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# Investigating the abiotic factors that affect the size of Ivy leaves in shaded and unshaded habitats.

## Introduction

Ivy is any one of a large number of creeping or climbing vines. These vines have different botanical names, and the word ivy, as commonly used, does not belong to any one plant. It often applies to climbing vines, especially to those that are ornamental. The particular one being looked at in this experiment is the common, or English, ivy. English ivy is the plant that makes such an attractive picture as it climbs over walls and tree trunks in Europe and North America. Its waxy leaves usually have five points, or angles. They are dark green in summer and turn bright scarlet in the fall. The plant retains its leaves all year. English ivy also bears tiny flowers. This ivy clings to smooth surfaces with the fine roots on its stems. It does not grow well in the bright sun of the central, southern, and western United States. But in shady locations, it can be grown as far north as Ontario, Canada. It makes an excellent covering for buildings. Its leaves and berries are poisonous. English ivy belongs to the ginseng family, Araliaceae. The scientific classification would be Hedera helix.

Being an evergreen plant it has the advantage of being able to photosynthesis during the winter months whereas deciduous trees are dormant. The increased light that is available, by the absence of deciduous leaves allow it to grow more rapidly up the trunk of the host tree. The evergreen leaves of the plant also inhibit the leaves of the deciduous tree thereby suppressing the growth of the host tree. The increased openness of the tree crown further stimulates the growth of the vine. As the ivy climbs up the host tree to reach the canopy, the density of the vine as well as the weight of the water and ice on the leaves increases the weight of trees. This often results in branches breaking during heavy winds.

The aim of this experiment is to investigate whether abiotic factors contribute to the size of ivy leaves in a shaded and unshaded habitat.

## Prediction

Organisms capable of synthesising their own food are known as Autotrophs. Of the autotrophs, the phototrophs or 'light feeders' which rely on the sun as their source of energy, and the chemotrophs which rely on the energy from breaking chemical bonds to synthesise their food. Ivy is a phototrophic plant.

Photosynthesis is the process by which phototrophs convert carbon dioxide and water into simple carbohydrates and oxygen in the presence of chlorophyll, using sunlight. Photosynthesis is summarised by the equation:

$$\text{Carbon Dioxide} + \text{Water} \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} \text{Glucose} + \text{Oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} C_6H_2O + 6O_2$$

However this equation is somewhat miss leading, as photosynthesis is a two-stage process. The light-dependent reactions produce materials, which are then used in the light-dependent stages. The whole process takes place all the time during the hours of daylight, but only the light-independent reactions of photosynthesis are sometimes referred as the dark reactions (however this does not mean they only occur in the dark, where as in fact they occur continuously).

Light energy is trapped in the chloroplast lamellae by photosynthetic pigments which are either chlorophylls e.g. chlorophyll a and b or caratenoids (e.g. carotene and xanthophylls). The chlorophyll a pigment absorbs light energy in the red and blue wavelengths of light in the spectrum. They reflect green light, which is the reason why the leaves appear green. The more light availability there is the

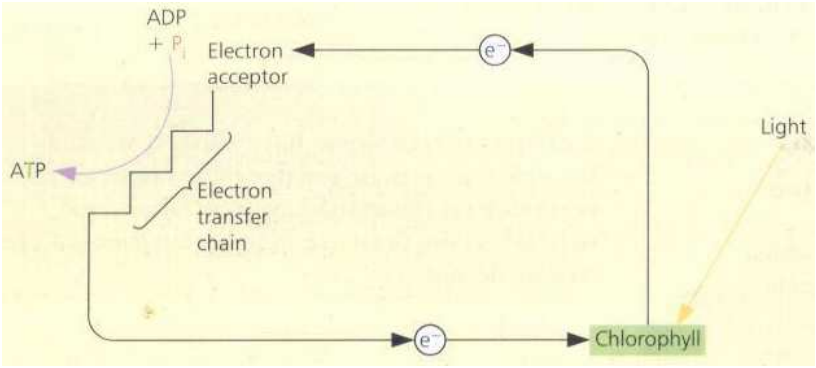
more likely light energy is to get absorbed at the correct wavelength. Different pigments absorb different wavelengths of light.

The Light-Dependent Stage

This stage has two main functions. Water molecules are split in a photochemical reaction. This provides hydrogen ions, which can then be used to reduce fixed carbon dioxide and so produce carbohydrates. Also ATP is made, which supplies the energy for the synthesis of carbohydrates. When a photon of light hits a chlorophyll molecule, the quantum of energy is transferred to the electrons of that molecule. The electrons are excited - they are raised to higher energy levels. One may be raised to a sufficiently high energy level to leave the chlorophyll completely. If this happens a carrier molecule will pick up the excited electron, and this can result in the synthesis of ATP by one of two processes - cyclic or non-cyclic photophosphorolation.

