Project title:	The development of an experimental deep pool hydroponics system to investigate its potential for cut flowers.
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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

Headlines

- Deep and shallow pool hydroponics seem to be possible systems for cut flower production.
- Column stocks production has been challenging in deep pool hydroponics owing to disease issues and a high oxygen requirement in the solution.

Background

The control of *Fusarium oxysporum* is a major issue for flower growers especially those producing *Matthiola incana* (column stocks) and Lisianthus. Despite a number of AHDB funded projects, the only reliable control is still the expensive and time consuming technique of steam sterilisation, even this is only a partial cure and large losses can still be seen in steamed glasshouses. In an attempt to overcome these issues the industry has been looking at the possibility of moving completely out of soil into a hydroponics system. The preferred option was some form of solution hydroponics rather than substrate hydroponics and the simplest system seemed to be deep pool hydroponics where the crop is grown on floating rafts in a large pool of water 25 to 30 cm deep. After a trip in December 2014 to look at lettuce production in deep pool hydroponics, Phil Collison of J A Collison and Son decided to construct a small trial pool (7 m x 3.8 m) in order to undertake AHDB funded trials during 2015. There was very little documented work on the production of stocks in a solution hydroponics system and none in deep pool. The purpose of the trial was therefore to simply explore some of the basics of production to determine if a marketable crop was even possible.

Summary

The deep pool hydroponic trial facility was constructed in December 2014 and was then filled with water in mid March 2015 ready for the trial to commence in late March 2015.

A number of different floating trays were made from 600 mm x 400 mm x 25 mm dense polystyrene sheets which enabled both plugs and blocks to be investigated. The nutrient status was controlled by an existing "Heron" controller using a traditional A and B tank as well as concentrated nitric acid for pH control. The initial nutrient recipe was drawn up by Paul Challinor of May Barn Consultancy and this was slightly modified for the use of either reservoir or mains water. The water was constantly circulated and entered the pool via a perforated pipe at one side of the pool and was drawn out by a similar perforated pipe at the other side. Oxygenation was initially provided by a "Venturi" which introduced air into the solution. The first plantings were a mixture of stocks propagated in both blocks and plugs, floats of lettuce blocks to act as a "check" species as well as blocked statice and Lisianthus plugs.

It soon became clear that the stocks were not thriving and while the other species (especially the lettuce) were growing away very vigorously, the stocks looked very sick. The block propagated stock plants initially seemed to be performing better but as soon as the roots reached the water they began to turn brown and decay. This contrasted starkly with the lettuce which were ready to harvest within a few weeks and had very vigorous, healthy white roots. This clearly demonstrated that there was no fundamental problem with the pool design but in its current form it was obviously not conducive to the production of column stocks.

A number of brassica were then planted to determine if the system was suitable Cruciferae (the same family as stocks) in general in the deep pool system. A modified air gap was also introduced to some of the stock trays so that the block or plug was not directly sitting in the water. Aster ericoides and chrysanthemums were also planted at this stage to broaden the assessment.

A month later the brassica (including, cabbage, sprouts and cauliflower) had put on substantial growth, the aster ericoides and lettuces were thriving but the stocks continued to die. None of the changes that had been made seemed to have made any difference but there were a few random stock plants that had made a marketable flower despite those around them being either dead of very sick. This suggested that stocks has potential to thrive in the system with further development of the set up.

After researching the issue further the one factor that kept coming up was oxygenation of the water and there was a suspicion that perhaps stocks required more oxygen than the other crops that were growing in the pool. Accurate oxygen measuring kit and some additional oxygenating equipment in the form of air pumps and air stones were obtained to test this theory. Without additional oxygenation (beyond the venturi system) initial measurements of dissolved oxygen were low (around 2 mg/l or 20% saturation) but once the air stones were introduced, the area immediately around the stone rose to around 8.5 mg/l (85% saturation) and the concentration a few feet away from the stone rose to around 6 mg/l (60% saturation). Soon after increasing the oxygen concentration positive results were seen, with the stock plants immediately above the air stone producing both healthy leaves and more significantly, healthy white roots. However this positive effect was very localised with plants growing two rafts away from the air stone being no better than before even though the oxygen saturation had increased three fold. This clearly demonstrated that stocks seem to need a much higher oxygen concentration than anyone had initially appreciated.

Unfortunately two weeks later some of the healthy plants in the floats over the air stones began to wilt. Closer inspection showed that the problem was in the stem base which resulted in the roots and stem being detached from one another. This was subsequently confirmed by STC plant clinic as being *Phytophthora* and a recommendation was made to apply metalaxyl as Subdue to the pool. Unfortunately because it was by now so late in the season, no more plugs could be obtained so it was only possible to look at the effect of Subdue on the existing plants rather than a new batch. However the results of the Subdue did seem to be quite significant and very few additional plants seemed to succumb to *Phytophthora* although those already infected did not of course recover. By the end of September a number of flowering stems had been achieved and since the addition of the Subdue, it seemed that the positive effect of the air stones was wider than just the float immediately above them.

In addition to the main deep pool trial a small secondary trial was undertaken in three 1.2 m x 1.2 m shallow pools which are only 10 cm deep and are designed to be used with rolling tables. This was started very late in the season so only one round could be produced hence the results must be treated with caution. However, one of these shallow pools had the addition of an experimental form of electrolysed water which allows free available chlorine (FAC) to be released into the solution and this produced some of the best stems of the season although they did not crop until late October.

To summarise, for stocks in the deep pool hydroponics system, none of the earlier variables that were investigated i.e. plugs or blocks, different forms of air gap (or no air gap), different varieties and different planting dates made any difference to the performance of the plants. It was only the introduction of additional oxygen bringing the level up to around 8 mg/l (80% saturation) that started to result in the production of marketable stems even though some of these subsequently succumbed to *Phytophthora* before Subdue was introduced to the water.

The additional trial looking at shallow pool hydroponics has given an indication that it may also be a system that can be utilised for column stock production but as with the deep pool trials it needs to be further investigated to ensure that the encouraging results obtained at the end of the 2015 trials can be both repeated and replicated.

Financial Benefits

This work is at such an early stage that it is not possible to yet provide financial benefits.

Action Points

- Consider small scale trials of deep and shallow pool hydroponics for cut flowers.
- Keep up to date with future AHDB funded trials in 2016 and beyond.

SCIENCE SECTION

Introduction

Most protected cut flower production in the UK (excluding bulbs such as lilies in crates and tulips in "water") still takes place in the border soil and employs an intensive cropping regime that tends to favour the build up of diseases. The most troublesome disease in recent years has been *Fusarium oxysporum* which has resulted in crop losses of over 80% in some protected crops of column stocks (*Matthiola incana),* which is currently the most important spring and summer UK protected cut flower crop. It can also be a serious problem in Lisianthus production. Despite a number of growers own trials and AHDB funded work, steam sterilisation is still the only option for controlling this disease but it is expensive (both in terms of fuel and labour), not sustainable in the long term and does not fully control the disease especially if soil conditions are not perfect at the time of steaming.

