Abstract

An experiment was carried out, to identify any differences that occurred, during the growth of hyacinths grown hydroponically, when different content of solutions were used. Over a period of eight weeks, data has been collated and analysed to find the most favourable solution for the best growth medium for hyacinths.

Introduction

It was required to research an area of environmental science, for this assignment, to develop independent scientific investigation. The aim was to collect relevant information, design an experiment, collect and record data. The data will then be analysed and conclusions will be drawn from this. As this is not an area that I am familiar with, I decided to opt for a simple experiment, with the intentions of progressing on to a more complex one in further investigations. After intensive background reading I decided to opt for something that I had some understanding of and thought that I would investigate the growth of plants. I felt this investigation could advance my subject knowledge and therefore improve my teaching in this area.

Primarily, I needed to formulate a hypothesis. As a novice, I was unaware that plants could be grown in water alone, and was interested to investigate how well this could be carried out. Therefore my hypothesis is:

The comparison of medium solutions, for growing hyacinths.

Winterborne (1997) suggests "plants grown in a hydroponic system can be given very exact and specific doses of nutrients….will develop optimum levels of appearance, yield and flavour" (p4)

I will endeavour to make predictions, and then discover the difference medium solutions make to the growing of hyacinths, by investigation and extensive reading. Primarily some background information is required before proceeding with the experiment.

Background Information

Harlen (1996) defines " scientific activity is characterised by developing theories which fit the evidence available but which may be disproved when further evidence comes to light"(p5) This definition appears appropriate to my research, as it is a small research, which could be disproved by a larger investigation; however, this research has been beneficial to my understanding and knowledge, of teaching science. Halen goes on to say scientific literacy means " functioning with confidence in relation to the scientific aspects of the world around, being able to look at something 'in a scientific way'"(p7) which has been my aim.

Hyacinth Bulbs.

The definition of a bulb is any plant that stores its complete life cycle in an underground storage structure. The primary function of this underground storage a structure is to store nutrients reserves to ensure the plants' survival. Bulbs are usually perennials. They have a period of growth and flowering, this is followed by a period of dormancy where they die back to ground level at the end of each growing season. The bulb can be categorized into five different types, which are:

- True bulbs (tunicate and imbricate bulbs);
- Corms;
- Tubers;
- Tuberous roots;
- Rhizomes.

Hyacinths are true bulbs (tunicate bulbs). In the basal centre portion of the bulb are the leaves cradling a baby bud. Surrounding the bud is a white, meaty substance called the scales. In the true bulb the scales that contain all the food the bulb will need to flower and thrive. Anchoring the scales and the floral stalk that holds the bud is the basal plate. This plate at the bottom of the bulb also holds the roots of the plant. A thin outer skin called the tunic protects the whole bulb. This protects the scales from drying and from injury.

Drawing of a bulb.

Pictures of Bulbs

Bulbs grown hydroponically

When grown hydroponically, the bulb should be placed in conical shaped container so that the bulb can sit on the top and the water placed underneath so that the bulb can smell the water and send out roots. The bulb should never touch the water, as it will cause it to rot. The bulb should be put in a cool dark area (about 50°) until the roots are well developed. It is important not to store fruit near the bulb as ripened fruit releases ethylene gas which can kill or damage the flower that is inside the bulb. When the shoots are two inches tall, the roots should be well extended. Then the containers should be moved into slightly warmer temperature. After a few days, they should be moved to a sunny windowsill. The flowers should be turned a bit each day so that they do not lean towards the sun.

The term hydroponics was coined in the mid 20th Century. It is a term used to express a technique for growing plants in a soil less medium; the flooding of the Egyptian Nile is an example of hydroponics.

Hydroponics plants are grown in a static medium and fed water and nutrient. Plants that are grown in soil have to continuously develop their root balls in search of water, nutrients and air so the majority of plants available energy is spent on the lower root development restricting its upper growth. In hydroponics, the water, nutrient and air are mainlined directly to the root ball, freeing the plant to use its available energy in its upper leaf, fruit or flower development. As the roots of plants grown in soil-less medium do not need to constantly grow in search of nutrient; more plants can be grown in a smaller area. The solution that the plant is in must be aerated for optimal growth. If it is not aerated the plant will be in short supply of oxygen, and become anoxia. Anoxia inhibits the respiration of root cells and reduces nutrient uptake. The container that the plant is place should be dark to keep the light out. This is so that algae do not grow in the water and take some of its nutrients.