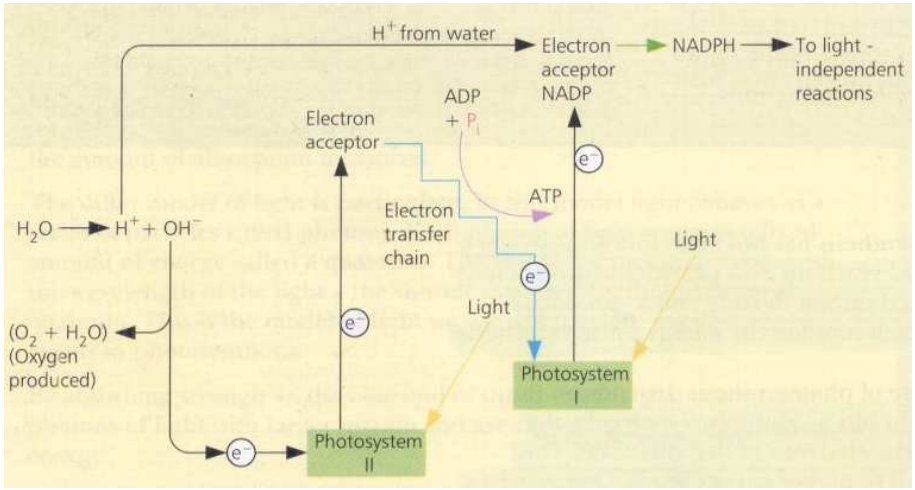
Cyclic photophosphorolation

The light-excited electron may be passed along an electron transfer chain, with each member of the chain at a lower energy level, until it is returned to the chlorophyll molecule that is came from. As the electron moves along the chain, down the energy levels, ATP is produced by the phosphorylation of ADP. The electron leaves the chlorophyll and returns to it, so may then be excited in exactly the same way again.




Non-cyclic photophosphorylation

The excited electron may instead be used to provide the reducing power needed in the second, light-independent stage of the photosynthetic process. Water dissociates spontaneously into hydrogen ($H^+$) ions and hydroxide ($OH^-$) ions. As a result there are always plenty of these ions present in the cell, including in the interior of the chloroplasts. Interactions between these ions and chlorophyll molecules bring about the process of non-cyclic photophosphorylation.



There are two types of photosynthetic pigments; primary and accessory pigments. The primary pigments are two forms of chlorophyll a, with a slight difference in their absorption peaks. The accessory pigments include other forms of chlorophyll a, chlorophyll b and the caratenoids. The pigments are arranged in light-harvesting clusters called photosystems. In a photosystem, several hundred accessory pigment molecules surround a primary pigment molecules and the energy of the light absorbed by the different pigments is passed on to the primary pigment. These are said to act as reaction centres. Photosystem I is arranged around a molecule of chlorophyll a with a peak absorption at 700nm. The reaction centre is therefore known as P700. Photosystem II is based on a molecule of chlorophyll a with a peak absorption of 680nm, so is known as P680.

An excited electron from photosystem II passes to an electron acceptor and down an electron transfer chain to photosystem I, which is at a lower energy level than photosystem II. This loss of energy allows the synthesis of a molecule of ATP. Light energy can then excite an electron from photosystem I, and this excited electron passes to another electron acceptor - nicotinamide adenine dinucleotide phosphate (NADP). NADP also takes up a hydrogen ion from water and is thus reduced, forming NADPH. The NADPH is a source of reducing power for the light-independent reactions.

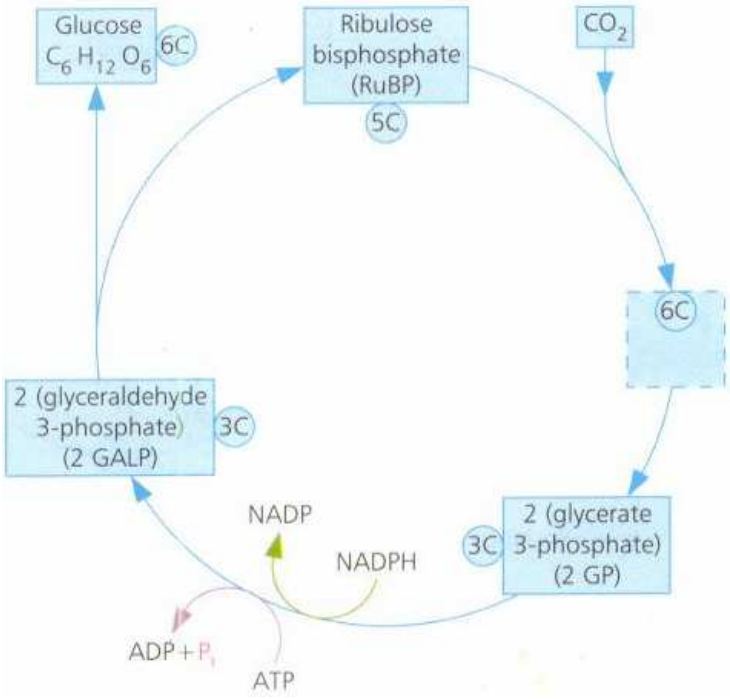
So photosystem I receives electrons via the electron transfer chain from photosystem II. This leaves photosystem II electron deficient. The electron from photosystem II is replaced by an electron from a hydroxide ion:

$4OH^- - 4e^- \rightarrow O_2 + 2H_2O$

The hydroxide ions are 'left behind' from the hydrogen ions taken up in the reduction of NADP to NADPH. The removal of the electrons from hydroxide ions by the photosystem II results in the by-product oxygen. Thus the reactions of the light-dependent stage of photosynthesis provide a source of reducing power (NADPH) and the universal energy-supplying molecule ATP, with oxygen gas given off as a waste product. To find out how the NADPH and ATP are used to make carbohydrates we must move on and consider the reactions of the light-independent stage.

The Light-Independent Stage

The light-independent reactions are known as the Calvin cycle. This is a cyclic reaction consisting of a series of small steps resulting in the reduction of carbon dioxide to bring about the synthesis of carbohydrates. NADPH and ATP from the light-dependent reactions provide the reducing power and the energy needed for the various steps. The stages of the cycle are controlled by enzymes and are independent of light.



Carbon dioxide from the air combines with ribulose bisphosphate (RuBP), a 5-carbon compound which fixes the carbon dioxide by accepting it and making it part of the photosynthetic reactions. The enzyme ribulose bisphosphate carboxylase is necessary for this step. The result is a theoretical highly unstable 6-carbon compound which immediately splits to give two molecules of glycerate-3-phosphate (GP), a 3-carbon compound. This is reduced to give glyceraldehyde-3-phosphate (GALP), a 3-carbon sugar. The hydrogen for the reduction comes from NADPH and the energy required from ATP, both produced in the light-dependent stage. Some of the glyceraldehyde-3-phosphate is synthesised into the 6-carbon sugar glucose, which is supplied to the cells or converted to starch for storage. However, much of the glyceraldehyde-3-phosphate is passed through a series of steps to replace the RuBP, without which further carbon dioxide cannot enter the cycle.

The products of photosynthesis, although initially carbohydrates, are rapidly fed into other biochemical pathways to produce amino acids and lipids for the requirements of the cells of the plant.

If the leaves have a larger surface area they would absorb a large amount of light energy and this will increase the rate of photosynthesis provided that there are no other limiting factors such as availability of water. The leaves would also have a large number of stomata, which allow gaseous exchange, and this would increase the amount of water vapour lost by the plant through transpiration. Transpiration occurs as the sun warms the water inside the blade. The warming changes much of the water into water vapour. This gas can then escape through the stomata. Transpiration helps cool the inside of the leaf because the escaping vapour has absorbed heat.

Transpiration also helps to keep water flowing up from the roots. Water forms a continuous column as it flows through the roots, up the stem, and into the leaves. The molecules of water in this column stick to one another. As the molecules at the top of the column are lost through transpiration, the entire column of water is pulled upward. This pulling force is strong enough to draw water to the tops of the tallest trees. In addition, transpiration is necessary for mineral transport from the soil to the plant for cooling the plant through evaporation, to move sugars and plant chemicals, and for the maintenance of turgor pressure. The amount of water lost from the plant depends on several environmental factors such as temperature, humidity and wind/air movement. As increase in temperature or air movement decreases relative humidity and causes guard cells in the leaf to shrink, opening the stomata and increasing the rate of transpiration. A plant may lose much water through transpiration. A corn plant, for example, loses about 4 quarts (3.8 litres) of water on a hot day. If the roots cannot replace this water, the leaves wilt and photosynthesis stops.

A larger surface area of leaves would also affect the rate of which enzymes such as ribulose carboxylase, work. The larger the surface area the larger the increase in the rate at which these enzymes work. A plant that is grown in full sun often produces leaves having a light shade of green then the same plant grown under low light intensity (shaded plants) in part this is attributable to different portions of the two chlorophyll pigments, because chlorophyll b is very abundant in shaded leaves, to improve light capturing capability of the chloroplast. Thus, shaded leave having adaptations for capturing the low intensities of sunlight are not designed for optimal photosynthesis when given full exposure to direct sunlight.

Leaves that are not receiving much light grow bigger in order to absorb as much light as they can, the larger leaf size, is almost like compensating for growing at a low ground level where light is scares. Therefore I would expect the leaves in the shaded region to be bigger than those in the unshaded region, which are receiving plenty of light.

Biotic environment includes such factors as soil, water, atmosphere, and radiation. The biotic environment is made up of many objects and forces that influence one another and influence the surrounding community of living things. Other biotic factors include the amount of living space and certain nutrients (nourishing substances) available to an organism. All organisms need a certain amount of space in which to live and carry on community relationships. They also must have nonliving nutrients, such as phosphorus, to maintain such body activities as circulation and digestion. Ecology is the study of the relationships between organisms and their environment.

