Research Question: What is the effect of potassium ion concentration (ppm) on the initial (day 0 to day 2) rate of growth of *Hygrophilla difformis* through mass change per day (g/day) over a period of 1 week?

By Ardon Moiz Pillay

1: Introduction

*Hygrophilla difformis* (Krishanu, 2012), or water wisteria (Krishanu, 2012), is a biologically and chemically important freshwater plant, one that has the unique ability to reduce the size of algal blooms. Due to its high rate of growth (Krishanu, 2012), the wisteria absorbs aqueous nutrients at an exponential rate, particularly potassium and nitrate ions. These ions are essential for the growth of algal blooms, creating a bottom up limiting factor for the algae, reducing their growth capability. Algal blooms, such as cyanobacteria blooms, impede the diversity of aquatic ecosystems by increasing the biochemical oxygen demand, hence causing aquatic plants and animals to die out due to oxygen deprivation. Hence, increasing the water wisteria's efficiency in absorbing nutrients would allow us to preserve aquatic ecosystems and maintain their biodiversity. A possible way to increase the efficacy of the water wisteria would be to increase the concentration of potassium ions (**K**⁺). **K**⁺ ions facilitate osmosis in the stomata - when they enter the guard cells due to low concentrations of abscisic acid, they allow water to enter the guard cells, causing the stomata to open due to higher turgidity having been induced in the guard cells. I specifically chose this research question because I feel strongly that the biodiversity of aquatic ecosystems should be maintained, and the eutrophication caused by algal blooms does nothing but deteriorate overall health of aquatic ecosystems and cause a decline in biodiversity. Freshwater lakes are home to approximately 41% of all fish species in the world (Helfman, 2007) and a decrease in biodiversity would irreversibly reduce the total number of living fish species. Hence, optimising the ability of water wisteria to absorb nutrients would assist in the maintenance of biodiversity in aquatic ecosystems.

2: Investigation

2.1: Hypothesis

**H₁:** As potassium ion concentration increases, the rate of growth of *Hygrophilla difformis* increases.

**H₀:** As potassium ion concentration increases, there is no effect on the rate of growth of *Hygrophilla difformis*.

2.2: Background Knowledge

Potassium ions are key nutrients for all plants, mainly because **K**⁺ concentration is directly proportional to adenosine triphosphate (ATP) production as the **K**⁺ ions balance the charges inside the mitochondria, where respiration occurs (Armstrong, 1998). As the extent of charge balance increases, the amount of ATP produced during respiration would increase significantly. A higher quantity of ATP facilitates more growth processes, such as mitosis and hypertrophy, per unit time. This is because ATP would be used in the anabolic reactions required to synthesise duplicated chromosomes in mitosis and to extend the polysaccharide based cell wall in cellular hypertrophy. Hence increasing the potassium ion concentration would increase the rate of growth of *Hygrophilla difformis*.

Furthermore, **K**⁺ ions are also essential for protein synthesis (Armstrong, 1998). **K**⁺ ions are theorised to be used in the activation and synthesis of the enzyme nitrate reductase, an enzyme that
is involved in the production of amino acids and amides (Armstrong, 1998). Therefore, a higher concentration of K⁺ ions would consequently increase the enzyme activity of nitrate reductase, hence causing the production of amino acids and amides to increase; this increases the availability of proteins used in growth processes in the plant, because a higher quantity of amino acids results in an increased rate of translation (Proud, 2004).

