

# No soil required!



Maximising crop yield using vertical hydroponic growing systems.

RHS Bursary Work placement - 3 July to 30 August 2023

**W Perrett**

Undergraduate Horticulture Student

W. Perrett

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## Introduction

Traditional methods of plant production involving the use of large areas of land, high volumes of water and the discharge of fertilizers into local environments, are being challenged. Exciting new methods of plant production are being developed such as hydroponics and aeroponics. For my A levels I studied Biology, Environmental Science and Geography and for my career I want to develop methods of plant production blending science and technology that produce high quality and environmentally sustainable products. Climate change and the effects of regional conflicts, such as the war in the Ukraine are raising the profile of national food security. Plant production is becoming an increasingly important topic in a world with a growing population, water supply challenges and greater transglobal connectivity.

I wanted to understand how hydroponics systems work in practice and gain work experience in this area. Saturn Bioonics gave a presentation at my university, and I went to visit their company. They are a pioneer in hydroponic science and technology with 10 years of research and trials across 4 climate zones, 6 years of commercial crop production with over 250 varieties grown and 300 crop cycles. They are developing low costs, adaptable, high density growing systems harnessing science and technology, and with a strong emphasis on sustainability such as using solar energy. I am excited by their aims. They have a strong research department, and I was assisting with this work during my placement. In addition, Saturn allowed me to conduct my own mini research project.

*“Hydroponic Science is an interdisciplinary science combining the art of hydroponics, including hard and soft technologies, and plant sciences including crop molecular genetics, evolution, plant cell biology and plant physiology. It is the most direct way to interact with the plant.”*

Saturn Bioonics

## **Location of Work Placement**

I undertook my work placement at Saturn Bioponics, which is a biotechnology company based in England, UK. They supply sustainable hydroponic cultivation science and technology for low-cost, high-quality crop production on a commercial scale. Saturn have links to a commercial grower, whose premises I visited, where research outputs can be trialled on a commercial basis.

I undertook my work placement as a Hydroponic Trial Technician and assisted in the implementation, maintenance, and data collection of hydroponic trials using the Saturn Grower. The placement involved working with hydroponic systems, working closely with the Research and Development team to execute trials, monitor plant growth, collect data, and ensure trials are conducted safely and efficiently.

## **Main Aims**

Plant growth, and therefore plant yield, is affected by a variety of different variables:- light, temperature, water, humidity, nutrition, growing medium (substrate) and plant variety. Plant yield is of key importance to the success of a commercial horticultural company, nation states, and global demand in times of a rising world population and threats to crop production. As hydroponics is a relatively new form of crop production, research into the best combinations of these variables in which to grow plants is important. During my time at Saturn Bioponics, I was involved in trials looking at the effect of 3 different variables on the yield of a brassica :-

Trial 1 . – growing medium (substrate) for germination of seeds

Trial 2. – nutrition treatment/food solution for feeding mature plants

Trial 3. – plant variety

I had to sign a non- disclosures agreement not to reveal any sensitive commercial information about the trials so the different substrates, nutrition treatments and plant varieties have been allocated codes. The brassica was chosen for the trials because it is a fast-growing plant and I wanted to complete the trials within my 6-week placement. For all trials other variables were kept consistent – i.e. light, temperature, water, humidity. The plants were grown in an enclosed polytunnel system.

## Methodology

### Trial 1 . – growing medium (substrate) for germination of seeds

When growing plants using a hydroponic system, the mature plant does not require a substrate (growing medium) such as soil. However, for germination a substrate is required for a seed to grow into a plant plug with a mature root system that can then be transplanted into hydroponic towers. The aim was to investigate how different substrates, which were not soil, affected the size of the final plant plug. I used 3 different substrates:

