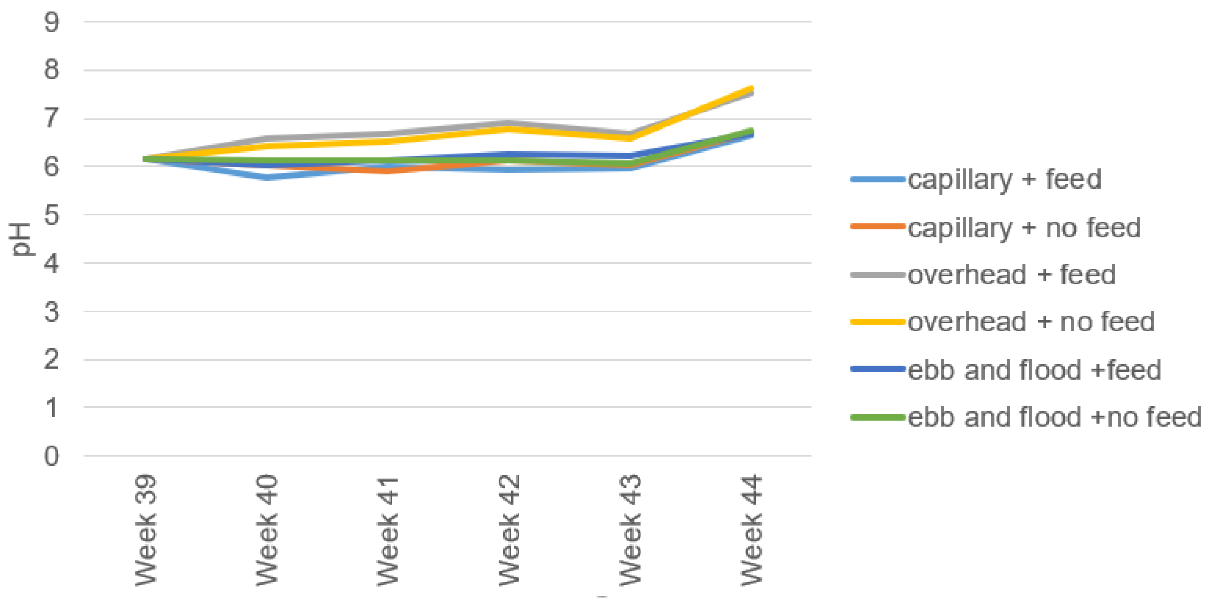


Figure 9. pH over duration of trial in peat and woodfibre mix growing media treatments

Results for the weekly EC readings are very varied but overhead irrigation again gave the lowest final EC readings for all growing media mixes. When comparing the fresh weight results with the growing media analysis, the EC results for the low weight results on capillary matting with feed correspond to higher levels of EC that other irrigation treatments.

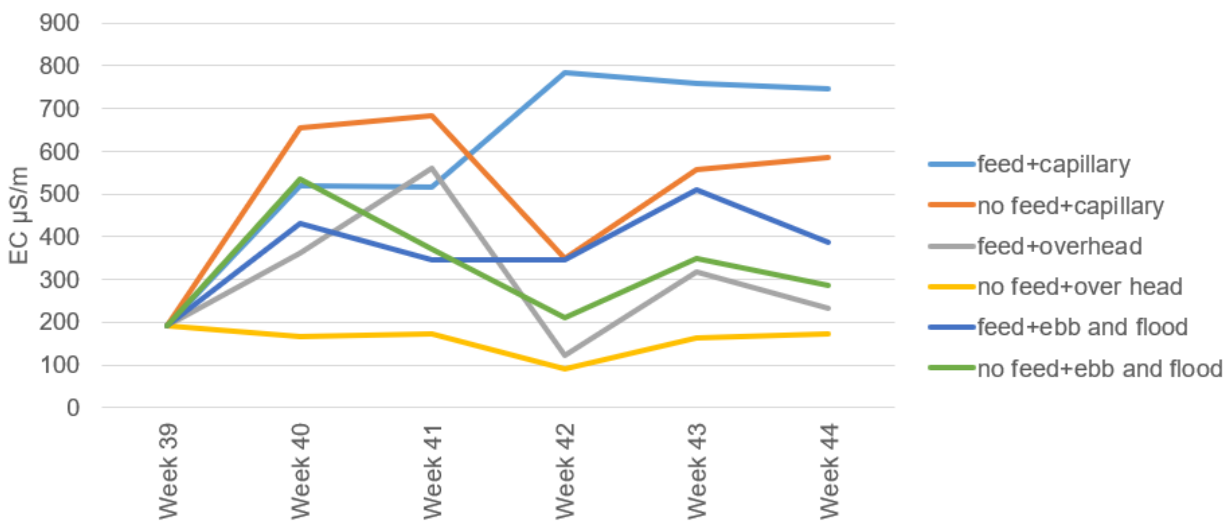


Figure 10. EC over duration of trial in Peat and Perlite mix growing media treatments

Full details of the weekly pH and EC observations can be found in appendix 5.

The total irrigation water applied to each bench was calculated by measuring the run-off from the benches where this occurred. Table 17 shows the amounts of water available to each of the benches

Table 17. Calculated water usage for each bench in litres

Irrigation system	Capillary	Capillary	Overhead	Overhead	Ebb and Flood	Ebb and Flood
Bench number	1	2	3	4	5	6
Treatment number	7,8,9	16,17,18	4,5,6	13,14,15	1,2,3	10,11,12
Date						
02/10/2019	9.0	9.0	4.3	4.7	8.5	12.3
04/10/2019	9.0	9.0	3.3	4.6	5.5	8.7
08/10/2019	0.0	0.0	4.3	4.8	0.0	0.0
11/10/2019	9.0	9.0	5.2	4.2	9.5	7.7
17/10/2019	0.0	0.0	4.7	5.5	0.0	0.0
18/10/2019	9.0	9.0	0.0	0.0	7.8	12.3
21/10/2019	9.0	9.0	4.9	4.9	0.0	0.0
24/10/2019	0.0	0.0	5.4	4.9	0.0	0.0
25/10/2019	9.0	9.0	3.2	3.7	11.2	5.3
30/10/2019	9.0	9.0	4.4	4.8	11.0	7.0
01/11/2019	0.0	0.0	5.8	4.1	4.0	9.0
06/11/2019	9.0	9.0	4.5	4.0	3.0	3.5
Total number of irrigation events	8	8	9	9	7	7
Total water applied	72.0	72.0	49.9	49.9	60.5	65.7
Average water per event	6	6	4	4	5	5

The results obtained from observing the run-off from the overhead irrigation bench and ebb and flood irrigation bench show that there was an increase in the EC of the water from the overhead irrigation, suggesting leaching of ions from the growing media during watering.

Table 18. Comparison of average EC of irrigation water and feed with run-off from benches

	Irrigation water + feed	Run-off from overhead benches Treatments 4,5,6	Run-off from ebb and flood benches Treatments 1,2,3
Average EC (µs)	1159	1450	995

<u>Trial 3</u>

Observations of the length of a fully expanded typical leaf, and coverage of the pot surface by the leaves were taken. No statistical analysis of variance was undertaken as the aim of the trial been to force expression of ‘leaf edge scorch’ and too many variables had been used to do that to make the analysis valid. The results obtained are intended to inform the design of the year two trial, on which full statistical analysis will be carried out.

Based on 1 year only of data the following has been seen:

The highest leaf coverage was seen in the optimal and high EC treatments, with the same or similar results. The extremes of pH were lower in this respect and the lowest results were seen in these treatments where the humidity had been raised. Both of these treatments under the higher humidity conditions only had an average of 50% leaf coverage of the pot surface.

Table 19. Result of leaf coverage observed on 25/02/2020

Treatment code	A	B	C	D	A	B	C	D
Treatment description	Optimal	High EC	High pH	Low pH	Optimal	High EC	High pH	Low pH
Humidity level	low	low	low	low	high	high	high	high
Average	4.96	4.04	3.44	3.48	4.96	4.44	3.04	2.92

Raw data can be found in appendix 8.

The results for leaf length show a similar result, however leaf length was greater under high humidity than under the low. This is likely to be as a result of the slightly warmer conditions that were a result of reduction in air movement, and slightly lower light levels.

The environmental data obtained shows an average difference in humidity of around 10% between the high and low treatments, the absolute values for humidity obtained from the Blue Maestro environmental loggers were too high but they were accurate relative to one another. Data for the environmental loggers can be found in appendix 7.