2.3: Variables

**Independent Variables:** K⁺ ion concentration (ppm) (± 0.01 ppm)

**Dependent Variable:** Rate of growth (g/day⁻¹) (±0.01 g)

**Controlled Variables:**
- The volume of water in each fish tank was kept at 5.00 dm³. After every reading, 0.10 dm³ of tap water was added to the tanks. The preliminary experiment identified this quantity as being the amount of water that should be added every two days to ensure a constant volume of water in each tank.
- The temperature of the environment was maintained at 25°C (the optimal temperature for the growth of Hygrophilla difformis) (Krishanu, 2012).
- All samples were sourced from Sammy’s Pet Store, 82 Marine Parade Central, Singapore 440082.
- The time of day when the readings were taken was kept constant (10:30 am); to ensure the time gap between recordings was precisely 2 days.
- The source of K⁺ ions was always KCl, because different potassium compounds disassociate into K⁺ ions in varying amounts, hence maintaining KCl as the source allowed for accurate calculations in appendix 1A, because KCl completely disassociates into K⁺ and Cl⁻ ions.
- The number of stirs and the direction of stirring when KCl was being dissolved was kept constant at 20 stirs, in a counter-clockwise direction. This was kept constant because different degrees of stirring, in different directions, would dissolve the KCl to different extents, hence the marked K⁺ ion concentration would not necessarily be representative of the actual concentration. 20 stirs were chosen as this would be sufficient to dissolve all the KCl.

2.4: Preliminary Experiment

A preliminary experiment was carried out over 1 week to assess if any alterations to the original methodology were necessary. The method used for the preliminary experiment was identical to that in section 3.3, save for the fact that the K⁺ ion concentration in the preliminary experiment was measured in moldm⁻³ (moles per decimetre cubed) as opposed to parts per million (ppm). This was changed in the final experiment after further research revealed that the concentration of potassium ions in freshwater ecosystems is mainly measured in ppm. In the preliminary experiment, when the mass of each sample was measured (every 2 days), water was added in varying amounts each time through the use of a graduated measuring cylinder. This was to determine the volume of water that should be added to compensate for evaporation. This value was found to be 0.10 dm³.
3: Procedure

3.1: Apparatus

1) 5-10.00dm³ fish tanks (24.4cm x 35.5cm x 18.2cm) – used to store the water wisteria samples
2) 0.624 g of Potassium Chloride (KCl)
3) 25 samples of Hygrophilla difformis
4) Mass balance (± 0.01g when measuring mass of the samples) (± 0.001g when measuring masses of KCl) - used to measure the mass of KCl and the mass of each sample
5) A 0.50dm³ beaker (± 0.01dm³) – used as a medium to measure the mass of the samples, as well as to fill up the fish tanks
6) A spatula – to transfer KCl to the beaker
7) A hand towel – to dry the mass balance and beaker

3.2: Photograph of set-up

A photograph taken by myself using an iPhone 6, on 8/11/2015, that displays the Hygrophilla difformis samples in the 0ppm K⁺ solution

3.3: Methodology

1) Prepare 5 fish tanks
2) Pour 5.00dm³ of tap water into 1 of the fish tanks, using the 0.5dm³ beaker
3) Set the air-conditioning at 25°C.
4) Measure the mass of 5 new Hygrophilla difformis samples using the mass balance
5) Label each of them, from A to E (this was to allow for the identification of the individual samples when their masses were measured) and place them in the fish tank – this allowed for 5 repeats, which increases the accuracy of my data
6) Place the 5 measured samples into the fish tank
7) Calculate the mass of potassium chloride needed for 2.00ppm, 200.00ppm, 400.00ppm and 1000.00ppm of K⁺ ions in the manner shown in appendix 1A.
8) Place a beaker on the mass balance and set the balance to 0
9) Using a spatula, transfer sufficient quantities of potassium chloride to the beaker until the calculated mass required for 2.00ppm is found.
10) Repeat step 2.
11) Place the beaker of potassium chloride under water inside the newly filled tanks and invert the beaker.
12) Stir the water in a fish tank with a glass rod counter-clockwise 20 times.
13) Repeat steps 4 and 5
14) Mark this tank with its respective potassium ion concentration
15) Repeat steps 4-8 with the calculated masses of potassium chloride required for 200.00ppm, 400.00ppm and 1000.00ppm.
16) On every other day, over a period of 7 days, measure the masses of each of the 5 samples in all 5 tanks, having thoroughly cleaned and dried each sample with a hand towel. Additionally, following each reading, add 0.10dm³ of tap water to each tank.

3.4: Justification

The presented independent variable values were used for specific reasons. 0.00ppm functioned as a control, 2.00ppm represented the average K⁺ ion concentration in freshwater lakes (LWTS), 200.00 and 400.00ppm were representative of the average range of K⁺ ion concentration in saltwater seas (LWTS); and 1000.00ppm was a representation of an excess of K⁺ ions.