Substrate trial
Substrate 1
Substrate 2
Substrate 3

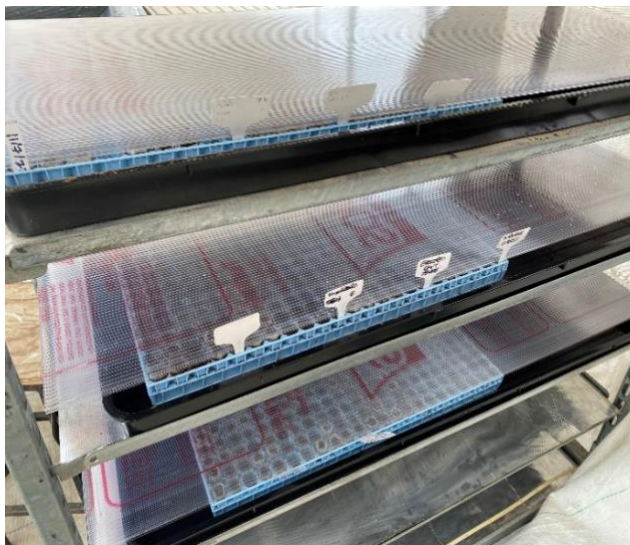


Photo: Planting out seedlings

I planted the seeds in the 3 different substrates on 11.07.23. The main focus was on substrates 1 and 2, only 100 seeds were planted for substrate 3. A key aim for hydroponics is to reduce reliance on using soil as a substrate because large areas of land are required. Although, the substrates cannot be named, substrate 1 was the most similar to soil in terms of its physical structure of small particles close together. Substrate



2 was more compact than soil and substrate 3 was less compact than soil with large spaces between particles.

Trial 2. – nutrition treatment/food solution for feeding mature plants

Once mature plant plugs had been created in Experiment 1., the aim was to investigate how different nutrient treatments affected the size of the final plant. I used 2 different treatments and a control using standard nutrient levels. 3 different varieties of the brassica were used.

Nutrition treatment trial
Control nutrient solution
Added minerals nutrient solution
Added bacteria nutrient solution



Photo: Checking pH levels and electrolyte levels



Photo: Seedling plugs

Once the plant plugs had matured, they are planted in vertical towers at a horizontal angle within loose clay balls. A nutrient solution flows from the top to the bottom of the tower in a continuous loop. No substrate or soil is used, the roots are fed directly by the percolating solution. 1 tower contains 48 plant plugs. Plugs were planted on 01.08.23 and data collected on 07.08.23 and 30.08.23.

### Trial 3. – plant variety

To investigate how plant variety impacts on plant growth, mature plant plugs (all grown using substrate 1) were transplanted into growing towers. All were fed the same nutrient solution, but the variety of brassica was altered. 12 varieties of the brassica were used in the trial. Plugs were planted on 01.08.23 and data collected on 07.08.23 and 30.08.23.

Variety trail
Pk 001 v plant
Pk 002 v plant
Pk 003 v plant
Pk 004 v plant
Pk 005 v plant
Pk 006 v plant
Pk 007 v plant
Pk 008 v plant
Pk 009 v plant
Pk 010 v plant
Pk 011 v plant
Pk 012 v plant





Photo: Bio control sachets for pests

Photo: Plant plugs growing of 12 different varieties

Throughout the trials I was responsible for checking that the pH levels and electrolyte levels in the growing towers were maintained within set parameters (see Appendix A.).

I made observational notes (see Appendix B.)

I collected data (data cannot be shared due to non-disclosure clause)

## Data Analysis

### Trial 1 . – growing medium (substrate) for germination of seeds

On 01.08.23 data was collected as the plant plugs were now 5 – 10cms tall with a mature root system and ready to be transplanted into hydroponic growing towers.

### Results

Substrate 1 – A high percentage of seeds germinated into viable plant plugs ready for transplant. The particles within the substrate were of a similar size to soil and so root systems were able to successfully develop. The success rate was 68% so there is room for fine tuning ways of using substrate 1. to raise the success rate above 68%.



Substrate 2 – A low percentage of seeds germinated into viable plant plugs resulting in a high level of wasted seeds. The particles within the substrate were too compact to allow a root system to develop.

Substrate 3 – No seeds germinated into viable plant plugs ready for transplant, all seeds were wasted. The particles within the substrate were too loose to allow a root system to develop and lots of seeds just fell out of the bottom of the substrate.