Figure 11. Images of low humidity treatment plants dated 7/02/2020

Figure 12. Images of high humidity treatment plants dated 7/02/2020

No obvious deficiency symptoms were observed in the trial during 2019, growth was very slow due to poor light level in the period October 2019 to January 2020 and there was little observable difference between treatments. Growth increased between January and March with improving light, and the first deficiency symptoms were seen in early February. Figure 13 shows symptoms seen in the plants in 'optimal' treatment A.

The yellowing of the margin was seen in treatments A, B and C, the marginal necrosis in A and B.

Figure 13. Leaf symptoms in treatment A dated 16/03/2020

The results of the analysis seen in table 20 shows that Calcium and Magnesium are present in the leaf tissue in higher amounts under the lower humidity conditions and more than double the amount in the case of Mg. For Boron the same is true for treatments A and B however, in D the 'low pH' treatment the opposite has been observed with higher levels of B in high humidity conditions and to a lesser extent the same is true for treatment C.

Full details of the growing media and tissue analysis can be found in appendix 9.

Table 20. Result of leaf coverage in comparison to tissue and growing media analysis- observation taken on 25/02/2020

Treatment code		A	B	C	D	A	B	C	D
Treatment description		Optimal	High EC	High pH	Low pH	Optimal	High EC	High pH	Low pH
Humidity level		low	low	low	low	high	high	high	high
Average		4.96	4.04	3.44	3.48	4.96	4.44	3.04	2.92
Leaf Tissue analysis (mg/l)	B	6.78	4.41	3.25	1.68	1.79	1.1	3.91	2.77
	Ca	369.19	354.39	369.06	356.96	173.74	173.25	194.24	110.68
	Mg	419.57	496.32	508.9	431.77	246.64	228.66	261.63	131.88
Growing media analysis (mg/l)	B	0	0.06	0.07	0.08	0.13	0.06	<0.05	0.09
	Ca	22.7	9.8	6.6	2.4	40	5.4	4.1	2.8
	Mg	19.3	10.6	5.7	0.5	48.9	4.6	2.8	0.6

The analysis of the growing media shows that Ca was available in the growing media in treatment A in higher quantities under high humidity conditions but that it was not as present in the leaf tissue.

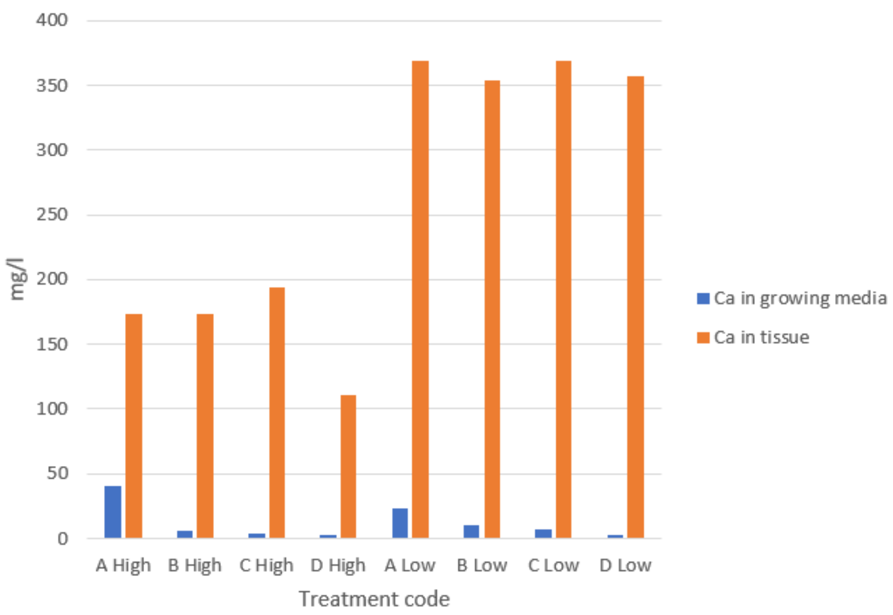


Figure 14. Comparison of Calcium content of leaf tissue and growing media from all treatments in mg/l – samples taken 10/03/2020

Trial 4 and 5 (work package 6)

In year 1 only base line observations have been taken from which we can draw no conclusions as treatment has not varied between plots. The first findings from these trials will be presented in the next annual report.

Discussion

In the two trials carried out on work package 2 looking at the interaction between irrigation type, growing media type and pot size with relation to the delivery of liquid feed there were a number of similar results.

Early stages of growth in both crops appeared unchecked in the unfed treatments, the plants appeared to be sustained by the nutrient levels in the water supply as there was no base feed in the growing media. Differences between treatments were more visible in later growth stages and particularly the flowering of the pansy trial. This may have been a result of the increased demand as the plants grow, or a lag affect from early stages.

The difference in results was greater between the irrigation systems than it was between the different growing media mixes in each system. This suggests that the method of delivering the feed had a greater impact than the media mixes we used. In the trial 100% of the plant nutrition was delivered by the irrigation system in order to test this, which would not normally be the case as a base feed in the growing media would normally be present.

In both trials where overhead or ebb and flood irrigation was used the composition and rate of feed used gave an acceptable crop. Where irrigation (and feed) was supplied via trickle tape onto capillary matting the resulting fresh weights were lower, and in the case of autumn grown pansy very poor. When looking at the cause of this it is important to consider the quantity of water applied via the different irrigation systems as it will directly relate to the amount of nutrition made available. For the petunia trial the volume was lower on the capillary matting benches compared with the manual overhead benches, with a volume of 11.4 litres per irrigation event compared with 18.2ltr. These figures do not consider run-off from the overhead irrigation benches so it is not possible to say how much was retained, so we cannot draw any conclusion regarding the amount of feed present.

In the pansy trial the relative volumes of water applied were different, with more being applied to the capillary matting benches compared with the manual overhead benches 9ltr compared with an average of 6ltrs per irrigation event. In this trial the run-off was measured and taking that into account only around 5ltrs was retained to be used by the plants on the overhead irrigation compared with the entire 9ltrs in the capillary system, meaning 56% more feed remained in the capillary irrigation system than in the overhead.

We cannot extrapolate from one trial to the other with regards to water usage due to the additional environmental variables, and the difference in pot size. What we can see is that due to the holding capacity of the capillary matting (2.5ltr/m^2) in order to keep it moist and make water more available to the plants, a similar amount of water had to be applied at each event during both summer and autumn.

The physical property of the capillary matting holding and making water available to the plants over time has been acceptable in summer when water demand is high but has produced a smaller plant. It is likely that less irrigation and consequently less feed was applied to these benches than compared with ebb and flood and overhead irrigation leading to lower weights. We should also consider that in overhead irrigation the soluble fertilizer in the irrigation water is left on the foliage, allowing nutrients to be absorbed by the plant through the leaf stomata and epidermis. The uptake of nutrients via that route as well as through the roots could be leading to better performance of the plant.

In the autumn when conditions were dull and transpiration would have been lower, the moist capillary matting will have created a more humid microclimate around the crop likely to have reduced transpiration further. The poor growth could have resulted from lower uptake of nutrients due to low transpiration rate, this and the high water volume needed to keep the capillary matting wet caused an accumulation of excess ions in the growing media resulting in toxicity indicated by the high EC results in the growing media.

The cell size and drainage design will have also been a factor in the high moisture content of the growing media, the small cell size will mean there was little drainage by gravity, and this has probably led to anaerobic conditions in the growing media.

The lowest concentrations of leaf tissue Phosphorus were also observed in plants grown on the capillary matting which is a finding that will be followed up in year 2.

Due to the alkalinity of our irrigation water we would expect the growing media pH to increase over time, and that this effect would be greatest in the smaller cells due to reduced buffering capacity (Bragg 1995) The varying trends in growing media pH observed under the different irrigation systems indicate where nutrient availability might be limited. Increasing pH over time in overhead irrigation to could start to limit the availability of nutrient including Iron, Manganese, Copper, Zinc and Boron. However, this was not evident from the tissue analysis and it is unlikely that the level was not extreme enough.

High EC was observed in the collected run-off irrigation in overhead system, showing washing out of nutrients which was confirmed by the decreasing EC of the growing media over the period of the trial. These in themselves are not indicators of poor performance, in both trials the plant fresh weight and visual appearance was good. However, they do give indicators to how the frequency of feeding, and the required physical properties of the media would need to be considered in order to supply enough nutrition. The media would need to hold the influx of water and nutrient and have the properties both physical and chemical to make it available to the plant until the next irrigation event. Growing media with a high AFP (air filled porosity) and low water holding capacity would not be appropriate but may be suitable for an ebb and flood system to avoid waterlogging of the growing media.

