An Experiment to Determine the Water Potential (Ψ) of a Plant Tissue, using Discs of Beetroot

Introduction

Water potential (Ψ) is the measurement of the ability of water molecules to move within a cell. A high water potential (Ψ) is achieved when there is a high water concentration within a cell. The water molecules create an outward force on the cell membrane and wall, which makes the pressure within the cell high. Plant cells with a high water potential (Ψ) become turgid, because of the cell wall's ability to stretch slightly to reduce the pressure within the cell. Animal cells do not have cell walls and therefore lack in the ability to reduce this pressure. If the water potential (Ψ) in an animal cell becomes too great, the cell membrane will break and the cell will have burst under the pressure.

The concentration of water in a cell is controlled by several factors:

- Solute potential (Ψs) – If there is a higher water concentration in the cell than there is in the surrounding solution, water molecules will move out of the cell. This is because osmosis (the net movement of water molecules through a partially permeable membrane) is taking place. Osmosis ALWAYS involves water molecules moving DOWN the concentration gradient, from where they are in a high water concentration (where Ψ is close to 0) to where they are in a low water concentration(where Ψ is a more negative number). If the water potential in the cell is lower than that of its surrounding environment, osmosis will occur from the surroundings to the cell's cytoplasm.

- Pressure potential (Ψp) - This is the amount of force exerted on the cell wall by the water molecules that are within the cell. The cell wall will push back at these water molecules so that their force is cancelled out.

- Water potential (Ψ) = solute potential (Ψs) + pressure potential (Ψp)

The highest water potential (Ψ) is found in pure water. It has a water potential of 0. Solutions with lower water potential (Ψ) will have a negative Ψ. Water will move from an area with a high water potential (Ψ) (i.e. –0.03) to an area with a low water potential (Ψ) (i.e. –30).

	Ψ
Pure water	0.00
Soil & plant root	-0.03
Xylem vessel	-0.30
Humid Air	-30.0

This table shows the typical water concentrations.

Aim

The aim was to place discs of beetroot in different concentrations of water and observe the change in their mass. The movement of water molecules between the cells of the beetroot and the surrounding solution will indicate the water potential of the cells of beetroot.

Hypotheses

Null Hypothesis: -

Hypothesis: -

When the water potential is higher than that of the beetroot cell, the water molecules will move into the cells of the beetroot. These cells will gradually become turgid and increase in mass. If the water potential is highest in the cells, the water molecules will move from the cells into the surrounding solution. The cell will decrease in mass and become flaccid.

Prediction

The beetroot discs will increase in mass when the sucrose solution has a higher water potential (Ψ) than the beetroot cells., because there will be a net movement of water molecules from the high water concentration, in the solution, to a low water concentration, in the beetroot cells, by the process of Osmosis. Osmosis will occur until equilibrium between the beetroot cells and the sucrose solution is achieved.

The increase in mass will indicate that the water potential of the beetroot cell is lower than that of the surrounding sucrose solution.

The beetroot discs will become flaccid and decrease in mass if the water potential of the surrounding solution is lower than the water potential inside the beetroot cells.

Osmosis will not occur if the water potential of the sucrose solution and the water potential of the cell's cytoplasm are equal.

The graph above shows the relationship between the water potential of the sucrose solution and the change in mass of the beetroot discs. The point at which the line crosses the x-axis, the water potential of the solution is equal to the water potential in the cell.

Flaccid and turgid cells occur as the result of the movement of water molecules. Flaccid cells occur when the water concentration (potential) of the surrounding substance is lower than the cell's water potential. A turgid cell occurs when the water potential inside the cell is much lower than that of the surrounding substance. Turgid and flaccid cells are a result of steep water concentration gradients between two materials.

Apparatus: beetroot, 6 test tubes with bungs, distilled water, 1 molar sucrose solution, cork borer, blotting paper (paper towel), weighing scales, 10cm^3 pipette will pipette filler.

Method

Six test tubes were labelled with the sucrose solutions: 0.00, 0.10, 0.25, 0.50, 0.75, and 1.00. Using a 1 molar sucrose solution and distilled water, these concentrations were made with the aid of a pipette and pipette filler for accurate measurements. The dilution table is as follows:

Conc.of sucrose solution (molarity)	Volume of Sucrose soln. cm³	Volume of Water cm³
0.00	0	20
0.10	2	18
0.25	5	15
0.50	10	10
0.75	15	5
1.00	20	0

When the concentrations had been made, they were shaken to mix the sucrose solution and distilled water to ensure a constant concentration throughout the solution.

Using a cork borer, discs of beetroot were cut. Each disc had a height of 1mm. They were blotted dry on a paper towel to ensure excess water did not affect the mass.

Six of the beetroot discs were placed in each of the six test tubes and left, with the bung on, for an hour.

After an hour, the discs were removed from the solutions, blotted slightly, and weighed. The original mass and final mass for each of the six concentrations were recorded. From these values, the mass change (loss or gain) could be calculated.

Results

Conc. Of Sucrose Solution	Starting mass (g)	Final mass (g)	Change in mass (g)
0.00	0.50	0.60	+0.10
0.10	0.60	0.70	+0.10
0.25	0.60	0.70	+0.10
0.50	0.70	0.75	+0.05
0.75	0.55	0.50	-0.05
1.00	0.65	0.55	-0.10

From the results table above, we can calculate the % change in mass by using the formula:

$$\% \text{ change in mass} = \text{change in mass} \div \text{initial mass} \times 100$$

Conc. of solution (molarity)	% Change in mass
0.00	+0.10 ÷ 0.50 x 100 = 20.0 %
0.10	+0.10 ÷ 0.60 x 100 = 16.7 %
0.25	+0.10 ÷ 0.60 x 100 = 16.7 %
0.50	+0.05 ÷ 0.70 x 100 = 7.14 %
0.75	-0.05 ÷ 0.55 x 100 = -9.09 %
1.00	-0.10 ÷ 0.65 x 100 = -15.3 %