## Introduction

Brassica rapa is an extremely fast growing species of plant, finishing its life cycle in around 38 days. The plant is a form of turnip with medicinal properties linking it with the suppression of breast and skin cancer.

I will grow these plants under conditions where they have all the nutrients required (the Control) and under conditions where one of the essential macro elements is absent. The six macronutrients, Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) are required by plants in large amounts.

The macro elements absent in the different plants in the investigation are Calcium, Phosphorous, Magnesium and Potassium.

Calcium is an important component of plant cell walls and in the structure and permeability of cell membranes. The elongation and division of cells requires Calcium. Calcium aids in the uptake of nitrogen. Calcium deficiency can prevent the lateral buds and root tips from forming resulting in reduced growth.

Phosphorous is used in energy transfers and storage in plants. Adenosine di- and triphosphate are important forms that phosphates occur in that are involved in the energy transfer processes e.g. from the cytochrome system in glycolysis. The uptake of nutrients and their movement through transpiration require these energy transfer processes. Also, Phosphorous is important as a component of many proteins, enzymes, and nucleic acids. Phosphorous is a component of phospholipids which make up most of cell membranes. Phosphorous increases root growth which allows the plant to take up water and nutrients at a higher rate. Phosphorous increases rate of flower and fruit production.

Magnesium is used to produce chlorophyll molecules and is also used in enzyme activation. Most energy processes involving ATP require Magnesium. Magnesium is also a component of ribosomes in plants.

Potassium is important as a regulatory molecule in photosynthesis, energy production, starch synthesis, and protein synthesis. Potassium is different than the other nutrients since it is not incorporated into any organic compounds but remains as an ion in the plant. It forms part of the cytoplasm and helps to lower water loss from the leaves and increase water uptake by the plants roots. Potassium increases the growth of tubers and bulbs if they are present in the plant. It helps improve the plant's disease resistance and lowers the numbers of insect problems. It increases the strength of the stems and also improves the colour of leaves and flowers.

## Aim

To determine the effects of macro element deficiencies in plants by investigation.

## Summary

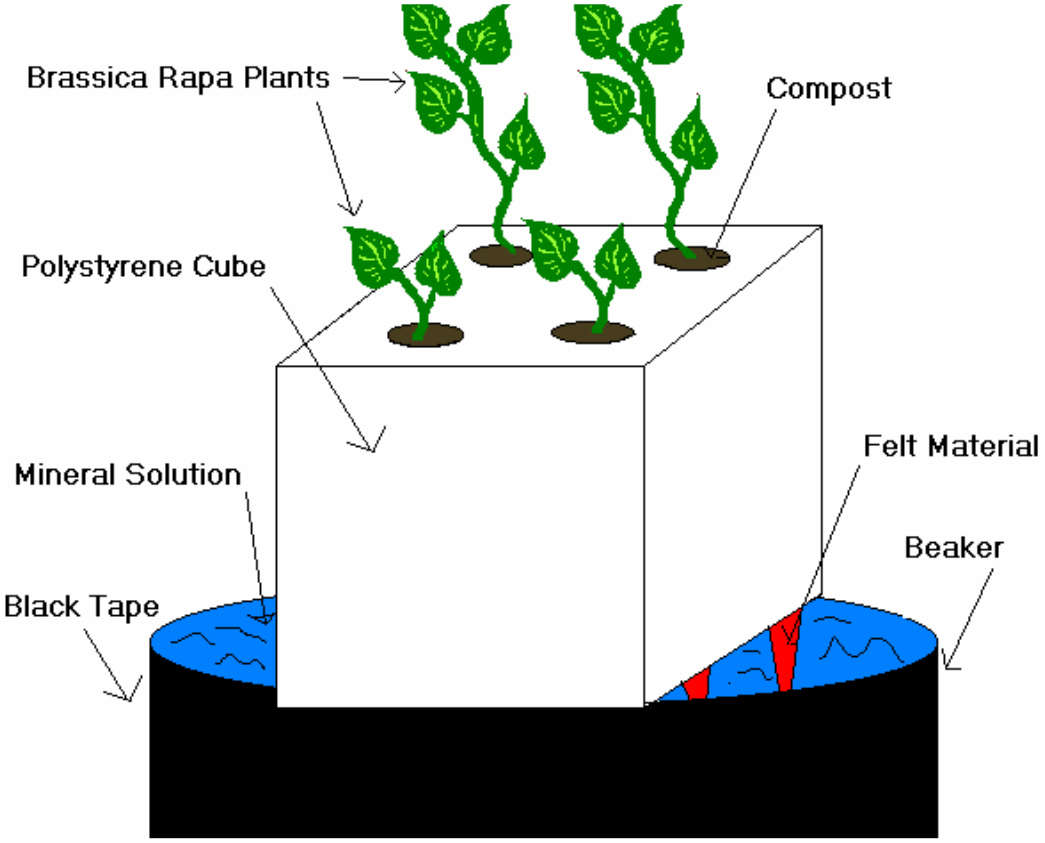
All plants but the control should develop some form of deficiency symptom. Extra quantitative results were taken in relation to water uptake levels since this information shows aspects of the deficiencies that cannot be accurately measured such as leaf surface area and root size/length.