Biotic factors will also have to be taken into consideration; these include things like food, plants, animals, and their interactions among one another and the biotic environment. One factor that may need to be taken into consideration could be how vulnerable the ivy leaves are to human or animal

interference, for example trampling. Human activities produce a wide variety of pollutants of land, air and water. The closeness and intensity of any human activities will be considered as well. All these biotic factors will need to taken into account while carrying out the experiment in both the regions in the woodlands.

**Null Hypothesis**

There will be no difference between the sizes of leaves growing in the shaded and unshaded region; any difference in size will be due to chance.

**Risk Assessment**

In order to make sure, that no damage or accidents happen while I am carrying out my experiment, I am going to take the following safety precautions:

- ➔ Safety Goggles and gloves must be worn when carrying out the pH and NPK test.
- ➔ If there is any spillage of solutions from the pH and NPK test then it must be cleared immediately.
- ➔ Care must be taken when using expensive equipment such as probes.
- ➔ The whole experiment should be carried out in a mature and responsible fashion.
- ➔ If any chemicals are spilt on your hands, you must immediately wash them under water.

**Variables**

The ivy leaves, which are to be used in the investigation, are going to be taken from a shaded and an unshaded region of the same woodland. The biotic factors, which would affect the growth of the ivy leaves and the ones I will be measuring in my experiment include the following:

- **Light intensity** – As light is the ultimate source of energy for all ecosystems. This is the variable that is being investigated in my experiment. I will be expecting to see a significant difference in the surface area of a leaf in a shaded (low light intensity) and in an unshaded region (high light intensity). Where in the shaded region the surface area of the ivy leaves will tend to be greater than those that grow in an unshaded region.
- **Air humidity** – An increase in humidity causes a direct increase in transpiration, this is due to the rate of water movement from inside of the leaf to the outside surrounding area of the leaf. The greater the difference in humidity the faster water moves. Water vapours move from an area of high relative humidity to an area of low relative humidity.
- **Wind Speed** – This factor is linked to humidity, and will also often results in an increase in transpiration as well. This is due to the fact that once the water vapour has diffuses out of the leaf into the surrounding air, if wind is present, it will move away these humidity bubbles. As a result this will cause a new desirable diffusion gradient for more water vapour to rush out when the stomata opens, causing a transpiration to occur at a faster rate.
- **pH of soil** – This is another important factor as it is affected by the availability and absorption of several elements needed for plant growth. Maximum absorption of these elements is found at pH readings 5.5 to 6.5. The pH of a soil influences its physical properties and the availability of certain minerals to plants. If the pH of the soil falls below the given range it results in less availability of the elements N, P, K, and the absorption of the micronutrients can reach toxic levels. Moreover enzymes have an optimum pH at which they work at, if the soil is too acidic or to alkaline, this will denature the enzymes, which will affect the rate of photosynthesis and affect the size of the leaf.
- **NPK-nutrient concentration of soil**
    - Nitrogen – this element is a constituent of amino acids, proteins, coenzymes, nucleic acids and chlorophyll. Nitrogen has a great effect on plant growth. If missing, then plant will be underdeveloped and old leaves would turn yellow.
    - Phosphate – the element is involved in photosynthesis, and needed in the light independent stage to be more precise. If this element is not available the young leaves will turn purple and roots will struggle to grow.
    - Potassium – this element is needed by enzymes which are involved in photosynthesis and respiration. A shortage of potassium would result in leaves turning yellow and developing dead spots.
- **Temperature of air and soil** – All chemical and biological activities of a soil are influenced by temperature. The temperature of a soil may be from that of the air above it. Evaporation of water from soil may cool it to below that of the air, whereas solar radiation may raise it above

air temperature. Soil temperature affects plant growth indirectly by affecting water and nutrient uptake as well as root growth.

**Reliability, Measurements and Accuracy**

In this investigation, 60 ivy leaves from a shaded region and another 60 leaves from an unshaded region from the same woodland will be measured. The abiotic factors in both areas will be measured too.

Two 10m tape measures will be placed at right angles to each other. The square quadrat will then be placed using random co-ordinates. This method seems to be the most efficient and reliable way to locate and measure ivy leaves randomly, in each region. The square quadrat is a better option than the point quadrat because due to the lack of time the square quadrat is a quicker and more appropriate way to collect my sample of ivy leaves. Moreover, the ivy leaves that are going to be used in the sample will all be from within the square quadrat, so they are all likely to be in the same environmental condition as each other; this adds a sense of fair testing to my experiment.

Ivy leaves present inside the square quadrat will be traced around on 1mm graph paper. The squares will be counted to give the cross-sectional area of the leaf, in $mm^2$. Moreover if the ivy leaf covers more than half the square it will be counted as one. If it covers less than half the square it will not be counted at all. This is a much more accurate method compared to measuring just the length of the ivy leaf, from tip of leaf to steam using a cm ruler.