**Conclusion** – seeds grown in substrate 1 demonstrated the best levels of growth.

#### Trial 2. – nutrition treatment/food solution for feeding mature plants

On 29/30.08.23 data was collected as the plant were fully grown

#### **Results**

(data cannot be shared due to non-disclosure clause)

**Conclusion** – plant plugs grown in the added minerals nutrient solution demonstrated the best levels of growth.

#### Trial 3. – plant variety

On 29/30.08.23 data was collected as the plant were fully grown

#### **Results**

(data cannot be shared due to non-disclosure clause)

**Conclusion** – plant variety had no significant impact on crop yield.

### **Overall Conclusion**

The way to produce the highest plant yield, using a hydroponics growing system, would be to germinate seeds using substrate 1 and grown mature plants in the added minerals solution.

### **Work Programme**

I arrived on time to start my placement on the 3<sup>rd</sup> July 2023. The first task was to read through all the health and safety sheets and sign a non-disclosure agreement. My first actual job at work was strawberry husbandry. I cut the runners off the strawberries and put out hanging bags and boxes that contained beneficial insects to eat the pests present in the area. I also carried out data

collection on strawberry crops where I measured the yield and waste and noted any diseases or pests present. There was an issue with the watering system, which was fixed quickly after it happened, but while it was broken, I had to manually water the crops in the towers. I talked to my supervisors about my experiments and started to plan the experiment.

My second week started on 10<sup>th</sup> July. I did more strawberry husbandry. I cut the runners off the strawberries and did data collection on strawberry crops where I measured the yield and waste and noted any diseases or pests present. My plan for the experiment was finalised. I was shown how to hand sow the seeds into the plugs. Then I covered the trays and waited for them to germinate. Some strawberry plants had to be moved into other towers, so I helped plant them. I also helped in collecting harvest for some Pak choi. With all this happening the area got dirty, so I cleaned up after the harvest and removed old plugs from a previous experiment.

My third week started on 17<sup>th</sup> July. The seedlings had germinated. The trays were put onto irrigation tables after I had cleaned them all. The irrigation tables automatically water the plugs throughout the day. I was told how the irrigation system works so I could water the plugs myself if they become dry through the day. I was also told how to measure the pH and the EC of the water tanks connected to the irrigation table. The trays used for germination had become dirty, so I cleaned them all. To protect my seedlings, from insect damage, I put out sticky bug tape around my seedlings. I also helped the team with planting some lettuce and harvesting some other lettuce and some Pak choi.

My fourth week began on the 24<sup>th</sup> July. I did my daily checks on my plants and wrote up my observations on their size, condition, colour, and germination yield. I also checked the water tanks and watered my plants. I had been given an area where I would do my experiment. After making a layout of where the plants would go, I had to build the towers I needed and clean them. The floor also had to be cleaned. I had to clean and check the main watering tanks. Afterwards I had to check that all the sprayers that fed water into the towers were working and replaced any that were blocked. I then started to plant out the plants that were big enough to be used. I labelled my towers with the plant variety as per

my layout plan. I turned on the watering system for the towers daily to make sure all the sprayers were cleaned and that all the plants were getting watered.

My fifth week began on the 31<sup>st</sup> July. Every day I checked the pH and EC readings of my tanks (see Appendix A.) and checked my sprayers were unblocked and that all the plants were getting watered. I wrote down any observations I noticed with the system or the plants (see Appendix B.) If plants had dried up and died, I removed them and recorded my losses. Some towers had to be adjusted slightly to make them straighter for more equal watering, so I had help moving them. My plants were being damaged by thrips, so I put up more sticky bug tape. Thrips are insects which feed by sucking sap from plants. I collected data on my plants:- height, width, colour, and leaf count. I went back onto helping with the strawberry harvest. More of my plants were ready in the other substate I was using for my trial. I had enough to plant two towers of the same variety into my system. Plants that had been left after planting my first substate were binned and the irrigation trays they were in, cleaned. The filters from the irrigation trays to the water tanks were dirty and clogged up with substrate so I replaced and cleaned out the dirty filters. I cleaned the floor to remove any bug eggs and remove dirt that could encourage disease.