As well as quantitative results, observational results were taken in the course of the investigation within a log book since these results are more important than the other results as they deal with aspects such as colour, leaf death, wilting and degree of branching in root system.

## Hypothesis

My hypothesis is that the plants grown in Calcium deficient solutions will show stunted growth of stalk and roots as well as the appearance of curved leaves.
The plants grown in Phosphorous deficient solutions will have very stunted growth, red/purple bases, older leaves becoming purple and poor flower growth.
The plants grown in Magnesium deficient solutions will develop thin etiolated stalks with chlorotic leaves. Some of the leaves will experience early death or an off-coloured red appearance.
The plants grown in Potassium deficient solutions will have their older leaves show signs of chlorosis followed by a red appearance on the edges resulting in death which spreads toward the centre of the leaf.

## Experimental Method




Polystyrene cubes used to contain the plants – each cube has four holes inserted into it to allow space for the soil. A two inch long piece of felt was fastened to each hole by a needle to keep the soil in and to allow absorption of solution from a beaker underneath. Holes were then filled with compost almost to the top (no fertiliser is added); two seeds inserted in each hole, then another 5mm of compost was added to this. Ten of these were set up (2 Control; 2 Calcium deficient; 2 Phosphorous deficient; 2 Magnesium deficient; 2 Potassium deficient). A Control was also used which has no macro element deficiencies. The solutions were prepared from a nutrient powder which is weighed according to the bottle's directions and dissolved in one litre of distilled water. More of these solutions were made up when needed, eventually leading to a total of 3 litres of solution being made up for each plant set. Since the solution was added to a beaker where the felt reaches the bottom, it did not matter how often the solutions were topped up, although this was done several times a week.

Each cube is placed on top of a beaker full of solution, so that there are two beakers, and therefore sixteen plants for each solution. Each of the beakers has been covered in black tape to prevent algal growth in the solutions which could give inaccurate results for the investigation by absorbing some of the nutrients themselves. The experiment is placed in a light box and elevated to within a few centimetres of fluorescent tubes that provide warmth, and light for when seeds sprout. A dropper is used to moisten the surface with liquid since the movement of water up into the compost is too slow without the roots of the plants present.

One week later all the seeds have sprouted and have grown a few centimetres. One plant from each hole is removed to lower competition (the weaker plant is removed). There is now no need for the lab jacks. After a few days some of the plants have grown too high and have to be propped up with sticks and rubber fasteners. Three weeks after planting, the plants exhibit features of nutrient deficiency.

Many results were taken every 1 to 3 days including plant heights, internode length, number of flowers appearing on each plant, and eventually the number of seedpods appearing, were taken over a five week period. After this time the plants died. All of these factors vary depending on the (chemical) conditions the plants are in.

I also noted my observational results since some of these cannot be presented in a numerical form.

After a period of five weeks the plants finished their life cycle and died, before which all the macro element deficiency characteristics had appeared in all plants.

