Irrigation Experiments

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February 2020 – December 2020

How can we save water and reduce work with vegetable growing?

Design framework: SADIMET
Tools: SMART goal, PMI, pattern analysis
Principles:
The problem is the solution,
Cycling of energy, nutrients and resources
Obtain a yield,
Creatively use and respond to change
Small scale intensive system

<u>Irrigation Experiments</u>

Contents

Irrigation Experiments

Vision: Which irrigation method gives the best growth for the least amount of water?

1. Introduction

'**The problem is the solution**' definitely applied to this project. In the 2018 drought I lost lots of plants, both in pots and perennials in the beds. I had decided only to water perennial plants when they are getting established as well as annuals in the vegetable beds. It was impossible in the summer heat to keep up with the watering, without wasting water. The water seemed to evaporate before it even got to the roots of the plants. We had also run out of rainwater so we were reliant on mains water so I wanted to find a better way.

Aubergine plants with and without a plastic bottle

The following year, I experimented with growing aubergines using a submerged plastic bottle[1]. I grew one aubergine plant with a plastic bottle and one aubergine plant without a plastic bottle as a comparison. I saw a remarkable difference in plant height (see photo). The plant with the plastic bottle grew significantly taller than the one without. This gave a qualitative result but as both plants didn't set fruit it was difficult to know if this method would result in an improved yield generally. I wanted to quantify this apparent growth more scientifically.

Furthermore, I wanted to be able to report to the Peddie Family Resource Centre, Eastern Cape, South Africa, which methods were most effective and might be able to help them too as water scarcity is a serious issue in this region. The Peddie Family Resource Centre is endeavouring to help young children after school, giving them a meal and support in often very difficult circumstances. We have been supporting them for a number of years through our family ties to the community (for more information about the centre see appendix 3).

Family Centre Peddie, Eastern Cape

Also Gaynor Grace in Permaculture magazine[2] indicated how imperative the need to conserve water has become. There has been much focus on Capetown[3] being a large city and a centre for tourism, the situation is bad, if not worse, in the Eastern Cape where extreme poverty makes the situation worse.

2. Design Approach

The **SADIMET** design approach was followed, as mentioned in Aranya's 'Permaculture Design'[4]. It was the most appropriate method for these experiments as the results would be generated in a linear fashion.

Namely:
Survey
Analysis
Design
Implementation
Maintenance
Evaluation
Tweak

3. Survey

A search was made for methods of irrigation that would be low tech, readily available and cheap. There are many ideas available, particularly on the internet.

3.1 Traditional literature search

I cannot rate 'Gardening with less water'[5] highly enough, it is a really useful book full of helpful ideas. There were several articles in permaculture magazine but the one from Graham Burnett[6] was particularly helpful.

3.2 Internet search for methods

There were many examples which included ideas for drip irrigation[7, 8, 9] bottles next to plants in trays[10], clay pots submerged in soil next to plants[11]. Also there were examples where bottles were submerged into the soil next to plants[12, 13].

3.3 Other Research

I also wanted to check for previous research into the relationship between plant height/leaf number and fruit yield. The research regarding plant height related only to etiolated plants that were tall because they were trying to reach more sunlight. The research for leaf area dated from 1936 where they saw an increase in tomato production with greater leaf area[14].

I have been using clay pots which have been submerged in the soil next to plants as a method for watering plants for some time. I had found it helpful as it allowed plants to access water even when the soil was dry (see Permaculture Bed – Project 1 and Anne-Marie's Garden – Project 2). However, I hadn't tested the efficacy of clay pots scientifically. Therefore, the use of clay pots would definitely be one condition in the experiments.

Furthermore, I had previously tried using cotton cord with a plastic bottle as a drip irrigation system but it did not work. The wick only carried water for a short time before algae started growing on it and that stopped capillary action.

4. Analysis

4.1 SMART goal

Vision: Which irrigation method gives the best growth for the least amount of water?

What am I actually trying to discover? Can I define the vision further? The aubergine plant grew taller, so in other words had more vegetative growth resulting from the bottle irrigation, however, as no aubergines grew, could I assume that generally more vegetative growth would result in more fruit, as has been suggested by scientific research[14] Also, the water volume required in order to generate this growth was a factor in determining the effectiveness of this or any irrigation system.

Therefore, the focus of the design was to determine answers to the following questions:
Which irrigation method resulted in the most growth?
Does plant height or leaf number relate to fruit production?
Does soil hydration relate to plant growth?
Which method used the largest volume of water?

Therefore, the more defined, smart goal is:

Smart goal
To determine which irrigation method resulted in the most fruit production for the least amount of water?

Specific – the goal is defined above
Measurable – the results will be measured in terms of leaf number, plant height, fruit number and water volume required.
Achieveable – the results should be achievable as the resources were either already available or not expensive. This included access to greenhouse and having time available.
Relevant – the results would be relevant to both us and the people in Peddie Family Resource Centre.
Timely – These experiments are intended to be carried out during one growing season.

4.2 Choice of irrigation experiments

Many options were considered. When I looked online there were plenty of options using plastic water bottles but I was wary, after my previous years' experience of algae problems, by those which required the use of capillary action through thin cord. Also, having had the successful vegetative growth with the half submerged plastic pot, I thought that I needed to try this method in a quantitative rather than qualitative way. Furthermore, I decided to opt for low-tech and cheap solutions which could be applied in South Africa as much as here. Finally, I also considered what materials I had available such as some old plastic boxes that had been used for storage in the garden shed. I wanted to use options that could be applied both to pots as well as directly into beds.

5. Design

Irrigation experiments

Tomas, my tutor, made a good point and suggested that n=5 per condition group would be a sensible idea because with vegetable plants so many things can happen during a growing season.

Project Design Conditions

1. Water bottles submerged in the plant pots
2. Capillary action: Fabric strips from a plastic bottle reservoir
3. Plants in trays with a water bottle as a reservoir
4. Half-submerged clay pots placed in larger tubs
5. Self-watering reservoir using plastic storage boxes.

The project would also include controls for all of the above.

Conditions	Plus	Minus	Interesting
1. Water bottles submerged in the plant pots	Uses free material that would be discarded. The set-up won't take up much space in the greenhouse. I already have quite a few plant pots large enough for the experiments.	Uses plastic that we are trying to reduce. The water will potentially seep quite quickly into the soil. Requires plastic plant pot.	The water bottle will direct the water directly to the roots of the plant.
2. Capillary action: Fabric strips from a plastic bottle reservoir	Uses old fabric for capillary action so there is no expense.	Requires sufficient fabric for all the experiments for replicate conditions more exactly. The reservoir bottles can easily be knocked over	The capillary fabric can be directed to the roots of the plants. Hopefully, this will help to reduce the demand for water.
3. Plants in trays with a water bottle as a reservoir	The trays were plastic but they were pre-existing and will be re-used many times. The bottles would have been discarded.	The set up takes up a lot of space in the greenhouse.	It is a set-up that could work for house plants as well.
4. Half-submerged clay pots placed in larger tubs	The clay pots were pre-existing so did not cost anything; the large tubs were discarded from the council.	The tubs were large and needed lots of space in the greenhouse.	The volume of the clay pot can be pre-determined to reduce the measuring required.
5. Self-watering reservoir using plastic storage boxes.	These were old toy boxes. I managed to tidy and recycle the contents so I could use them for the experiments and reduce clutter.	They are plastic boxes and are not recyclable.	The boxes are stackable and can create a good sized reservoir between them.

The requirement for the experiment conditions are shown below

Requirements

Condition	Description	No. plants needed	No. 3l pots needed?	Other
1	Plastic bottles in plant pots	5	5	5 old plastic bottles
2	Capillary action: Water reservoirs with fabric strips	5	5	5 old plastic bottles, fabric to act as capillary wick
3	Tray with bottle acting as a reservoir	5	5	5 old plastic bottles, felt to act as a capillary mat.
4	Clay pots in large plant pot	10	None	2 Large boxes and 2 large clay pots with rubber bungs and plant trays as lids.
5	Self-watering tub	10	None	3 stacking boxes, tubing, fabric to act as a capillary wick
Control	Pepper plants in pots with no water saving features.	5	5	
Total		**40**	**20 x 3l pots**	**15 plastic bottles, fabric, 2 clay pots with bungs, 3 stacking boxes, tubing**

Note: the plastic bottles were all the same size and shape to ensure a fair comparison.

Additional requirements

Other materials that I needed for the project are listed below. They had a price next to them only if I needed to purchase them.

- Measuring beakers/jug
- Thermometer
- Hydrometer
- Tape measure
- Weighing scales
- Notepad
- Seed trays
- Pots of the same size, some from a friend a few needed to be purchased 4.99
- Coir plugs 13.99
- Pots for potting on
- Hydrometer £7.99
- Thermometer £0.99
- Measuring beakers £3.99

- Organic Sweet Pepper – Marconi Rosa Organic seeds £2.49
- 3 x stacking boxes
- Pipe
- Old towel
- Old fabric e.g. t shirt
- Felt or other close-woven fabric
- Water proof pen and labels
- Green house
- The means to compile the large amount of data is also needed for example: Excel or other spreadsheet software.
- Fertiliser for tomatoes: in this case a Comphrey tea solution was used due to availability.
- **Total: £ 34.44***

*The prices were given when only when a purchase had to be made, everything else was already available

6. Implementation

The project was implemented following the timeline (see below).
The seeds were planted in March in equal sized coir plant plugs in order to keep the conditions as similar as possible. Harvested rainwater was used for most of the experiment depending on availability.

Project timeline

Element	Time of year			
	Early Spring 2020	Late Spring 2020	Summer 2020	Autumn 2020
Plant seeds in plugs				
Pot on plugs in small pots				
Repot small pots into 3litre pots				
Set up experiments				
Measure plant heights, and count leaf numbers, measure hydration levels, temperature, count tomatoes/peppers.				
Terminate experiment, weigh fruits, plant weights upon completion.				

6.1 Experiment set up
I chose Sweet Pepper 'Marconi Red' for the experimental plants as I usually have no problems growing them. I judged that we could eat/give away large numbers of them as they taste delicious and normally cost more than normal bell peppers to buy in a shop.

The seeds were planted in coir-based plant plugs in March. These were beneficial because they were quick to prepare, the plugs didn't take up much space so it was easier to find places to set the seeds growing indoors. They also had a good success rate for germination as well as being similar in weight so the growing conditions for all the seeds were as comparable as possible.

When the experiment was set up, I treated the seeds in the same way. Therefore when I measured the weights of all the plants and pots/soil they were similar. When I potted these on, I put them into pots of the same size and measured the soil to ensure the weight was the same (+ or - 3g). I used the same potting compost for all the pots. I needed more than one bag so I mixed two bags in a wheelbarrow to reduce the chance of each bag being different.

Seed plugs before water

Seed plugs after water

Difficulty: Unfortunately, not enough pepper seeds germinated so I could not apply all the conditions to one type of plant and have enough to include 5 plants for each condition and control. Thankfully, I had sufficient tomato plants (Gardener's Delight) for the clay pot condition and control and another tomato plant (Galia) for the self-watering condition and control. Fortunately, these tomatoes were grown from seed that I had kept from last year so there was no cost implication. Additionally I had grown them in coir plugs which had been potted on in matching plant pots so the plants were consistent within each experimental group. Unfortunately, it means that the tomato results will not be directly comparable to each other or to the other experimental conditions.

6.2 Methods

It was important to ensure that the only factors which were altered within each experiment were the experimental conditions, i.e., the method of irrigation. Therefore, all the other elements were kept consistent including:

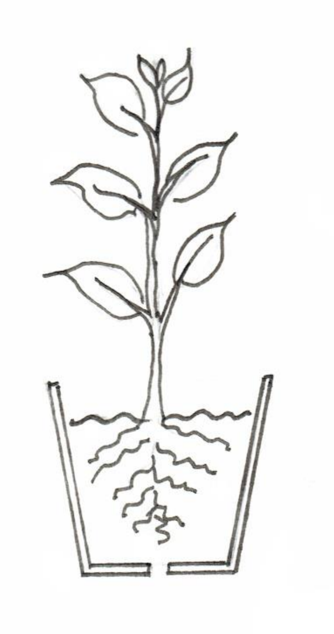
- Same weight of soil for each plant across all the pepper plants
- Same sizes of bottles (1 litre), trays (35 x 23 cm), plant pots (3litre), fabric pieces, self-watering tubs and boxes.
- Same weight of soil in the control and experiment tubs for the clay pots condition and also for the self-watering reservoir condition.
- The self-watering reservoir tub had the same number of holes as the control, drilled into the base.