My last week started on the 8<sup>th</sup> August. I am still checking the pH and EC of my tanks. I planted up the last tower. I had to bin all the other plants I hadn't planted up. I cleaned the irrigation trays. With all the knowledge I have learnt from using the trial watering systems, I went on a tour of the grower's watering system which is located next to us. I finished the data collection and put all the data onto a spreadsheet. I went on a visit to another grower with my supervisor to see other techniques of growing plants. I wrote up all my notes and data that I have collected over my placement.

My harvest was completed on 29/08/23 and 30/08/23. I filled in the data collection sheets with the information about which plants we were harvesting. The information we collected was the weight of each individual plant from selected towers. We also recorded the amount of wastage from each tower. We packed the plants into crates and labelled them. After the harvest we cleaned up the area. We then selected the most average looking plants from each crate and

weighed them. The team labelled and took pictures of the plant to use as company data to see if the experiment was a success or failure.

## **Conclusions and future plans**

I have gained practical experience of how hydroponics growing systems work. I want to work in this sector on leaving university and this work placement has provided me with a basic skill set upon which I can build. I will be able to develop a professional online media profile using information from the placement.

I have gained scientific research skills. I like doing scientific research and this placement has allowed me to develop these skills in a commercial setting.

I have gained knowledge that makes it easier for me to understand units in my next year at university on crop production and experimental design and analysis.

I would like to visit other hydroponics settings to expand my skill set and knowledge about this exciting new method of food production in Europe e.g. the Netherlands and in the wider world e.g. Singapore. I get to blend my love of plants with my love of science. I would like to thank all at Saturn Bioponics for the opportunity to start on this exciting career.

## **Acknowledgements**

I would like to thank the following for their assistance with this placement:

Saturn Bioponics – an amazing team and a special thank you to Kirstie.

My lecturers at university Mark Oxenbury and David Jukes



Royal Horticultural Society for their bursary

The Merlin Trust for their bursary

## **Final Budget Breakdown**

Description	Actual Cost
<b>Travel</b>	
<b>Car Expenses</b> <b>Mileage: -</b> Own Car- <b>864</b> @ 25p per mile Weekly travel costs from Malmesbury to Evesham for 7 weeks	£ 216.00
<b>Subsistence</b>	
<b>Accommodation: 24</b> nights Weekly accommodation costs from at Premier Inn, Evesham for 6 weeks	£ 1706.50
<b>Food:</b> 26 days @ £30.00 per day maximum Daily food costs for 7 weeks  <i>(RHS recommendation is a maximum of £30 per day)</i>	£ 443.50
<b>TOTAL</b>	£ 2366.00
<b>RHS BURSARY AWARD</b>	£ 1314.00
<b>Merlin Trust BURSARY AWARD</b>	£ 1000.00
<b>Personal Contribution</b>	£ 52.00