In 1860, Julius Sachs, a German botanist, demonstrated that plants could be grown to maturity in defined nutrient solutions without the use of soil. By the mid nineteenth century, Sachs and other colleagues became interested in discovering the minimal nutrients of a plant. Sachs devised an experimental system so that the roots grew in aqueous solution of mineral water. He then demonstrated the growth of plants to maturity using a nutrient solution containing six inorganic salts.

The composition of Sachs nutrient solution.

Salt	**Formula**	**Approximate Concentration (mM)**
Potassium nitrate	KNO	9.9
Calcium phosphate	Ca; (PO4)2	1.6
Magnesium sulphate	MgSO4 7H2O	2.0
Calcium sulphate	CaSO4	3.7
Sodium Chloride	NaCL	4.3
Iron sulphate	FeSO4	trace

There are some disadvantages to growing plants in this way as selective ion depletion and the changes of the PH in the solution as the roots take up nutrients. Plants will only grow healthily, only if the solution is replaced on a regular basis.

The nutrient solution devised by Sachs contributed a total of ten mineral nutrients, (carbon, oxygen and hydrogen are omitted from the above table as they are provided in the form of carbon dioxide and water and are not considered mineral elements). It was at least a half a century before others demonstrated the need for additional mineral elements. Analytical techniques have now improved, where it is possible to detect mineral contents several orders of magnitude lower than was possible in Sachs time. Most mineral elements are now measured by atomic absorption, spectrometry or atomic emission. These techniques involve vaporization of the elements at temperatures of several thousand degrees. In the vapour state, the elements will either absorb or emit light. The light absorbed or emitted is detected in the proportion of the concentration of the sample.

What plants need to grow.

"Most plants require a relatively small number of nutrient elements in order to successfully complete their life cycle" (Hopkins 1995 p68).

For healthy growth plants need water carbon dioxide, light and small amounts of mineral ions. Plants absorb these mineral ions from the water.

Elements needed for healthy growth.

Element	Ion	Use
Nitrogen (N)	Nitrate, NO^{3}-	By the plant to make amino acids for protein
Phosphorus (P)	Phosphate, PO 4^{3}	Involved in energy transfer in photosynthesis and respiration. Nucleic acids (DNA) also contain phosphorus.
Potassium (K)	Potassium, K+	Many enzymes need potassium to work. It is also necessary for the opening and closing of stomata.
Magnesium (Mg)	Magnesium, Mg^{2}+	Part of the chlorophyll molecule.
Iron (Fe)	Iron Fe^{2}+	Needed for chlorophyll synthesis.

According to E. Epstein (1972) there are seventeen nutrient elements that are essential for healthy growth. The elements are put in two categories; macronutrients and micronutrients. Nine elements are macronutrients and are needed in larger amounts, which are:

- Hydrogen
- Carbon
- Oxygen
- Nitrogen
- Potassium
- Calcium
- Magnesium
- Phosphorous
- Sulphur.

The other eight are micronutrients, and are needed in smaller quantities:

- Chlorine
- Boron
- Iron
- Manganese
- Zinc
- Copper
- Nickel
- Molybdenum

There are four other elements that are beneficial elements. These elements are not always necessary but can be helpful to their growth. These are:

- Sodium
- Silicon
- Cobalt
- Selenium.

Tables of Functions and Deficiencies of Macronutrients

Mineral	function	deficiency	excess
Hydrogen	From H2O essential to build sugar		
Carbon	From CO2 in air, to build sugar		
Oxygen	Essential for photosynthesis		
Nitrogen	Essential for photosynthesis, growth and respiration	Pale yellow leaves, stunted growth, poor fruit	Dark green foliage
Potassium	Encourages flowering, important in osmosis	Poor growth	Can cause deficiency in calcium and magnesium
Calcium	Cell growth	Reduced growth	
Magnesium	Essential for chlorophyll molecule, vital for photosynthesis and respiration	Chlorosis, leaves that are pale yellow	
Phosphorus	Essential for reproduction and photosynthesis and root growth	Slow development and poor growth	
Sulphur	Improves root growth and seed production	Yellowing leaves	