Note: Appendix 1 details the irrigation experiment options because my Aunt had asked me to send the information to her in South Africa. She gave it to the Family Centre in Peddie to help them with their vegetable growing. They were very interested but decided to wait until next growing season to see which method worked the best before trying them out for themselves.

Then the initial readings with the hydrometer, the initial plant height, number of leaves were noted for each plant. The weights of the plants were noted too. These were carried out for all five plants in each condition or control.

The different experiments and controls were set-up as illustrated below:

1. Control for Pepper plants
No irrigation but matching pots to the experimental conditions.

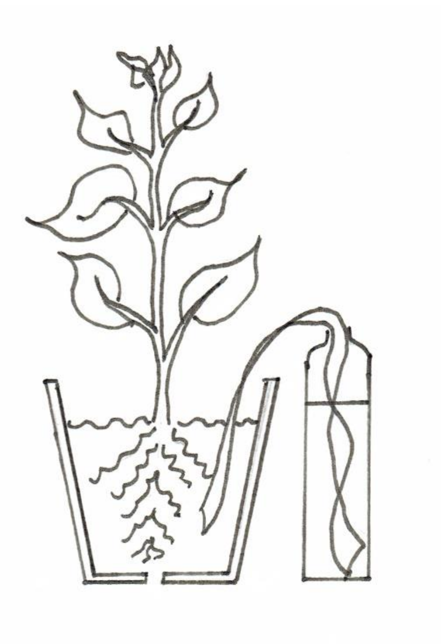


2. Water bottles in the plant pots

The same size and type of bottles were used (I litre), the bases were removed and then the same number of holes drilled into each lid. The lid was then

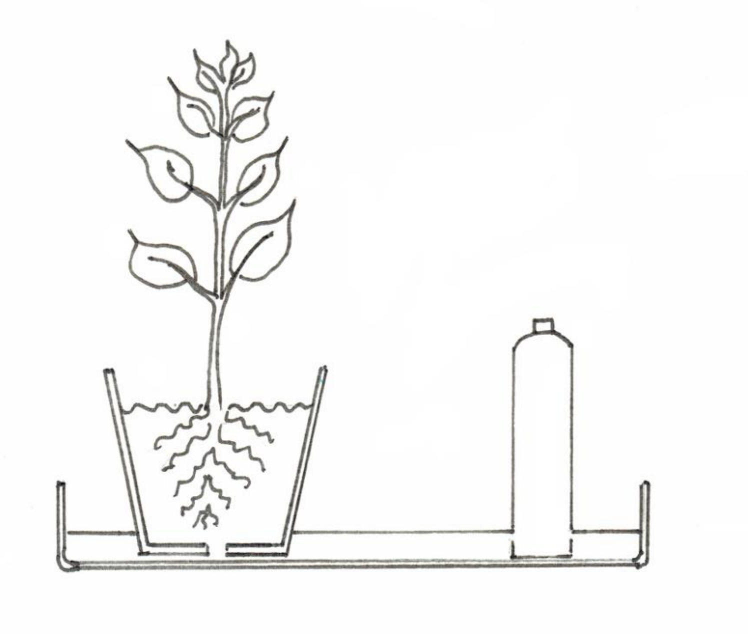
replaced on the bottle and the bottle was inserted next to the plant pot, fill with soil. Ensure that all water goes into the bottle on watering. This directs the water more directly to the roots of the plant.

3. Capillary Action: Water bottle reservoir and t-shirt strips



Equal sizes of t-shirt strips (40cm x 7 cm) were used with equal sizes of bottle reservoirs. The fabric wasn't long enough to reach the bottom of the bottle so two pieces were tied together for each plant pot. One end was tucked in next to the plant and the other submerged in the water bottle. The soil was then added to the plant pots

4. Tray with water bottle

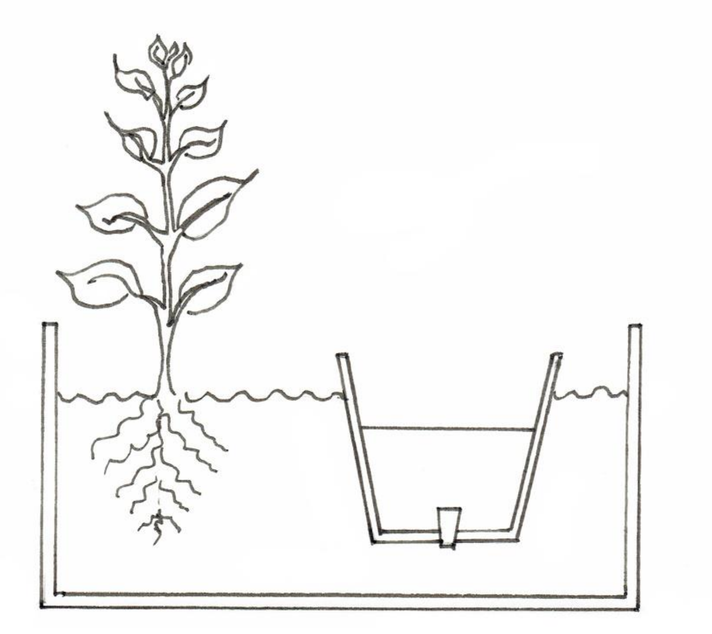


The felt in each tray was cut to 35 x 23 cm. The bottles in each tray had three equal sized small holes. These holes should be at the height that you would like the water to remain in the tray.

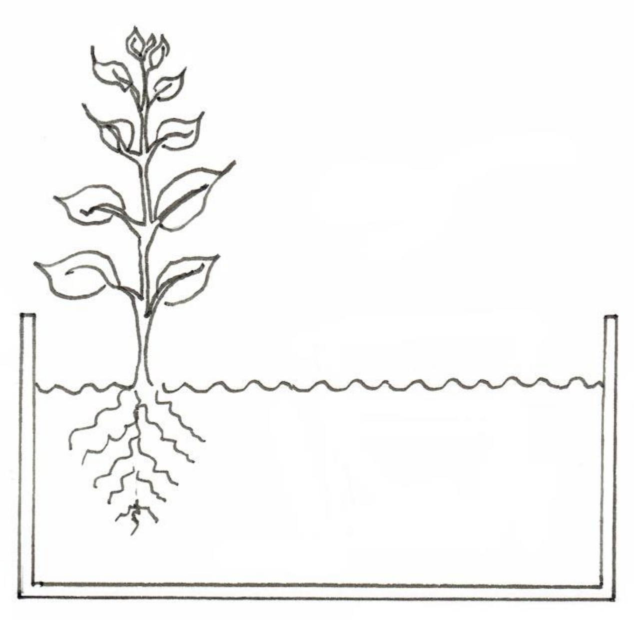
Fill the bottle with water, keeping your fingers on the holes as you do so. Then add the bottle lid on quickly. Place the bottle into the tray and the water will fill the tray up to the level of the holes.

5. Clay pots in boxes – experiment and control

Experiment



Control



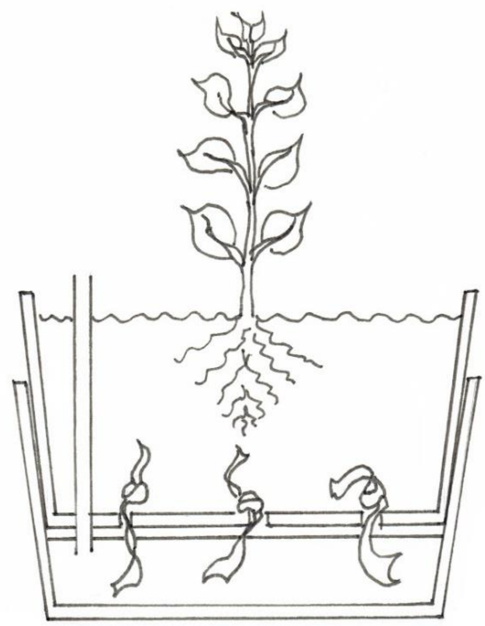
The same weight of soil was added to the experiment and the control boxes. The clay pot has either a blob of silicone or a bung inserted into it to prevent water loss through the hole. Therefore the water should only come out through the pores of the clay. It is important to check this before setting up the experiment. (Note: sometimes old clay pots can be greasy and so the clay pores can become blocked).

Box prior to planting

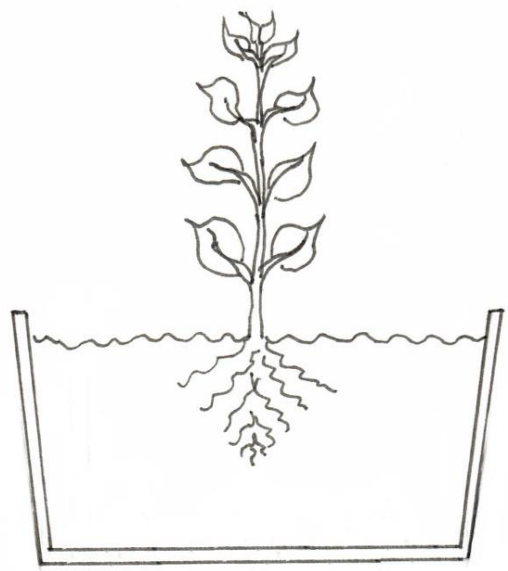
Boxes containing experiment and controls

Place the clay pot into the soil so that it is partially submerged. Put your plants into the tubs. Fill the pots with water and then, if you have it, cover the pots with plates, trays or anything you can find to reduce evaporation of the water.

6. Self-watering reservoir – experiment and control



Experiment



Control

You will need 3 equally sized stacking storage boxes for this

Drill 4-5 holes in the base of one of the boxes. These should be approx. 16-22mm wide. Then drill one hole the same width as a piece of pipe.

Cut a towel into the same number of strips as you have holes in the box. Push the towel strips into the holes, leaving the towel hanging down on the outside. Tie a knot in the towel strips on the inside, leaving long tails to go into the soil in the box.