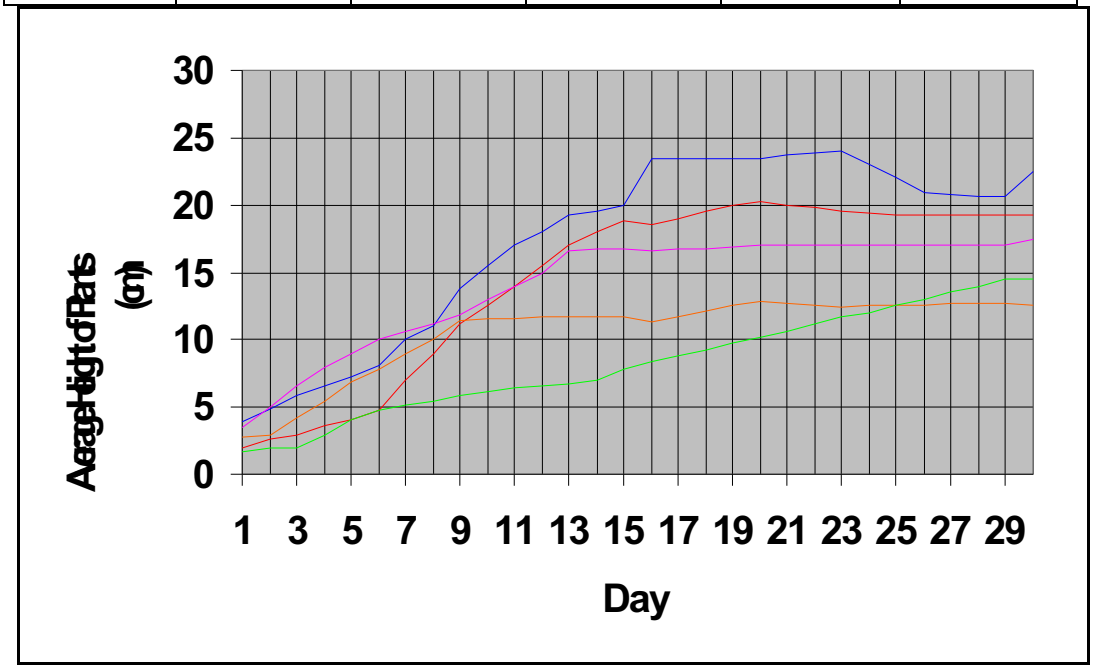
During the investigation an additional experiment was set up consisting of a beaker, covered in black tape, with a polystyrene cube (without any holes) placed on top. This was then filled with a known volume of water and left for several days in order to find the rate of evaporation of water in the given conditions. The surface area of the water exposed in the beaker was the same as the area of water exposed in the experiments themselves. I found the evaporation rate to be 4.6 $cm^3$.

## Results

Note that day '1' is the first day of actual result taking, i.e. when sufficient plants have germinated. The result taking process was delayed slightly due to illness. Also note that the colour of each heading in the table corresponds to the colour of its respective line on the graph.

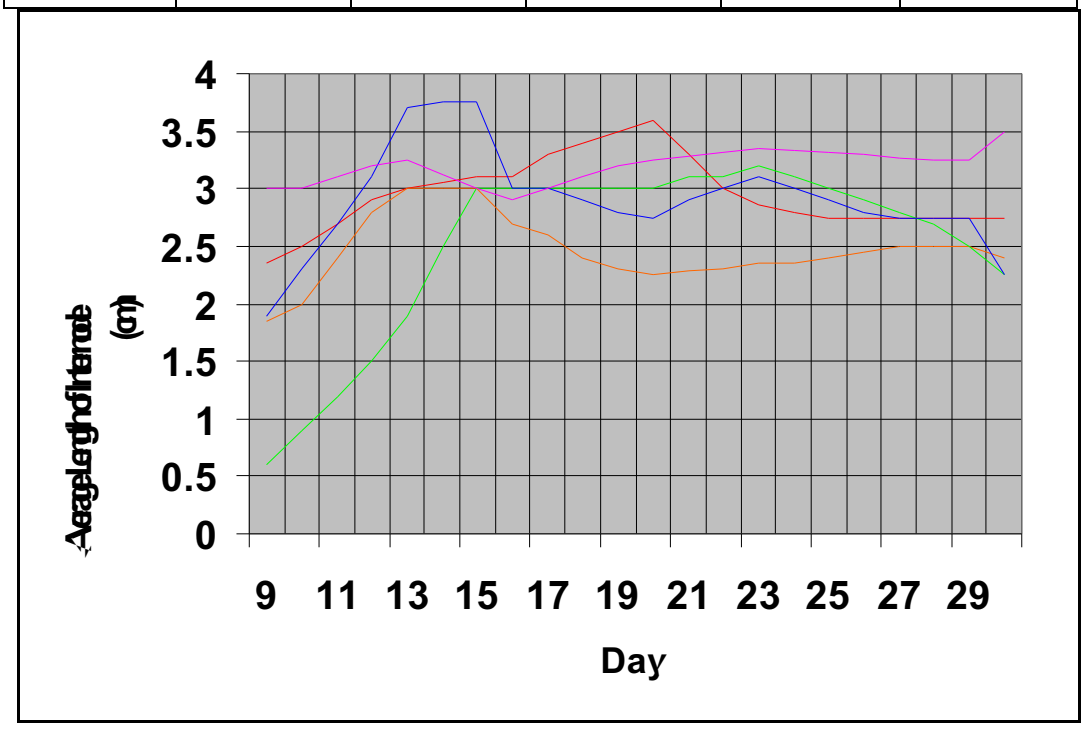
Average Height of Plants (cm)