A radical alternative method of production would be to move out of the soil and grow the crop in some form of hydroponics system. This is an alternative that has been investigated by a number of key column stock growers (representing about 70% of the total UK stock area) over the past 3 years or so. In order to move this forward the AHDB commissioned a review of previous work on hydroponics and this was undertaken by Dr Paul Challinor in 2013/14 (PO 018). After studying the findings of the review and a very timely visit to a South Coast lettuce producer, the growers decided that deep pool hydroponics was the system that they most wanted to investigate further. Deep pool hydroponics is a system where young plants are suspended from pierced floating rafts (e.g. polystyrene) over a reservoir of water which is usually 25 to 30 cm deep.

Substrate hydroponics (e.g. growing in peat or Coir) is a more established method of production and has been trialled by some growers in the past couple of years. While column stocks appear to grow well in these systems, the growers felt that it had a number of inherent problems such as cost, sustainability of supply, disposal issues, the need for sterilisation etc. Because of these issues, the growers felt that production in water is the way forward, with deep pool hydroponics appearing to be the simplest and most practical system currently available. However, very little information was available about the growth of cut flowers in such a system and in order to further their knowledge a grower trip was organised to look at a South coast lettuce deep pool facility.

The outcome of this trip was a decision to trial deep pool hydroponics by the building of a small trial pool (courtesy of Phil Collison of J A Collison and Son) and an application to the

AHDB for funding to run the trial for a year with the aims of determining some basics of production including, types of tray (floats), plugs or blocks and nutrient recipe etc.

Materials and methods

The trial was undertaken on a commercial nursery in a small glasshouse compartment measuring 6 m x 10 m separated from the main glasshouse via a glass partition and with its own independent manual vents. The deep pool hydroponic trial tank was built to fully fill the compartment and measures 7 m x 3.8 m with a 1 m walkway all the way round the tank to enable easy access to all areas of the pool throughout the trial (see Figure 1). The nutrient and pH control was achieved by using a Heron MPD-4 controller (see Figure 2) which had been moved from another glasshouse on the nursery. The nutrient controller uses the traditional A and B tank but rather than having a separate mixing tank, the actual deep pool was considered to be the mixing tank with the nutrient being injected directly into the water in the pool. The pool was constructed in late December 2014 by the nursery's own staff and was filled with water for the first time on 21st March 2015. The water was constantly circulated within the pool by a pump sucking water out of the pool via a 50 mm plastic pipe with 15 mm holes drilled 1 m apart. This pipe ran along the whole of right hand side of the pool (as in Figure 1). The water was re-injected by an equivalent pipe that ran all the way along the left hand side of the pool. A Venturi was fitted to the outlet pipe from the pump in order to introduce oxygen into the pool.

Figure 1. The experimental deep pool hydroponic facility in December 2014.

Figure 2. The EC and pH controller used for the trial.

The crop was planted in polystyrene floats which were made from 400 mm x 600 mm x 25 mm sheets of dense polystyrene sheets. These were either drilled out with a 20 mm drill for planting the plugs which was just the right size to support the size of plugs used i.e. those from a standard 600 mm x 400 mm, 600 cell polystyrene tray (see Figure 3) or a square hole created with a bespoke cutter made from 45 mm x 45 mm box iron for planting with blocks (see Figure 4). Each float had 3 rows of 5 holes with the holes being spaced at 6.5 cm from the edge of the float to the middle of the hole and 12.5 cm from the centre of each hole to the next. The aim of this spacing was to achieve a density of 64 plants per sq/m which is the norm for a soil grown crop.

Figure 3. Polystyrene floats used for the plug plants.

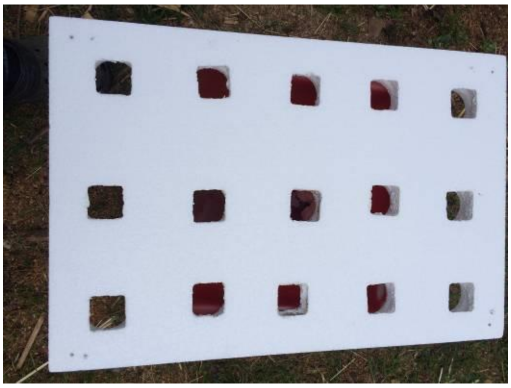

Figure 4. Polystyrene floats used for the block plants.

From information obtained from lettuce growers it was thought that the plants may require an air gap underneath each plug and this was achieved by drilling a 50 mm hole in either a 25 mm thick or 10 mm thick sheet of polystyrene (see Figure 5 and 6) with a view to attaching these under some of the plug and block floats at planting.

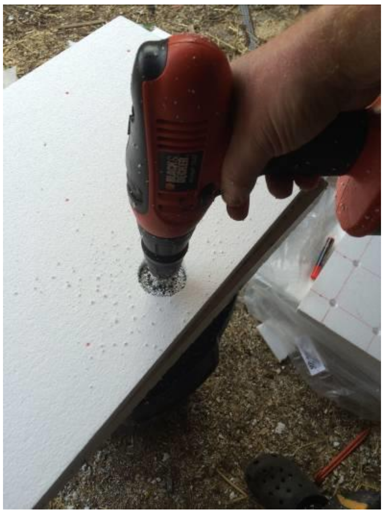

Figure 3. Drilling out the 50 mm air gaps.

Figure 4. A completed float of 50 mm air gaps.

During the 8 months of the trial, a number of different plantings and modifications were made to the trial and the clearest way to present these is under a date heading for each action which can then be clearly tied into the results section.

Trial timeline

March 5th 2015

Plugs of column stocks (variety Figaro lavender) were transplanted into 4 cm peat blocks to be grown on and then transferred to the block floats once they were large enough.

March 27th 2015

The first batch of floats were planted which comprised of 14 floats of blocked stocks of which 4 had 25 mm deep air gaps and a further 4 had 10 mm air gaps: 3 block floats of lettuce of which one had a 25 mm air gap; 39 floats of plug column stocks (variety Figaro lavender) of which 5 had 25 mm deep air gaps and a further 5 had 10 mm air gaps and finally 3 floats where the plugs were planted into the empty trays that the plug plants were propagated in. The remaining area of the pool that was not planted with floats was covered with a black reservoir liner to exclude light and hence reduce algal growth. See Figures 7 and 8.

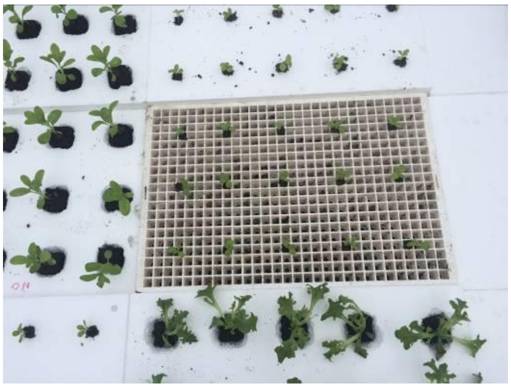

Figure 7. Newly planted floats showing plugs and blocks.

Figure 8. Overall shot of the newly planted floats.

April 27th 2015

Removed many sick looking trays of stocks from the pool and added modified air gaps to the floats that showed some promise. The modified air gaps comprised of either the original 50 mm gaps but with added channels to join them together (see Figure 9) or thin strips of either 10 or 25 mm polystyrene (see Figure 10).