5 repeats were carried out at each concentration to improve the accuracy of the data gained from the experiment. Tap water was used because, according to the PUB Drinking Water Quality Report, there is no potassium present in the tap water in Singapore (PUB, 2015). This could have potentially affected the rate at which the water wisteria samples grew. Furthermore, other nutrients that could potentially affect the growth of *Hygrophilla difformis* are in very small concentrations. For example, the concentration of nitrate ions is 0.32mg/dm³ (PUB, 2015), a negligible amount.

The dependent variable (mass change per day) was chosen because the rate of growth is dependent on the rate of mitosis. Based on research by Andrea Bryan, the mass of yeast cells undergoing mitosis increased as mitosis progressed from G₁ to cytokinesis (Bryan, 2009). Therefore, the rate of mass change would be a representation of the rate of growth.

3.5: Risk Assessment

**Safety Issues:** The KCl used in the experiment was a mild hazard due to its properties as an irritant (Avogadro Chemistry). Hence to minimise the risk of any skin irritations, gloves were worn to handle the KCl.

**Ethical Issues:** There were no ethical issues to be taken into account.

**Environmental Issue:** K⁺ is a nutrient that can promote eutrophication; hence if it was disposed through a sink, it could promote eutrophication. Hence, at the end of the experiment, I distilled the KCl out of the water used and reused it as a fertiliser for my home plants.
### Raw Data

**Raw Data Table 1:** A table showing how the mass of 5 *Hygrophilla difformis* samples (±0.01g) varies over 7 days in a 5.00dm³ solution with 0.00ppm concentration of K⁺ ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0 Mass (g) (±0.01g)</th>
<th>Day 2 Mass (g) (±0.01g)</th>
<th>Day 4 Mass (g) (±0.01g)</th>
<th>Day 6 Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>73.31</td>
<td>76.36</td>
<td>77.47</td>
<td>83.69</td>
</tr>
<tr>
<td>B</td>
<td>69.99</td>
<td>70.91</td>
<td>74.49</td>
<td>78.38</td>
</tr>
<tr>
<td>C</td>
<td>65.70</td>
<td>66.74</td>
<td>67.00</td>
<td>67.53</td>
</tr>
<tr>
<td>D</td>
<td>74.99</td>
<td>73.48</td>
<td>70.32</td>
<td>73.27</td>
</tr>
<tr>
<td>E</td>
<td>65.40</td>
<td>72.73</td>
<td>75.01</td>
<td>85.15</td>
</tr>
</tbody>
</table>

**Raw Data Table 2:** A table showing how the mass of 5 *Hygrophilla difformis* samples (±0.01g) varies over 7 days in a 5.00dm³ solution with 2.00ppm (±0.01ppm) concentration of K⁺ ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0 Mass (g) (±0.01g)</th>
<th>Day 2 Mass (g) (±0.01g)</th>
<th>Day 4 Mass (g) (±0.01g)</th>
<th>Day 6 Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>72.51</td>
<td>78.23</td>
<td>83.43</td>
<td>84.79</td>
</tr>
<tr>
<td>B</td>
<td>76.11</td>
<td>75.45</td>
<td>77.68</td>
<td>88.37</td>
</tr>
<tr>
<td>C</td>
<td>72.13</td>
<td>75.67</td>
<td>79.43</td>
<td>82.86</td>
</tr>
<tr>
<td>D</td>
<td>78.28</td>
<td>80.13</td>
<td>83.42</td>
<td>83.74</td>
</tr>
<tr>
<td>E</td>
<td>75.61</td>
<td>88.93</td>
<td>90.21</td>
<td>90.28</td>
</tr>
</tbody>
</table>

**Raw Data Table 3:** A table showing how the mass of 5 *Hygrophilla difformis* samples (±0.01g) varies over 7 days in a 5.00dm³ solution with 200.00ppm (±0.01ppm) concentration of K⁺ ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0 Mass (g) (±0.01g)</th>
<th>Day 2 Mass (g) (±0.01g)</th>
<th>Day 4 Mass (g) (±0.01g)</th>
<th>Day 6 Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>76.79</td>
<td>84.56</td>
<td>84.69</td>
<td>85.03</td>
</tr>
<tr>
<td>B</td>
<td>71.61</td>
<td>74.45</td>
<td>78.32</td>
<td>78.44</td>
</tr>
<tr>
<td>C</td>
<td>68.79</td>
<td>72.28</td>
<td>80.17</td>
<td>80.67</td>
</tr>
<tr>
<td>D</td>
<td>69.64</td>
<td>73.09</td>
<td>75.58</td>
<td>75.74</td>
</tr>
<tr>
<td>E</td>
<td>69.37</td>
<td>78.93</td>
<td>79.76</td>
<td>81.43</td>
</tr>
</tbody>
</table>