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 1 | 1.9 | 2.75 | 1.7 | 3.85 | 3.5 |
| 2 | 2.6 | 3 | 1.9 | 4.85 | 5 |
| 6 | 4.75 | 7.75 | 4.8 | 8.15 | 10 |
| 9 | 11.1 | 11.5 | 5.85 | 13.75 | 11.9 |
| 13 | 17 | 11.7 | 6.75 | 19.25 | 16.55 |
| 15 | 18.85 | 11.7 | 7.85 | 20 | 16.8 |
| 16 | 18.5 | 11.35 | 8.4 | 23.5 | 16.65 |
| 20 | 20.25 | 12.9 | 10.2 | 23.5 | 17 |
| 23 | 19.5 | 12.4 | 11.75 | 24 | 17 |
| 29 | 19.25 | 12.65 | 14.5 | 20.65 | 17 |
| 30 | 19.25 | 12.5 | 14.5 | 22.5 | 17.5 |



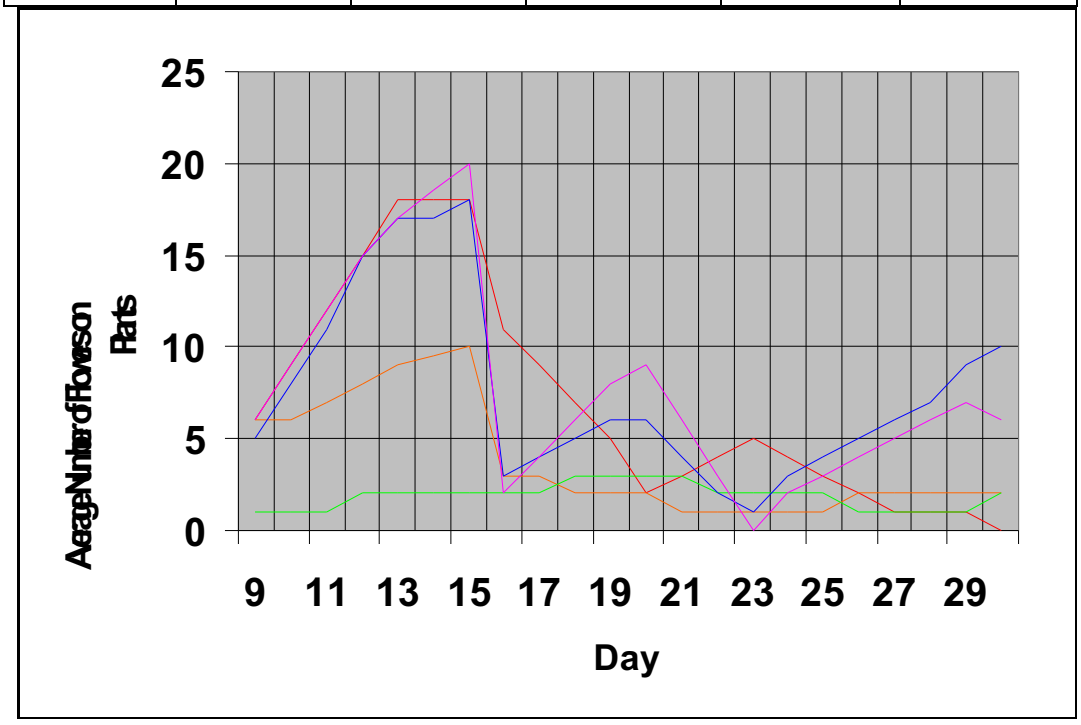
Average Length of Internode (cm)

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 9 | 2.35 | 1.85 | 0.6 | 1.9 | 3 |
| 13 | 3 | 3 | 1.9 | 3.7 | 3.25 |
| 15 | 3.1 | 3 | 3 | 3.75 | 3 |
| 16 | 3.1 | 2.7 | 3 | 3 | 2.9 |
| 20 | 3.6 | 2.25 | 3 | 2.75 | 3.25 |
| 23 | 2.85 | 2.35 | 3.2 | 3.1 | 3.35 |
| 29 | 2.75 | 2.5 | 2.5 | 2.75 | 3.25 |
| 30 | 2.75 | 2.4 | 2.25 | 2.25 | 3.5 |