Figure 9. Modified air gap by the addition of channels to produce uninterrupted air flow.

Figure 10. Air gap created by the use of thin strips of polystyrene.

Also planted 18 new floats of plug grown column stocks (see Figure 11) of which 2 had the modified 50 mm air gap, 2 had the 25 mm strips and a further 2 had the 10 mm strips. For the plugs that did not have an air gap care had to be taken when planting to ensure that the plug was inserted to the bottom of the float in order for the roots to be able to take up water. The trays with an air gap required overhead irrigation (in this case using a watering can) until the roots had grown long enough to touch the water.

In order to rule out any issues with the brassica family per-se (column stocks are a member of the cruciferae family) a float each of cauliflower, cabbage, calabrese and sprouts were planted (see Figure 12). Three floats of Lisianthus were also planted with one of them having a 25 mm thick air gap.

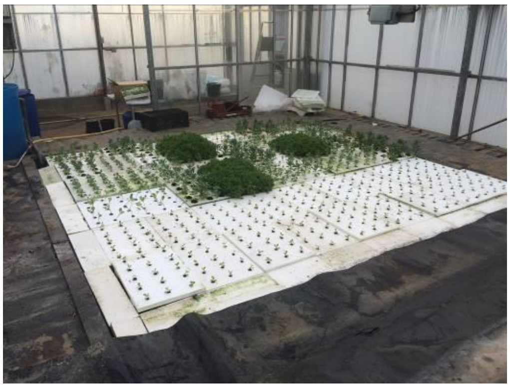

Figure 11. The pool on April 27th 2015 showing newly planted floats and the remainder of the original planting.

Figure 12. Floats with newly planted brassica plugs.

May 21st 2015

Three trays of blocked aster ericoides cv Cassandra (see Figure 13) and one tray of blocked statice were planted. Two of the original 3 trays of lettuce were removed from the pool (see Figure 14).

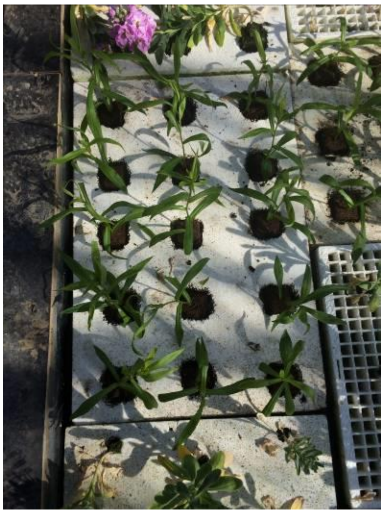

Figure 13. A float of blocked aster ericoides cv Cassandra planted on May 21st 2015

Float 14. Lettuce removed from the pool. These were planted on March 27th 2015.

June 12th 2015

A dissolved oxygen meter (Hanna Instruments model HI 98193) was purchased to enable the oxygen levels in the pool to be monitored throughout the remainder of the trial. The pool was cleared of all of the floats except for the Lisianthus, asters and statice. It was drained of water, cleaned and refilled with new water (this time primarily mains water) and replenished with nutrients. The floats to be kept were placed on wooden supports laid across the pool (see Figure 15) while it was being cleared out before being refloated in the fresh solution (see Figure 16) and the roots were therefore out of the water for about 5 hours.

Figure 15. Aster, Lisianthus and statice removed from the pool while it was cleaned.

Figure 16. Aster, Lisianthus and statice refloated after pool was refilled.

June 16th 2015

Planted another 18 floats of plug grown column stocks (variety Figaro lilac).

June 17th 2015

Planted a further 9 trays of Lisianthus plugs (variety Picolo 2 deep blue).

June 29th 2015

In order to increase the oxygen levels a large aquarium pump (see Figure 17) and large air stones (see Figure 18) were purchased and set up in the pool. Initially 4 air stones were placed in the pool and these were attached to bricks with cable ties in order to keep them submerged.

Figure 17. Air pump to increase oxygen levels in the pool.

Figure 18. Air stone attached to brick and placed under individual floats.

July 1st 2015

Nine new floats of a wide range of column stock varieties were planted. These were Centum white, Centum Apricot, Centum deep blue, Centum lavender, Jordyn white, Jordyn apricot, Jordyn red, Lucinda rose and Lucinda red. These were from a different propagators and because they were supplied in a smaller plug, new floats had to be made with the same spacing as previously but with a 15 mm hole to support the plug. Another air pump and 8 additional air stones were purchased and the stones were placed under random trays throughout the pool. Nine plug floats of Centum cream were also planted.

July 20th 2015

Three floats of chrysanthemums (variety Chivenor) were added to the pool.

July 21st 2015

Two further floats of aster ericoides plugs were planted and little Gem lettuce blocked.

July 29th 2015

The project manager had been working with a company developing electrolysed water for a number of different uses in the Agri food sector. Discussions about the deep pool hydroponic trial resulted in a suggestion to try using one of their experimental solutions to add to the hydroponics solution to create a level of free active chlorine (FAC) that will be harmless to the plants but at a high enough concentration to control both alga and diseases. In order to trial this theory an additional experiment was set up using 3 shallow pools which were obtained from a local bulb nursery which are designed to sit within the frame of a standard rolling bench. The dimensions of each pool was 1.2 m x 1.2 m x 10 cm deep and they were positioned on beams of wood that spanned the far end of the main pool (see Figure 19) They were filled using solution from the main pool. Each of the shallow pools was supplied with additional oxygen via a pump and 2 long air stones (see Figure 20).

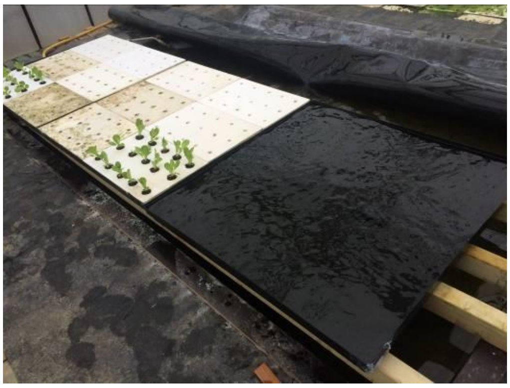

Figure 19. The three additional shallow pools supported on beams above the main pool.

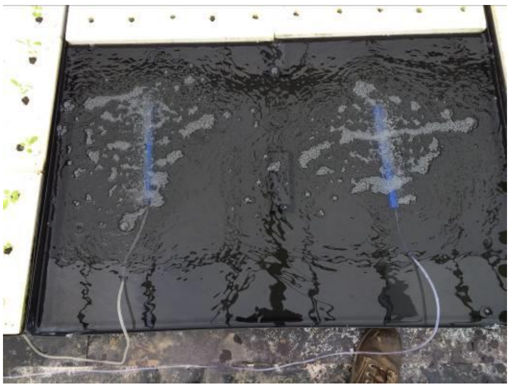

Figure 20. A single pool showing the 2 long air stones to increase oxygen levels.

The 3 shallow pools were planted up with one float of blocked lettuce and 5 floats of plug stocks, variety Centum red (Figures 21 and 22)

Figure 21. The shallow pools partially planted on July 29th 2015.