Table of Functions and Deficiencies of Micronutrients

Mineral	Function	Deficiency	Excess
Chlorine	Important in fluid balance	Wilted leaves becoming bronze	Salt injury causing leaf burn
Boron	Important for phloem transport and cell elongation	Leaf discolouration	Leaf tips are yellow, looking scorched and fall
Iron	Important for enzyme synthesis and function and chlorophyll synthesis	Chlorosis yellow/white areas on upper leaves	May cause leaf bronzing with tiny brown spots
Manganese	Essential part of chlorophyll molecule vital for photosynthesis and respiration	Chlorosis, mottled leaves followed by brown spots	Reduced growth
Zinc	Enzyme cofactor growth hormone synthesis. Transformation and carbohydrates and sugar consumption.	Interveinial chlorosis/yellowing leaves, reduced leaf size	May cause iron deficiency
Copper	Important in reproductive growth	Similar to iron deficiency	Distortion in new growth
Nickel	Needed to help form urease to break down urea nitrogen for plant use	Decreased iron utilization	Chlorosis and necrotic leaf margins
Molybdenum	Essential component of enzymes for nitrogen fixing	Interveinial Chlorosis on leaves	

Taken from www.passionflow.co.uk/mineral

Respiration in the root hair cells provides the energy needed to pump the ions. Once ions are in root hair cells they are taken up in solution in the xylem vessels to the leaves. If a plant does not get enough of one or more of the ions it needs then it will not grow as well. After a while it will shows signs of disease.

Plants keep growing until they die. Young seedlings grow in length with cell division occurring in the tip of the roots and shoots. Growth also occurs at the tips of side buds and in the side roots. Cells divide to increase the number of cells. Each time a cell divides in two, one of the new cells divides again, while the other absorbs water and enlarges. As the cells in the root enlarge lengthways they cause the root tip to be pushed further down into the water (or soil); the cells in the stem push the shoot tip into the air.

Plant growth regulators (plant hormones) control the activities of plant cells. The auxins are a group of plant growth regulators. They are made in shoots tips, young leaves and developing fruits. As auxin passes through the plant it controls the growth and development of cells. It can stimulate the lengthways growth of cells and can prevent growth by stopping side branches growing out from the stem, which encourages the plant to grow tall and straight. Auxins also cause the ovaries to develop into a fruit.

A leaf can lose water that can evaporate from the plant cell walls in to the atmosphere. This process is called transpiration. To replace the water lost, plants absorb water called the transpiration stream. Transpiration acts to pull up a column of water from the stem and roots in the xylem. This ensures a constant supply of water to the cells in the leaves. Transpiration also causes a movement of water bringing ions like nitrates to the roots. After the ions are absorbed into the root they are carried to the leaves in the transpiration stream. Plants are organisms that carry out photosynthesis, which have cellulose cell walls and complex cells. Plants are autotrophs; they make carbohydrates from water and carbon dioxide, and are the primary producer in all food chains, therefore, animal life is dependant on them. They play a vital part in the carbon cycle, removing carbon dioxide from the atmosphere and generating oxygen. The plant is divided into three parts; root, stem and leaves. The cellular structure of the stem carries water and salt from the roots to the leaves in the xylem, and sugar from the leaves to the roots in the phloem. The leaves make the food by photosynthesis, which occur in the chloroplasts they contain.

Photosynthesis is a process by which green plants trap light energy and use it to drive a series of chemical reactions that lead to the formation of carbohydrates. Fosbery and Mclean (1996) state “the best conditions vary in different plants” (p77). For photosynthesis to occur, the plant must have chlorophyll (a green pigment) and must have a supply of carbon dioxide and water. The chemical reaction of photosynthesis occurs in two stages; light reaction and dark reaction. During the light reaction, sunlight is used to split water (H_2O) into oxygen (O_2) protons (hydrogen ions, H^+), and electrons, and oxygen is given off as a by product. In the dark reaction, sunlight is not required, the protons and electrons are used to convert carbon dioxide into carbohydrates. Photosynthesis depends on the ability of chlorophyll to capture the energy of sunlight and use it to split water molecules. Other pigments, such as carotenoids, are also involved in capturing light energy and passing it on to chlorophyll.