Based on the measure used in the analysis (plant fresh weight) peat and wood fibre mix growing media gave the poorest results. It is known that wood fibre has higher biological activity than the other growing media components in the trial, and it is possible that this has resulted in locking up of the available nitrogen, however this is not clear from our tissue or growing media analysis as N content in the leaf is not the lowest in all treatments. The plants in this mix were the first to show symptoms of Phosphorus deficiency, with leaf purpling in unfed treatments showing first. As young plants have a high demand for P it is perhaps more likely that this has been responsible for the smaller plants in both crops. The analysis of the tissue shows plants grown in the wood fibre mix have the lowest amount of P in four of the 6 combinations of irrigation type and feed/no feed in the Petunia trial.

The use of high P feed for the first few weeks in order to establish a good root system is common practice and would appear relevant here as we see P deficiency early. The images taken of the roots at the end of each trial do not appear to indicate any significant differences between growing media mixes but they are distributed differently within the growing media depending on the irrigation source with capillary and ebb and flood irrigation showing roots concentrated more towards the base of the pot that those that were overhead irrigated. See appendices 3 (Petunia) and 6 (Pansy) for root images.

In the WP7 experimental work carried out on Primula our tissue analysis shows a relationship between high humidity conditions and the amount of Calcium in the leaf tissue, Ca is an immobile ion and is moved through the plant by transpiration. Under high humidity the lower transpiration rates will be lower, moving less of the nutrient to the leaf and in particular to the leaf margin. The levels are further reduced in the plants low pH growing media, which is as expected. From the growing media analysis, we can see under high humidity conditions the 'optimal' treatment growing media has Ca present, but the leaf analysis shows it is not being taken up.

In the WP7 observation there is also a pattern in the level of Boron seen in the leaf tissue, in the 'optimal' and 'high EC' the B levels are highest in the low humidity conditions with the 'high pH' and' 'low pH' treatment being lower. However, the opposite was observed in the higher humidity conditions, with higher leaf tissue levels of Boron in the 'high pH' and 'low pH treatments. This pattern is not as expected and will be investigated further.

The low levels of Ca and B did not always translate to obvious symptoms; these were mainly seen in plants in the 'optimal' treatment under higher humidity and lower light levels. These plants were growing more rapidly probably due to the slightly warmer conditions, and it is likely that the additional requirement for nutrient and faster leaf expansion had resulted in the deficiency symptoms. As several nutrients are in low levels in the leaf tissue it is not possible to definitively say what has caused the marginal chlorosis and necrosis, and it may not be a single cause. The experimental work does show the link between media pH and the availability of key nutrients, and the impact of environmental conditions in the movement of these within the plant.

Root images in appendix 10, show that the poorest performing plants (low and high pH growing media) had very underdeveloped root systems which lacked the fine fibrous roots seen in other treatments.

Conclusions

As only 1 year of experimental work has been carried, with each crop undergoing 1 trial it is not possible to make robust recommendations for nutrition. However, we can conclude the following points in relation to the project aim, these will be further tested in the second year of experimental work.

When considering the interaction between irrigation type, growing media type and pot size with relation to the delivery of liquid feed (work package 2).

- Overhead irrigation will cause nutrient leeching and increase the pH of the growing media over time. However appropriate liquid feed, and feeding intervals can counteract the impact of this

- Additional Phosphorus for early stage growth appears more significant in growing media with wood fibre content
- Irrigation water analysis is important to understand the level of ions that are already present in the water supply
- It is important to know how much feed is available to the plants due to the quantity of irrigation that is applied and how much is run-off
- If capillary matting is used to delivery irrigation a different approach to delivery of feed is need compared with overhead and ebb and flood irrigation
- High EC levels can occur in the growing media when using capillary matting in period low transpiration
- High levels of K appear present in mixes with coir and this will need to be evaluated.

When considering how environment and growing media pH affected boron and calcium nutrition in Primula (work package 7), we can so far conclude that.

- Rapidly growing leaf tissue is most like to express marginal necrotic deficiency symptoms, where growth is slow symptoms to not appear to be expressed even if key nutrients are at low levels in the tissue
- It is possible to improve Calcium nutrition by avoidance of high humidity conditions, and low pH growing media
- Boron nutrition can also be improved this way but the link with pH is more complex, but is more available at lower pH

Knowledge and Technology Transfer

How plants affect the rhizosphere during nutrient uptake – Talk by Hilary Papworth, AHDB event, Alternative growing media for ornamental plant production (10/07/2019)

Glossary

Nitrate Vulnerable Zones (NVZs) - The European Commission (EC) nitrates directive requires areas of land that drain into waters polluted by nitrates to be designated as Nitrate Vulnerable Zones (NVZs). Farmers with land in NVZs must follow mandatory rules to tackle nitrate loss from agriculture.

Nitrogen reduction – The process by which plant convert the nitrate absorbed through the roots into amino acids.

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Appendices

Appendix 1: Trial 1 data and statistical analysis

Analysis of variance -variate: height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	Sig
Feed	1	3218770	3218770	1765.23	<.001	***
Irrigation_code	2	81128	40564	22.25	<.001	***
Substrate_code	2	46715	23358	12.81	<.001	***
Feed.Irrigation_code	2	202929	101464	55.64	<.001	***
Feed.Substrate_code	2	3612	1806	0.99	0.372	N.S.
Irrigation_code.Substrate_code	4	11327	2832	1.55	0.186	N.S.
Feed.Irrigation_code.Substrate_code	4	5888	1472	0.81	0.521	N.S.
Residual	378	689257	1823			
Total	395	4259625				

Tables of means

Grand mean 348.6

		Substrate_code		
	Irrigation_code	SA	SB	SC
Feed N	1A	261.8	251.6	259.5
	1B	240.4	227.4	237.8
	1C	286.5	261.9	299.2
Feed Y	1A	491.2	452.3	495.3
	1B	439.7	428.6	442
	1C	394.3	381.2	424.2

25.32 - any differences between 2 values of 25.32 or above are significantly different @ 95%

Observations - plant height

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	350	390	362	278	145	264	470	415	487	273	270	322	480	382	352	215	211	229
	355	355	420	254	246	280	482	460	506	225	219	245	436	505	446	210	245	220
	410	338	450	309	246	367	442	492	500	300	250	172	445	440	376	230	182	235
	365	345	382	225	294	285	500	562	456	240	230	270	446	374	412	330	215	232
	350	391	468	290	289	321	606	317	458	257	240	220	435	515	370	222	256	250
	388	412	402	305	257	271	578	481	472	246	222	267	472	465	465	229	220	241
	456	320	422	345	269	308	444	478	521	280	235	260	412	442	461	300	246	240
	422	400	440	274	266	300	577	364	425	260	220	276	458	420	415	195	224	237
	466	375	444	276	265	298	500	484	405	335	273	281	459	330	425	233	210	270
	387	420	460	326	266	292	420	496	555	212	230	264	356	465	405	175	217	227
	385	345	485	319	278	322	537	522	533	215	168	266	336	429	531	242	229	246
	437	515	382	268	229	285	512	416	492	269	272	300	409	365	450	268	191	226
	310	342	442	365	260	342	400	533	524	280	270	250	471	436	450	241	338	235
	375	408	440	280	302	298	496	402	480	220	232	330	499	384	452	255	250	200
	361	342	442	258	258	298	450	418	460	280	279	259	481	415	402	254	255	244
	423	405	418	291	315	269	498	526	519	220	354	245	494	432	506	305	245	294
	358	370	370	321	275	317	542	409	541	262	268	237	451	374	492	214	274	245
	434	296	342	319	284	324	534	462	496	260	270	230	430	482	492	263	165	257
	450	460	448	252	268	269	434	414	504	340	290	255	445	421	426	260	203	208
	431	465	500	268	238	270	372	414	453	256	220	264	428	462	410	210	235	232
	315	311	432	304	235	288	481	428	594	272	305	245	340	472	530	200	202	270
	446	381	381	175	276	314	532	458	515	258	218	250	490	420	456	237	190	194
SE	45.78	53.34	40.83	41.39	33.83	26.11	59.66	58.92	43.31	34.18	38.73	33.04	46.27	47.04	48.75	37.55	36.74	22.77
Average	394.3	381.2	424.2	286.5	261.9	299.2	491.2	452.3	495.3	261.8	251.6	259.5	439.7	428.6	442.0	240.4	227.4	237.8