Figure 22. The shallow pools fully planted on July 29th 2015.

An additional 9 trays of column stock, Anytime red, were also planted in the main pool. Owing to no more plugs being available from the propagators, this was the last planting to be made in 2015.

August 10th 2015

Subdue (metalaxyl-M) was added to the main pool at a rate of 1 ml per 100 l of solution.

August 13th 2015

It has been hoped to add the electrolysed concentrate to the shallow pools as soon as the crop was planted but unfortunately owing to some logistical issues it was not delivered until August 13th 2015, some weeks after the crop was planted. The plants in pool 3 looked very sick (owing to an issue with the air stones) so this was abandoned and the electrolysed solution was only added to pool 1 (25 ml with the aim of producing a FAC level of 0.5 to 0.6 ppm) with pool 2 acting as a control.

September 3rd 2015

The lettuce floats were removed from the shallow pools because they had reached maturity. Pool 1 was topped up with another 10 ml of electrolysed water concentrate.

September 27th 2015

Most of the floats were cleared from the main pool except a few trays of Anytime column stocks, chrysanthemums, asters and statice.

November 6th 2015

Samples of Centum red were harvested and taken to a local packer for vase life testing.

November 11th 2015

Both the deep pool and shallow pools were completely cleared out and all of the floats cleaned dried and stored away.

Nutrient Recipe

The following tables show the target values for the nutrients and ratios in the deep pool solution supplied by Dr. Paul Challinor, May Barn Consultancy Ltd.

Table 1. Hydroponic cut flower rootzone pH and EC targets

RAG Chart: Protected Flower Crops	Red: Likely to result in plant damage	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	RAG Chart: Protected Flower Crops
pH	< 5.5	6.0	> 6.5	Target range: 5.8-6.2
EC µS / cm	< 1,800	2,500	> 3,500	> greater than < less than

Table 2. Hydroponic cut flower rootzone main element target concentrations

RAG Chart: Protected Flower Crops	Red: Likely to result in plant damage	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	RAG Chart: Protected Flower Crops
Major Elements mg / litre				> greater than < less than
NH4-N	0	2	> 10	As low as possible
NO3-N	150	200	> 250	
P	20	30	> 50*	*Induced Zn+Cu deficiency likely
K	< 200	250	500	Toxicity: rare
Ca	150	200	> 300	
Mg	< 30	40	> 60	High K inhibits Mg absorption

Table 3. Hydroponic cut flower rootzone unwanted ion target concentrations

RAG Chart: Protected Flower Crops	Red: Likely to result in plant damage	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	RAG Chart: Protected Flower Crops
Unwanted Ions mg / litre				> greater than < less than
Na	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Cl	< 100	200	> 400	
SO4-S	< 50	100	> 200	

Table 4. Hydroponic cut flower rootzone trace element target concentrations

RAG Chart: Protected Flower Crops	Red: Likely to result in plant damage	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	RAG Chart: Protected Flower Crops
Trace Elements mg / litre				> greater than < less than
Fe	< 2.0	3.0	> 5.0	
Mn	< 0.3	0.5	> 0.8**	**Toxicity risk higher
B	< 0.3	0.4	> 0.8	
Zn	< 0.3	0.5	> 1.0	Link with P and Mn
Cu	< 0.05	0.1	> 0.2	
Mo	< 0.01	0.03	> 0.1	

Table 5. Hydroponic cut flower rootzone main element nutrient ratios

RAG Chart: Protected Flower Crops	Red: Likely to result in plant damage	Amber: Likely to result in nutrient deficiency	Green: at or near the optimum concentration	RAG Chart: Protected Flower Crops
Nutrient Ratios				> greater than < less than
K:N	> 1.6	1.25	< 1.1	
K:Ca	> 1.6	1.25	< 1.1	
K:Mg	> 7.5	6.0	< 4.0	
K:Na	> 3.0	1.25	< 1.1	Important in recirculation
K:Cl	> 3.0	1.25	< 1.1	Important in recirculation

Based on the water analysis at Appendix 1, the following nutrient recipe was used for the initial solution made up from rain water.

A TANK Compound	Weight	B TANK Compound	Weight
Calcium nitrate 19%Ca, 16% N	4.0kg	Potassium nitrate 38%K, 13% N	3.0kg
Potassium nitrate 38%K, 13% N	0kg	Mono-potassium phosphate 29%K, 23% P	2.5kg
Potassium chloride 50%K, 45% Cl	1.5kg	Magnesium sulphate 10%Mg, 13% S	2.0kg
DTPA iron chelate 6%	225ml	Manganese sulphate 32%	20g
		Zinc sulphate 23%	5g
		Borax 21%	40g
		Copper sulphate 25%	2g
		Sodium molybdate 40%	1g

Notes:

Input EC: 2,000 to 2,200 uS/cm

Tank sizes: 100 litres

Dilution: 1 in 100

Nitric Acid input required to reduce solution pH to 6.0 (range: 5.8 to 6.2)

Based on the analysis of the mains water (Appendix II), the following recipe was used when the pool was refilled with mains water on June 12th 2015.

ATANK Compound	Weight	B TANK Compound	Weight
Calcium nitrate 19%Ca, 16% N	4.0kg	Potassium nitrate 38%K, 13% N	2.0kg
Potassium nitrate 38%K, 13% N	1.0kg	Mono-potassium phosphate 29%K, 23% P	1.5kg
Potassium chloride 50%K, 45% Cl	0kg	Magnesium sulphate 10%Mg, 13% S	2.0kg
DTPA iron chelate 6%	250ml	Manganese sulphate 32%	20g
		Zinc sulphate 23%	6g
		Borax 21%	30g
		Copper sulphate 25%	1g
		Sodium molybdate 40%	0.5g

Notes:

Input EC: 2,000 to 2,200 uS/cm

Tank sizes: 100 litres

Dilution: 1 in 100

Nitric Acid input required to reduce solution pH to 6.0 (range: 5.8 to 6.2)

Results

The nature of the trial and the actual results obtained were not easy to record as traditional data and most of the results are therefore presented as observations on specific dates backed up with photographic evidence. Wherever possible the following results tie in with the dates outlined in the materials and methods section.

April 22nd 2015

A Management Group (MG) meeting was held on site to discuss the results to date and determine any changes to be made to the trial.

Overall the column stock plugs and blocks planted on March 27th looked very sick and none could be considered to be growing adequately (see Figure 23). This was in stark contrast to the blocked lettuce which were growing away very vigorously and almost ready to be harvested (see Figure 24).

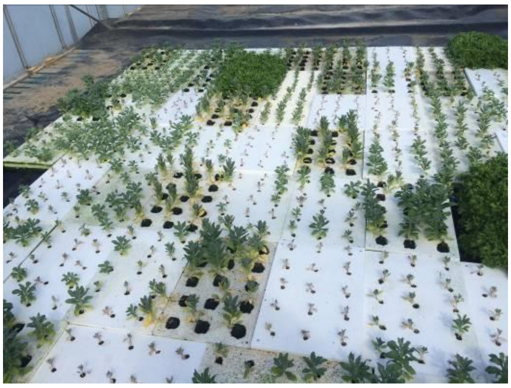

Figure 23. Overall view of the trial on April 27th 2015 showing poor growth of column stocks contrasted with the 3 lettuce floats.