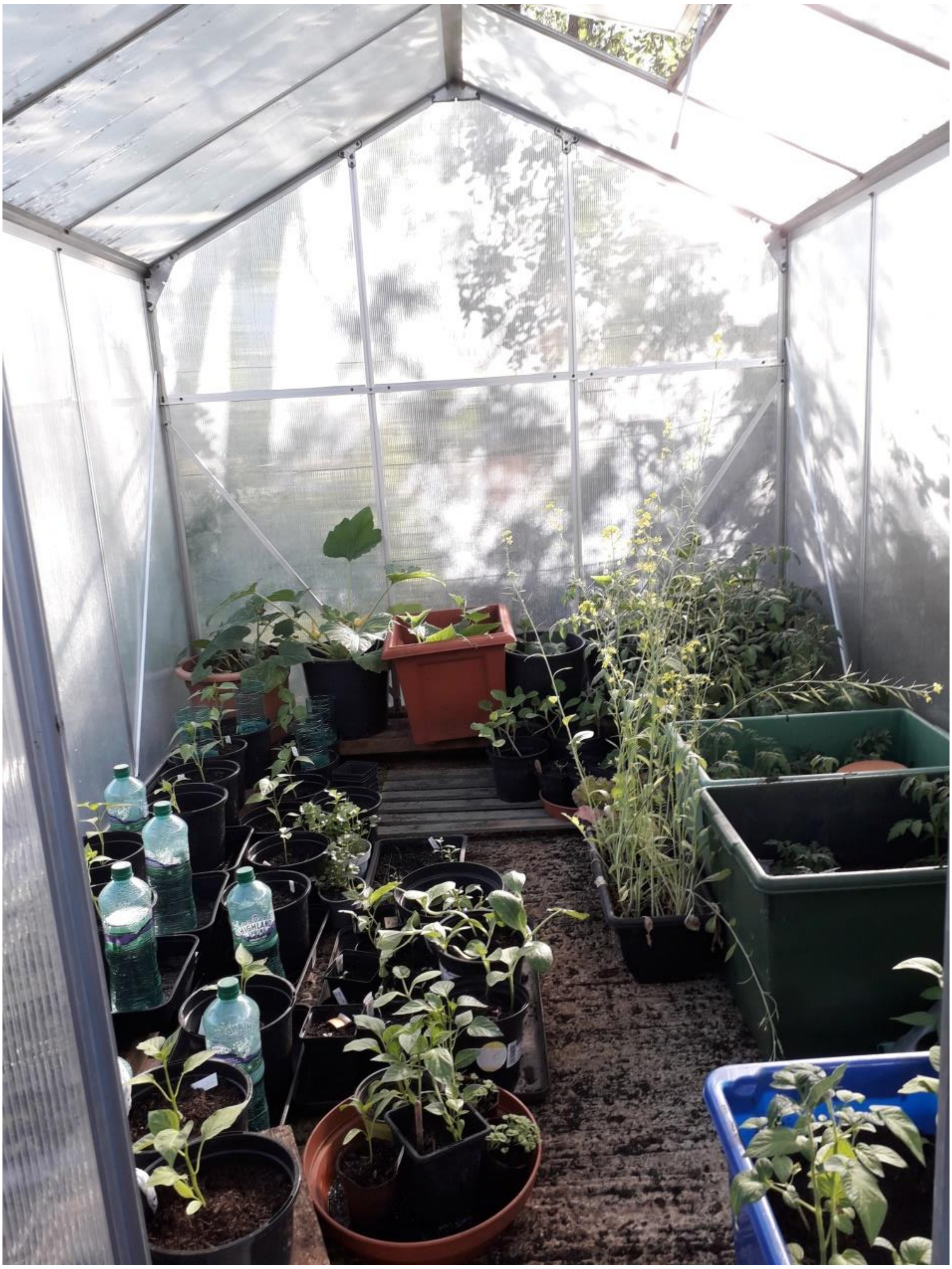
Note: in this case, the towel used was cut into strips of 67 x 9 cm and acts as moisture wick. The pipe was added so that it was a tight fit within the base of the experimental box and was long enough to protrude above the level of the soil. Therefore, it could easily be accessed for filling the reservoir below. Put the box into another box that doesn't have holes in it so it can retain the water.

The control experiment did not have any towel strips but had the same weight of soil as the experiment.

The maximum volume of water in the reservoir was measure during set up to help reduce the possibility of over-filling.

Plants were then potted into both the experimental and control boxes.

7. Maintenance



Greenhouse at the beginning of the experiments

Tasks required:

Daily:
The level of hydration in the soil for each of the plants using the hydrometer was measured and on a basis of this the volume of water, if any, was added and then noted. A note of time and temperature in the greenhouse was taken.

Weekly:
The plants were moved around the greenhouse to ensure light was equally distributed. The plants were checked for pests or for any signs of poor growth. The plant heights were measures and the leaf numbers counted. When fruit appeared these were also counted. The fruit was picked when mature and then weighed. At the end of each week, all the data was uploaded onto an Excel spreadsheet. Comphrey solution was given to the plants every fortnight as a fertiliser.

irrigation experiments plant heights and leaves				
date				
Experiment number	plant number	Plant type	Heights of plants	no of leaves
bottles in pots				
1	1,1	pepper marconi rosso		
	1,2			
	1,3			
	1,4			
	1,5			
control				
	1,6			
	1,7			
	1,8			
	1,9			
	1,10			
water with t shirt strips				
2	2,1	pepper marconi rosso		
	2,2			
	2,3			
	2,4			
	2,5			
tray with bottle				
3	3,1	pepper marconi rosso		
	3,2			
	3,3			
	3,4			
	3,5			

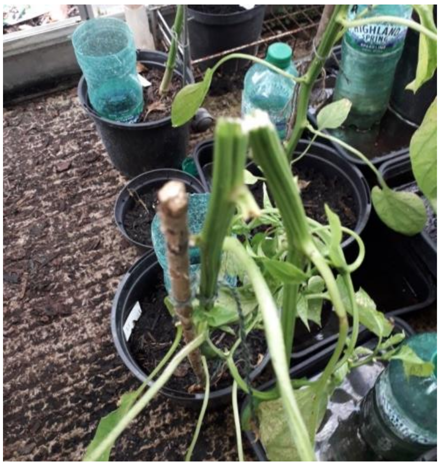
At the end of the experiment:
The weekly tasks were performed and additionally, the final weights of the plants in each condition were determined.

Tips:

- Spreadsheets from Excel were devised and printed out to record the experimental data. I hung these up in a plastic folder with a pen.
- To save time, a milk bottle was used as a large measuring jug. It had been labelled with waterproof marker pen using volumes from a measuring cylinder to improve accuracy. This sped up the watering time .
- The use of the same bottles for each of the bottles in pots experiments was helpful because the 500ml volume of water mark happened to be where there was a kink in the shape of the bottle making it much faster to fill up to the same mark each time.
- The clay plant pots had a capacity of 1 litre, this meant that there was less measuring required and that saved time.

irrigation experiments plant water and hydration					
date					
temp C					
Experiment number	plant number	Plant type	hydrometer	water	h
bottles in pots					
1	1,1	pepper marconi rosso			
	1,2				
	1,3				
	1,4				
	1,5				
control					
	1,6				
	1,7				
	1,8				
	1,9				
	1,10				
water with t shirt strips					
2	2,1	pepper marconi rosso			
	2,2				
	2,3				
	2,4				
	2,5				
tray with bottle					
3	3,1	pepper marconi rosso			
	3,2				
	3,3				
	3,4				
	3,5				

8. Evaluation



To consider the effectiveness of these experiments the smart goal was considered again (section 4.1) to see how my results answered my questions.

<u>Please note:</u> that the results for each condition were the average of the five plants, except for 'the bottles in pots' experiment where the results were based on four plants as one of them had an unfortunate accident involving a retractable tape measure.

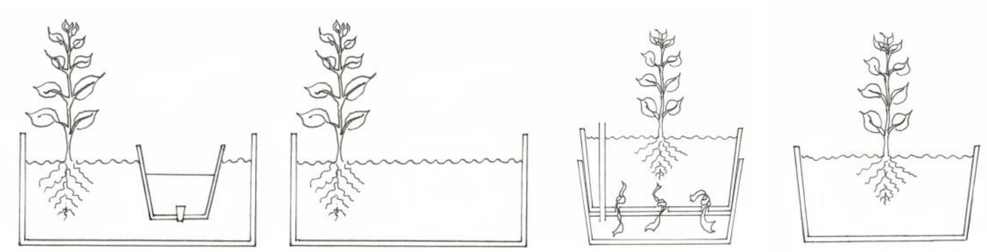
8.1 Which irrigation method resulted in the most growth?

Peppers

Control | Capillary action | Bottles in pots | Bottles in trays

Tomatoes

Gardener's Delight ***Galia***



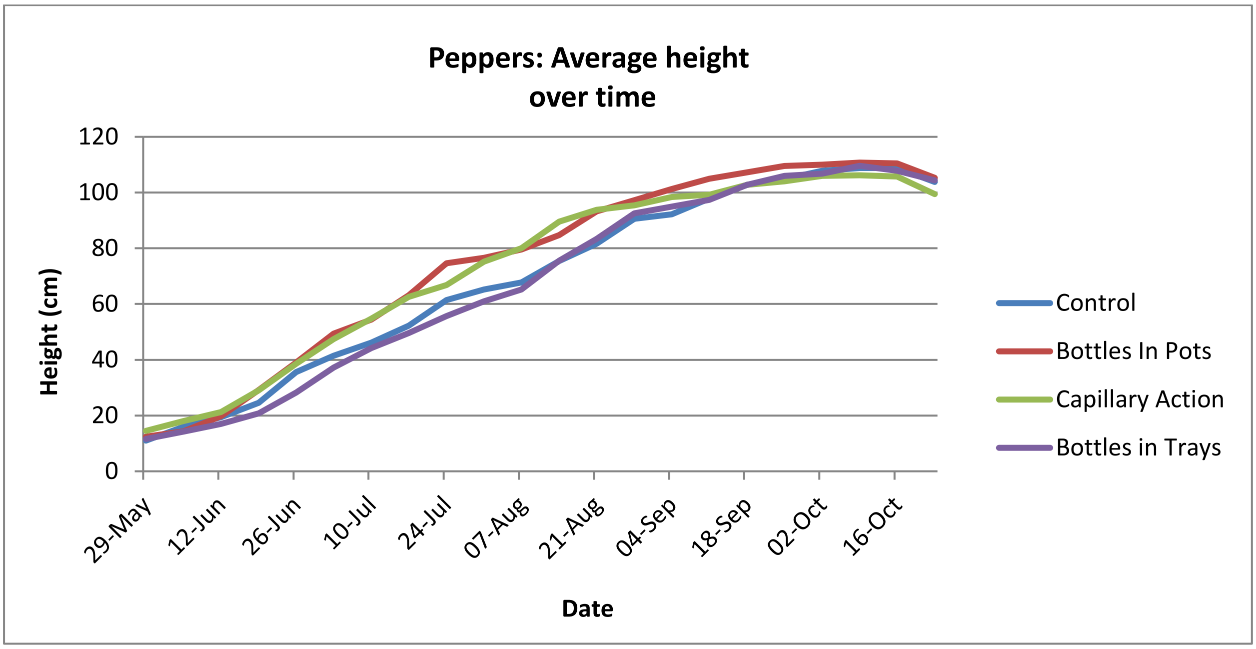
Clay Pot in boxes experiment | Clay Pot in boxes Control | Self-water Experiment | Self-water Control

Note: The tomatoes in each of the two conditions cannot be compared to each other directly as they are two different types (bush and vine). I have placed them for practical reasons on the same graph so trends can be compared but not absolute values.

The data was inserted into Excel and then graphs were generated as follows:

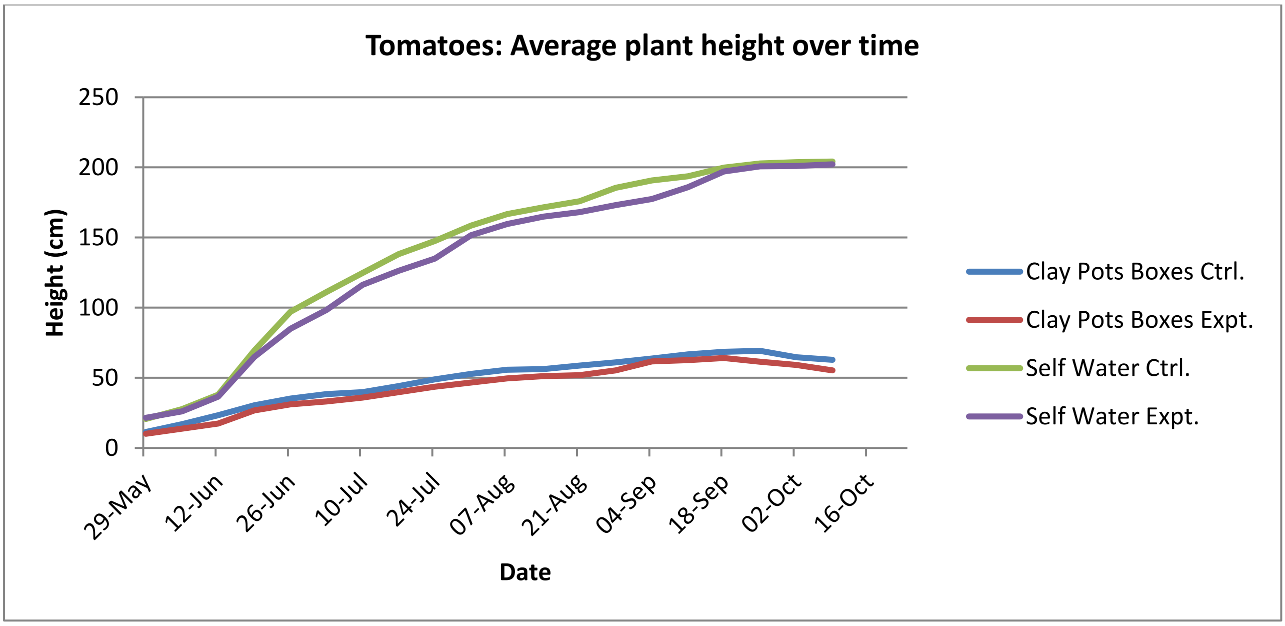
First Pepper and tomato plant heights against time were plotted.