**Signed: W. Perrett**

**Date: 01.09.23**

## Appendices

- A. Tank readings
- B. Observational Notes

## **Appendix A. – Tank readings**

Date	Time	Tank number	pH	EC
19/07/2023	8:30am	1	5.9	1.1
19/07/2023	8:30am	2	7.0	1.4
19/07/2023	8:30am	3	8.1	0.8
19/07/2023	3:00pm	1	5.4	1.3
19/07/2023	3:00pm	2	6.1	1.5
19/07/2023	3:00pm	3	5.8	0.9
20/07/2023	8:30am	1	5.6	1.3
20/07/2023	8:30am	2	6.1	1.5
20/07/2023	8:30am	3	6.9	0.9
20/07/2023	12:30pm	1	5.7	1.3
20/07/2023	12:30pm	2	6.2	1.5
20/07/2023	12:30pm	3	7.0	0.9
24/07/2023	8:30am	1	6.9	1.2
24/07/2023	8:30am	2	6.8	1.4
24/07/2023	8:30am	3	7.5	0.9
25/07/2023	8:30am	1	7.1	1.2
25/07/2023	8:30am	2	6.8	1.4
25/07/2023	8:30am	3	7.3	0.9
26/07/2023	8:30am	1	7.3	1.2
26/07/2023	8:30am	2	6.8	1.5
26/07/2023	8:30am	3	7.4	0.9
27/07/2023	8:30am	1	7.5	1.1
27/07/2023	8:30am	2	6.9	1.4
27/07/2023	8:30am	3	7.3	1.0
31/07/2023	8:30am	1	7.6	1.2
31/07/2023	8:30am	2	7.3	1.2
31/07/2023	8:30am	3	7.4	0.9
31/07/2023	8:30am	9	7.6	1.8
31/07/2023	8:30am	10	7.6	0.8
31/07/2023	8:30am	11	7.4	2.1
31/07/2023	8:30am	12	7.5	1.8
01/08/2023	8:30am	1	7.6	1.2
01/08/2023	8:30am	2	7.2	1.2
01/08/2023	8:30am	3	7.5	0.9
01/08/2023	8:30am	9	7.6	1.4
01/08/2023	8:30am	10	7.7	0.6
01/08/2023	8:30am	11	7.5	2.0

01/08/2023	8:30am	12	7.7	1.3
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02/08/2023	8:30am	1	7.6	1.3
02/08/2023	8:30am	2	7.1	1.2
02/08/2023	8:30am	3	7.6	0.9
02/08/2023	8:30am	9	7.9	1.0
02/08/2023	8:30am	10	7.9	0.9
02/08/2023	8:30am	11	7.7	1.7
02/08/2023	8:30am	12	8.0	1.0

03/08/2023	8:30am	1	7.8	1.1
03/08/2023	8:30am	2	7.3	1.1
03/08/2023	8:30am	3	7.6	0.9
03/08/2023	8:30am	9	7.9	0.9
03/08/2023	8:30am	10	7.5	0.5
03/08/2023	8:30am	11	7.8	1.7
03/08/2023	8:30am	12	7.8	0.9

07/08/2023	8:30am	1	7.9	1.0
07/08/2023	8:30am	2	7.3	1.1
07/08/2023	8:30am	3	7.5	1.0
07/08/2023	8:30am	9	7.9	0.7
07/08/2023	8:30am	10	7.8	0.4
07/08/2023	8:30am	11	7.9	1.0
07/08/2023	8:30am	12	7.8	0.7
07/08/2023	2:30pm	9	1.6	6.4
07/08/2023	2:30pm	10	1.9	6.9
07/08/2023	2:30pm	11	1.6	6.7
07/08/2023	2:30pm	12	1.7	6.7

08/08/2023	8:30am	1	8.0	1.1
08/08/2023	8:30am	2	7.3	1.0
08/08/2023	8:30am	3	7.5	1.0
08/08/2023	8:30am	9	7.7	1.1
08/08/2023	8:30am	10	7.8	0.7
08/08/2023	8:30am	11	7.8	1.2
08/08/2023	8:30am	12	7.7	1.1

## Appendix B. – Observational Notes

### Observations Notes



### 19/7/23

- Some seeds from all plants after a week still have not emerged.
- All plants still have cotyledons, but older plants are forming true leaves.
- Plants are growing better in Substrate 1 than Substrate 2 in the same variety.
- Plants from 11/7/23 are averaging 1.5cm – 2cm in height.
- Plants from 13/7/23 are averaging 0.5cm – 1cm in height.
- Some insects present in substrate.
- All plugs are damp.
- Some difference in leaf shape and colour but generally all similar.

### 20/7/23

- Roots are appearing to break through the Substrate 1 and Substrate 2.
- All plugs are wet.
- Insects still present on plugs.
- Some cotyledons are yellow/white coloured on some plants.
- No roots have appeared breaking through the Substrate 3.
- A few plants are growing at an angle but everything else is growing straight.
- Some plugs have two seedlings.
- Some varieties are very uniform in growth stages. (Pk 003 t plant)
- Some plants are not uniform in growth. (Pk 002 t and Pk 001 t)
- The growth pattern is either random and scattered or they group up around the centre or the sides.
- The plugs were dry in the afternoon, so they got watered.