Figure 24. Growth of the lettuce on April 27th 2015 contrasted with the very poor growth of the column stocks.

Most of the column stock plugs were either dead or very sick (see Figure 25), and while the blocks looked more healthy they were by no means growing away as would have been expected 4 weeks after planting (Figure 26).

Figure 25. Poor growth of column stock plugs plants on April 27th 2015.

Figure 26. Growth of column stock blocks on April 27th 2015.

All of the column stock plants (plugs and blocks) had very poor roots which turned brown and in most cases died completely when they grew into the water (Figure 27). It would appear that the block plants looked more healthy than the plugs because of having an initial larger reservoir of roots to sustain the plants. There was no apparent difference between any of the floats with or without air gaps. This was in stark contrast to the lettuce roots which were vigorous, white and healthy (Figure 28)

Figure 27. Poor root growth of the blocks of column stocks.

Figure 28. Root growth of the lettuce blocks planted at the same time as the stocks in Figure 27.

May 5th 2015

Most of the blocked stocks were now looking as sick as the plugs (Figure 29) although some floats (especially those directly above the return pipe from the pump) were looking healthier and had produced a bud (Figure 30). There were also the odd random healthy plants or two in some of the plug floats despite the fact that all of the other plants around them were either dead or very sick. No obvious reason could be deduced for these anomalies

Figure 29. Poor growth of column stocks grown from blocks.

Figure 30. Blocked column stocks showing better growth.

May 21st 2015

The floats of brassica were growing away vigorously indicating that there was no issue with producing cruciferae in a deep pool hydroponic system (Figure 31). The lettuce floats had also grown vigorously and 2 of the floats were removed in order to make space around them (Figure 32). The third float was left in place to see if the leaves showed any signs of nutrient deficiency as they matured.

Figure 31. Vigorous growth of the brassica plugs that were planted on April 27th 2015.

Figure 32. Vigorous growth of the lettuce blocks planted on March 27th 2015.

A few of the healthier looking block grown column stock floats with air gaps (planted on March 27th 2015) had by now produced quite strong stems (Figure 33) but the roots were only white and healthy in the air gap whereas the roots in the water were brown and dying (Figure 34).

Figure 33. One of the healthier stems of block raised column stocks showing poor quality roots.

Figure 34. Close up of the roots showing the white root which developed in the air gap and brown root growing in the water.

May 26th 2015

Another MG meeting was held on site to discuss the progress of the trial. None of the changes made to the air gaps on April 27th 2015 had made any difference to the growth of the column stocks. Most had either died or looked very sick but a few random stems had produced flowering stems but these were randomly scattered throughout the pool with no obvious pattern (Figures 35 and 36). By contrast the statice, asters, lettuce, brassica and Lisianthus continued to grow vigorously with healthy white roots (Figures 37 and 38)

Figure 35. Overall view of the trial at the MG meeting on May 26th 2015.

Figure 36. One of the random healthy stems of stocks from the original planting of March 27th 2015.

Figure 37. View showing the vigorous growth of the brassica and lettuce contrasted with the poor growth of the stocks

Figure 38. View showing healthy growth of Lisianthus (front left), aster ericoides (front centre) and statice (middle right)

June 12th 2015

At the time of clearing the dead and sick plants from the pool there were no more than 10 stems of stocks that had flowered and produced what could just about be considered to be marketable stems (Figure 39). The remainder of the poor plants had brown and decaying roots (Figure 40)

Figure 39. View of the pool on June 12th 2015.

Figure 40. Decaying roots of column stock on June 12th 2015.

The roots shown in Figure 40 contrast markedly with the healthy roots and growth of the Lisianthus (Figure 41), aster (Figure 42) and statice (Figure 43).

Figure 41. Lisianthus on June 12th 2015.

Figure 42. Aster ericoides on June 12th 2015.

Figure 43. Statice on June 12th 2015.

Before the pool was cleared and drained, the oxygen level was measured and was found to be very low at 1.7 mg/l (18% saturation).

June 16th 2015

Four days after the Lisianthus were left out of the water for 5 hours while the pond was cleaned, the healthy plants rapidly started to wilt and die (Figure 44). The roots literally seemed to dissolve in the water and they were surrounded by a milky liquid. This did not happen to any of the other species and at the time of writing the report could not be explained.

Figure 44. Wilted plants on June 16th, 4 days after the pool was cleared and refilled.

July 7th 2015

The first flush of statice (which was planted on May 21st) was harvested (Figures 45 and 46) in order to encourage the production of new stems.

Figure 45. Statice plants before harvesting on July 7th 2015.

Figure 46. Statice plants after harvesting on July 7th 2015.

July 21st

Three weeks after the oxygen concentration was increased by use of an aquarium pump and air stones, there was a dramatic improvement in the growth of the plants in the floats directly above the air stone (Figure 47). And for the first time during the trial, the column stocks had developed healthy white roots when growing into the water (Figure 48)

Figure 47. Healthy growth of a float of column stocks immediately above an air stone.

Figure 48. Healthy roots of column stocks from the float shown in figure 47.

However the effect of the extra oxygen concentration rapidly diminished away from the air stone and was not evident two full floats away (Figures 49 and 50). This was very surprising because even though the oxygen level immediately above the air stone was measured at 8.1 mg per litre (81.5% saturation) other areas of the pool were still 4 times higher than the initial levels at around 6.5 mg/l (65% saturation).

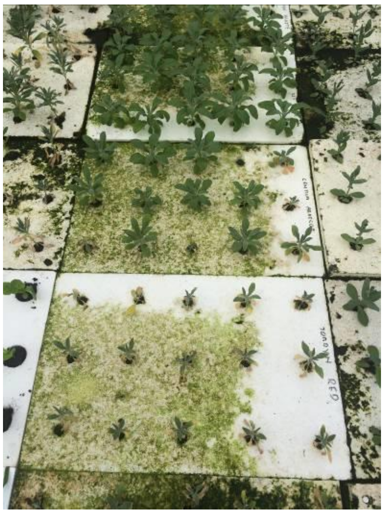

Figure 49. Differences in growth two trays away from the air stone. The float at the top middle of the picture is the one shown at Figure 47 and 48.

Figure 50. A comparison of the float immediately over the air atone and the second float from the air stone i.e. the top and bottom trays of Figure 49.

July 27th 2015

A number of the apparently healthy plants growing in the floats above the air stone were now showing signs of wilting (Figure 51). Close examination showed that problem was actually in the stem base which resulted in the root and stems being detached from each other (Figure 52). Samples of the wilting plants were sent to STC plant clinic and *Phytophthora* was identified.

Figure 51. Wilted plants in the floats above the air stones.

Figure 52. Plant showing *Phytophthora* affecting the stem base.

August 29th 2015

After the addition of Subdue to the water, the problem of wilting and stem base rot reduced considerably. It was not possible to say that it had been eliminated completely owing to infections that would have occurred before the problem was diagnosed. By the end of August the chrysanthemums, asters, statice and lettuce continued to thrive (Figure 53) while the Lisianthus appeared to have stopped growing and was suffering from severe tip burn. The column stock floats above the air stones, while far from being the best quality were probably growing as well as could be expected for the time of year (Figure 54)

Figure 53. Continued strong grow of lettuce, asters, statice and chrysanthemums.