Analysis of variance - Variate: Number of flowers

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	Sig
Feed	1	13638.83	13638.83	457.5	<.001	***
Irrigation_code	2	383.37	191.68	6.43	0.002	**
Substrate_code	2	2923.1	1461.55	49.03	<.001	***
Feed.Irrigation_code	2	1252.4	626.2	21	<.001	***
Feed.Substrate_code	2	930.85	465.43	15.61	<.001	***
Irrigation_code.Substrate_code	4	182.06	45.51	1.53	0.194	N.S.
Feed.Irrigation_code.Substrate_code	4	275.15	68.79	2.31	0.058	N.S.
Residual	378	11268.91	29.81			
Total	395	30854.66				

Tables of means

Grand mean 20.12

		Substrate_code		
	Irrigation_code	SA	SB	SC
Feed N	1A	19.09	10.59	12.68
	1B	16.45	10.23	12.45
	1C	19.59	12.68	14.45
Feed Y	1A	29.86	24.55	31.27
	1B	30.00	23.18	28.14
	1C	21.68	17.09	28.09

3.237 - any differences between 2 values of 3.237 or above are significantly different @ 95%

Observations - number of flowers

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	31	23	31	21	7	19	33	21	32	22	9	20	26	35	36	20	13	14
	16	14	38	22	11	15	30	23	23	17	10	12	31	22	34	20	10	15
	14	24	21	25	13	14	33	29	27	17	9	9	26	19	24	16	13	13
	19	26	32	27	10	16	41	15	35	18	10	14	32	31	25	15	10	13
	27	12	28	20	18	13	46	23	26	17	8	13	30	23	29	22	13	16
	17	12	34	15	18	17	24	26	23	19	9	14	44	24	19	15	11	13
	26	11	31	27	15	11	28	22	34	20	10	14	35	25	24	21	11	9
	19	26	34	11	8	11	28	16	33	19	10	12	27	24	28	18	14	9
	24	20	26	13	9	17	41	11	41	22	13	10	18	26	35	14	11	11
	10	8	31	18	16	12	33	35	34	13	11	8	24	23	24	11	12	12
	38	17	17	17	13	8	32	33	43	15	12	17	38	27	27	7	9	15
	26	25	19	16	9	15	26	34	35	21	9	10	37	23	37	21	11	13
	11	18	31	16	12	9	13	41	29	18	12	16	31	31	28	24	11	13
	29	12	27	14	11	16	28	19	30	21	9	14	30	26	32	18	10	8
	9	18	26	16	16	14	23	23	26	19	10	9	31	23	20	10	5	12
	32	21	28	22	7	7	32	25	35	16	7	13	29	29	25	19	7	13
	22	13	28	26	17	15	18	39	27	26	13	11	29	12	30	11	7	13
	27	12	18	22	19	13	20	21	31	18	11	17	52	16	33	14	10	19
	26	12	33	24	15	15	46	26	32	25	14	17	22	17	35	16	9	10
	20	20	36	23	9	29	22	17	37	18	11	9	32	14	34	10	7	9
	15	17	25	16	9	15	25	21	27	23	14	13	15	21	22	15	7	9
	19	15	24	20	17	17	35	20	28	16	12	7	21	19	18	25	14	15
SE	7.64	5.42	5.76	4.69	3.91	4.47	8.59	7.81	5.30	3.19	1.89	3.39	8.23	5.65	5.81	4.83	2.49	2.72
Average	21.68	17.09	28.09	19.6	12.7	14.5	29.9	24.5	31.3	19.1	10.6	12.7	30.0	23.2	28.1	16.5	10.2	12.5

Analysis of variance - variate: weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	Sig
Feed	1	231758.6	231758.6	1845.91	<.001	***
Irrigation_code	2	6277.5	3138.8	25	<.001	***
Substrate_code	2	19841	9920.5	79.01	<.001	***
Feed.Irrigation_code	2	15765.2	7882.6	62.78	<.001	***
Feed.Substrate_code	2	3473.4	1736.7	13.83	<.001	***
Irrigation_code.Substrate_code	4	626.6	156.6	1.25	0.29	N.S.
Feed.Irrigation_code.Substrate_code	4	992.8	248.2	1.98	0.097	N.S.
Residual	378	47458.7	125.6			
Total	395	326193.7				

Tables of means

Grand mean 53.59

		Substrate_code		
	Irrigation_code	SA	SB	SC
Feed N	1A	37.18	18.09	24.86
	1B	35.73	20.73	30.82
	1C	42.86	21.82	32.50
Feed Y	1A	92.14	79.23	98.50
	1B	83.00	70.77	82.05
	1C	66.64	51.27	76.45

6.643 - any differences between 2 values of 6.643 or above are significantly different @ 95%

Observations - plant fresh weight

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	79	56	73	38	18	28	84	76	94	47	22	35	80	79	78	40	18	28
	56	46	76	35	20	26	83	78	97	33	15	27	80	93	77	39	26	31
	53	70	78	51	27	35	101	96	101	26	16	21	70	63	81	28	25	32
	62	59	96	42	19	38	100	81	101	32	18	28	83	90	79	40	17	29
	78	38	68	56	30	30	111	68	85	40	14	26	66	67	74	33	20	33
	46	33	74	33	30	40	89	78	78	45	18	25	145	90	66	30	25	26
	54	34	70	48	25	27	81	66	96	41	18	22	94	75	69	38	19	27
	64	60	90	30	15	37	95	54	96	34	20	26	73	59	71	34	28	29
	68	67	83	32	24	37	93	57	114	46	21	25	68	70	75	35	22	33
	52	40	73	52	22	31	90	87	104	21	18	20	69	56	76	38	22	31
	96	40	54	36	20	31	105	99	120	26	13	30	72	65	106	30	18	33
	78	62	56	30	18	30	96	82	104	32	21	19	79	100	138	33	20	33
	44	52	77	54	19	20	58	102	87	35	17	26	74	64	67	40	20	30
	96	44	80	42	20	34	90	70	97	35	15	21	125	58	118	41	17	32
	35	67	79	49	20	32	99	75	88	44	18	18	102	63	62	33	16	31
	92	66	84	38	13	27	86	101	113	39	20	23	62	87	94	38	25	30
	75	48	70	36	20	27	83	90	99	38	23	28	90	61	81	26	19	29
	74	39	76	59	32	25	87	70	93	40	21	29	122	64	92	38	24	34
	74	57	85	55	28	40	108	82	84	46	19	28	62	64	87	39	19	33
	71	57	88	50	24	46	86	66	107	34	14	20	80	59	77	36	15	30
	41	49	86	41	14	32	85	77	109	46	17	25	58	68	73	35	23	30
	78	44	66	36	22	42	117	88	100	38	20	25	72	62	64	42	18	34
SE	17.46	11.47	10.24	9.18	5.21	6.35	12.53	13.36	10.45	7.19	2.78	4.11	22.37	13.06	18.36	4.42	3.59	2.24
Average	66.6	51.3	76.5	42.9	21.8	32.5	92.1	79.2	98.5	37.2	18.1	24.9	83.0	70.8	82.0	35.7	20.7	30.8