### 24/7/23

- All the plants in Substrate 1 now have true leaves, plants from 11/7/23 have 3-4 true leaves.
- The younger plants from 13/7/23 measure 1-3cm in Substrate 1 but less than 1cm in Substrate 2.
- The older plants from 11/7/23 measure 5-6cm.
- Substrate 3 plants measure 1cm but coverage is random.
- Algae has grown on the Substrate 2.
- Substrate 2 and Substrate 1 coverage is still random.
- Some thrip damage on the leaves.
- The colour on the plants is bold and bright, 1 variety is yellow/white, another variety is red.
- Seedling growth rates on variety trail is around 70% from using opened packets.
- Big roots on average on the Substrate 1 but only a few roots on average for the Substrate 2.

### 27/07/23

- Plants put into the towers that were seeded from 11-14<sup>th</sup> in Substrate 1 substrate.
- Pk 001 t are smaller but have more and longer roots.
- Pk 003 t plant has good roots too.
- Pk 002 t has less developed roots.
- Substrate 2 plants are still tiny.

### 31/7/23

- The Pk 003 t plant in Substrate 2 plants are the only plants that have fully grown out of the seedlings stage with an average height of 5cm with thrip damage.
- All other Substrate 2 trays are still tiny with a few taller plants.
- The plants have yellowing leaves which is from a nutrient deficiency.
- The last variant for the variety trail was planted on 19/7/23 with an average of 5cm.
- The plants in the Substrate 3 have the same problems as the Substrate 2.
- All the plants in the towers are all standing upwards.
- There are a few dry plugs due to the lean of the towers.
- Roots are growing out into the centre of the columns.

2/8/23

- I have removed 3 dead plants from different towers, which dried up due to the lean of the towers.
- I have tried to move the towers, so they are straighter.
- Some towers were leaking because they were blocked and have been unblocked now.
- All the plants are growing well.
- The difference in growth rates can be seen now throughout the towers.
- The cotyledons have either come off or started to come off.
- There are no diseases present but all plants from thrip damage.
- More bug tape has been put up.
- All plants now have a minimum of 3 or 4 true leaves.
- A tray of Pk 003 t plant in Substrate 2 was big enough and has been planted into 2 towers in system 10 which is the control for the treatment trail.

3/8/23

- The plants that were dry are still dry but have laid their roots into the wet clay.
- The Substrate 2 plants are getting an even watering and the plants look like they are growing well.
- I can see their roots breaking through the Substrate 2 and into the clay.
- Looking around at all the plants they're all doing well with no diseases but thrip damage is still present.
- All the leaves are green and bright.
- No towers are leaking on the floor.
- The other Substrate 2 plants in the irrigation trays are still being watered.

7/8/23

- All plants are growing well and are beginning to spread out the leaves and are beginning to swell in the centre, but the leaves are spreading out and are blocking each other.
- Some of the sticky tape had attached itself to the plants, removing them damaged the plants.
- Another Substrate 2 tray has grown where and it is planted into the system.
- Some varieties are doing much better than others in the variety trail.
- The Substrate 1 plugs are much easier to place into the towers than the Substrate 2 plugs.
- The plant leaves have less thrip damage.
- The plants in the irrigation trays have been thrown away.

9/8/23

- The roots on the Substrate 1 cover the whole plug and are smaller but fluffy, the Substrate 2 roots are later and do not cover the whole plug and are not fluffy.
- Some of the Substrate 2 plugs are very dry but their roots are in the clay, so it is just the outside of the plug that is dry, and the plant is not wilting.
- Some of the plants when put into the towers they had stretched stems and now they are bigger the stretched stem has continued growing.
- There are still pests like sciarid flies present on the plants but there is lots of sticky tape collecting the pests.
- A few plants have holes in their leaves from been eaten from thrips.
- Some plants are spreading out more rather than swelling up in the centre like most of the other plants are doing.
- The younger plants all have purple stems which change to green as they grow older.