Figure 54. Row of column stocks on the left showing good growth over the air stones. The second row from the left is Lisianthus showing poor growth even over an air stone.

September 23rd 2015

The Anytime red planted on July 29th (Figure 55) and the Centum cream (Figure 56) planted on July 1st had now produced a number of marketable stems, mainly in the floats over the air stone. These had fallen over owing to lack of support but the number of good stems was quite surprising given the time of year.

Figure 55. Marketable stems of Anytime red planted on July 29th.

Figure 56. Marketable stems of Centum Cream planted on July 1st.

November 6th 2015

The shallow pool which had been dosed with the electrolysed water had now produced a number of strong marketable stems (Figure 57) with a strong, healthy and vigorous root structure (Figure 58) whereas the column stocks in the shallow pool without the dosing had either died or looked very sick. The results from the dosed shallow pool did in fact produce some of the strongest stems seen through the whole of the 2015 trial and the quality very much surprised the MG members who met on site in early November. However, it must be noted that even in such a shallow depth of water the best growth occurred directly over the air stone where the oxygen concentration was measured at around 8.5 mg/l (high 80's% saturation) whereas away from the air stone in areas of poor growth it was still around 7 mg/l (low 70's% saturation).

Figure 57. The shallow pool dosed with the electrolysed water (on the right) which produced a large number of marketable stems.

Figure 58. Strong healthy roots of the column stocks growing in the shallow pool dosed with electrolysed water.

A number of stems of Centum red from the dosed shallow pool system were harvested and taken to a local packer for vase life testing (Figure 59)

Figure 59. Stems of Centum red harvested from the dosed shallow pool on November 6th 2015.

November 11th 2015

The chrysanthemums and aster ericoides were in full flower by the beginning of November (Figure 60). The quality and stem strength of the chrysanthemums was superb although they would require adequate crop support in a commercial situation (Figure 61).

Figure 60. Chrysanthemum and aster in full flower on November 11th 2015.

Figure 61. Close up of chrysanthemum float on November 11th 2015.

Both the deep pool and shallow pools were then cleared and emptied of water and all of the floats washed before being stored away.

A number of samples of the nutrient solution were analysed by Eurofins (Appendix III) and the results interpreted by Dr Paul Challinor. It is interesting to note that despite numerous breakdowns and issue with the old Heron controller, the nutrient analysis remained very stable and on target, hence demonstrating the substantial buffering effect of a deep pool system. It was only towards the end of the project that the pH started to rise (owing to the acid dosing system irreparably breaking down) hence affecting the nutrient balance.

Discussion

The 2015 trial has shown that a simple deep pool hydroponics system has the potential to produce a range of cut flowers to a commercial standard. In these trials statice, aster ericoides and chrysanthemums grew adequately and all produced what would have been a marketable stem had adequate crop supports have been in place. Two of these species i.e. asters and statice grew in the pool for the most of the trial i.e. from April to November with no issues with the health of the roots. The statice cropped consistently from early July through to being removed from the pool in mid November.

Lettuce was used as a "check" species throughout the trial because its performance in such a system is clearly understood. In all cases the lettuce grew vigorously with a mass of healthy white roots and was ready for harvesting within a few weeks. This clearly demonstrated that there was nothing fundamentally wrong with the deep pool system that was being used for the experiment.

The performance of the Lisianthus was less consistent and difficult to fully explain. The initial planting of April 27th 2015 grew away well and produced healthy white roots up until being removed from the water for about 5 hours while the pool was emptied, cleaned and refilled on June 12th 2015. Four days after being returned to the pool the Lisianthus began to wilt and the roots appeared to dissolve producing a mass of milky white liquid in the area around the roots. It is not easy to explain this but perhaps the delicate root hairs were destroyed while out of the water but this was not an issue with the statice or asters. The second planting of Lisianthus also failed to perform as expected and never grew more than 15 to 20cms tall and suffered from severe tip scorching. This is a crop that has been trialled in Holland and been shown to grow in "water" so the results in this trial are surprising. It is possible that the subsequent rise of PH owing to issues with the acid dosing system could have contributed to some of the growth problems that were observed.

The main objective of the 2015 trial was to determine if column stocks could be successfully grown in a deep pool hydroponic system. As can be seen from the results, the process of determining the ideal conditions for column stock production was difficult and protracted. A number of variables were explored including plugs and blocks, different varieties and propagators, air gap, no air gap and different sizes / types of air gap and adding additional oxygen to the water. As can clearly be seen by the photographic record in the results section, the only variable that consistently improved the growth of the column stocks was the addition of increased oxygen, but even then only when it was around or above 8 mg/l (80% saturation). Before starting the trial it had been assumed that the nutrient recipe was one of the most important factors to consider but the results to date indicate that for column stocks the oxygen concentration in the water is by far the most important issue.

As would perhaps be expected, root and stem diseases are a potential issue with a solution hydroponic system, hence the need to treat the trial pool with Subdue to control *Phytophthora.* However, it must be noted that because of the location of the trial facility (it shared a main access with an adjoining commercial glasshouse where intensive cropping was undertaken in the soil) it was not possible to apply a hygiene regime that was as high as would be the case in a commercial nursery dedicated to just hydroponics.

The additional experiment looking at the use of electrolysed water to control alga and diseases produced some interesting results in the fact that the treatment resulted in some of the best stems of the whole trial. This not only demonstrated that the treatment had real potential but it also opened up the possibility of stock production in a shallow pool system, something that had not been considered at the time of submitting the initial proposal to the AHDB. However, at this stage caution must be exercised in the interpretation of these results owing to it being a single un-replicated and unrepeated trial. Further work is required confirm the provisional 2015 findings.

While the positive results of increasing the oxygen concentration seemed to be consistent during the 2015 trial, it must be pointed out that because of the lateness in the year, it was not possible to produce a full crop of stocks which had been subject to both high levels of oxygen in water dosed with Subdue from day 1 of planting the plugs. As with the shallow pool trial, further work is required to confirm and replicate the 2015 findings.

As a closing point of discussion the following pictures show the results of the first and final plantings of column stocks in 2015 trial. This clearly demonstrates the progress that has been made in meeting the objectives' of this project.

Figure 62. First planting of column stocks (27th March 2015) showing poor growth on June 1st 2015. The lettuce is the furthest float and the brassica the closest float.

Figure 63. Final crop of column stocks (29th July 2015) produced in the dosed shallow pool showing marketable stems on November 6th 2015.

Conclusions

- Deep pool hydroponics has the potential to be used for growing a wide range of cut flowers.
- Column stock production should be possible in a deep pool system but they appear to require very high oxygen concentrations.

- The additional trial looking at shallow pool hydroponics has demonstrated that such as technique may be a feasible option for column stock production.

Knowledge and Technology Transfer

The main KT actions were ongoing posts on the blog of the Cut Flower Centre website, an Open Day on 5th August 2015 in conjunction with the CFC annual Open Day and finally a 3 page article in the December 2015 / January 2016 issue of the AHDB Grower.