Appendix 2: Trial 1 tissue and growing media analysis

Petunia leaf tissue SAP analysis results

treatment no.	Description	RESULTS (are expressed as mg/l) PH	NH_4	NO_3	total N	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
1	feed+Ebb and Flood +Perlite mix	5.78	160	430	590	0	0.43	798	0.41	1.27	3327	559.4	3.77	0.14	1307	200.7	317.6	1.3
2	feed+Ebb and Flood+woodfibre mix	6.03	100	260	360	0	0.39	612	0.29	1	2527	353.6	2.49	0.13	1066	132.9	235	1.36
3	feed+Ebb and Flood+coir mix	6.08	38	165	203	0	0.55	296	0.21	0.81	4405	87.13	1.2	0.06	374.4	90.5	179.9	0.68
4	feed+Overhead +Perlite mix	6.31	42	348	390	0	0.4	860	0.21	0.87	2103	583.2	3.38	0.24	1147	199.7	258.6	0.69
5	feed+Overhead+woodfibre mix	6.68	40	260	300	0	0.44	803	0.33	0.77	2550	426.6	2.94	0.31	995.5	119	213.2	0.75
6	feed+Overhead+coir mix	6.6	30	276	306	0.01	0.62	533	0.32	0.76	6040	144.2	1.79	0.29	319.3	136.1	299.8	0.69
7	feed+Capillary +Perlite mix	6.2	90	188	278	0	0.17	828	0.27	0.87	2738	536	2.66	0.17	978.1	78.78	205.9	0.74
8	feed+Capillary+woodfibre mix	6.08	120	186	306	0.09	0.24	956	0.36	0.87	2413	546.4	3.56	0.23	894.3	54.53	201.5	1.26
9	feed+Capillary +coir mix	5.76	48	120	168	0	0.41	471	0.22	0.58	4269	166.3	1.79	0.04	320.8	57.05	166.8	0.52
10	no feed+Ebb and Flood +Perlite mix	6.6	30	0	30	0	0.15	1204	0.26	0.71	645	891.6	3.52	0.03	1370	97.98	219.6	1
11	no feed+Ebb and Flood+woodfibre mix	6.71	15	8	23	0	0.2	1584	0.15	0.67	462	1139	5.78	0.07	1379	27.02	248.1	1.22
12	no feed+Ebb and Flood+coir mix	6.43	6	6	12	0	0.63	1060	0.08	0.47	2998	744.9	3.07	0.04	326.2	32.9	323.8	0.54
13	no feed+Overhead +Perlite mix	5.97	20	0	20	0	0.38	873	0.2	0.82	473	885.9	4.83	0.03	1472	65.57	194.3	1.25
14	no feed+Overhead+woodfibre mix	6.23	0	15	15	0	0.3	1354	0.17	0.62	584	1085	5.46	0.04	1325	40.96	226.1	1.58
15	no feed+Overhead+coir mix	5.58	24	0	24	0.01	0.82	539	0.18	0.66	3513	386.4	3.62	0.01	318.3	45.51	250.4	0.91
16	no feed+Capillary +Perlite mix	6.27	78	0	78	0	0.33	1136	0.14	0.86	599	1147	4.61	0.05	1528	49.33	225.8	0.7
17	no feed+Capillary+woodfibre mix	6.33	128	0	128	0	0.29	1577	0.15	0.75	482	1219	5.74	0.02	1331	25.33	262.9	1.23
18	no feed+Capillary +coir mix	5.57	30	12	42	0.05	0.68	650	0.14	0.55	3607	443.6	3.64	0.03	342.5	38.06	276.8	0.86

Growing media analysis results

treatment no.	Description	PH	EC @20c	RESULTS (are expressed as mg/l) CL	P	K	Mg	Ca	Na	NH_4	NO_3	total sol N	S	B	Cu	MN	Zn	Fe
1	feed+Ebb and Flood +Perlite mix	5.7	510	146.80	3.50	4.7	187.3	111.2	66.6	2.5	19.0	21.40	988.7	0.10	0.02	0.17	0.05	0.59
2	feed+Ebb and Flood+woodfibre mix	5.7	325	101.40	<1	10.2	102.3	59.5	69.4	2.6	5.0	7.50	602.1	0.13	0.01	0.05	<0.02	0.48
3	feed+Ebb and Flood+coir mix	4.4	303	77.50	3.60	115.7	23.6	16.5	123.2	4.1	2.0	6.10	510.7	0.28	<0.01	0.10	<0.02	0.62
4	feed+Overhead +Perlite mix	6.5	142	33.50	4.70	18.6	15.9	34.3	23.4	1.5	30.3	31.70	104.1	0.12	0.01	<0.01	0.03	0.15
5	feed+Overhead+woodfibre mix	6.6	149	37.20	4.80	18.4	16.2	42.4	26.4	2.1	25.2	27.30	134.5	0.21	0.01	0.02	<0.02	0.18
6	feed+Overhead+coir mix	5.9	112	29.40	2.50	22.2	6.8	23.8	25.6	3.9	19.3	23.20	91.6	0.18	0.01	0.01	0.05	0.28
7	feed+Capillary +Perlite mix	5.5	338	116.00	5.60	9.1	115.6	64.2	72.5	8.8	26.1	34.90	599.7	0.08	0.01	0.17	0.02	0.47
8	feed+Capillary+woodfibre mix	5.7	363	127.30	2.90	11.3	112.3	67.8	80.5	7.8	9.7	17.50	619.4	0.11	0.01	0.23	0.04	0.47
9	feed+Capillary +coir mix	4.5	319	112.90	1.60	133.3	23.5	16.5	136.3	2.0	2.2	4.20	493.2	0.25	<0.01	0.10	<0.02	0.40
10	no feed+Ebb and Flood +Perlite mix	6.7	75	40.80	<1	2.0	8.3	13.4	14.7	1.2	1.4	2.60	57.3	0.06	<0.01	<0.01	<0.01	0.20
11	no feed+Ebb and Flood+woodfibre mix	6.7	80	46.90	<1	3.0	5.1	13.0	18.7	1.6	0.8	2.40	49.3	0.07	<0.01	<0.01	<0.02	0.16
12	no feed+Ebb and Flood+coir mix	6.0	73	45.20	<1	4.0	3.0	10.2	1.8	<0.6	2.3	2.30	52.5	0.11	<0.01	<0.01	<0.02	0.24
13	no feed+Overhead +Perlite mix	5.7	333	169.60	3.70	5.8	108.6	62.9	49.7	2.0	2.9	4.80	496.7	0.14	0.02	0.03	<0.02	0.40
14	no feed+Overhead+woodfibre mix	5.6	342	206.20	<1	6.7	95.8	60.4	85.0	1.4	0.7	2.10	440.8	0.15	0.02	0.03	<0.02	0.33
15	no feed+Overhead+coir mix	4.5	378	249.30	4.40	179.9	23.4	18.8	159.2	2.5	<0.06	2.90	363.9	0.47	0.01	0.09	<0.02	0.46
16	no feed+Capillary +Perlite mix	5.6	560	388.10	3.30	5.1	201.2	109.9	95.5	3.9	2.0	6.00	757.3	0.14	0.02	0.09	0.02	0.43

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

Trial 1 Growing media pH values obtained from bulk samples from each treatment

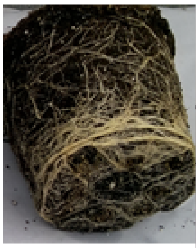
	Observation date						
Treatment	21/06/2019	28/06/2019	05/07/2019	12/07/2019	19/07/2019	26/07/2019	04/08/2019
1	5.3	5.44	5.32	5.35	5.5	4.8	5.46
2	5.4	5.42	5.27	5.24	5.39	4.78	5.16
3	4.7	4.25	4.16	4.11	4.28	3.8	4.16
4	5.3	6.08	6.2	6.24	6.48	6.11	6.68
5	5.4	6.1	6.16	6.12	6.6	6.41	6.97
6	4.7	5.26	5.54	5.68	6.28	5.91	6.27
7	5.3	5.3	5.36	5.34	5.18	5.15	5.17
8	5.4	5.38	5.25	5.25	5.36	5.01	5.27
9	4.7	4.26	4.15	4.21	4.26	4.02	4.13
10	5.3	5.3	5.37	5.28	5.32	4.98	5.34
11	5.4	5.16	5.26	5.04	5.13	4.77	5.13
12	4.7	4.14	4.15	4.16	4.16	3.86	4.18
13	5.3	5.99	5.05	6.41	6.49	6.15	6.79
14	5.4	5.97	6.02	6.7	6.52	6.25	6.9
15	4.7	5.06	5.56	5.96	6	5.75	6.22
16	5.3	5.19	5.27	5.08	5.2	4.89	5.1
17	5.4	5.23	5.07	5.11	5.15	4.85	5.12
18	4.7	4.21	4.09	4.11	4.23	3.9	4.16

Trial 1 Growing media EC readings (in µS) obtained from bulk samples from each treatment using SME

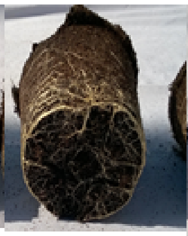
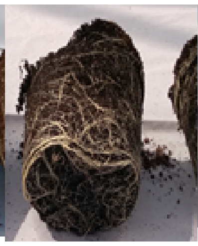
	Observation date						
Treatment	21/06/2019	28/06/2019	05/07/2019	12/07/2019	19/07/2019	26/07/2019	04/08/2019
1	621	1858	1688	1647	962	2290	2180
2	531	827	1255	1104	680	1811	2490
3	742	2160	1904	1853	1196	1989	2230
4	621	826	350	399	249	399	438
5	531	801	338	439	192	380	341
6	742	755	448	419	140	375	326
7	621	806	812	831	1075	2340	2970
8	531	686	1105	1143	1082	1523	2520
9	742	2400	2180	2490	2200	3260	3260
10	621	1751	1547	1762	1022	1060	1308
11	531	1708	1140	2080	1390	1112	2280
12	742	2460	2010	1981	1418	1974	1373
13	621	616	368	276	242	317	417
14	531	445	474	218	195	255	327
15	742	461	261	158	122	188	353
16	621	1233	632	1856	1272	1306	2880
17	531	1293	1053	1626	1415	1292	2990
18	742	2610	2620	2760	2190	2080	3470