Peppers:



This graph indicated that the 'bottles in pots' and the 'capillary action' conditions appeared to grow faster than the other two conditions. The Capillary Action condition's rate of growth slowed down in August and this was when the algae had grown over the t-shirt strips so no water was passing into the plant. The water was subsequently poured from the top of the pot in the same way as with the control experiment. This reduction in the rate of growth fell to the same as and then below the control experiment by 18th September. By the end of the experiment, the average heights of all the pepper plants were very similar.

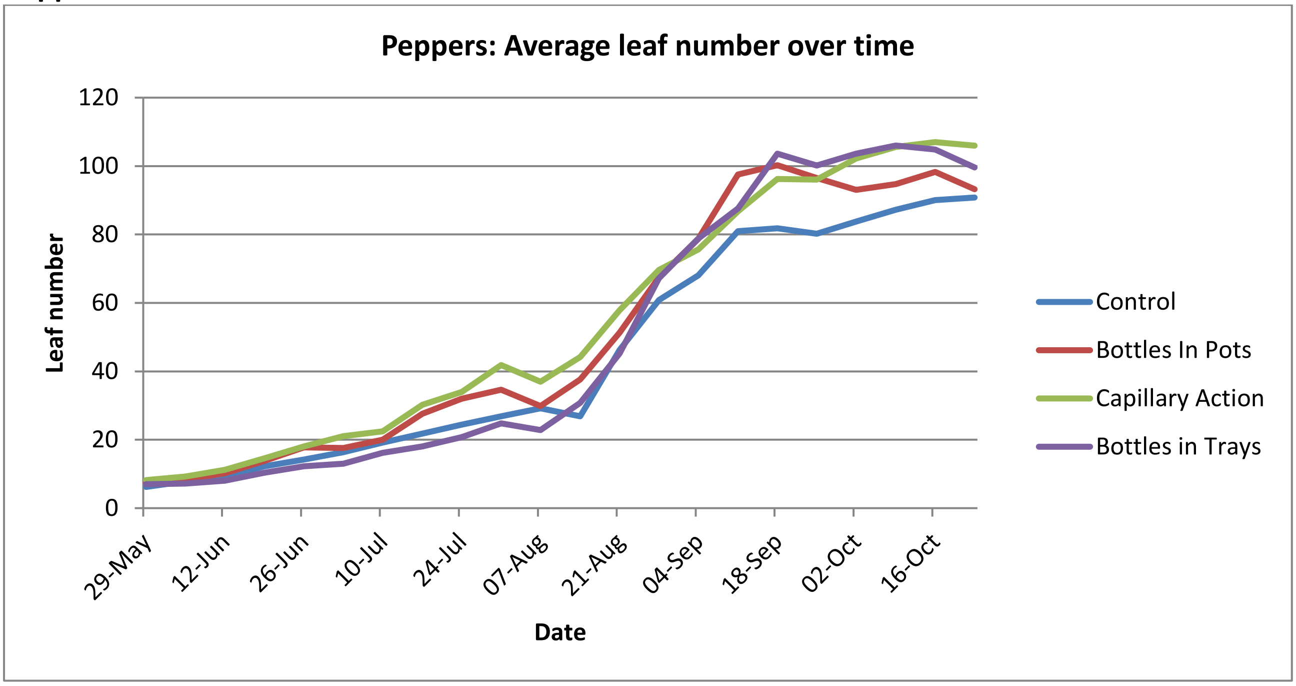
Tomatoes:



In both experiments above the tomatoes in the controls grew taller and quicker in the control versus the experimental conditions. This was unexpected; it may have been that the tomatoes actually preferred the slightly drier conditions seen in the control conditions.

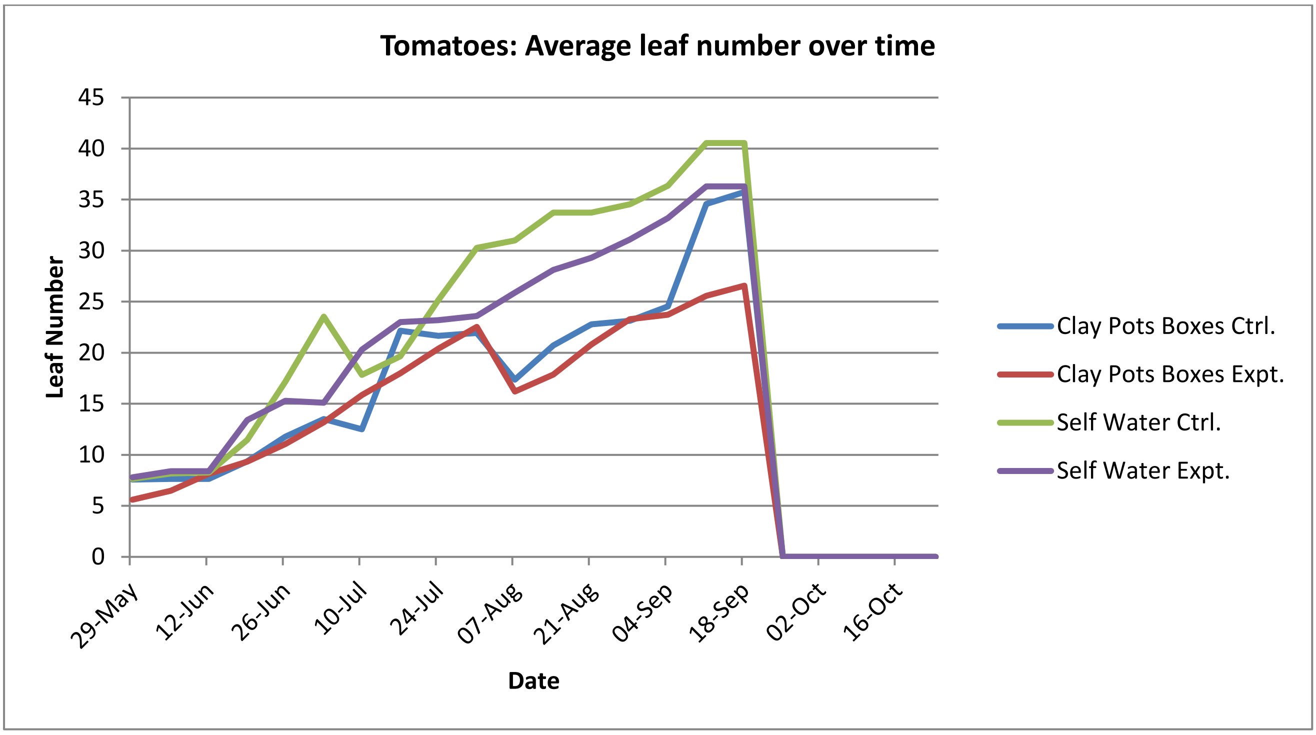
To look at this further, it was considered that leaf number might form a better indicator for plant growth as reflected in general literature[14].

Peppers:



The results indicate that after about 14th August experimental conditions performed better than the control but none of the experimental conditions performed consistently above the others.

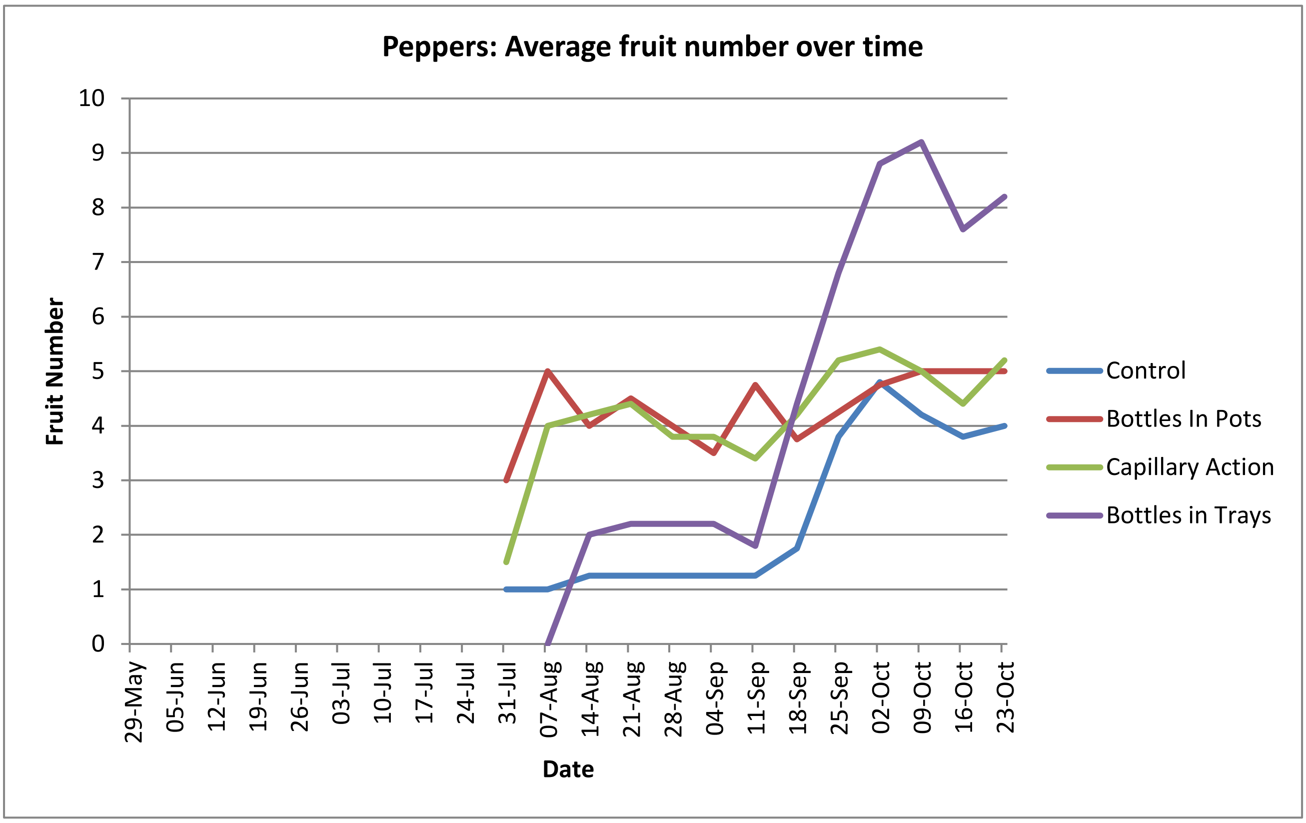
Tomatoes:



In both the clay pots and the self-watering conditions the number of leaves was higher in the controls than in the experiments. This was again unexpected. By midway through September the plants stopped growing and died suddenly. This sudden death could have been due to changes in other factors such sunlight levels, temperature which were unrelated to the experimental conditions.