**Raw Data Table 4:** A table showing how the mass of 5 *Hygrophilla difformis* samples (±0.01g) varies over 7 days in a 5.00dm³ solution with 400.00ppm (±0.01ppm) concentration of K⁺ ions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0 Mass (g) (±0.01g)</th>
<th>Day 2 Mass (g) (±0.01g)</th>
<th>Day 4 Mass (g) (±0.01g)</th>
<th>Day 6 Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>61.39</td>
<td>74.43</td>
<td>69.95</td>
<td>76.36</td>
</tr>
<tr>
<td>B</td>
<td>70.62</td>
<td>83.12</td>
<td>71.83</td>
<td>80.00</td>
</tr>
<tr>
<td>C</td>
<td>67.65</td>
<td>53.12</td>
<td>68.12</td>
<td>68.14</td>
</tr>
<tr>
<td>D</td>
<td>66.10</td>
<td>78.85</td>
<td>66.24</td>
<td>67.89</td>
</tr>
<tr>
<td>E</td>
<td>67.87</td>
<td>93.53</td>
<td>67.95</td>
<td>69.57</td>
</tr>
</tbody>
</table>
Raw Data Table 5: A table showing how the mass of 5 Hygrophilla difformis samples (±0.01g) varies over 7 days in a 5.00dm³ solution with a 1000.00ppm (±0.01ppm) concentration of K⁺ ions

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0 Mass (g) (±0.01g)</th>
<th>Day 2 Mass (g) (±0.01g)</th>
<th>Day 4 Mass (g) (±0.01g)</th>
<th>Day 6 Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>68.77</td>
<td>86.72</td>
<td>77.99</td>
<td>79.67</td>
</tr>
<tr>
<td>B</td>
<td>75.74</td>
<td>82.14</td>
<td>81.00</td>
<td>83.81</td>
</tr>
<tr>
<td>C</td>
<td>76.25</td>
<td>97.19</td>
<td>86.72</td>
<td>86.79</td>
</tr>
<tr>
<td>D</td>
<td>72.20</td>
<td>93.83</td>
<td>89.31</td>
<td>91.36</td>
</tr>
<tr>
<td>E</td>
<td>74.28</td>
<td>98.72</td>
<td>76.90</td>
<td>75.71</td>
</tr>
</tbody>
</table>

5: Processed Data

Processed Data Table 1: A table showing how the average mass of Hygrophilla difformis varies across 7 days

<table>
<thead>
<tr>
<th>ppm (±0.01ppm)/days</th>
<th>Day 0 Average Mass (g) (±0.01g)</th>
<th>Day 2 Average Mass (g) (±0.01g)</th>
<th>Day 4 Average Mass (g) (±0.01g)</th>
<th>Day 6 Average Mass (g) (±0.01g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>69.88</td>
<td>74.04</td>
<td>72.86</td>
<td>77.60</td>
</tr>
<tr>
<td>2.00</td>
<td>74.93</td>
<td>79.68</td>
<td>82.83</td>
<td>84.01</td>
</tr>
<tr>
<td>200.00</td>
<td>71.24</td>
<td>76.66</td>
<td>79.70</td>
<td>80.26</td>
</tr>
<tr>
<td>400.00</td>
<td>66.73</td>
<td>76.61</td>
<td>68.82</td>
<td>72.39</td>
</tr>
<tr>
<td>1000.00</td>
<td>73.45</td>
<td>91.72</td>
<td>82.38</td>
<td>83.47</td>
</tr>
</tbody>
</table>

Calculation of average mass: \( \frac{\sum \text{Mass on each day for each repeat}}{\text{Number of repeats}} \)

Example calculation for average mass

Average mass for plants at 0.00ppm on day 0: \( \frac{70.31+69.99+63.70+74.99+65.40}{5} = 70.31 \text{ (rounded to 2 decimal places [2.d.p], because the uncertainty of the mass is ±0.01g).} \)

All values in processed data table 3 were also rounded to 2.d.p for the same reason.