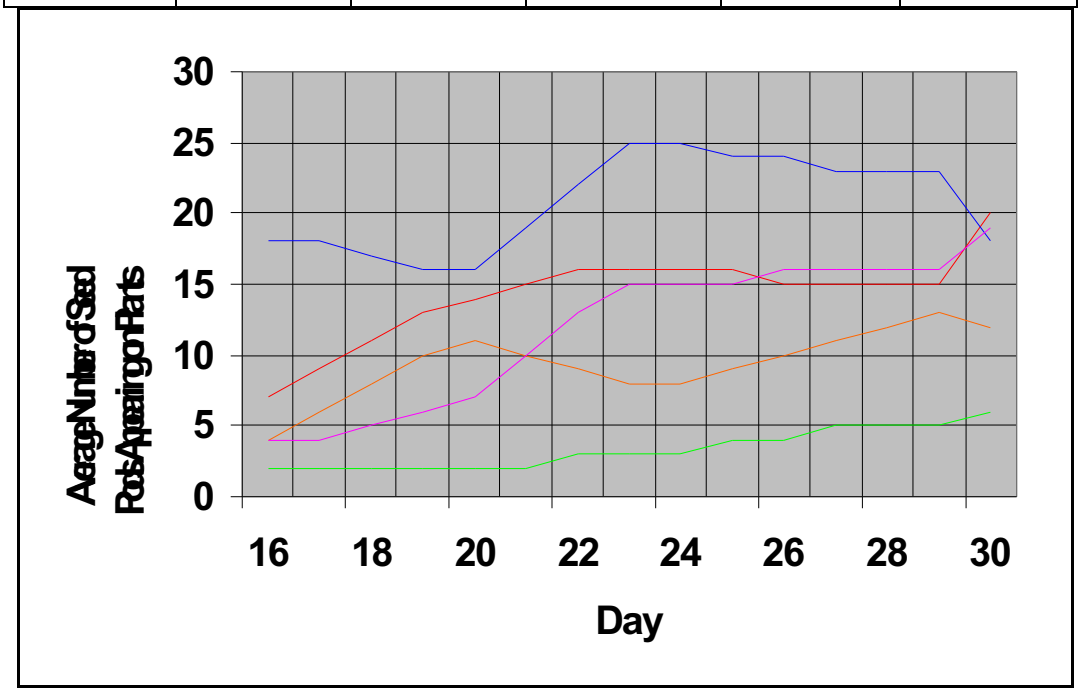
Average Number of Flowers on Plants

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 9 | 6 | 6 | 1 | 5 | 6 |
| 13 | 18 | 9 | 2 | 17 | 17 |
| 15 | 18 | 10 | 2 | 18 | 20 |
| 16 | 11 | 3 | 2 | 3 | 2 |
| 20 | 2 | 2 | 3 | 6 | 9 |
| 23 | 5 | 1 | 2 | 1 | 0 |
| 29 | 1 | 2 | 1 | 9 | 7 |
| 30 | 0 | 2 | 2 | 10 | 6 |



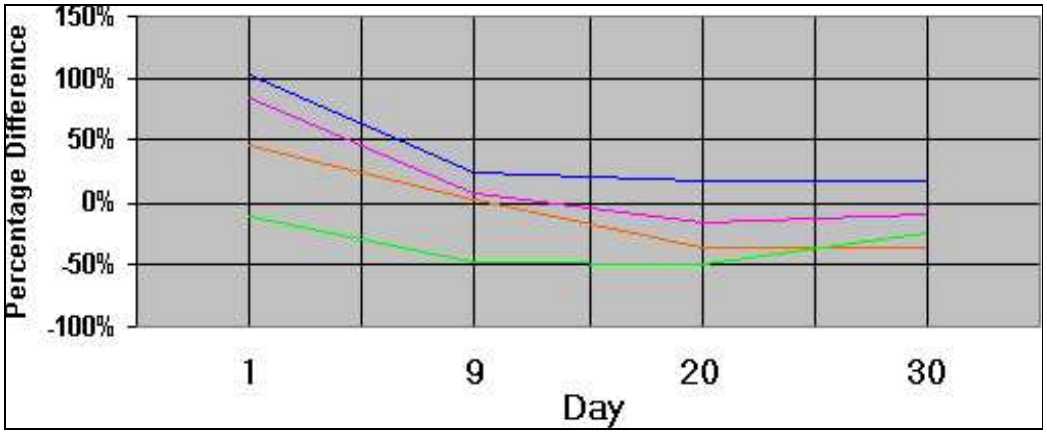
Average Number of Seed Pods Appearing on Plants