As light intensity is the main abiotic factor being investigated, three light intensities will be measured in each area at different distances from the ground (50cm, 100cm, and 150cm). This way the best possible value for light intensity in the area overall can be measured. When light intensity is measured using the light probe, the probe will be directed towards a clipboard from each height. This is to ensure a consistent, reliable and reflection is detected by the light meter. Whilst light intensity is the only abiotic factor being investigated, it would be ideal if all other abiotic factors remain the same in both areas, throughout the experiment. However this may not be the case as we cannot control them, but any differences will be taken into account. To minimise the effect of each variable, the investigation will take place on the same day.

**Apparatus**

1. Tape Measure (50m) – needed to mark the area which is being used in the experiment.
2. Square quadrat – where the square quadrat is placed according to the coordinates chosen randomly, the ivy leaves present within the square quadrat will be used in the experiment.
3. Meter Ruler – used to measure distance from ground.
4. Light probe/light metre – measure light intensity in both areas.
5. Soil temperature probe – measure soil temperature.
6. Air temperature probe – measure air temperature.
7. Clipboard – placed on the ground when measuring light intensity to give a uniform surface.
8. Whirling Hygrometer – used to measure the humidity in region.
9. Anometer – used to measure wind speed.
10. Trowel – used to dig up the soil sample from the two different areas.
11. 3 x Small plastic bags – carrying the soil sample.
12. pH and NPK testing kit – measure pH and NPK content in the soil samples.
13. Safety Goggles – used when carrying out the pH and NPK test.
14. Plastic gloves – used when carrying out the pH, NPK test, and digging up the soil sample.
15. Stickers (A packet) – used to mark which leaves have already been used in the experiment.

**Apparatus for pH and NPK testing kit**

- Syringe
- Spoon
- Filter paper
- pH indicator
- P1 solution
- N1 solution

- K1 solution
- N2 powder
- P2 (tine wire-phosphate reactant)
- K2 solution
- pH and NPK reading charts

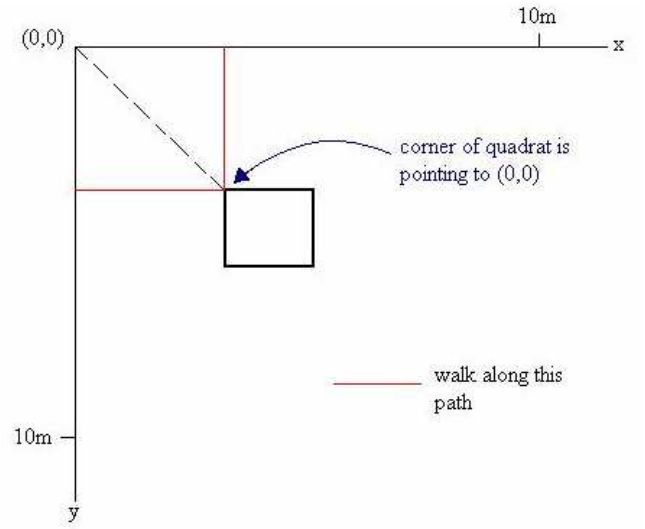
**Method**

**1.** Collect apparatus on the list.

**2.** Find a shaded and unshaded region were ivy leaves are present.

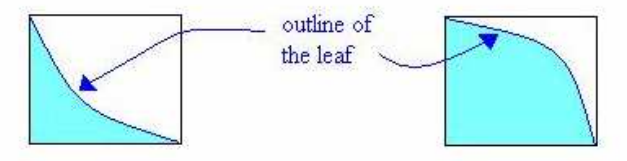
**3.** Take two measuring tapes and place at right angles to each other then draw each tape to 10m. So an area of 10m by 10m is covered, forming two axis (x,y).

**4.** Two people chose random co-ordinates and each then walk along the tape measure until they meet. Where they meet a quadrat will be placed so that the corner of it is facing towards the co-ordinates (0,0).




**5.** Once the quadrat has been placed. An outline of 60 ivy leaves will be done; after this is complete a sticker will be placed on the leaves that have already been used in the experiment. The stickers however, will be removed when the whole experiment is complete. (See appendix 1 showing some of the ivy leaf drawing)

**6.** The leaves will be drawn onto 1mm graph paper, as this will be more accurate to measure the surface area of the leaf. If the leaf covers half of a 1mm square then it will be counted as 1mm but if it covers less than half of a 1mm square then it will not be counted. This is better explained in the diagrams shown below:




This would **not** be counted as the leaf does not cover half the 1mm square.

This would be counted as it covers more than half the 1mm square.

**7.** The biotic factors were measured as follows:-

**Light intensity**

- A clipboard was placed within the quadrat, to form a uniform surface.
- A meter was then stood next to the clipboard.
- The light probe was taken and pointed towards the clipboard to give three different values at 50cm intervals (at 50cm, 100cm and 150cm).

**Air Humidity**

- Using a whirling hygrometer. Consists of thermometers; the bulb of one being kept dry while the other permanently wet. Both are mounted on a frame. The hygrometer will be rotated in the air until both thermometers give a constant reading.
- The wet bubble thermometer will always give a lower reading than the dry bubble one, due to the cooling effect of the evaporating water. Then by looking at the different between the two thermometers and using a special scale we can work out the humidity as a percentage.