Plants respond slowly to changes in their environment by growing. During the early growth of a seedling it is important that it responds to gravity and to light. Roots and shoots can emerge from the seed pointing in any direction. The root must immediately grow downwards to find sources of water and minerals. The shoot must grow upwards to reach a source of light for photosynthesis. When the shoot comes out into the light, the seedling must adjust the position of its leaves so that they receive the maximum amount of light. The responses essential for the survival of the plan are called tropisms. Auxins can make plant cells grow faster. Phototropism occurs when a plant only receives the light from one side it will lean towards it. When the light source is above the plant the auxin is distributed evenly so that the shoot grows upwards. When the light source is only received from one side, auxin collects on the dark side of the shoot making it grow faster. This is how it bends towards the light source.

Before the experiment took place a plan and predictions were made.

Plan

- Buy the hyacinths, (same colour and quality);
- Carry out a pilot test;
- Plant hyacinths in containers of the same shape and size;
- Using the containers, plant the bulbs in four different types of water;
- Put them on the window sill and record observations (see appendix);
- Research plant physiology and bulbs grown hydroponically;
- Research intended growing mediums;
- Carry out experiment.

Predictions

It was predicted that the bulbs grown in Gem houseplant Food (GHF) will grow most healthily. This is because it has added nutrients that plants need for optimum growth. I predict that the bulbs grown in GHF will have the longest and plumpest roots and have the best flowers.

I t was also predicted that the tap water solution bulbs will grow quite well but not as healthily as the GHF bulbs. Other predictions were that the filter water bulbs would grow quite well but not as well as the others because they have nutrients taken out of it, as this water is recommended for drinking. Calcium, Magnesium, copper, chalk, chloride and lead are filtered out of the water. I predict that the bulbs will still grow but now as big and healthily as the GHF bulbs.

Other Considerations

It was necessary to have a variable so differences can be established; also the needs for constants were essential so that it would be a fair test. The bulbs were bought at the same shop, at the same time to ensure that the quality would be the same. Also it was essential that the same colour was used in case this made a difference. The bulbs were put in a warm place (airing cupboard) until the roots were well established. Then they were put in a warm but not too hot area in my dining room, in a position where they would receive the same amount of sunshine, without draft. They were positioned for easy access without any disturbances during monitoring. The variable for this experiment would be:

- Water solutions.

The different types of water to be used are:

- Tap water;
- Filter water;
- Water with Gem Houseplant food added;
- Evian spring water.

The plants were then measured in three different ways:

- The height of the leaves;
- The length of the roots;
- The weight of the dried roots.

A mark was made on each of the leaves that were measured, so that I did not make any mistakes by measuring the wrong leaf. They could have all been measured and the average taken, but it was decided that this would be too time consuming. The roots were measured in the same way, using one root from each bulb, which had been marked. From this data it would be able to assess which solution was most favourable in the healthy growth of hyacinth bulbs.

A pilot test was carried out to give some insight as to what to expect for the experiment. Also, as my knowledge of growing bulbs is limited, it would give me some ideas as to the problems that may occur.
The observation notes were of vital importance if the experiment should be carried out to the best of my ability and as accurately as possible. The dates are also important so that I will know how long each process will take.

Equipment used.

- 12 Conical containers;
- Water;
- 12 Hyacinth bulbs;
- Measuring cylinder;
- String;
- Tape measure;
- Weighing scales;
- Sticky labels;
- Camera;
- Marker pen.

All the equipment used in the experiment is of the same standard except for the variable (water) so that it can be a fair test.

Method

The solutions were made up using 100 mls of each and were kept constant during the experiment. The conical containers were then filled with the solutions and a label attached to identify each container. The containers were wrapped in tin foil to keep out the light. This was carried out so that an alga does not form in the water; algae can take some of the nutrients from the water. The bulbs were then placed on top of the containers, making sure that the bottom was not immersed in the solution otherwise it would rot. The containers were then kept in a warm place, so that the roots grow. When the roots and leaves started to grow, they were marked for identification. The water was then aerated so that the bulbs receive plenty of oxygen. The solutions were changed weekly so that nutrients were not lost. The measurements were taken every three days, over a period of eight weeks and recorded in millimetres. .

Bulbs on windowsill at early stages of growth

Solutions to be used as variables.

Tap Water.

The water in my region of residence comes from Anglian Water, and the supply is from the Pulloxhill zone.

The Drinking Water Inspectorate (DWI) checks on behalf of the Government that water companies supply water that is safe to drink. In 2001 99.64% of more that 205,000 tests met the drinking water standards. Although the 2001 results were good, there are still some matters for concern.

Coliform Bacteria.