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 16 | 7 | 4 | 2 | 18 | 4 |
| 20 | 14 | 11 | 2 | 16 | 7 |
| 23 | 16 | 8 | 3 | 25 | 15 |
| 29 | 15 | 13 | 5 | 23 | 16 |
| 30 | 20 | 12 | 6 | 18 | 19 |



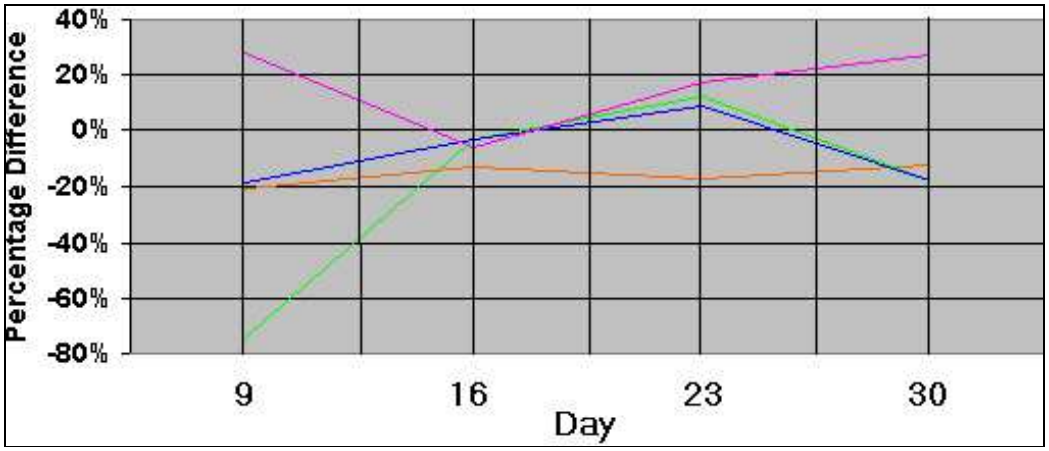
Percentage Differences in Height of Plants

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 1 | 0 | +44.73% | -10.52% | +102.63% | +84.21% |
| 9 | 0 | +3.6% | -47.29% | +23.87% | +7.21% |
| 20 | 0 | -36.29% | -49.63% | +16.05% | -16.05% |
| 30 | 0 | -35.06% | -24.68% | +16.88% | -9.09% |



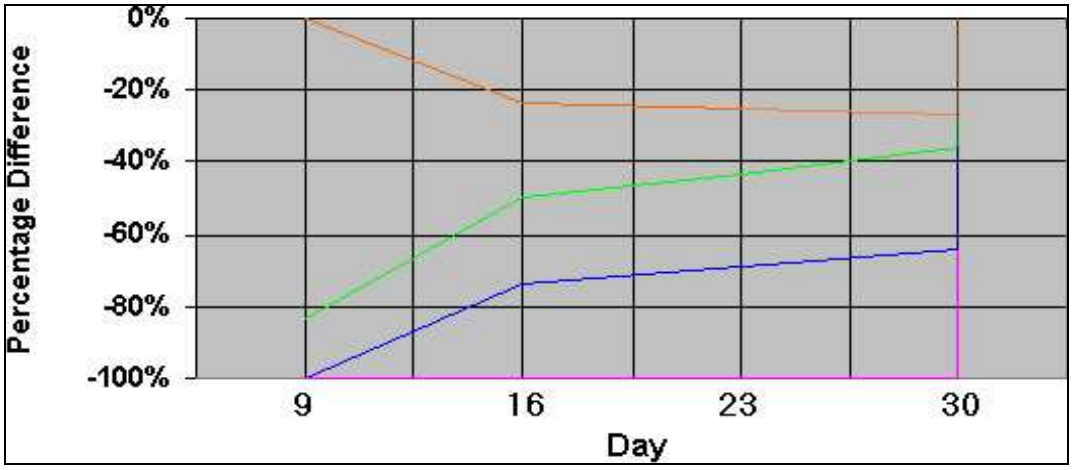

Percentage Differences in Internode Length

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 9 | 0 | -21.28% | -74.47% | -19.15% | +27.66% |
| 16 | 0 | -13.03% | -3.23% | -3.23% | -6.45% |
| 23 | 0 | -17.54% | +12.28% | +8.77% | +17.54% |
| 30 | 0 | -12.72% | -18.18% | -18.18% | +27.27% |