**Air Temperature**

- The probe was held at 1m above the ground and the reading displayed was recorded.

**Soil Temperature**

- The probe was placed into the soil within the quadrat.
- It was pushed into the soil until it reached a maximum; the value displayed was then recorded.

**Wind Speed**

- This was done by twisting an anometer in the direction of the wind.
- Value was recorded.

**pH Meter**

- This was placed within the area where the quadrat had been placed.
- It was pushed into the soil until it reached a maximum the value was then recorded.

**8.** Now take a soil sample using a trowel and place in a plastic bag, take this back to the classroom to find out the pH and nutrient contents of the soil. (Details of the pH and NPK test are after the method)

**9.** Now repeat the above steps again in the unshaded region. Once all the results have been obtained from both habitats, the t-test or $Chi^2$ tests are statistical tests, which can be used to analyse the results. To show whether there is a significant difference between the two sets of data. I will be using the t-test (justifications of using this method of analysis are explained before carrying out the test).

**pH Test**

Fill 1 of test tubes with day soil to 1ml mark. Add 1 spoon of barium sulphate then add the pH test solution to the 2.5ml mark. Cap the test tube and shake-leave to settle for 10mins. If the solution is taking too long to settle, add another spoon of barium sulphate and re-shake. Compare the colour against the reading chart.

| | | |
|---|---|---|
| pH 7.5 | Darker Green | Alkaline |
| pH 7.0 | Dark Green | Neutral |
| pH 6.5 | Green | Slightly Acid |
| pH 6.0 | Light Green | Acid |
| pH 5.5 | Orange | Acid |
| pH 5.0 | Burnt Orange | Very Acid |
| pH 4.5 | Red | Very Acid |

**Potassium Test**

✧ Preparing the filter device

Unscrew the cap on the filtering device and remove plunger. Place 1 of the filter papers into the bottom of the plunger, ensuring a neat fit by using the end of the spoon.

✧ Filtering the nutrient

Fill the barrel to the 0.5ml mark with the dry soil and add K1 test solution to the 2ml mark. Insert plunger just inside barrel of device and gently shake mixture for 30 seconds. Press the plunger down slowly until it touches the mixture, place on the cap and screw down slowly until you see the solution filter into plunger. Compress out as much solution as is possible without forcing the cap.

Unscrew the cap and pour solution into 1 of the test tubes to make 1ml mark. Now add K2 test solution to the 1.5ml mark. Let the solution stand for 5 minutes before taking a reading. The solution will have degrees of cloudiness according to how much potassium is present. Place the test tube on the square printed over the black shaded rectangles first and move it down the chart until one of the boxes is just visible.

High 900mg/l

High to Medium 600mg/l

Medium 400mg/l

Medium to Low 200mg/l

Low 0-50mg/l

**Nitrate Test**

Test Solutions: N1 Nitrogen Extractant
N2 Nitrogen Reactant

This nutrient is essential for the growth of vegetation especially grass and leafy plants. The right amount of nitrogen allows for health growth but too much is equally damaging and will affect the plants structure.

✧ Preparing filter device

Unscrew the cap on the filtering device and remove plunger. Place 1 of the filter papers into the bottom of the plunger, ensuring a neat fit by using the end of the spoon.

✧ Filtering the Nutrients

Fill the barrel to the 1ml mark with the dry soil and N1 test solution to 2.5ml mark. Insert plunger just inside barrel of device and gently shake mixture for 30 seconds. Press the plunger down slowly until it touches the mixture, place on the cap and screw down slowly until you see the solution filter into plunger. Compress out as much solution as is possible without forcing the cap.

Unscrew the cap and pour solution into one of the test tubes to the 1ml mark. Now add one level spoon of N2 powder. Cap the test tube and gently shake for 10 seconds and stand for 5 minutes. Place the test tube on the square printed over the black shaded rectangles first and move it down the chart until one of the boxes is just visible.

**Phosphorus Test**

✧ Preparing filter device

Unscrew the cap on the filtering device and remove plunger. Place 1 of the filter papers into the bottom of the plunger, ensuring a neat fit by using the end of the spoon.

✧ Filtering the Nutrients

Fill the barrel to the 0.5ml mark with the dry soil and P1 test solution to 2ml mark. Insert plunger just inside barrel of device and gently shake mixture for 30 seconds. Press the plunger down slowly until it touches the mixture; place on the cap and screw down slowly until you see the solution filter into plunger. Compress out as much solution as is possible without forcing the cap.

Unscrew the cap and pour solution into one of the test tubes to the 1ml mark. Now add one level spoon of N2 powder. Cap the test tube and gently shake for 10 seconds and stand for 5 minutes. Place the test tube on the square printed over the black shaded rectangles first and move it down the chart until one of the boxes is just visible.