Appendices

Appendix I Nutrient analysis of reservoir water on 17th February 2015

Appendix II Nutrient analysis of mains water on 20th February 2015

Appendix III Various analyses of the pool water throughout the period of the trial.

Appendix I Nutrient analysis of reservoir (rain) water on 17th February 2015

eurofins

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AFA Number	02347153

AR-15-UD-061800-01

Reported on	20/02/2015
Reported by	Sarah Smith, Analytical Services Manager

Page 1 of 2

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45000316	Received on	17/02/2015
Your sample reference	Water	Your sample code	P Collison Rainwater

	Sample Result				Optimum Values			
pH	6.7				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	135	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<1	mg/l	<0.07	mmol/l	0	2	> 10	As low as possible
Nitrate-N	4.79	mg/l	0.34	mmol/l	150	250	> 300	
Phosphorus	<1	mg/l	<0.03	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	0.726	mg/l	0.02	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	24.3	mg/l	0.61	mmol/l	150	250	>300	
Magnesium	0.652	mg/l	0.03	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	4.08	mg/l	0.18	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	14.0	mg/l	0.40	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	2.22	mg/l	0.07	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	<0.02	mg/l	<0.36	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	<0.02	mg/l	<0.36	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	<0.05	mg/l	<4.55	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.08	mg/l	1.18	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	<0.01	mg/l	<0.16	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	0.15				> 3.0	2.0	< 1.6	
K:Ca Ratio	0.03				> 3.0	2.0	< 1.6	
K:Mg Ratio	1.11				> 8.0	6.0	< 5.0	
K:Na Ratio	0.18				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	0.052				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

Green: At or near optimum concentration
Orange: Likely to result in nutrient deficiency
Red: Likely to result in plant damage

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Appendix II Nutrient analysis of mains water on 20th February 2015

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Page 1 of 2

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45000317	Received on	17/02/2015
Your sample reference	Water	Your sample code	P Collison Mains

	Sample Result				Optimum Values			
pH	6.7				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	680	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<1	mg/l	<0.07	mmol/l	0	2	> 10	As low as possible
Nitrate-N	8.80	mg/l	0.63	mmol/l	150	250	> 300	
Phosphorus	1.45	mg/l	0.05	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	2.72	mg/l	0.07	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	139	mg/l	3.47	mmol/l	150	250	>300	
Magnesium	2.51	mg/l	0.10	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	19.0	mg/l	0.83	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	76.6	mg/l	2.16	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	9.36	mg/l	0.29	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	<0.02	mg/l	<0.36	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	<0.02	mg/l	<0.36	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	<0.05	mg/l	<4.55	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	<0.02	mg/l	<0.31	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.01	mg/l	0.22	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	0.31				> 3.0	2.0	< 1.6	
K:Ca Ratio	0.02				> 3.0	2.0	< 1.6	
K:Mg Ratio	1.08				> 8.0	6.0	< 5.0	
K:Na Ratio	0.14				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	0.036				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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Appendix III Various analyses of the pool water throughout the period of the trial.

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AR-15-UD-130523-01

Reported on 14/04/2015
Reported by Tracie Elwell, Customer Services Advisor

Page 1 of 2

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45000797	Received on	10/04/2015
Your sample reference	Hydroponics	Your sample code	P Collison Next To Tank

	Sample Result				Optimum Values			
pH	6.0				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2010	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	5.44	mg/l	0.39	mmol/l	0	2	> 10	As low as possible
Nitrate-N	126	mg/l	9.00	mmol/l	150	250	> 300	
Phosphorus	90.7	mg/l	2.93	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	392	mg/l	10.05	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	108	mg/l	2.71	mmol/l	150	250	>300	
Magnesium	32.3	mg/l	1.35	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	5.98	mg/l	0.26	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	92.8	mg/l	2.61	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	46.4	mg/l	1.45	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.56	mg/l	27.83	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	1.00	mg/l	18.17	µmol/l	< 0.4	0.5-0.8	> 1.0***	***Toxicity risk higher
Boron	1.15	mg/l	104.13	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.30	mg/l	4.67	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.09	mg/l	1.43	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	2.98				> 3.0	2.0	< 1.6	
K:Ca Ratio	3.63				> 3.0	2.0	< 1.6	
K:Mg Ratio	12.14				> 8.0	6.0	< 5.0	
K:Na Ratio	66				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	4.2				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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AR-15-UD-130524-01

Reported on 14/04/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45000798	Received on	10/04/2015
Your sample reference	Hydroponics; P Collison Far Corner of Tank	Your sample code	P Collison Far Corner of Tank

	Sample Result				Optimum Values			
pH	5.9				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2000	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	5.29	mg/l	0.38	mmol/l	0	2	> 10	As low as possible
Nitrate-N	133	mg/l	9.47	mmol/l	150	250	> 300	
Phosphorus	90.4	mg/l	2.92	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	426	mg/l	10.91	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	108	mg/l	2.70	mmol/l	150	250	>300	
Magnesium	32.2	mg/l	1.34	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	6.78	mg/l	0.29	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	93.9	mg/l	2.64	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	46.4	mg/l	1.45	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.55	mg/l	27.60	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	1.00	mg/l	18.12	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	1.14	mg/l	104.03	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.30	mg/l	4.55	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.09	mg/l	1.39	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	3.08				> 3.0	2.0	< 1.6	
K:Ca Ratio	3.94				> 3.0	2.0	< 1.6	
K:Mg Ratio	13.23				> 8.0	6.0	< 5.0	
K:Na Ratio	63				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	4.5				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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AR-15-UD-182312-01

Reported on	27/05/2015
Reported by	Sarah Smith, Analytical Services Manager

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45001072	Received on	22/05/2015
Your sample reference	Hydroponic; P Collison	Your sample code	Main Production Tank

	Sample Result				Optimum Values			
pH	5.8				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2210	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	2.74	mg/l	0.20	mmol/l	0	2	> 10	As low as possible
Nitrate-N	179	mg/l	12.75	mmol/l	150	250	> 300	
Phosphorus	74.3	mg/l	2.40	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	348	mg/l	8.93	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	194	mg/l	4.84	mmol/l	150	250	>300	
Magnesium	34.1	mg/l	1.42	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	15.0	mg/l	0.65	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	101	mg/l	2.84	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	52.8	mg/l	1.65	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.17	mg/l	20.93	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	0.97	mg/l	17.55	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	1.01	mg/l	91.80	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.29	mg/l	4.47	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.07	mg/l	1.06	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.91				> 3.0	2.0	< 1.6	
K:Ca Ratio	1.79				> 3.0	2.0	< 1.6	
K:Mg Ratio	10.21				> 8.0	6.0	< 5.0	
K:Na Ratio	23				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	3.4				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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AR-15-UD-250069-01

Reported on 21/07/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45001460	Received on	16/07/2015
Your sample reference	Hydroponics: Perch Holme NRY. Hydroponic Pond	Your sample code	Perch Holme NRY