5.1: Statistical Test

To establish a statistical difference between the 5 different groups, a one-way ANOVA (analysis of variance) test was conducted on processed data table 1 using StatPlus (a software that allows for statistical tests on Microsoft Excel). This test allowed me to test for a statistical relationship across all my 5 different K⁺ ion concentrations.

\( H_0 \) (Null hypothesis): There is no statistically significant relationship between potassium ion concentration and the average mass of Hygrophilla difformis over 6 days.

\( H_1 \): There is a statistical significant relationship between potassium ion concentration and the average mass of Hygrophilla difformis over 6 days.

The results of the test can be seen in processed data table 2.

The null hypothesis was tested through the ANOVA test.
Processed Data Table 2 (screenshot from Microsoft Excel): A table displaying how the ANOVA test was carried out

<table>
<thead>
<tr>
<th></th>
<th>Sample site</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>44</td>
<td>73.585</td>
<td>10.19317</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>80.3825</td>
<td>16.46589</td>
</tr>
<tr>
<td>200</td>
<td>4</td>
<td>76.985</td>
<td>17.08683</td>
</tr>
<tr>
<td>400</td>
<td>4</td>
<td>71.1375</td>
<td>18.77129</td>
</tr>
<tr>
<td>1000</td>
<td>4</td>
<td>82.755</td>
<td>65.8687</td>
</tr>
</tbody>
</table>

Note:
Results Format
Results: $F$ [degrees of freedom (d.f) between groups, d.f total] = $F$ value $p$ (probability level)

Results: $F (4, 19) = 3.81821$ $p = 2.46921\%$

Based on the low probability value of 0.024621 ($p \leq 0.05$), the null hypothesis was rejected and hence, $H_1$ is accepted. Therefore there is a statistically significant relationship between potassium ion concentration and the average mass of *Hygrophilla difformis* over 6 days. However, the test does not show how the potassium ion concentration affects the average rate of growth of *Hygrophilla difformis*. Hence, further data processing needs to be conducted.

Due to water wisteria’s high rate of growth (Krishanu, 2012), the initial rate of growth was used as a measure of the rate of growth as this is the point at which it would be at its highest.

Using the formula $\frac{\text{Average mass on day 0} - \text{average mass on day 2}}{0-2}$, we can find the initial average rate of growth of the water wisterias for the 5 different concentrations.

*Example calculation for 2.00ppm*

$$\frac{74.93 - 79.68}{0 - 2} = 2.38 \text{ gday}^{-1} (\text{rounded to 2. d.p})$$

Processed Data Table 3: A table showing how the average initial rate of growth of *Hygrophilla difformis* varies with K⁺ ion concentration (ppm) (± 0.01ppm)

<table>
<thead>
<tr>
<th>ppm (±0.01ppm)</th>
<th>Average initial rate of growth (gday⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>2.08</td>
</tr>
<tr>
<td>2.00</td>
<td>2.38</td>
</tr>
<tr>
<td>200.00</td>
<td>2.71</td>
</tr>
<tr>
<td>400.00</td>
<td>4.94</td>
</tr>
<tr>
<td>1000.00</td>
<td>9.14</td>
</tr>
</tbody>
</table>
Graph 1: A graph showing how K+ ion concentration (ppm) affects the average initial rate of growth of Hygrophilla difformis (g/day⁻¹)

The error bars were set to the maximum error per reading, which as found to be 0.0162% [rounded to 3 significant figures (s.f)].

Calculation for maximum percentage error

\[
\text{maximum} = \frac{\text{Uncertainty of apparatus used to measure dependent variable}}{\text{Lowest dependent variable value}} \cdot 100\% \\
= \frac{0.01}{61.39} \cdot 100\% = 0.0162\% \text{ (rounded to 3 s.f)}
\]

The high R² value of the line of regression indicates a strong positive correlation between K+ ion concentration and the average initial rate of growth.