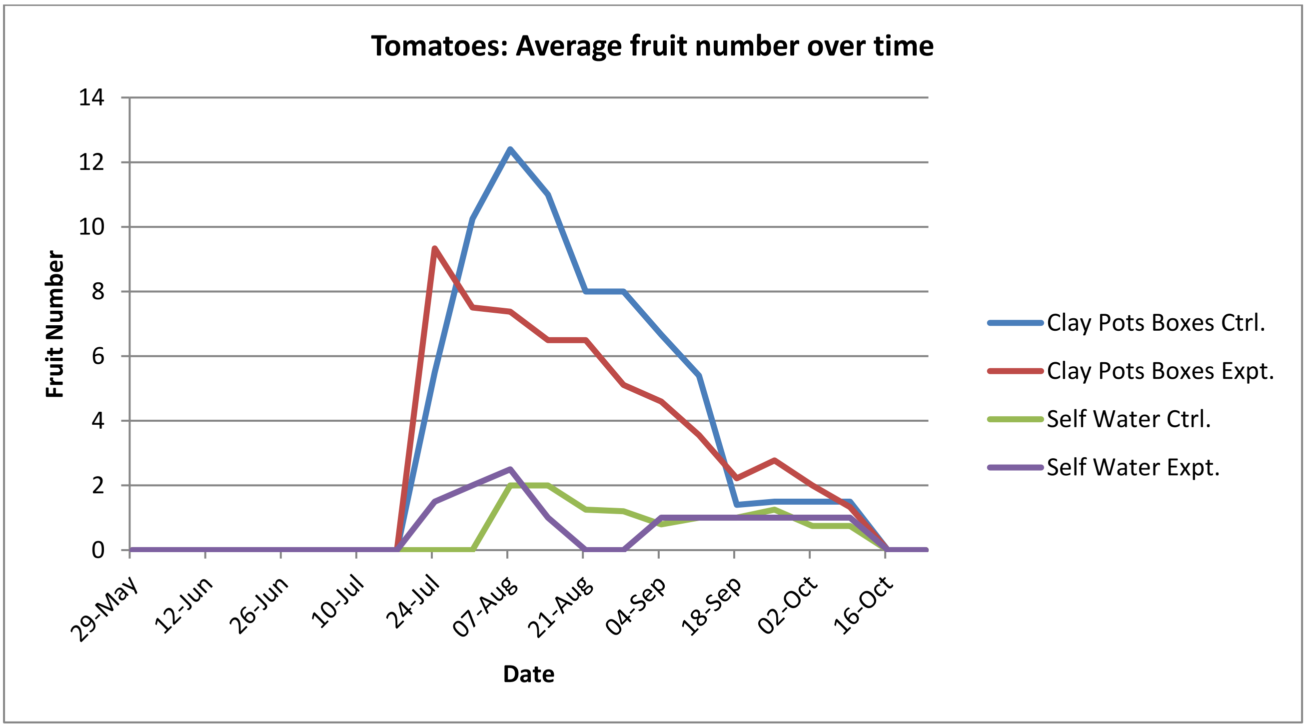
8.2 Does plant height or leaf number relate to fruit production?
The number of fruit produced against time was then plotted.

Peppers:



Reviewing this graph, the pepper plants that appeared to be producing the most fruit were the ones with the bottles in trays. The other two experimental conditions produced more fruit than the control conditions. This related slightly more to the leaf number result than the plant height but there was not a significant correlation.

Tomatoes:

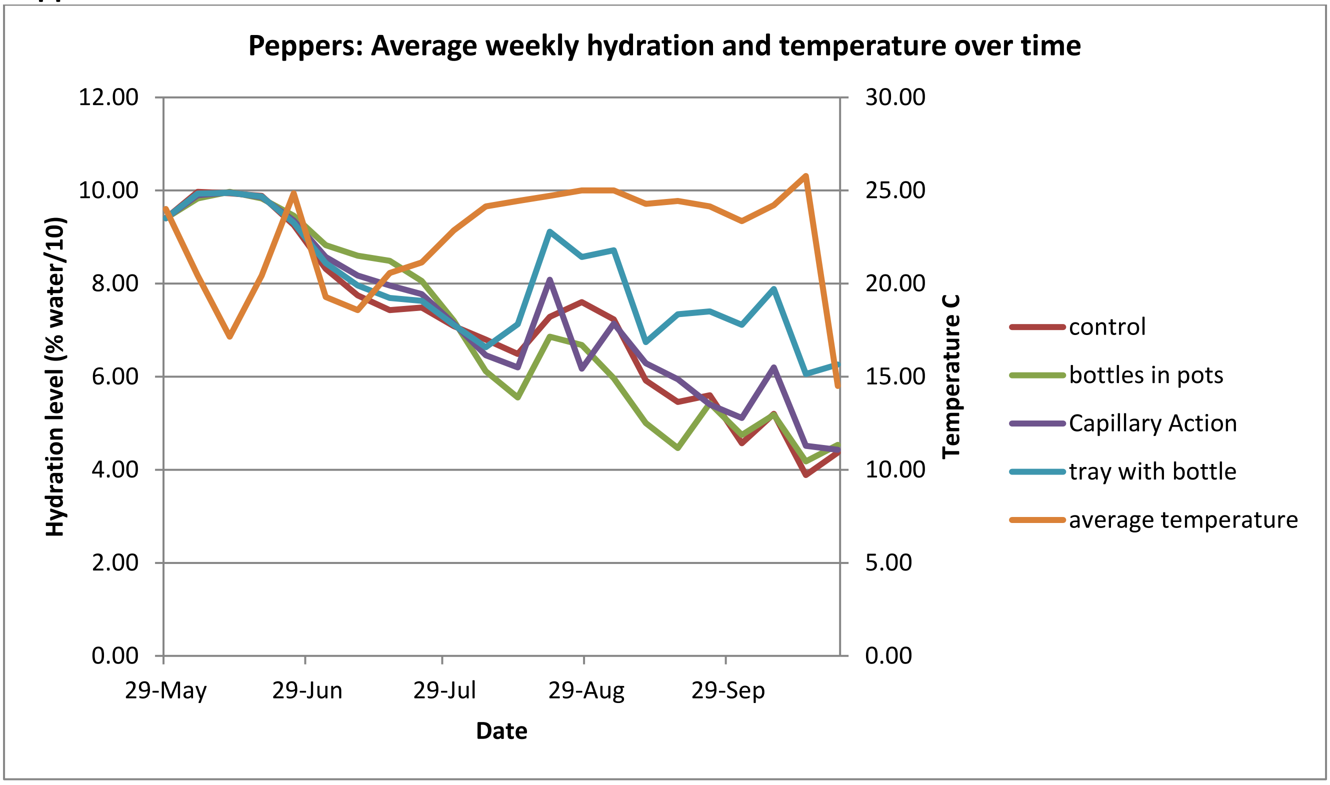


The fruit production from the tomatoes was quite low and again, the control conditions out-performed the experiments in the clay pots condition. The results of the self-watering experiments appeared to be very similar in both the experimental and control conditions. The graph indicated that the experimental conditions appeared to result in earlier fruit set than in the controls. The fruit number does not relate to the height or the leaf number as seen in the graphs above.

8.3 Does soil hydration relate to plant growth?

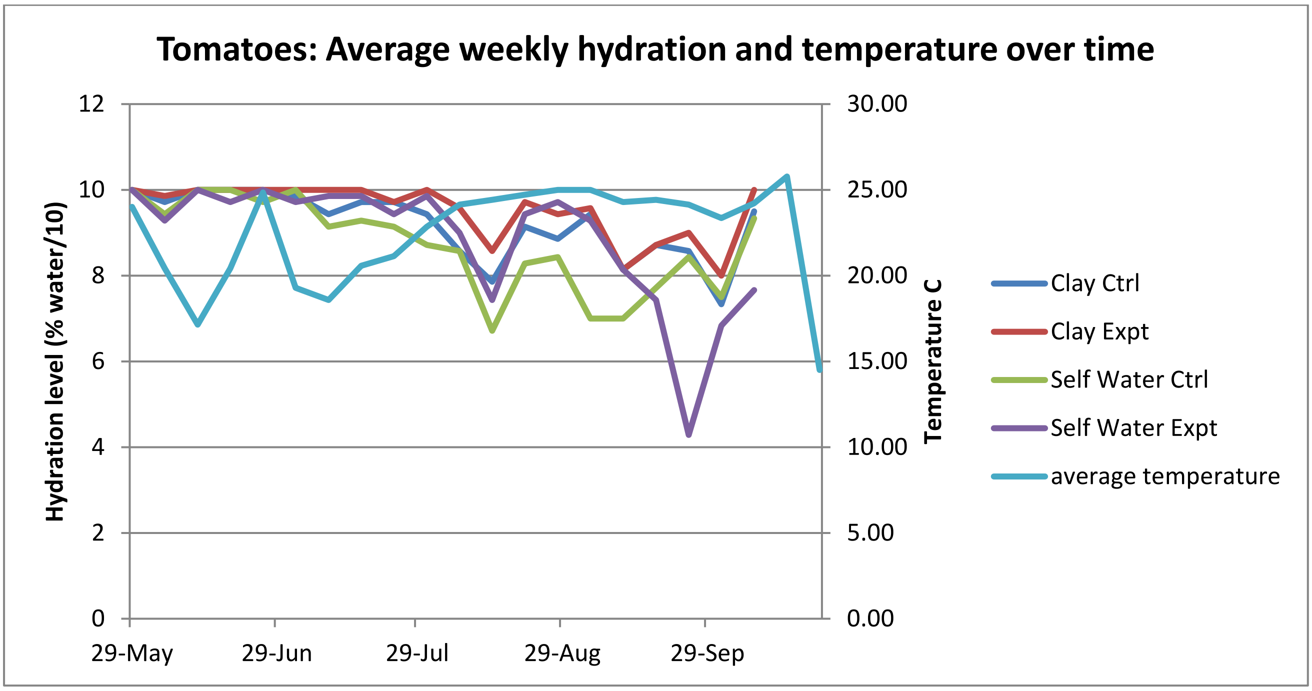
Could soil hydration relate to plant growth? The hydrometer gave readings between 1 and 10 where 10 is 100% hydration. The hydration levels over time, including the temperature of the greenhouse was plotted. Using the daily data, however, the results were difficult to determine as there were so many data points. Therefore, a weekly average of the data sets was calculated and plotted.

Peppers:

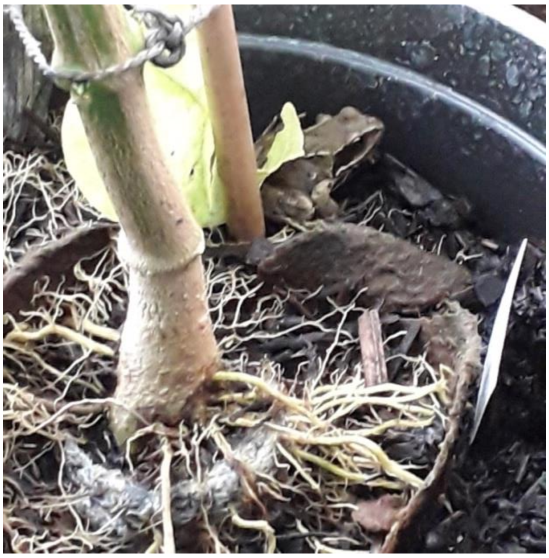


This graph shows more that the level of hydration of the soil does not relate directly to the ambient temperature as water is being added throughout the time of the experiment. The general downward trend in hydration levels could also be due, in part, to the amount of root growth over time so that there is less soil available to the plant to retain the water. It is interesting that the soil hydration of the bottles in trays condition is the highest and that is also the condition with the most number of fruits. In general, the experimental conditions had higher levels of hydration than the control.

Tomatoes:



As with the peppers there is a general trend for the hydration level in all the plants to reduce with time. Again, this could be due to the amount of soil available to the plants due to them being pot-bound. There appeared to be a general trend, although not completely consistent, for the experimental conditions to be more hydrated than the controls.

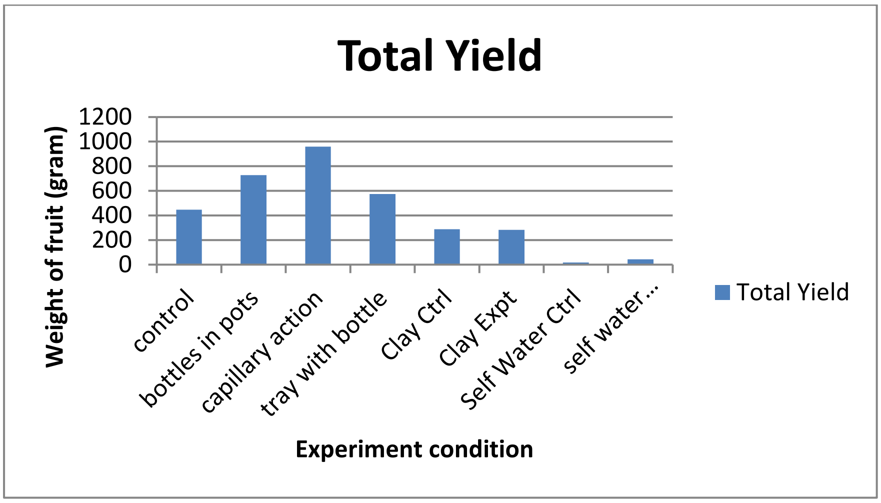


Furthermore, it was not possible to assume that fruit number is the same as fruit weight. Therefore, the weights of the fruit over time were measured both for the peppers and tomatoes. However, as the majority of the peppers were only picked at the end of the experiment in an attempt to gain larger (and sweeter) peppers. Therefore, the total weight of fruit was a more relevant figure to consider.