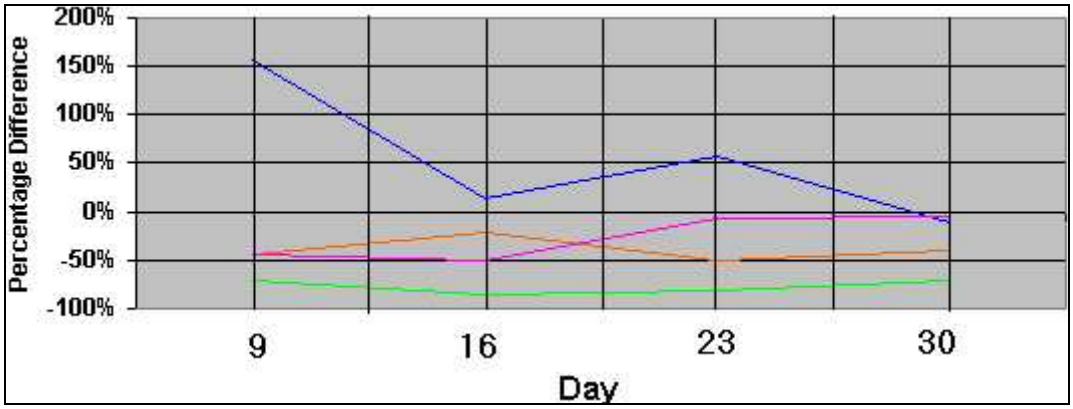
Percentage Differences in Number of Flowers on Plants

| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 9 | 0 | 0% | -83.33% | -16.67% | 0% |
| 16 | 0 | -72.27% | -81.81% | -72.72% | -81.81% |
| 23 | 0 | -80% | -60% | -80% | -100% |
| 30 | 0 | +∞% | +∞% | +∞% | +∞% |




Percentage Difference in Number of Seed Pods Appearing on Plants

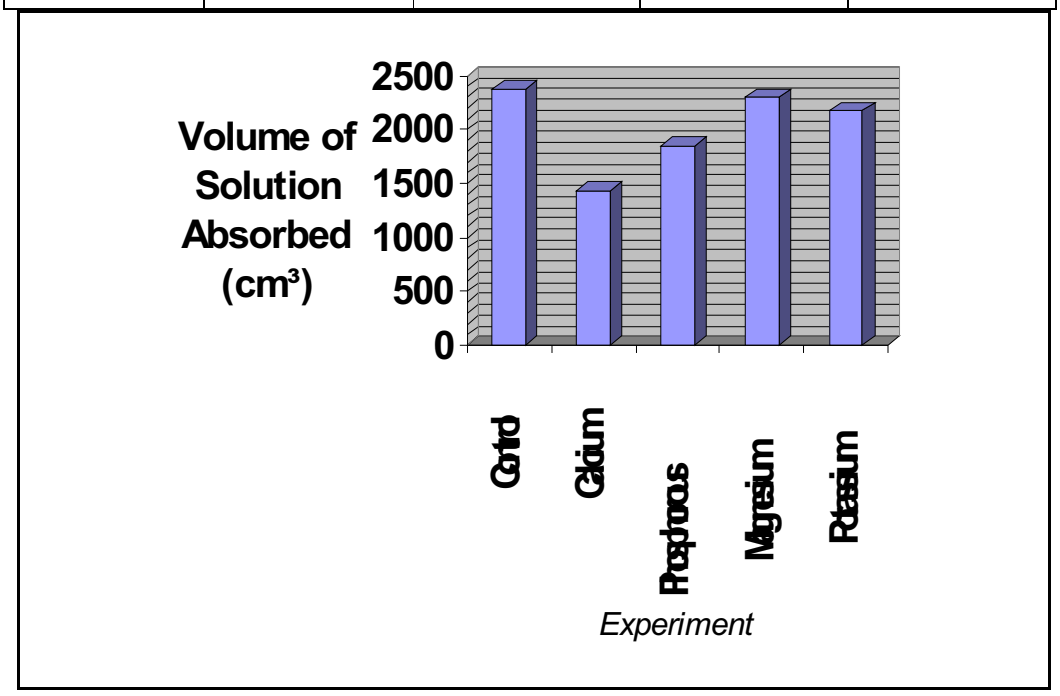
| Day | Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|---|
| 16 | 0 | -42.86% | -71.43% | +157.14% | -42.86% |
| 20 | 0 | -21.43% | -85.71% | +14.29% | -50% |
| 23 | 0 | -50% | -81.25% | +56.25% | -6.25% |
| 30 | 0 | -40% | -70% | -10% | -5% |