	Sample Result				Optimum Values			
pH	6.7				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2360	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	0.142	mg/l	0.01	mmol/l	0	2	> 10	As low as possible
Nitrate-N	176	mg/l	12.58	mmol/l	150	250	> 300	
Phosphorus	17.6	mg/l	0.57	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	331	mg/l	8.50	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	193	mg/l	4.82	mmol/l	150	250	>300	
Magnesium	39.6	mg/l	1.65	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	26.6	mg/l	1.16	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	51.5	mg/l	1.45	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	66.2	mg/l	2.07	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	2.17	mg/l	38.70	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	0.49	mg/l	8.97	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	0.75	mg/l	68.40	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.38	mg/l	5.83	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.07	mg/l	1.05	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.88				> 3.0	2.0	< 1.6	
K:Ca Ratio	1.72				> 3.0	2.0	< 1.6	
K:Mg Ratio	8.36				> 8.0	6.0	< 5.0	
K:Na Ratio	12				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	6.4				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- (green) At or near optimum concentration
- (orange) Likely to result in nutrient deficiency
- (red) Likely to result in plant damage

UKAS 0342

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PO Number 33482

AR-15-UD-396522-01

Reported on 19/11/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45002125	Received on	19/11/2015
Your sample reference	Water dample	Your sample code	LRM Horticultural Services Trial Tanl

	Sample Result				Optimum Values			
pH	7.2				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2940	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<0.05	mg/l	<0.00	mmol/l	0	2	> 10	As low as possible
Nitrate-N	228	mg/l	16.26	mmol/l	150	250	> 300	
Phosphorus	1.93	mg/l	0.06	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	374	mg/l	9.58	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	229	mg/l	5.72	mmol/l	150	250	>300	
Magnesium	70.4	mg/l	2.93	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	49.7	mg/l	2.16	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	121	mg/l	3.40	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	97.8	mg/l	3.06	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.83	mg/l	32.75	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	0.04	mg/l	0.67	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	1.01	mg/l	91.83	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.75	mg/l	11.61	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.17	mg/l	2.72	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.64				> 3.0	2.0	< 1.6	
K:Ca Ratio	1.63				> 3.0	2.0	< 1.6	
K:Mg Ratio	5.31				> 8.0	6.0	< 5.0	
K:Na Ratio	7.5				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	3.1				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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PO Number 33482

AR-15-UD-396523-01

Reported on 19/11/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45002126	Received on	19/11/2015
Your sample reference	Water	Your sample code	LRM Horticultural Services Tank 2 af

	Sample Result				Optimum Values			
pH	8.1				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	3070	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<0.05	mg/l	<0.00	mmol/l	0	2	> 10	As low as possible
Nitrate-N	232	mg/l	16.60	mmol/l	150	250	> 300	
Phosphorus	3.11	mg/l	0.10	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	408	mg/l	10.47	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	225	mg/l	5.62	mmol/l	150	250	>300	
Magnesium	72.8	mg/l	3.04	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	54.0	mg/l	2.35	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	130	mg/l	3.66	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	102	mg/l	3.20	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.70	mg/l	30.35	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	<0.02	mg/l	<0.36	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	1.08	mg/l	98.31	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.82	mg/l	12.63	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.21	mg/l	3.27	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.76				> 3.0	2.0	< 1.6	
K:Ca Ratio	1.81				> 3.0	2.0	< 1.6	
K:Mg Ratio	5.60				> 8.0	6.0	< 5.0	
K:Na Ratio	7.6				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	3.1				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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PO Number 33482

AR-15-UD-396524-01

Reported on 19/11/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45002127	Received on	19/11/2015
Your sample reference	NFT	Your sample code	LRM Horticultural Services Main Tan

	Sample Result				Optimum Values			
pH	7.1				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2240	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<0.05	mg/l	<0.00	mmol/l	0	2	> 10	As low as possible
Nitrate-N	185	mg/l	13.20	mmol/l	150	250	> 300	
Phosphorus	8.77	mg/l	0.28	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	294	mg/l	7.53	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	177	mg/l	4.42	mmol/l	150	250	>300	
Magnesium	41.0	mg/l	1.71	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	28.4	mg/l	1.23	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	68.2	mg/l	1.92	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	66.4	mg/l	2.08	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	0.81	mg/l	14.52	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	<0.02	mg/l	<0.36	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	0.64	mg/l	58.28	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.38	mg/l	5.91	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.15	mg/l	2.33	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.59				> 3.0	2.0	< 1.6	
K:Ca Ratio	1.66				> 3.0	2.0	< 1.6	
K:Mg Ratio	7.17				> 8.0	6.0	< 5.0	
K:Na Ratio	10				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	4.3				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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AR-15-UD-396525-01

Reported on 19/11/2015
Reported by Tracie Elwell, Customer Services Advisor

Hydroponics Analysis Report (Tomato)

Sample number	400-2015-45002128	Received on	19/11/2015
Your sample reference	Water	Your sample code	LRM Horticultural Services Tank 2

	Sample Result				Optimum Values			
pH	7.9				< 5.5	6.0	>6.5	Target range: 5.8-6.2
Conductivity at 20°C	2950	µS/cm			< 2,500	4,000	> 6,000*	*Early season growth control
Major Nutrients								
Ammonium-N	<0.05	mg/l	<0.00	mmol/l	0	2	> 10	As low as possible
Nitrate-N	240	mg/l	17.16	mmol/l	150	250	> 300	
Phosphorus	3.57	mg/l	0.12	mmol/l	20	30-40	> 50**	**Induced Zn+Cu deficiency likely
Potassium	411	mg/l	10.54	mmol/l	< 400	500	1,000	Toxicity: rare
Calcium	202	mg/l	5.06	mmol/l	150	250	>300	
Magnesium	67.3	mg/l	2.81	mmol/l	< 65	80	> 100	High K inhibits Mg absorption
Undesirable Ions								
Sodium	48.2	mg/l	2.10	mmol/l	< 100	200	> 400	High Na inhibits uptake of K, Ca, Mg
Chloride	117	mg/l	3.31	mmol/l	< 100	200	> 400*	*Early season growth control
Sulphur	104	mg/l	3.25	mmol/l	< 50	100	> 200	
Trace Nutrients								
Iron	1.57	mg/l	28.00	µmol/l	< 2.0	3.0-4.0	> 5.0	
Manganese	<0.02	mg/l	<0.36	µmol/l	< 0.4	0.5-0.6	> 1.0***	***Toxicity risk higher
Boron	0.94	mg/l	85.43	µmol/l	< 0.3	0.4-0.6	> 1.0	
Zinc	0.84	mg/l	12.96	µmol/l	< 0.5	1.0	> 1.5	Link with P and Mn
Copper	0.17	mg/l	2.66	µmol/l	< 0.05	0.1	> 0.2	
Ratios								
K:N Ratio	1.71				> 3.0	2.0	< 1.6	
K:Ca Ratio	2.03				> 3.0	2.0	< 1.6	
K:Mg Ratio	6.11				> 8.0	6.0	< 5.0	
K:Na Ratio	8.5				> 5.0	2.5	< 1.25	Important in recirc.
K:Cl Ratio	3.5				> 5.0	2.5	< 1.25	Important in recirc.
Other								

Key to interpretation

- Green: At or near optimum concentration
- Orange: Likely to result in nutrient deficiency
- Red: Likely to result in plant damage

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