Appendix 3: Trial 1 images

Root ball images of all treatments according to irrigation system dated 07/08/2019

					
1 Peat and perlite Ebb & Flood Feed	2 Peat and wood fibre Ebb & Flood Feed	3 Peat and coir Ebb & Flood Feed	10 Peat and perlite Ebb & Flood No feed	11 Peat and wood fibre Ebb & Flood No feed	12 Peat and coir Ebb & Flood No feed

					
4 Peat and perlite Manual over head Feed	5 Peat and wood fibre Manual over head Feed	6 Peat and coir Manual over head Feed	13 Peat and perlite Manual over head No feed	14 Peat and wood fibre Manual over head No feed	15 Peat and coir Manual over head No feed

					
7 Peat and perlite Capillary + drip Feed	8 Peat and wood fibre Capillary + drip Feed	9 Peat and coir Capillary + drip Feed	16 Peat and perlite Capillary + drip No feed	17 Peat and wood fibre Capillary + drip No feed	18 Peat and coir Capillary + drip No feed

Appendix 4: Trial 2 data and statistical analysis

Analysis of variance – variate: Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.		
feed	1	907.12	907.12	25.8	<.001	***	
irrigation_code	2	55216.7	27608.3	785.11	<.001	***	
substrate_code	2	802.17	401.08	11.41	<.001	***	
feed.irrigation_code	2	696.52	348.26	9.9	<.001	***	
feed.substrate_code	2	72.46	36.23	1.03	0.361	N.S.	
irrigation_code.substrate_code	4	109.67	27.42	0.78	0.541	N.S.	
feed.irrigation_code.substrate_code	4	323.48	80.87	2.3	0.065	N.S.	(nearly *)
Residual	90	3164.83	35.16				
Total	107	61292.9					

Grand mean 58.86

		substrate_code		
	irrigation_code	SA	SB	SC
feed N	1A	39.00	37.17	36.83
	1B	42.67	39.50	45.17
	1C	42.00	38.00	42.50
feed Y	1A	51.17	45.50	55.17
	1B	86.17	85.17	96.83
	1C	96.00	86.17	94.50

6.802 any differences between 2 values of 6.802 or above are significantly different @ 95%

Observations - plant height

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	53	52	53	45	32	40	100	102	104	40	38	40	90	81	98	47	38	45
	53	38	55	42	38	45	78	70	95	34	35	35	104	84	92	44	41	51
	50	50	58	40	42	36	103	97	99	40	38	39	80	89	95	38	39	42
	50	50	55	45	38	43	102	72	95	40	37	40	81	92	89	42	38	46
	50	45	58	40	36	49	95	87	94	40	35	35	84	74	105	40	42	47
	51	38	52	40	42	42	98	89	80	40	40	32	78	91	102	45	39	40
SE	1.47	6.25	2.48	2.45	3.79	4.42	9.27	12.95	8.02	2.45	1.94	3.31	9.68	6.91	6.05	3.33	1.64	3.87
Average	51.17	45.50	55.17	42.00	38.00	42.50	96.00	86.17	94.50	39.00	37.17	36.83	86.17	85.17	96.83	42.67	39.50	45.17

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.		
feed	1	6.75	6.75	13.16	<.001	***	
irrigation_code	2	533.407	266.704	519.93	<.001	***	
substrate_code	2	2.7407	1.3704	2.67	0.075	N.S.	(nearly *)
feed.irrigation_code	2	4.6667	2.3333	4.55	0.013	*	
feed.substrate_code	2	1.5556	0.7778	1.52	0.225	N.S.	
irrigation_code.substrate_code	4	3.4815	0.8704	1.7	0.158	N.S.	
feed.irrigation_code.substrate_code	4	1.1111	0.2778	0.54	0.706	N.S.	
Residual	90	46.1667	0.513				
Total	107	599.88					

Grand mean 1.898

		substrate_code		
	irrigation_code	SA	SB	SC
feed N	1A	0	0.167	0
	1B	0.167	0	0.167
	1C	0	0.167	0
feed Y	1A	5.0	5.0	5.67
	1B	4.0	5.17	5.33
	1C	1	1	1.333

0.8215 any differences between 2 values of 0.8215 or above are significantly different @ 95%

Observations - number of flowers

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	1	2	1	0	0	0	4	7	7	0	1	0	5	5	5	1	0	0
	2	1	0	0	0	0	4	5	5	0	0	0	5	5	5	0	0	1
	1	2	2	0	0	0	5	6	5	0	0	0	4	6	6	0	0	0
	0	0	1	0	1	0	4	5	5	0	0	0	4	6	4	0	0	0
	1	1	2	0	0	0	6	4	6	0	0	0	3	5	5	0	0	0
	1	0	2	0	0	0	7	3	6	0	0	0	3	4	7	0	0	0
SE	0.63	0.89	0.82	0.00	0.41	0.00	1.26	1.41	0.82	0.00	0.41	0.00	0.89	0.75	1.03	0.41	0.00	0.41
Average	1.00	1.00	1.33	0.00	0.17	0.00	5.00	5.00	5.67	0.00	0.17	0.00	4.00	5.17	5.33	0.17	0.00	0.17

Analysis of variance - variate: fresh weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.	
feed	1	68.641	68.641	15.59	<.001	***
irrigation_code	2	8237.93	4118.96	935.45	<.001	***
substrate_code	2	188.187	94.093	21.37	<.001	***
feed.irrigation_code	2	35.842	17.921	4.07	0.02	*
feed.substrate_code	2	2.996	1.498	0.34	0.713	N.S.
irrigation_code.substrate_code	4	139.3	34.825	7.91	<.001	***
feed.irrigation_code.substrate_code	4	19.362	4.841	1.1	0.362	N.S.
Residual	90	396.288	4.403			
Total	107	9088.54				

Grand mean 12.27

		substrate_code		
	irrigation_code	SA	SB	SC
feed N	1A	5.65	4.77	5.62
	1B	5.22	4.78	6.42
	1C	5.8	4.57	5.5
feed Y	1A	25.47	22.3	28.42
	1B	22.32	20.67	28.42
	1C	9.27	6.83	8.95

2.407 any differences between 2 values of 2.407 or above are significantly different @ 95%

Observations - plant fresh weight

Feed code	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N
Irrigation type code	IC	IC	IC	IC	IC	IC	IA	IA	IA	IA	IA	IA	IB	IB	IB	IB	IB	IB
Growing media type code	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	4	5	6	13	14	15
Observations	9.6	6.6	8.7	5.8	4.3	6.1	20.7	25.8	31.6	5.8	5.1	6	23.5	20	28.9	6.1	4.3	6.6
	8.7	6.4	8.6	6.8	3.9	5.2	17.6	20.8	24.7	5.6	4.7	5.4	24.2	21.8	23.3	5.4	4.9	6.6
	9	8.5	9.2	5.6	4.3	5.3	29.6	27.8	28.9	5.2	4.3	4.8	21.1	23.2	30.4	4.6	4.6	6.6
	8.4	6.9	8.6	5.8	6.6	5.1	28.8	19	30.8	5.8	5	5.6	20	23.3	25.6	5.1	4.7	6
	9.7	6.5	8.6	4.7	3.8	4.9	29.8	20.7	31.5	5.9	4.9	5.9	24	17.9	29.1	4.6	4.7	6.3
	10.2	6.1	10	6.1	4.5	6.4	26.3	19.7	23	5.6	4.6	6	21.1	17.8	33.2	5.5	5.5	6.4
SE	0.68	0.86	0.56	0.68	1.03	0.60	5.14	3.60	3.71	0.25	0.29	0.47	1.79	2.49	3.51	0.58	0.40	0.24
Average	9.27	6.83	8.95	5.80	4.57	5.50	25.47	22.30	28.42	5.65	4.77	5.62	22.32	20.67	28.42	5.22	4.78	6.42