During 2001, low numbers of Coliform bacteria were detected in the water. Coliform bacteria were detected in 0.4% of the water samples taken. Many of these failures may have been due to the condition of the tap and not the water itself. The standards permits 5% of samples to contain the bacteria so all zones met the standards.

Pesticides.

Anglian Water carried out more that 23,900 test for individual pesticides during 2001. All samples met the standards.

Lead.

Three of the 1,226 samples taken by Anglian Water failed the standards for lead during 2001. These failures were due to the consumers' water pipes being made of lead.

Iron and Manganese.

During 2001 only 21 of the 5,453 samples taken for iron failed the standard, and one of the 3,370 samples taken for manganese failed the standard. These two parameters give a good indication of the overall condition of the water supply.

Data Summary of tap water

Relevant elements for plant growth

	Prescribed concentration or value	min	mean	max
Magnesium	50mg/l	8.09	8.09	8.09
Potassium	12(15)mg/l	7.58	8.05	8.07
Iron	200 ug/l	<14	<16.6	74
Phosphorus	2200ug/l	873	1050	1170

Nitrogen	(see appendix)

Evian Water

Natural spring water: mg per litre

Calcium	78
Magnesium	24
Sodium	5
Potassium	1
Bicarbonate	357
Sulphate	10
Chlorides	4.5
Nitrates	3.8
Silica	13.5

Filter Water

To filter the water a Brita water filter system was used. When the tap water is filtered chlorine and organic impurities are removed. The exact amounts that are filtered out are unknown.

Gem Houseplant Food.

Gem houseplant food contains all the essential ingredients to help plants grow.

Ingredients

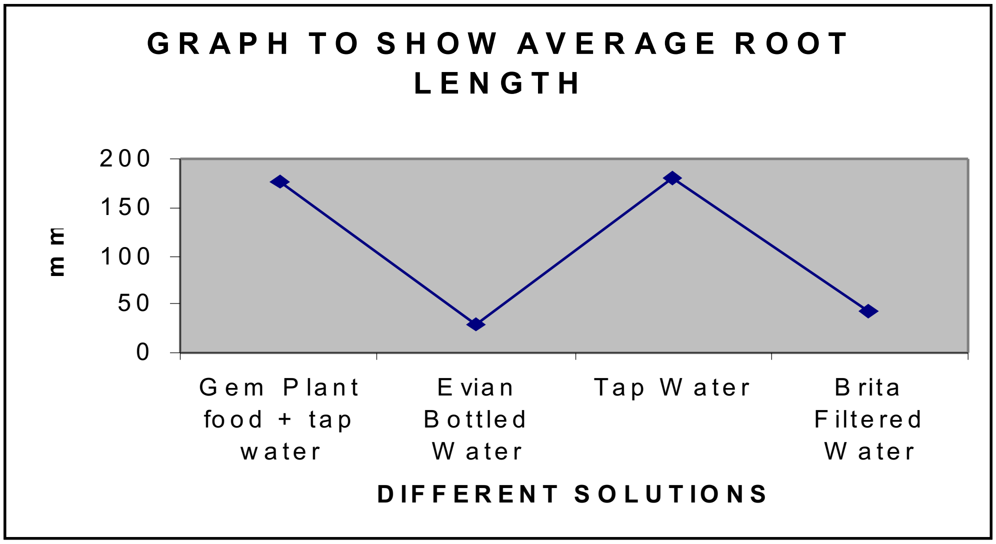
Nitrogen 2%
Phosphorus Pentoxide 2.5%
Total Potassium Oxide 2.5%
Magnesium Oxide 0.4%
Boran 0.02%
Copper 0.04%
Iron 0.08%
Manganese 0.04%
Molybdenum 0.001%
Zinc 0.015%
Water.