**Analysis**

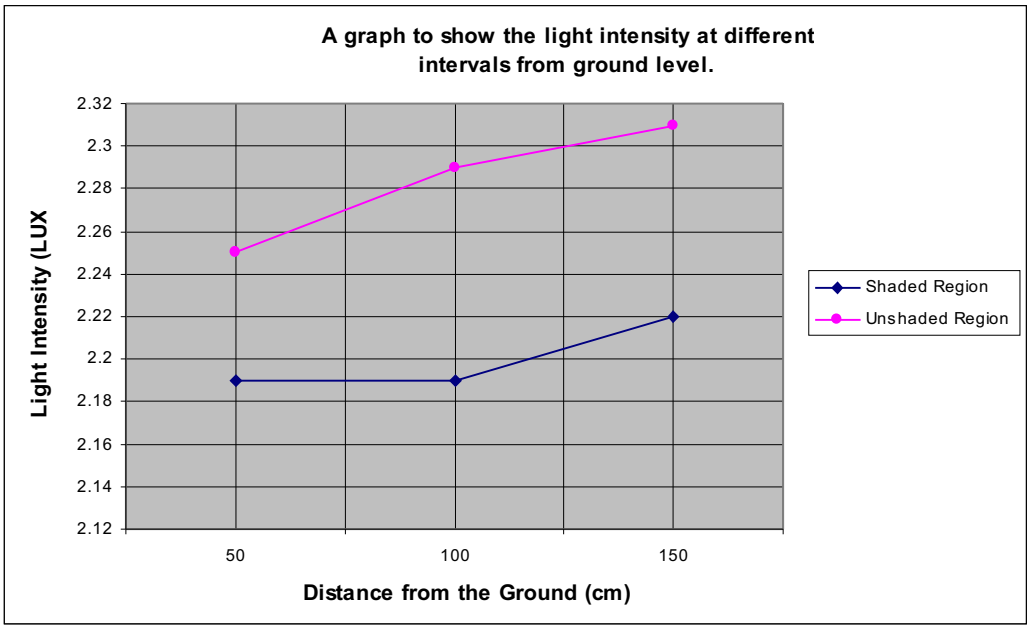
My graph shows a significant difference in the cross sectional area of an ivy leaf from a shaded and unshaded. The average cross sectional area of an ivy leaf in a shaded area is 3720.3mm$^2$ and the average cross sectional area of an ivy leaf in an unshaded area is 745.3mm$^2$. The mean light in the shaded area is 2.20 LUX whereas the mean light intensity in the unshaded area is 2.28 LUX.

The word photosynthesis means putting together with light. Green plants use energy from light to combine carbon dioxide and water to make food. All our food comes from this important energy-converting activity of green plants. Light energy is converted to chemical energy and is stored in the food that is made by green plants. Animals eat the plants, and we eat animal products as well as plants.

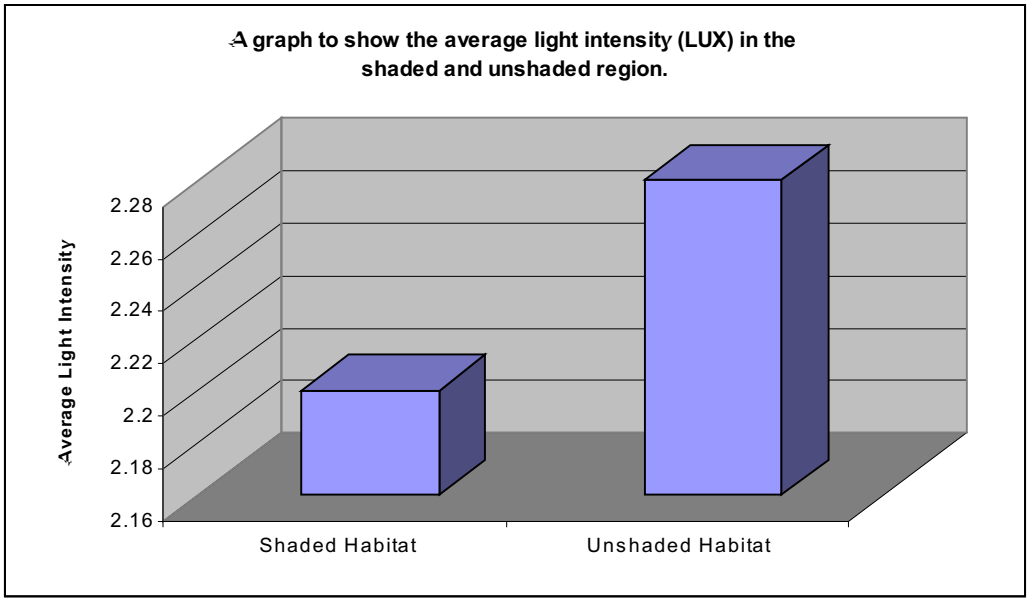
The light used in photosynthesis is absorbed by a green pigment called chlorophyll. Each food-making cell in a plant leaf contains chlorophyll in small bodies called chloroplasts. In chloroplasts, light energy causes water drawn from the soil to split into molecules of hydrogen and oxygen. In a series of complicated steps, the hydrogen combines with carbon dioxide from the air, forming a simple sugar. Oxygen from the water molecules is given off in the process. From sugar--together with nitrogen, sulphur, and phosphorus from the soil--green plants can make starch, fat, protein, vitamins, and other complex compounds essential for life. Photosynthesis provides the chemical energy needed to produce these compounds.