Total weight of peppers and tomatoes

	total weight each condition (g)
Pepper plants	
Control	447
Bottles in pots	727
Capillary action	960
Tray with bottle	573
Tomato plants	
Clay pots control	288
Clay pots in boxes experiment	282
Self-watering control	18.5
Self-watering experiment	44

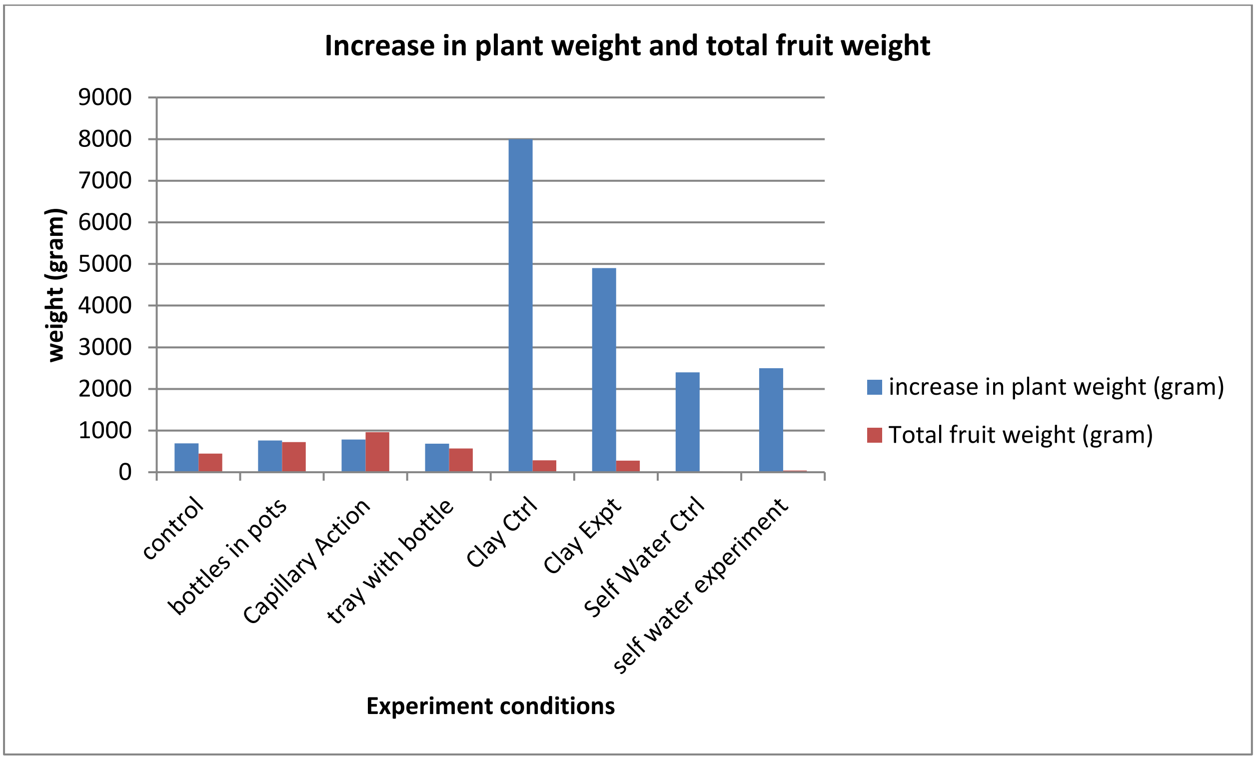
Plotting these results on a bar chart indicated that the highest yield of fruit was from the capillary action condition.



The bottles in the pots also had a high yield of fruit. There was no difference in the size or quality of fruit derived from the different experiments and control experiments.

The total weights of the plants before and after the experiment were also determined. Please note that the plant weights were determined after the remaining fruit had been picked at the end of the experiment. This data was plotted on a bar chart.

	increase in plant weight (gram)	Total fruit weight (gram)
control	696	447
bottles in pots	759.5	727
Capillary Action	784.6	960
tray with bottle	688	573
Clay Ctrl	8000	288
Clay Expt	4900	282
Self Water Ctrl	2400	18.5
self water experiment	2500	44



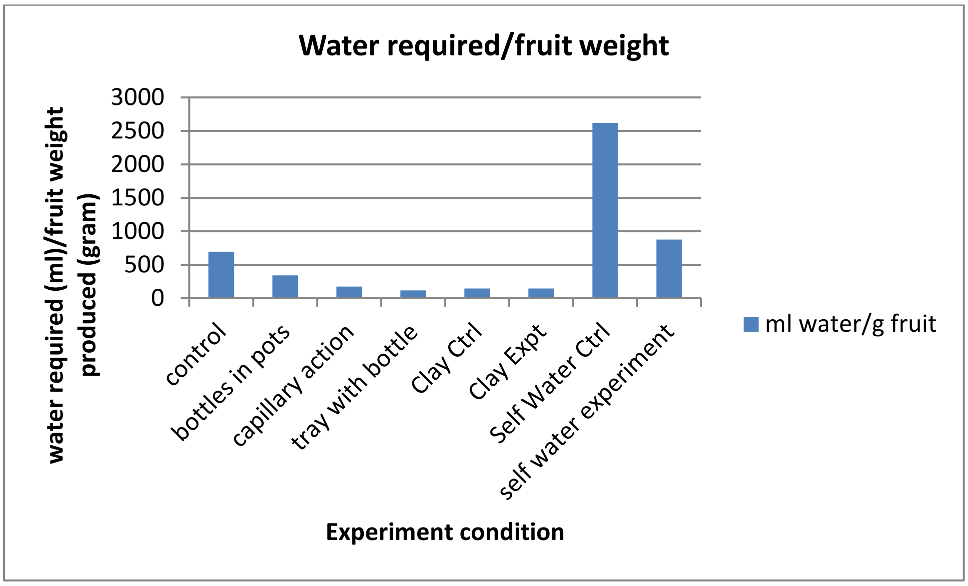
These results do not show a direct correlation between the yields of fruit and plant weight.

8.4 Which method used the largest volume of water?

The other element that was strategic to finding the best irrigation method was to consider the amount of water required to grow the fruit, this was calculated as ml water required by grams of fruit grown. The results are shown in the table below

	total weight each condition (g)	total water each condition (ml)	ml water required/g fruit	Amount of work required
Pepper plants				
Control	447	311250	696	Most days
Bottles in pots	727	247000	340	Most days
Capillary action	960	166750	174	Infrequent
Tray with bottle	573	68000	119	Infrequent
Tomato plants				
Clay pot control	288	42500	148	Most days
Clay pots in boxes experiment	282	41000	145	less frequent
Self watering tubs control	18.5	48500	2622	Most days
Self watering tubs experiment	44	38502	875	In frequent

To make it easier to evaluate the graph of total ml water/grams fruit was plotted as a bar chart (see below).



Peppers:
The best result in terms of water required was the bottle in a tray, followed by the capillary action condition with the t-shirt strips. The pepper plant experiment conditions all required less water to create fruit than the control.

Tomatoes:
The clay pots did not require much water to grow the tomatoes, but they were a different type of tomato to the ones used in the self-watering experiment so cannot be compared directly. The self-watering experiment did show that the principle of the self-watering reduced the amount of water needed.

8.5 Conclusions
Therefore, I have achieved my smarter goal:

Smart goal: To determine which irrigation method resulted in the most fruit production for the least amount of water?

Based on these experiments, the **bottles in trays** condition was the best.

If considering the amount of work required, the **Capillary action** experiments are also effective. They did not require watering as often, at least until the t-shirts were covered in algae. I would consider the other two methods as well depending on the materials I had available.

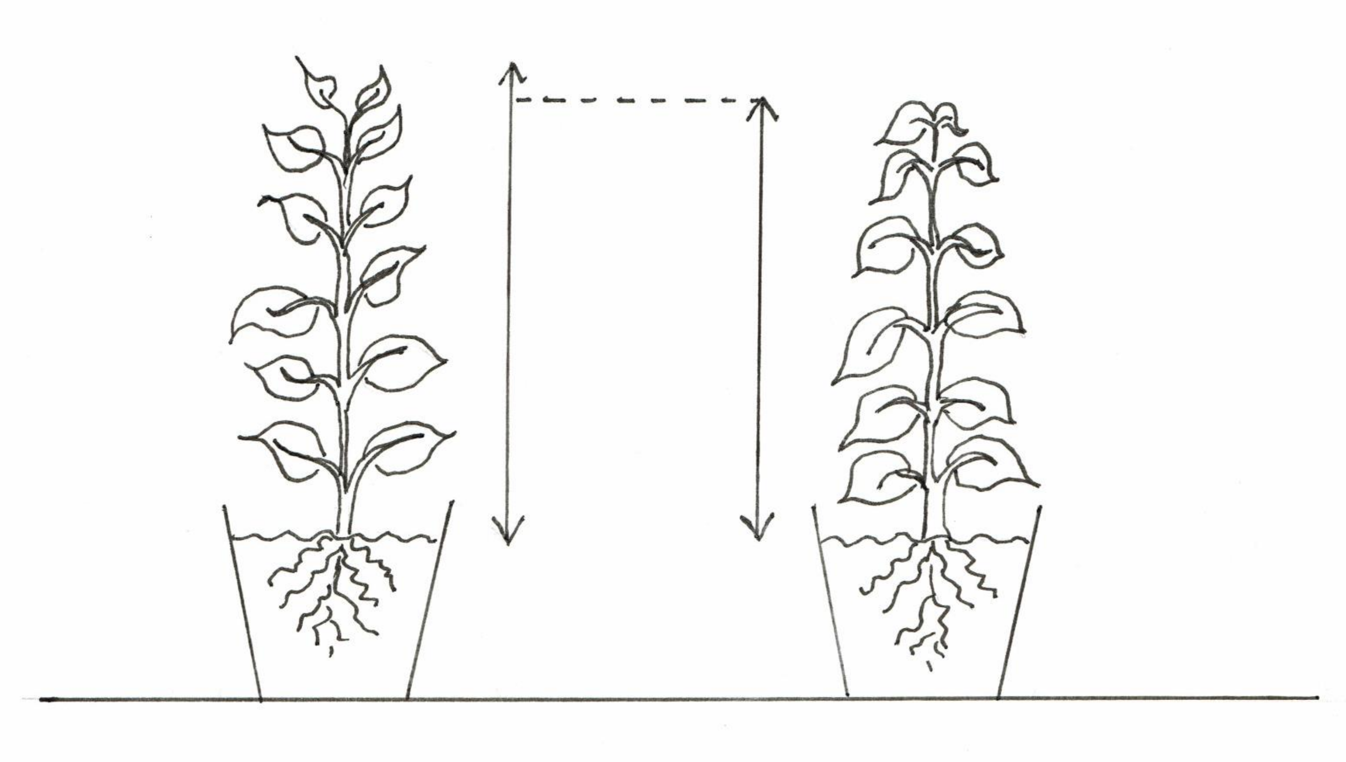
Looking at the bar chart for the tomato results, the clay pot experiment did not seem to be very effective. The self-watering experiment did not have much of a yield but the volume of water required was significantly less than the control.

8.6 Considerations and lessons learnt

Considerations
There are many factors that needed to be considered during these experiments. For example:

- What are the criteria for counting a leaf? How big does it need to be before it is counted? I decided on an arbitrary 1cm.