The error bars of the graph represent standard error on each data point and the R² value determines the suitability of the line of best fit. Their small sizes indicate a low chance of error, increasing the certainty and accuracy of the data gained through the experiment, as does the relatively small distance between each data point and the line of regression.

4.2: Notes and qualitative observations

1) The leaves of the 20 plants in solutions containing K+ ions felt more turgid to the touch on the second day of data collection than the first. The most turgid leaves were on the plants in the 1000.00 ppm solution, and the least turgid on the plants in the 0.00 ppm solution.
2) An algal-like growth had formed in the 400.00 ppm fish tank 4 days after the start of the experiment.
3) The leaves of all the samples tested gradually turned a darker green.
4) The width of the leaves of all the samples tested increased over the course of the experiment. This increase in width was most pronounced in the samples grown in 1000.00 ppm solution.
5) The stems of the samples in the 1000.00 ppm solution had a significant increase in girth and height.
5: Evaluation

5.1: Conclusion

From the results of the experiment, I can conclude that as K⁺ ion concentration increases, the initial rate of growth of *Hygrophilla difformis* increases. Therefore, the null hypothesis shown in section 2.1 is rejected and my initial hypothesis (H₁) is accepted. This is shown in graph 1 that has a R² value of 0.98135, a high R² value. This high R² value indicates a strong positive correlation between the initial rate of growth of *Hygrophilla difformis* and K⁺ ion concentration. This supports my hypothesis that as K⁺ concentration increases, the initial rate of growth of *Hygrophilla difformis* increases. This occurs because an increased concentration of K⁺ ions results in a higher rate of activation of nitrate reductase (Armstrong, 1998). This consequently increases the yield of amino acids, amino acids that are used in a series of anabolic reactions to duplicate chromosomes during the S phase of mitosis. As there are more amino acids to supplement mitosis, the rate of mitosis increases significantly, increasing the rate of growth of *Hygrophilla difformis*. This is evident from the data collected, since the average initial rate of growth (processed data table 3) at 1000.00ppm (9.14gday⁻¹) was significantly higher when compared to the average initial rate of growth at 0.00ppm (2.18gday⁻¹). Additionally, this also explains why the stems of the samples placed in the 1000.00ppm solution had a large increase in height and the largest increase in width, because the rate at which their cells divided was the highest of all the samples. The darker colour of the leaves came about due to a higher concentration of chlorophyll, which was facilitated by a high concentration of K⁺ (Jin, 2011). This link was shown by a study conducted by Jin and Huang in 2011.

Furthermore, the increase in turgidity of the plants immersed in solutions holding K⁺ ions can be explained by how an increased quantity of potassium ions facilitates a higher rate of osmosis in the cells of *Hygrophilla difformis*, increasing turgor pressure in the cells and resulting in higher turgidity. My results are consistent with that of R.T Besford and G. A Maw as in their experiment, the basul trusses with the highest concentration of potassium ions (10.23mg/dm³) had the highest increase in height (Besford, 1975). This corroborates my results. Additionally, the low uncertainties of the apparatus used increase my confidence in the outcome of the experiment. This is discussed further in section 5.2.

5.2: Strengths

The experiment had low systematic error due to the relatively low uncertainty of the apparatus used in the experiment, since the uncertainty of the mass of each plant was only ±0.01g, which is a small percentage error relative to the mass of the plants being measured that ranged from 61.39g to 91.36g. Furthermore, the small error bars on the graph also indicate a low chance of error, increasing the certainty and accuracy of the data gained through the experiment. This is a strength of the experiment.

5.3: Weaknesses

However, the humidity of the room was not maintained nor measured with a hygrometer. This lack of control over humidity could have resulted in different degrees of condensation occurring on the inner sides of the fish tank and the droplets produced could increase the volume of the water body, albeit only slightly. Despite this, there would still be dilution of the solutions, decreasing potassium ion concentration in the process. This would mean that the results gained could only correspond to lower potassium ion concentrations as opposed to the concentrations being investigated. This can be rectified by monitoring the changes in humidity and wiping off any droplets on the inner sides of the containers.
Moreover, the samples of water wisteria used were not sterilised. This resulted in an apparent fungal growth developing in the tank holding 400.00 ppm of potassium ions, possibly increasing the biochemical oxygen demand and hence restricting the availability of oxygen to the water wisteria samples. This consequently resulted in a lower rate of respiration, possibly decreasing the rate of growth in the samples due to decreased availability of ATP. This means that the mass changes in the water wisteria immersed in the 400.00 ppm solution were not caused entirely by the potassium ion concentration, impeding the reliability of the results. To rectify this, the plants to be used could have been wiped thoroughly with a hand towel to remove any spores that could have been present.