Appendix 5: Trial 2 Growing media analysis

Growing media analysis results

RESULTS (are expressed as mg/l)

treatment no.	Description	PH	EC @20c	CL	P	K	Mg	Ca	Na	NH_4	NO_3	total sol N	S	B	Cu	MN	Zn	Fe
1	feed+Ebb and Flood +Perlite mix	5.90	74.00	13.40	1.30	3.40	9.60	9.00	22.90	<0.6	<0.6	<0.6	104.7	0.14	0.01	0.02	0.08	0.34
2	feed+Ebb and Flood+woodfibre mix	6.00	73.00	10.40	1.60	4.20	8.20	9.40	18.30	<0.6	<0.6	<0.6	89.7	0.11	<0.01	0.01	0.08	0.32
3	feed+Ebb and Flood+coir mix	5.90	49.00	8.60	1.50	8.50	2.00	2.10	18.30	<0.6	<0.6	<0.6	49.1	0.12	0.01	<0.01	0.06	0.29
4	feed+Overhead +Perlite mix	5.90	72.00	5.10	1.20	2.90	7.30	6.40	20.90	1.00	1.70	2.80	103.9	0.10	0.02	0.02	0.08	0.35
5	feed+Overhead+woodfibre mix	5.90	131.00	13.10	1.40	3.50	22.70	21.60	31.40	<0.6	<0.6	<0.6	236.2	0.21	0.02	0.03	0.12	0.38
6	feed+Overhead+coir mix	6.20	79.00	11.00	2.20	24.20	0.90	1.10	23.20	2.10	2.50	4.60	80.0	0.25	0.01	0.01	0.07	0.45
7	feed+Capillary +Perlite mix	6.20	97.00	58.10	1.50	12.90	8.80	10.40	29.50	0.60	<0.6	0.60	58.0	0.13	0.01	0.02	0.10	0.26
8	feed+Capillary+woodfibre mix	5.80	102.00	67.30	1.00	7.30	9.90	9.90	31.90	<0.6	<0.6	<0.6	70.8	0.12	0.01	0.02	0.06	0.28
9	feed+Capillary +coir mix	6.00	114.00	70.70	1.20	45.50	4.40	4.70	40.20	<0.6	<0.6	<0.6	86.4	0.17	0.03	<0.01	0.05	0.31
10	no feed+Ebb and Flood +Perlite mix	6.10	56.00	28.80	1.20	1.70	4.60	4.10	19.70	<0.6	<0.6	<0.6	32.6	0.08	<0.01	0.01	0.04	0.27
11	no feed+Ebb and Flood+woodfibre mix	6.10	76.00	44.50	1.50	4.30	6.60	6.20	25.10	<0.6	<0.6	<0.6	38.3	0.11	0.01	0.02	0.05	0.28
12	no feed+Ebb and Flood+coir mix	6.20	89.00	54.20	1.60	31.40	1.20	1.20	31.90	<0.6	<0.6	<0.6	48.8	0.18	<0.01	0.01	0.05	0.44
13	no feed+Overhead +Perlite mix	6.40	47.00	32.70	1.10	2.30	3.30	3.50	17.30	<0.6	<0.6	<0.6	19.5	0.09	<0.01	<0.01	0.04	0.25
14	no feed+Overhead+woodfibre mix	6.20	54.00	36.00	1.20	3.60	4.70	4.40	18.20	<0.6	<0.6	<0.6	22.2	0.06	<0.01	<0.01	0.03	0.18
15	no feed+Overhead+coir mix	6.10	59.00	38.80	1.10	22.70	1.20	1.20	21.60	<0.6	<0.6	<0.6	25.7	0.05	<0.01	<0.01	0.03	0.29
16	no feed+Capillary +Perlite mix	6.00	77.00	57.90	<1	3.10	7.50	7.70	27.50	<0.6	<0.6	<0.6	41.5	0.16	0.02	0.02	0.03	0.17
17	no feed+Capillary+woodfibre mix	6.20	79.00	57.90	<1	2.90	6.70	8.40	25.00	<0.6	<0.6	<0.6	40.0	0.17	0.02	0.02	0.03	0.18
18	no feed+Capillary +coir mix	6.20	81.00	38.40	1.10	33.60	1.10	2.30	14.90	0.80	<0.6	0.90	42.3	0.14	0.02	<0.01	0.06	0.32

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

Trial 2 Growing media pH values obtained from bulk samples from each treatment

	Observation date					
Treatment	27/09/2019	04/10/2019	11/10/2019	18/10/2019	25/10/2019	01/11/2019
1	6.35	6.6	6.74	7.02	6.7	7.29
2	6.16	6.04	6.13	6.24	6.21	6.68
3	6.32	5.98	6.11	6.31	6.06	6.52
4	6.35	5.88	5.81	6.03	5.9	6.57
5	6.16	6.59	6.69	6.9	6.67	7.53
6	6.32	6.72	6.91	7.13	6.76	7.57
7	6.35	6.08	5.99	6.1	5.94	6.49
8	6.16	5.78	6.01	5.94	5.95	6.65
9	6.32	5.89	5.79	5.86	5.92	6.63
10	6.35	6.08	6.01	6.11	6.02	6.48
11	6.16	6.12	6.11	6.14	6.06	6.75
12	6.32	5.91	5.89	5.96	5.97	6.53
13	6.35	6.02	6.08	6.19	5.88	6.52
14	6.16	6.4	6.5	6.78	6.59	7.62
15	6.32	6.55	6.64	6.85	6.81	7.62
16	6.35	6.57	6.54	6.89	6.69	7.69
17	6.16	6.04	5.89	6.12	6.03	6.71
18	6.32	5.96	6.03	6.07	5.91	6.72

Trial 2 Growing media EC readings (in μS) obtained from bulk samples from each treatment using SME

	Observation date					
Treatment	27/09/2019	04/10/2019	11/10/2019	18/10/2019	25/10/2019	01/11/2019
1	192	432	345	346	511	386
2	163	672	430	482	419	541
3	291	674	456	326	370	602
4	192	361	559	122	316	232
5	163	283	404	157	221	145
6	291	391	467	276	346	149
7	192	518	515	784	757	745
8	163	888	754	674	1306	681
9	291	816	1085	643	836	459
10	192	534	370	210	348	285
11	163	473	103	324	434	315
12	291	522	434	451	518	288
13	192	165	174	90	164	173
14	163	246	243	143	216	143
15	291	234	197	128	223	188
16	192	655	684	348	556	585
17	163	429	577	465	623	570
18	291	703	609	519	463	794

Appendix 6: Trial 2 images taken 11/11/2019


1 Peat and perlite
Ebb & Flood
Feed


2 Peat and wood fibre
Ebb & Flood
Feed


3 Peat and coir
Ebb & Flood
Feed


4 Peat and perlite
Manual overhead
Feed


5 Peat and wood fibre
Manual overhead
Feed


6 Peat and coir
Manual overhead
Feed


7 Peat and perlite
Capillary and trickle tape
Feed


8 Peat and wood fibre
Capillary and trickle tape
Feed


9 Peat and coir
Capillary and trickle tape
Feed


10 Peat and perlite
Ebb & Flood
No feed

11 Peat and wood fibre
Ebb & Flood
No feed


12 Peat and coir
Ebb & Flood
No feed


13 Peat and perlite
Manual overhead
No feed


14 Peat and wood fibre
Manual overhead
No feed


15 Peat and coir
Manual overhead
No feed

16 Peat and perlite
Capillary and trickle tape
No feed


17 Peat and wood fibre
Capillary and trickle tape
No feed


18 Peat and coir
Capillary and trickle tape
No feed

Appendix 7: Trial 3 environmental data

Environmental data

Treatment		Temperature	humidity	dewpoint
Low humidity	average	10.3	91.2	8.8
	max	25.1	113.4	19.7
	min	5.4	49.2	3.6
High humidity	average	10.9	102.7	11.2
	max	27.1	117.0	27.6
	min	5.9	62.1	4.3
Difference between low humidity and high humidity				
	average	-0.6	-11.5	-2.4
	max	-2.0	-3.6	-7.9
	min	-0.5	-12.9	-0.7

Calculated from data obtained from Blue Maestro monitors taking readings every 30 minutes.