- How long before a pepper is counted? Similarly, I decided to wait until the set fruit is about 1cm in length.
- When measuring the height of a plant, I decided to measure from the top of the soil surface to the highest point of the top leaf (see diagram below). This meant that as the experiments progressed and the plants became pot-bound, the level of hydration in the soil decreased. Therefore, the turgidity of the top leaves, in particular was reduced (see diagram below). The height measurement would therefore look like it had decreased when it was not really the case.



The difference that good leaf hydration makes to the apparent height of a plant – a well hydrated plant is on the left and a poorly hydrated plant is on the right

- These experiments generated a huge amount of data. It took a long time to process this information. During the data collection phase I started with complicated colour coding scheme for the pepper plants, with plants that had flowers being coloured yellow and those with fruit being coloured red. It proved to be unnecessary and once I started seeing fruit I gave up with it.
- The data analysis was very time-consuming and complicated due to the messiness of the spreadsheet and the sheer volume of data. It required double checking in order to ensure no mistakes were made when data was transferred across spreadsheets.
- The average of all the plant sizes by each condition were used in order to create the graphs, this was made easier by using Excel.
- Excel was exceedingly good for creating graphs.
- It was not clear what the desirable level of hydration would be best for both the peppers and the tomatoes.
- Careful plant observation was essential in order to address the problems of pests and also any extra nutrient requirements.

Lessons learnt

- Be careful with the use of retractable metal tape measure as they can get entangled in fragile plants. Try a fabric one or a long ruler instead.

- When measuring the height of vine tomatoes, it became very difficult as the plants grew taller than the green house and flopped over. I learnt not to try growing them in my small greenhouse in the first place. Also, I would normally pinch out the tomatoes to stimulate lateral growth but then this would have affected the leaf number and plant height. Not pinching out will have also reduced the yield of fruit.
- Vine tomatoes are best measured using a piece of string. This is compared to the plant and then the string measured. This does take longer but gives more accurate results.
- A 3 litre pot was too small for the pepper plants, I would normally have potted them on but I didn't have enough larger pots or space in the greenhouse to put them. If the experiments were repeated, I would allow for this as an option.
- The plant overcrowding in a small greenhouse created an exceptionally humid environment. The roof light was open but the conditions were still very damp and that encouraged insects and other pests (see photos below).
- I had lots of difficulties with snails. In addition to loving the pepper plants in particular, they also climbed into the plastic data folder and damaged the paper spreadsheets for collecting data. Thankfully, no data was lost. After that point I used paper clips to fold down the top of the plastic folder.
- During the weekly data updates in Excel I also measured averages of plant heights, leaf number, and fruit number as a percentage increase from week to week. This data actually proved to be less than useful and wasn't needed in the final analysis. It made the spreadsheet look messy and then the useful data had to be extracted onto further spreadsheets, creating work. Therefore, an appropriate spreadsheet layout was important. If I did this again, I would have a separate spreadsheet for hydration, water volume given to the plants, fruit number, leaf number as well as plant heights.
- You need lots of time as measuring and caring for the plants is a very time consuming process.
- Data for time of day was not really necessary
- The level of hydration that was maintained for the tomatoes and peppers was just right for the peppers but was too wet for the tomatoes. It is for that reason that the results of the experiments for the tomatoes show that the control tomatoes out-performed the experimental ones

- I had a lot of problems with the labelling of the tomato plants. I had placed plastic labels (cut from an empty yoghurt pot) next to the roots of the plants but as the plants grew they were harder to find. Additionally, I therefore added cardboard plant labels further up the plants. Unfortunately, these were a favourite with the snails or else they just got damp. This was frustrating and required extra time to decipher which plant was which. I would definitely only use plastic labels higher up the plants next time.
- The Galia vine tomatoes grow very tall but did not give much fruit. They also branched a lot so it required some careful tracing back of the branches to discover which fruit were on which plant. This had the potential of damaging the plants in the process.
- The tomatoes were not a success; I would not use them for this type of experiment again.
- When the first insects appeared, I used a washing up liquid solution but this was not sufficient so then I used a neem oil/warm water solution (1 tablespoon neem oil to 1 gallon of water) [15]. It was disappointing to have to resort to these measures but it was effective and was essential to maintain this experiment. If the greenhouse had been less crowded the situation might not have arisen.

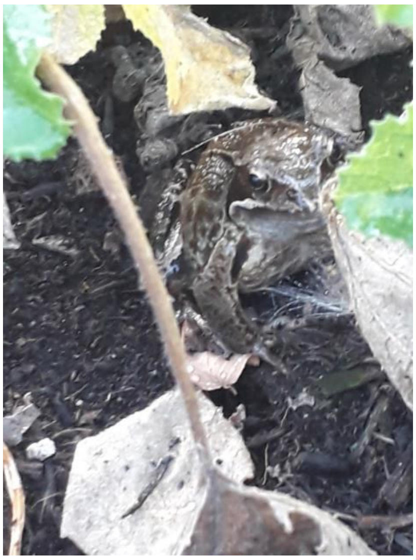
- The holes that were placed in the bottles in trays experiments were on three sides of the bottle. This proved to be difficult as my hands weren't large enough to cover all three holes when filling the bottles with water. I would consider changing the hole positions to make filling easier.
- The bottles in trays experiments started to get infested with fly larvae. In the end I opted to clean the trays and remove the felt. There was no obvious difference to the experimental results due to this. In the future, I probably would not use the felt.

Some of the not very welcome guests in the greenhouse

8.7 Coincidental benefits

There were some additional benefits from these experiments. Firstly, I had a large yield of delicious peppers. These became very much prized in the neighbourhood as they were so sweet. Additionally, there were cherry tomatoes and even a few yellow Galia ones. Furthermore, as I was also growing cucumbers in the greenhouse and space was tight, I decided to try to grow them vertically. I learnt that not only is that possilbe but I believe that the yield was better than normal. I think they preferred the extra light that was accessible to them compared to when they are trailing on the bottom of the greenhouse.

Another benefit of the experiment was creation of a great habitat for various frogs in the greenhouse.



We even had an occasional butterfly visitor such as this Gatekeeper. The greenhouse had definitely been used to the maximum effect, creating **a small scale, intensive system with stacking** demonstrated by the cucumbers and the plants of various heights.

8.9 Permaculture ethics

This project followed the permaculture ethics:

Care of the Earth: By using less water to grow food, there will be less precious water wasted. Combining this with the use of rainwater rather than mains helps to minimize the energy and hence the impact on the earth required to generate fruit. Spreading the word about irrigation techniques will have a larger impact to reduce water consumption and wastage.

Care of People: By creating more food by using less water this will help reduce the cost of growing and will also reduce the amount of work required to do so. Less work means more time available. Therefore the project can help the people in Peddie as well as us.

Fair shares: at the end of the project, the food was shared amongst friends and neighbours. I collected the seeds so I could share them as well. I have also shared the knowledge gained by these experiments with neighbours as well as with the people in Peddie.

Ecological impact: The hydrometer was the key investment. I can use this later on with houseplants and in the greenhouse generally. I used plants grown from seed so there was a minimal impact in terms of transportation costs. The results of this project may result in reduced water consumption for growing food and therefore may have a positive impact.

8.10 Permaculture principles

These experiments demonstrated several permaculture principles. For example, the daily tasks of giving an appropriate amount of water to each of the plants in response to the hydration levels shows the principle of observe and interact. However, the principles of **Obtain and yield** and **Creatively use and respond to change** are more relevant but also **Cycling of energy, nutrients and resources**.

Obtain a Yield

This project resulted in the creation of food. By choosing the Marconi peppers they were more attractive to the neighbours as they are normally quite expensive (£1.50 for two in Waitrose) so they are not a variety that they would usually buy. They were very sweet too.

The project also resulted in the production of pepper seeds which I have shared with my friends and neighbours as well as some of my fellow new allotment holders. Therefore, there is a yield of more food in the future for a larger number of people.

There is also the yield of knowledge which has been shared and can continue to be shared. The subsequent reduction in water requirement will reduce work as well as cost if people are growing food using mains water.

The yield is therefore multi-factorial.

Creatively use and respond to change

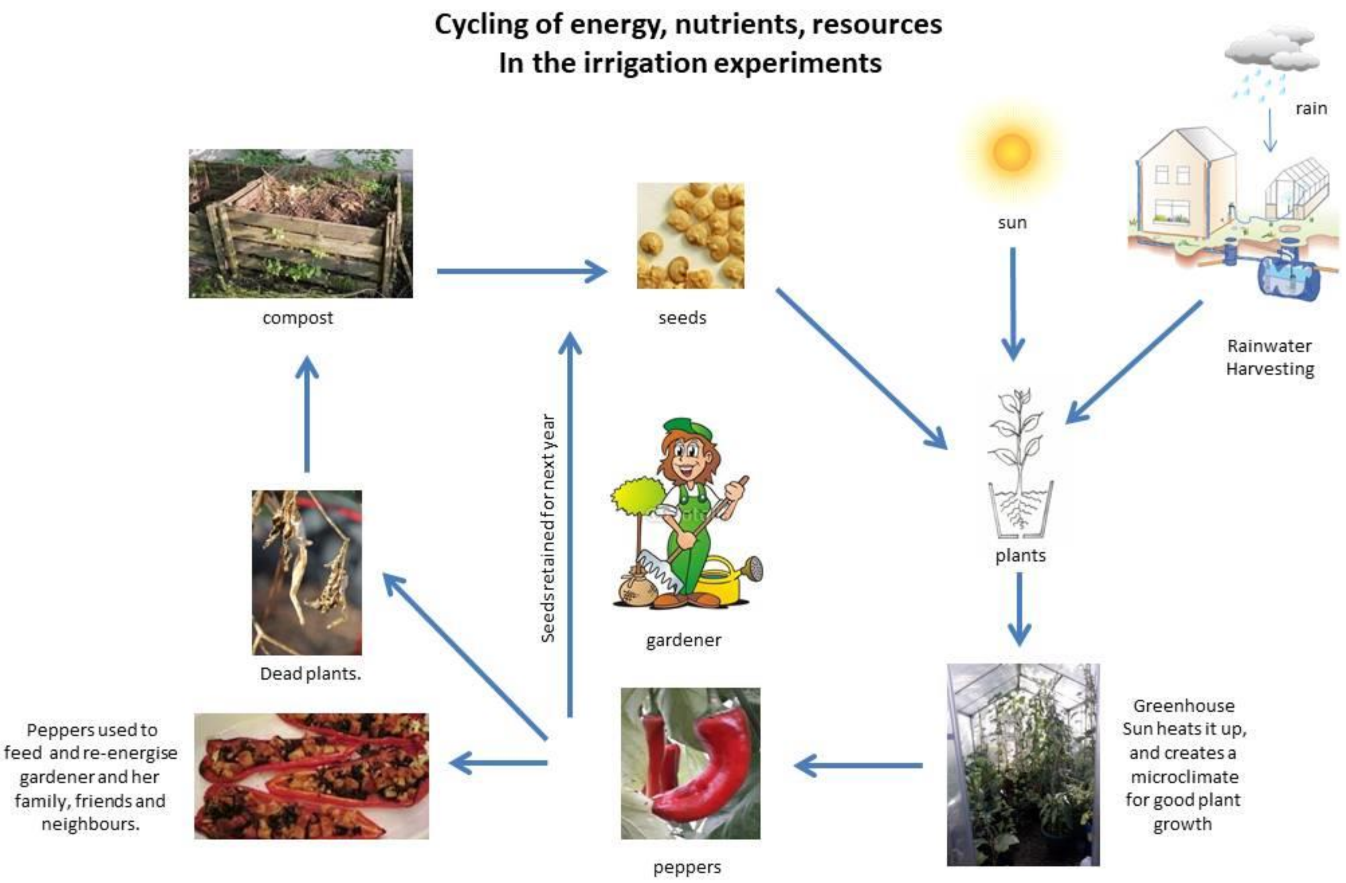
This project originated from the challenges that a comparatively short summer drought brought in a country where normally too much rain is the problem. The decision to consider how our food is grown as well as what food is grown became increasingly important.