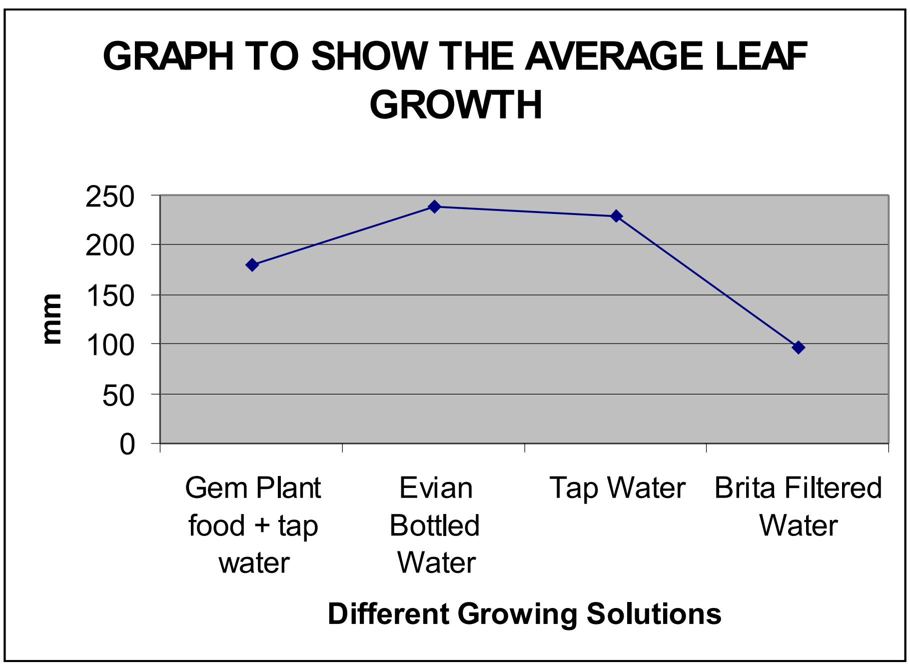
The concentrated food is added to tap water to make up the food. The water food is then changed one a week so that the bulbs can grow healthily.

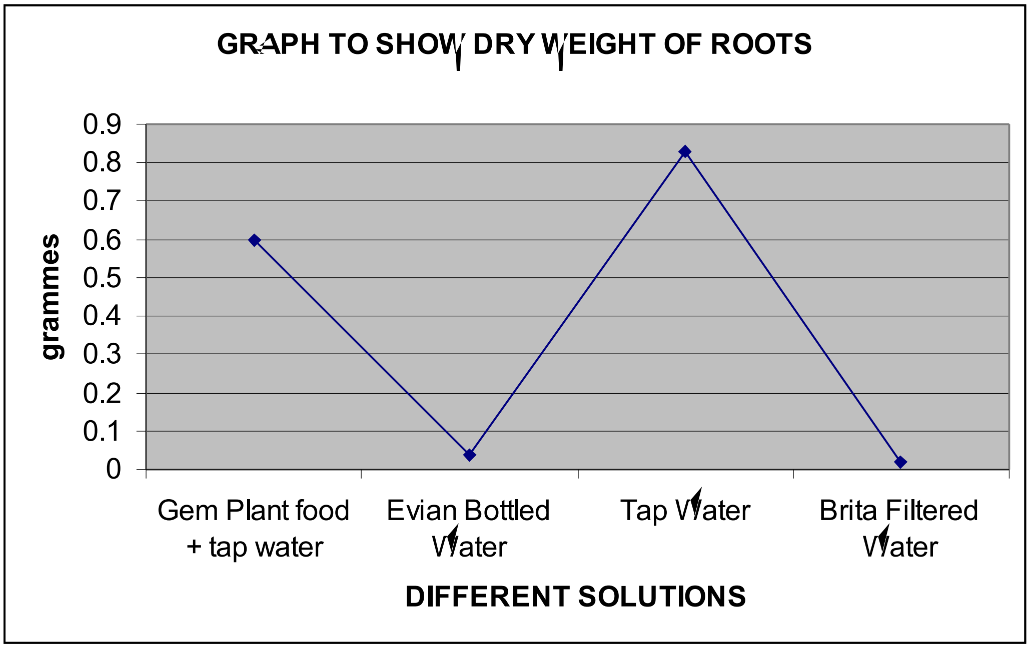
Results

The plants were measured in three ways;

- Height of leaf;
- Length of root;
- Weight of dried root.






GRAPH TO SHOW DRY WEIGHT OF ROOTS
0.9
0.8
0.7
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0.5
0.4
0.3
0.2
0.1
0
grammes
Gem Plant food + tap water
Evian Bottled Water
Tap Water
Brita Filtered Water
DIFFERENT SOLUTIONS

Bulbs at end of experiment

Bulbs grown in Evian Water

Bulbs grown in Gem houseplant Food

Bulbs grown in Tap Water

Bulbs grown in Brita Water

Do the results support the hypothesis?