Appendix 8: Plant observations

Observations - leaf coverage 1-5 scale

Treatment	A	B	C	D	A	B	C	D
Humidity level	low	low	low	low	high	high	high	high
Observations	5	4	3	4	5	5	3	3
	5	5	4	4	5	5	3	3
	5	4	3	3	5	5	4	3
	5	4	3	3	5	5	4	3
	5	4	4	4	5	4	2	2
	5	4	4	4	5	4	3	3
	5	4	3	4	4	5	3	3
	5	4	3	4	5	5	3	3
	5	4	3	4	5	3	3	4
	5	4	3	4	5	3	3	3
	5	4	4	3	5	4	3	3
	5	4	4	4	5	4	4	3
	5	4	4	4	5	4	3	3
	5	4	4	4	5	5	4	3
	5	4	4	3	5	5	3	3
	5	4	3	3	5	4	3	2
	5	4	2	3	5	5	4	3
	5	4	4	3	5	5	3	3
	5	5	4	3	5	4	3	3
	5	5	3	3	5	4	3	4
	4	3	3	4	5	4	2	3
	5	4	3	4	5	5	3	2
	5	4	3	2	5	4	3	2
	5	4	4	3	5	5	1	3
	5	3	4	3	5	5	3	3
SE	0.2	0.45	0.58	0.59	0.2	0.65	0.68	0.49
Average	4.96	4.04	3.44	3.48	4.96	4.44	3.04	2.92

Observations - leaf length in mm

Treatment	A	B	C	D	A	B	C	D
Humidity level	low	low	low	low	high	high	high	high
Observations	80	84	67	41	180	114	80	119
	106	74	50	39	134	122	90	85
	114	78	65	50	145	131	112	81
	150	69	65	72	154	121	119	69
	120	74	75	57	129	92	70	112
	115	67	64	55	132	100	98	124
	94	74	54	55	155	122	115	84
	112	95	76	54	141	92	96	84
	132	63	50	70	131	105	64	110
	132	75	55	56	129	103	79	104
	129	102	60	65	126	121	100	116
	100	107	75	67	150	90	96	115
	116	78	54	61	133	96	80	99
	110	75	75	50	142	108	80	55
	97	95	65	70	138	132	84	52
	120	65	60	49	121	106	108	115
	130	70	50	60	155	85	102	101
	101	70	80	55	125	124	106	126
	136	91	85	68	131	104	112	99
	115	86	85	73	119	85	98	95
	118	92	35	60	133	95	79	122
	130	85	65	76	140	117	79	136
	118	92	56	70	145	134	66	95
	109	69	56	50	135	112	94	50
	76	79	71	55	126	85	70	79
SE	17.12	11.97	12.2	9.94	13.46	15.48	16.07	23.74
Average	114.4	80.36	63.72	59.12	137.96	107.84	91.08	97.08

Appendix 9: Trial 3 tissue and growing media analysis

Primula leaf tissue SAP analysis results — RESULTS (are expressed as mg/l)

Treatment code	humidity	PH	NH_4	NO_3	Al	B	Ca	Cu	Fe	K	Mg	Mn	Mo	Na	P	S	Zn
A	High	6.84	77.00	88.00	0.25	1.79	174	0.44	0.52	3015	246.64	2.32	0.11	52.16	478.41	184.60	2.79
B	High	6.92	94.00	94.00	0.29	1.10	173	0.36	0.66	3254	228.66	1.54	0.07	21.57	272.23	145.30	2.67
C	High	6.84	90.00	63.00	0.30	3.91	194	0.42	0.56	2886	261.63	1.99	0.07	123.59	264.94	172.74	4.59
D	High	7.07	71.00	47.00	0.32	2.77	111	0.38	0.57	4058	131.88	1.55	0.07	49.76	240.52	166.50	3.37
A	Low	6.82	73.00	21.00	0.62	6.78	369	0.38	0.56	4021	419.57	3.75	0.12	161.75	594.87	337.70	6.64
B	Low	6.89	77.00	4.00	0.36	4.41	354	0.45	0.99	3046	496.32	4.16	0.66	102.47	192.29	167.93	4.46
C	Low	7.01	82.00	21.00	0.29	3.25	369	0.42	0.65	4106	508.90	3.76	0.28	122.95	232.07	166.32	3.88
D	Low	7.19	80.00	0.00	0.56	1.68	357	0.75	0.91	7936	431.77	5.75	0.26	115.45	275.82	254.51	3.84
Difference between Low humidity and high humidity treatments																	
A		0.17	5.00	-67.00	0.04	1.46	195.45	-0.02	0.13	1091.78	262.26	1.44	0.17	70.79	-246.34	-18.28	1.09
B		-0.03	-17.00	-90.00	0.07	3.31	181.14	0.09	0.33	-208.41	267.66	2.62	0.59	80.90	-79.94	22.63	1.79
C		0.35	-10.00	-63.00	0.26	-2.23	162.72	0.33	0.35	5050.06	170.14	3.76	0.19	-8.14	10.88	81.77	-0.75
D		-0.25	2.00	-26.00	0.30	4.01	258.38	0.00	-0.01	-36.73	287.69	2.20	0.05	111.99	354.35	171.20	3.27

Primula growing media analysis results

RESULTS (are expressed as mg/l)

Treatment code	humidity	pH	EC @20c	Cl	P	K	Mg	Ca	Na	NH_4	NO_3	total sol N	S (SO4)	B	Cu	Mn	Zn	Fe
A	High	5.90	204.00	20.80	25.30	10.40	48.90	40.00	38.30	2.20	16.20	18.50	310.00	0.13	0.02	0.18	0.13	1.10
B	High	6.30	64.00	22.20	2.30	4.70	4.60	5.40	21.00	0.90	10.20	11.10	43.60	0.06	0.03	<0.01	0.03	0.60
C	High	6.50	72.00	26.60	2.60	4.80	2.80	4.10	25.20	3.40	4.50	7.80	36.80	<0.05	0.02	<0.01	0.04	0.54
D	High	5.20	67.00	34.60	3.40	20.90	0.60	2.80	27.00	3.50	4.90	8.50	31.10	0.09	0.09	<0.01	0.03	1.18
A	Low	6.30	136.00	32.00	16.30	7.90	19.30	22.70	42.10	1.00	8.20	9.20	164.60	0.00	0.02	0.07	0.11	0.49
B	Low	6.30	136.00	32.00	16.30	7.90	19.30	22.70	42.10	1.00	8.20	9.20	164.60	0.00	0.02	0.07	0.11	0.49
C	Low	6.70	86.00	36.50	2.10	6.20	5.70	6.60	27.50	0.70	7.00	7.70	45.50	0.07	0.02	<0.01	0.04	0.43
D	Low	5.3	60	32	1.2	18.8	0.5	2.4	22.5	0.6	2	2.6	35.8	0.08	0.02	<0.01	<0.02	1.18
Difference between Low humidity and high humidity treatments																		
A		0.40	-68.00	11.20	-9.00	-2.50	-29.60	-17.30	3.80	-1.20	-8.00	-9.30	-145.4	-0.13	0.00	-0.11	-0.02	-0.61
B		-0.20	38.00	7.70	2.40	2.60	6.00	4.40	9.20	0.20	0.90	1.10	37.20	0.00	-0.01	0.00	0.08	0.98
C		0.20	14.00	9.90	-0.50	1.40	2.90	2.50	2.30	-2.70	2.50	-0.10	8.70	0.02	0.00	0.00	0.00	-0.11
D		0.10	-7.00	-2.60	-2.20	-2.10	-0.10	-0.40	-4.50	-2.90	-2.90	-5.90	4.70	-0.01	-0.07	0.00	0.00	0.00

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

Trial 3 Growing media pH values obtained from bulk samples from each treatment

Treatment code	humidity	05/12/2019	21/01/2020	06/02/2020	14/02/2020	21/02/2020	28/02/2020
A	High	6.3	6.2	6.19	6.34	6.66	6.38
B	High	6.9	6.9	6.38	6.58	7	6.65
C	High	7.2	6.8	6.64	6.64	6.73	6.64
D	High	6.5	6.5	5.84	5.91	6.12	5.78
A	Low	6.3	6.6	6.35	6.27	6.65	6.61
B	Low	6.9	6.5	6.43	6.44	6.81	6.67
B	Low	7.2	7.1	6.89	6.84	6.95	6.76
D	Low	6.5	6.5	5.89	5.7	6.17	5.81
Difference between Low humidity and high humidity treatments							
A		0	0.41	0.16	-0.07	-0.01	0.23
B		0	-0.4	0.05	-0.14	-0.19	0.02
C		0	0.3	0.25	0.2	0.22	0.12
D		0	0	0.05	-0.21	0.05	0.03

Trial 3 Growing media EC readings (in µS) obtained from bulk samples from each treatment using SME

Treatment code	humidity	05/12/2019	21/01/2020	06/02/2020	14/02/2020	21/02/2020	28/02/2020
A	High	186	317	256	178	65.4	145
B	High	370	1216	530	292	111	418
C	High	156	463	318	175	115	159
D	High	140	138	251	139	110.9	180
A	Low	370	403	352	374	183	316
B	Low	186	383	216	219	87	253
C	Low	156	380	261	234	162	189
D	Low	140	257	226	273	169	210
Difference between Low humidity and high humidity treatments							
A		184	86	96	196	117.6	171
B		-184	-833	-314	-73	-24	-165
C		0	-83	-57	59	47	30
D		0	119	-25	134	58.1	30

Appendix 9: Trial 3 images

Primula root images at end of trial – taken 16/03/2020

Treatment A low humidity

Treatment A high humidity

Treatment B low humidity

Treatment B high humidity

Treatment C low humidity

Treatment C high humidity

Treatment D low humidity

Treatment D high humidity