The data gained from the experiment is also strictly focused on the short-term impact of potassium ion concentration on the rate of growth of *Hygrophilla difformis*. This limits the extent to which it examines how the rate of growth varies with potassium ion concentration, as it does not represent the long-term impact of potassium ion concentration on the rate of growth. This can be rectified by conducting the experiment over a period of time longer than 1 month.

Furthermore, the experiment does not investigate the effect of K⁺ ion concentrations between 400.00 and 1000.00 ppm on the growth on water wisteria, hindering the extent to which the results show a positive correlation between the rate of growth of *Hygrophilla difformis* and K⁺ ion concentration. This is because the intervals between the values of the independent variables are uneven. This limits the certainty of the conclusion. However, this uncertainty can be rectified by testing K⁺ ion concentrations of 600.00 and 800.00 ppm to allow for regular intervals in the values of the independent variable (K⁺ ion concentration).

In addition, the uncertainty of one particular piece of apparatus was particularly high - that being the 0.50 dm³ beaker (± 0.01 dm³). The beaker was used to measure 0.50 dm³ of tap water when the tanks were being filled up before the start of the experiment. This relatively high error of 2% (error= \( \frac{0.01}{0.50} \times 100\% = 2\% \)) could still have resulted in a change in the actual concentration of potassium ions in all the set ups, restricting the reliability of the data gained as that data does not represent the effect of the true concentration on the initial rate of growth. This flaw can be addressed through the use of a 0.25 dm³ measuring cylinder, a piece of apparatus with significantly reduced uncertainty (± 0.005 dm³). This will in turn improve the precision of the experiment.

### 5.4: Extensions

A potential extension to this investigation would be a further study into how different Nitrogen-Phosphorus-Potassium (NPK) ratios affect the growth of an cyanobacteria algal bloom when *Hygrophilla difformis* samples are present. This would allow for more information on how algal blooms can be controlled. Another extension would be how K⁺ concentrations greater than 1000.00 ppm affect the growth of *Hygrophilla difformis*, given that the rate of growth of *Hygrophilla difformis* increases until this point. Therefore, it would be interesting to uncover if this trend still continues at higher K⁺ ion concentrations greater than 1000.00 ppm. A further interesting expansion for this investigation would be an experiment to deduce the effect of high concentrations of heavy metal ions on the growth of a cyanobacteria algal bloom, as the effect of these ions on the growth of algal blooms remains ambiguous.
Appendices

Appendix 1A

Calculations for masses of potassium chloride required
1. First, one part per million is assumed to be 1g/1,000,000cm³
2. Multiply the desired concentration of potassium ions (concentration/1,000,000) by 200
3. Divide this value by the atomic mass of potassium (39.10gmol⁻¹) (IBO, 2014)
4. The number produced by step 2 is the number of moles of potassium ions and this is equal to the number of moles of KCl required to generate the desired concentration
5. Hence, the number of moles of KCl required is multiplied by the molecular mass of KCl (74.55gmol⁻¹) (IBO, 2014) to generate the mass of KCl needed to create the desired concentration

Example Calculation for 2ppm

\[
\frac{2}{1,000,000} \cdot 200 = 4 \cdot 10^{-4} \text{grams}
\]

\[
4 \cdot 10^{-4} \text{g} \div 39.10 \text{gmol}^{-1} = 1.03 \cdot 10^{-5} \text{moles (rounded to 2 d.p)}
\]

\[
1.03 \cdot 10^{-5} \text{moles} \cdot 74.55 \text{gmol}^{-1} = 7.65 \cdot 10^{-4} \text{grams (rounded to 2 d.p)}
\]

Bibliography

2) Avogadro Chemistry., Material Safety Data Sheet – Potassium Chloride. ACC#19310. Sections 1-3