The results do not support the hypothesis, as I expected that the Gem Houseplant food would produce the best results. However, one of the gem plants did not grow, so this could have contributed to a false result. The tap water samples produced the most root length and the Evian water samples produced the highest leaf. The tap water samples produced the heaviest dried roots. The results were disappointing as two of the bulbs died and did not produce any roots and a short leaf; this lead to uncertainties in the results. Devereux (2000) expressed the need for adequate evidence, "The more evidence one gathers to support the outcome the more sure you can be of any conclusions "(p12). To have made this experiment more reliable, I would use more samples. As the bulbs were bought in October, but not planted till January; this may have had an effect on their growth. The bulbs were kept in a dark cool area, as suggested, and a pilot was undertaken. The pilot test appeared to be more successful than the actual project. As a novice to bulb growing, I can only assume that the time of year has an effect on their growth. In future experiments, I would aerate the water more often to see if this had any effect. Hopkins (1995) advised this, otherwise the plants will get a condition called anoxia. If I were to undertake this experiment again, these factors would be taken into consideration. One of the surprising aspects of this experiment was that the growth of the roots and the leaves tended to have periods where they grew and times were the growth was slower. This was surprising as I expected the growth to be constant throughout. Street and Opik(1986) explain that "Plant cells can grow only when they are turgid and even small decreases in water content below full saturation may result in decreased growth rate"(p47) Also, some of the leaves grew and the roots did not so much and vice versa. I would have expected there to be a uniformed pattern to the ratio of root growth and leaf growth, so this was a surprising factor. However, Popper (1999) confirms that "Science does not aim, primarily, at high probabilities. It aims at a high informative content, well backed by experience". Therefore any scientific investigation should be repeated several times before reliable evidence and conclusions are available.

Using this experiment in the classroom

The National Curriculum (key stage 1+2) (1999) states "Scientific method is about developing and evaluating explanations through experimental evidence and modelling" (p76).

During key stage 1 pupil's observe, explore and ask questions about living things, material and phenomena. They start to work together and collect evidence to link them to scientific ideas. They evaluate experiments by deciding if it has been a fair test.

The research that I have undertaken could be carried out as an experiment for all key stages. I have decided to look at how the experiment could be carried out for pupils in key stage 1. After consulting the national curriculum I found that the experiment could fit in to the following :

SC2 life processes and living things

1c to relate life processes to animals and plants found in local environment.

Green plants

3 a) to recognise that plants need light and water to grow;
b) to recognise and name the leaf, stem and root of flowering plants;
c) that seeds grow into flowering plants.

Investigative skills

2c think about what might happen before deciding what to do;
2d) Recognise when a test or comparison is fair.

Considering evidence and evaluation

h) Make simple comparisons;
i) Compare what happened with what they expected would happen, and try to explain it, drawing on their knowledge and understanding.

QCA Science Teachers guide.

The QCA (Qualification and Curriculum Authority) offers an optional teachers guide for a programme of study. It shows how science may be taught attaining at the level appropriate for their age. The scheme of work is underpinned by assumptions about the aims of the national curriculum by; knowledge and understanding, processes and skills, language and communication and values and attitudes.

Year one.

Pupils learn about growing plants. They learn about similarities and differences in plants. Children should be able to identify the leaf, root, stem and flower of a plant and recognise that plants are living and need water and light to grow.

Year two

Pupils will learn how plants reproduce, turn ideas into questions to be investigated, present results and draw conclusions. They also learn about the environment that plants grow in. They will be encouraged to suggest reasons why different plants are found in different environments.

Year three

Make careful measurements of height and volumes of water used to feed plants. Recognise that in experiments and investigations, a number of plants need to be used to provide reliable evidence.

Programme of Study

If the experiment that I have designed were to be used for year two pupils, a scheme of work would have to be devised.

Week 1	Introduce plants
Week 2	Plant bulbs in solutions and general outline of project
Week 3	Plants need light to grow
Week 4	Plants need water to grow
Week 5	Results and conclusions

The following lesson plans would be used to carry out this scheme of work.

Conclusion and Recommendations

The main points that were established through this research were:

- More samples are needed to validate results;
- The bulbs would have been more productive if they were planted in October;
- Tap water produced more roots that the other solutions;
- Evian water produced more leaves than the other solutions;
- The solutions should be aerated more often;
- Tap water produced more dried weight than the other samples.

If I were to carry out this investigation further, these aspects would be borne in mind to validate the results.

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