Total Volume of Solution Absorbed by Plant's Roots over 30 Days

By calculation, using the additional experiment described in the method section, I found the total volume of solution absorbed by the different plants. Using the rate of 4.6 $cm^3$ a day evaporation from the beakers, as well as the total volume of solution made up for each experiment (3 litres) I was able to calculate that each plant absorbed the following volumes of solution in the 29 days the experiment ran for. Values are in $cm^3$.

| Control | Calcium | Phosphorous | Magnesium | Potassium |
|---|---|---|---|---|
| 2373.6 | 1428.6 | 1847.6 | 2293.6 | 2176.6 |



## Observational Results

The root length was long in both the Magnesium deficient plant and the Control. The Phosphorous deficient plant had shorter roots while the Potassium deficient plant had extremely long roots. The Calcium deficient plants did not ever fully develop their roots during the experiment. Their roots only showed within the last two weeks of the experiment.

The Control plant grew as normal, flowered, produced seed pods, then died once it had completed its life cycle.

The Magnesium deficient plant was much the same, although it became chlorotic at the later stages of the experiment it still managed to produce seed pods.

The Calcium deficient plant was weak, grew slowly to a shorter height without developing its roots properly, and experienced early leaf death.

The Potassium deficient plant grew to a good height, though slightly shorter than the Control, and managed to develop its flowers and seed pods despite its early leaf death and red base.

The Phosphorous deficient plant developed red bases and grew to a much shorter height than the other plants. In spite of this it still managed to produce flowers and seed pods.

## Conclusion

All plants, as predicted, developed the deficiency symptoms as outlined in my hypothesis. The volumes of solutions absorbed, given in the results, give information about the features of the plants. The Control absorbs most solution since it has developed full and healthy leaves while the Calcium-deficient plant absorbs the least amount of solution since most of its leaves have shrivelled and died.

The plant heights and Internode lengths show the Magnesium-deficient plants to be taller than the Control, showing they are etiolated.

The Calcium, Phosphorous and Potassium-deficient plants are weaker plants and so do not develop as many flowers and eventually seedpods. The Phosphorous-deficient plants are much smaller and so this is also a large factor contributing to this feature.

The observational results also show my hypothesis to be correct. These results were more important than the quantitative results since these describe the main plants features such as colour of leaves and whether plant is wilting or not – these cannot be shown in a graph form, for example.

## Evaluation

There were some inaccuracies in the investigation which could not be helped. Human error was a factor in all of the results with the exception of the solution absorbency rates.

1. Lengths of plants/their internodes were hard to obtain with measuring tape.

2. Solution absorbency rates had inaccuracies in them since the evaporation rate can change from week to week depending on the room's conditions (e.g. room was much warmer at end of investigation than at start since investigation began in winter and finished close to March when weather was much improved). However these inaccuracies had no large effect on the results since the conditions of the room were the same for all plants throughout the investigation.

3. A major problem encountered during the experiment was the considerable water loss due to the lamps being on 24 hours a day – the problem was worst at the weekend when there is no way to water them.

The compost used was free of nutrients.

Although some plants from each set-up died in the course of the investigation, the results were hardly affected since an average of all other plants was taken and used. No more than 4 plants died from each set-up so this plant death was not a problem.

Readings for the Internode length were not taken until nine days into the experiment because all the plants had the same features in terms of size and appearance up to this point.

Readings for the number of flowers present on each plant were not taken until nine days into the experiment because up to this point there had been no significant development of the flowers.

There are significant differences in appearance between the percentage difference graphs of flowers and seed pods. This was due to the fact that it was often hard to distinguish between a flower and seed pod since the pod forms from the centre of the flower. A seed pod was termed a seed pod when the flower it came from had died.

## Acknowledgements

James A. Duke (1983) Handbook of Energy Crops. Visited March 2003. URL:
http://www.hort.purdue.edu/newcrop/duke_energy/Brassica_rapa.html

Thomas Wallace (1943) The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms Visited March 2003. URL:
http://www.luminet.net/~wenonah/min-def/list.htm

## Thanks

I would like to thank Mr X and the Technician staff for their great help during this long investigation.