Having an awareness of the impact of climate change on poorer communities in South Africa which are bearing the brunt of the water shortage at the moment, enabled me to understand that even small changes can have a bigger impact.

Further developments in my knowledge and understanding of irrigation methods should improve the support that I can offer to the Family Centre in Peddie.

Cycling of energy, nutrients and resources

The project also demonstrated the principle cycling of energy and resources as shown in the diagram below. If there was space indoors, the pepper plants themselves could have been over-wintered and they could have produced fruit for another year. Unfortunately, there was not enough space in this case and also the pepper plants had pests on them and would have suffered a re-infestation if brought into the warm environment indoors, contaminating the other plants inside. The plants were therefore put in the compost bin at the end of the season.



Note: Contains some clipart/stock images

9. Tweak

If there was time available, I would consider repeating the experiments using peppers for those experiments where I used tomatoes i.e. the clay pots and the self-watering systems. Ideally, all the experiments would be repeated in order to get a comparative result but I would likely have the same problems of space, insect infestation. It would be interesting to see if the results were different using peppers. Furthermore, I would only count fruit weight as well as water volume added in a repeat of the experiments to dramatically reduce the work. In an ideal world, I would repeat the experiment using other vegetables.

10. Reflection

This project was lots of work! It required a lot of dedication to check on the plants every day. Thankfully, we had lockdown during this time so I had no day job to do. When I started, I never imagined that the 20 minutes required to measure the plants, count the leaves and fruit every week would extend to nearly 3 hours! This was worse when I had to include spraying the plants with water, moving them around, spraying with neem oil solution and giving comfrey tea solution. Fortunately, my lovely neighbour would always come for a chat over the fence when she heard me counting.

Greenhouse in July

The problems with the tomato plants made me realize how the level of hydration needed for each plant type was very different. It was clear that the pepper plants like a lot of water available to them but the tomatoes less so. Therefore, a repeat of the tomato experiments using peppers would be useful. It is also important to consider whether different plants would prefer different irrigation methods. Although the pepper plants prefer the capillary action of the t-shirt strips in water, would other plants? I would suggest that it may be different with the different levels of hydration needed by each plant type.

It is clear with the pepper experiments that the plants benefit from having longer access to water as each of the irrigation methods out-performed the control. The more targeted watering of the t-shirt strips and the bottles in pots towards the roots of the plants also helped plant growth as well as reducing the amount of water needed. The bottles in pots experiments would probably have performed better if there had been a tray under the plants to capture any water that might have dripped out the base of the plant pot without being used by the plant.

The tools which I found were the most useful were Excel for data processing, despite the Herculean task; the software worked well and aided the generation of helpful graphs and bar charts. It would have been a very lengthy process otherwise and I would have been more likely to make mistakes. Another useful tool was a small stool that my son had purchased for me to help with gardening. This meant that I could sit comfortably while working in the greenhouse, particularly when it took a long time. I could not have carried out the experiments without my greenhouse. The rainwater harvesting tank in our house also allowed me to reduce the environmental impact of this project.

Other useful tools included discussions through WhatsApp with my Aunt. She visits the Centre in Peddie, South Africa as often as she can, although these visits have clearly been curtailed with the recent virus situation. I have had a number of communications from the wonderful ladies who run the Centre, thanking me for my help, along with photos of progress made on their vegetable projects.

The SADIMET design framework was definitely a good fit for these experiments, combined with the Smart goal as they helped me to define my intentions and to proceed to gain results in a logical way. On reflection of the smarter goal, I think the experiments explored the goal thoroughly by breaking down the goal into separate testable questions, in that way I was confident that I could reach a justifiable conclusion.

On a personal note, I enjoyed carrying out an experiment in a scientific way as it reminded me of my origins in Biochemistry. I also enjoyed the peace in the greenhouse away from the demands of daily life. Having also grown many peppers in a tiny greenhouse, I could see how beneficial my allotment could be to grow food for others as well as myself, particularly during these difficult times. One aim from that project would be to grow more than I need on the allotment so that I can give the extra food to our local foodbank and community fridge.

In the future, I would like to increase the range of experiments to include other methods of irrigation, such as the rain gutter system[16]. I would like to explore hydroponics too[17]. In the future I would like to set up self-watering systems in my new allotment because we do not have access to hoses.

I consider that these experiments have potentially been very useful. In the Eastern Cape the water crisis is very real. Even during the current Covid crisis, many people do not have access to clean water to drink, let alone to wash their hands. In Peddie, the Centre was supported in the purchase of rain water tanks, although of course, they require the rain in the first place.

The film Brave Blue World[18] was fascinating viewing because it showed how for so many people in the world, the water crisis is a daily problem of survival. It did have a positive message, focusing on the work of some very enterprising people and what they have done to alleviate the impact of their lack of clean water on small or larger scale. The very positive view point of this film made me realise that small improvements can have a larger benefit and how interconnected we are as a species on the planet and how dependent we are on the natural environment.

I think that this work has shown a development in my permaculture journey, not just because it has demonstrated my determination (or stubbornness) to finish a task, but also because I have considered the importance of sharing knowledge. The contacts in Peddie do not always have enough money for their phones to access the internet to gain information so their contact with my Aunt is very helpful. Fortunately, this project should benefit both them as well as others to show ways to grow annual vegetables with less work and water. I hope therefore that the comparatively small-scale problem faced in the UK will be able to offer a solution to the tough situation faced in Peddie. The Family Centre has had some successes this year despite the very difficult conditions, so when the Centre has been able to be open, they have been able to offer the children healthy, fresh food. I hope in the future their lives will become a little easier.

Sources

1. https://www.wikihow.com/Make-a-Drip-Irrigator-from-a-Plastic-Bottle
2. Gaynor Grace – 'On the Frontline of Climate Change'; issue 100 summer 2019 permaculture magazine
3. https://www.nationalgeographic.com/news/2018/02/cape-town-running-out-of-water-drought-taps-shutoff-other-cities/
4. Permaculture Design – Aranya published by Permanent Publications (2012)
5. David A. Bainbridge – 'Gardening with less water' Storey Publishing (2015)
6. Graham Burnett 'The peculiar people' issue 90 winter 2016 permaculture magazine
7. https://www.youtube.com/watch?v=MxI_lup0vtc
8. https://www.youtube.com/watch?v=1qeTXrj4qgE
9. https://www.youtube.com/watch?v=ZF-qmISIFj8
10. https://www.youtube.com/watch?v=ec4lT7JTNr8
11. https://www.youtube.com/watch?v=GRiLhrY2CMc
12. https://www.youtube.com/watch?v=3BQ7cPdVWSw
13. https://www.wikihow.com/Make-a-Drip-Irrigator-from-a-Plastic-Bottle
14. Plant Physiology; Vol. 11, No. 2, Apr., 1936 p 445-451 Published by: Oxford University Press
15. https://gardenbeast.com/neem-oil-guide/
16. https://www.youtube.com/watch?v=NyOIRVjatdg
17. https://www.youtube.com/watch?v=nXy32Dr4Z4A
18. Brave Blue World: Racing to Solve Our Water Crisis released October 2020, Netflix. https://www.netflix.com/gb/title/81326710

Appendix 1

Irrigation Types:

1. Plastic bottles in plant pots

1litre bottle, base removed

Drill 4-5 small holes in the lid of the bottle to stop the bottle losing water too quickly. Replace lid onto bottle

Insert the plastic bottle next to the plant pot, fill with soil. Ensure that all water goes into the bottle. This directs the water more directly to the roots of the plant.

Note: the plastic bottle can be placed next to a plant in a vegetable patch, not just in a pot.

2. Plastic bottle reservoir with t-shirt strips
Cut an old t-shirt into strips

Put one end of the t shirt under the plant and then add the soil.

Put the other end of the T shirt into a bottle full of water. If you need to , attach 2 strips of fabric together so the t-shirt reaches the bottom of the bottle.

Note: the t-shirt strip can be placed next to a plant in a vegetable patch, not just in a pot.

3. Tray with a plastic bottle reservoir

Cut a strip of water absorbant, tightly woven fabric to fit the base of a plant tray (this step is not essential if you don’t have suitable fabric).

Drill a couple of small holes right at the base of another plastic bottle. These should be at the height that you would like the water to remain in the tray.

Fill the bottle with water, keeping your fingers on the holes as you do so. Then add the bottle lid on quickly. Place the bottle into the tray and the water will fill the tray up to the level of the holes.

4. Clay pots in boxes

Insert either a bung or a large blob of silicone into the base of a clay pot so that no water can come out of the hole in the base

Fill a large tub with soil. Place the clay pot into the soil.

Put your plants into the tubs. Fill the pots with water and then, if you have it, cover the pots with plates, trays or anything you can find to reduce evaporation of the water.

Note: the clay pots can be placed next to a plant in a vegetable patch, not just in a tub

5. Self-watering reservoir

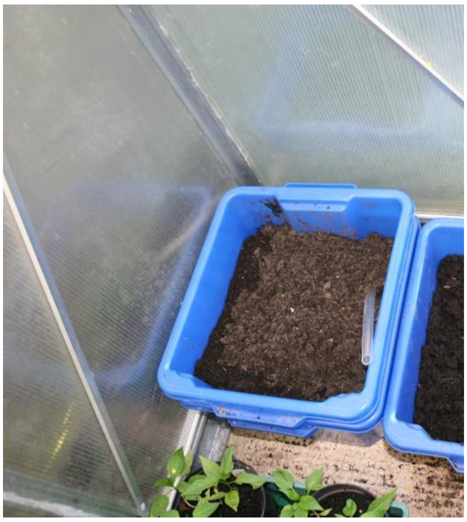
You will need 2 stacking storage boxes for this

Drill 4-5 holes in the base of one of the boxes. These should be approx. 16-22mm wide. Then drill one hole the same width as a piece of pipe.

Cut a towel into the same number of strips as you have holes in the box. Push the towel strips into the holes, leaving the towel hanging down on the outside.

Tie a knot in the towel strips on the inside, leaving long tails to go into the soil in the box.

Put the soil into the box with the pipe and towel strips in place.
Put the box into another box that doesn't have holes in it so it can retain the water.



Put plants into the soil.

You can top up the reservoir with water through the pipe

Appendix 2

Excel spreadsheets showing the raw data are available on request.

Appendix 3

SAKHULUNTU FAMILY RESOURCE CENTRE

We build our community

Newsletter - December 2018

Welcome to our first newsletter coming from our newly completed and renamed Sakhuluntu family resource centre in Peddie. It means so much to us and wouldn't have been possible without the support of many people, including the Monument Trust Sainsburys UK's generous starter fund.

This October, two new helpers, Sivuyele and Mvuyokazi attended a permaculture design course in East London. This was possible due to the financial support of many friends. The helpers returned with bringing energy and enthusiasm, sharing their knowledge with the community.

Mvuyokazi and Sivuyele

The Fruit Forest at Hope Farm Permaculture Centre, East London

Sivuyele admiring the Farm

Director Nabom Mgoduka with Mvuyokazi and Nomfundiso Mahlangu before the course.

Now the new centre vegetable garden is already starting to grow.

The main focus remains the children. Here they are enjoying a party in the new centre.

Nabom bringing the lunch

Sivuyele showing the children his dancing skills

Nabom and Lorraine joining in

Meeting Mrs Fezeka Mantakana, the Founder of the original centre

The Centre is already being used for a range of purposes, such as a location to counsel community members seeking advice from social development.

They are also beginning to establish it as a skills centre for adults and unemployed youths and of course a centre to teach permaculture.

There is still a long way to go. Financial support is always needed for the vegetable growing project, the computer room, sewing and crafts, and furniture.

The Centre would like to thank you for your support and making all this possible

The reading room

Director Nabom Mgoduka says (in a WhatsApp):

These are the pictures of the new building and the permaculture students. I have not much words to say but only thanks to u all. I don't want to mention names because I don't want to miss anyone who put his/her effort to build the centre that is taking care of vulnerable families and children. We also thank Lorraine who build the relationship between us. The centre sends the Seasonal Greetings to u all with many blessings. From Peddie Family Resource Centre Staff