A plant's growth is shaped by both its heredity and its environment. A plant's heredity, for example, determines such characteristics as a flower's colour and general size. These hereditary factors are passed on from generation to generation. Environmental factors include sunlight, climate, and soil condition. All plants need light, a suitable climate, and an ample supply of water and minerals from the soil. But some species grow best in the sun, and others thrive in the shade. Plants also differ in the amount of water they require and in the temperatures they can survive. Such environmental factors affect the rate of growth, the size, and the reproduction of all plants.

Light energy is essential for photosynthesis to occur. In areas where light is insufficient for this process of photosynthesis to occur, then other measures have to be taken by the plant to maintain a steady rate of producing chemical energy to survive. Two ways the plant does this is to firstly, increase the size of its leaves and secondly to produce more photosynthetic pigment. A graph showing the difference in light intensity at different heights from ground level, in both areas can be seen below:




From the above graph I was able to calculate an average light intensity for each area, which is presented below in a graph:




The graph clearly shows that light intensity is higher in the unshaded region.

Photosynthesis is the essential process which plants undergo in order to survive. Available of light and pigment such as chlorophyll are two essential inputs for this process to be possible. In the shaded region, the amount of sunlight is lower. In effect, the leaves are larger so that as much sunlight can be trapped in order for photosynthesis to take place at a suitable rate for the plant to survive. The leaves tend to be a darker shade of green, due to the presence of more photosynthetic pigments in the shaded region. This adaptation helps to maximise the use of any sunlight available. Therefore, the leaves in the shaded area are larger, a darker green and glassier in appearance as opposed to the leaves present in the unshaded region. Where light intensity is higher, and photosynthesis can take place easily. Due to the greater amount of sunlight, the amount of photosynthetic pigment can be low. So the leaves in the unshaded region are smaller and a lighter shade of green.

The overall equation for photosynthesis can be summarised as below:

$$\text{Carbon Dioxide} + \text{Water} \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} \text{Glucose} + \text{Oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} C_6H_2O + 6O_2$$

But now it is known that photosynthesis is a two stage process. The first stage is the light-dependent reaction (includes photolysis of water), and the second the light-independent stage.

The main purpose of the light-dependent reaction is to synthesis ATP, either by the process of cyclic or non-cyclic photophosphorylation. During these reactions the photosynthetic pigments of the chloroplast absorb light energy and give out excited electrons used to synthesise ATP.

Water is split by photolysis to give hydrogen ions, electrons and oxygen. The hydrogen ions and electrons are used to reduce NADP and the oxygen is given off as a waste product. The two reactions that occur in photolysis of water are shown below:

$H_2O \rightarrow 2H^+ + 2e^- + \frac{1}{2}O_2$
$2H^+ + 2e^- + NADP \rightarrow$ Reduced NADP

ATP and reduced NADP are the two main products of the light-dependent reactions and pass to the light-independent reactions.

Carbon dioxide is trapped and reduced to carbohydrate in the light-independent reactions of photosynthesis, using ATP and reduced NADP from the light-dependent reactions. This fixation of carbon dioxide requires an acceptor molecule, ribulose bisphosphate, and involves the Calvin cycle. (The process of photosynthesis is explained in more detail in my prediction)

Although light intensity seems to be the major factor affecting the size of ivy leaves, there may have been some influence from other abiotic factors that have also been measured and taken into account in this experiment.

Temperature of air and soil was measured. The soil and air temperature both, were generally higher in the unshaded region. The air temperature and soil temperature in the shaded region was 14.3 $^{o}$C and 13.3 $^{o}$C. Whereas in the unshaded region the air temperature and the soil temperature was 15.5 $^{o}$C and 14.1 $^{o}$C. This shows clearly that the air and soil temperature was higher in the unshaded region.

The temperature in the shaded region is lower than the temperature in the unshaded region. This may affect the enzyme activity which is constantly taking place in the plant. The enzymes working in the shaded may be working at a slightly slower rate due to the lower temperature, which means photosynthesis is likely to be occurring at a slightly slower rate too. So, if the leaves are larger surface area, although the enzymes are working at a lower rate, the fact that the leaves are larger and are trapping more sunlight, outweighs the low temperature effect. Hence the plant is able to survive as a whole. In the unshaded region, the temperature is higher, so the enzymes can work more efficiently. It is likely that the enzymes will be closer to their optimum temperatures. So, the leaves wil1 not need to be quite as large as the leaves in the shaded region, as photosynthesis is probably occurring at a good, steady rate.

Enzyme activity is also influenced by pH, if the pH is too acidic or alkaline, then the enzyme is likely to denature, resulting in it not being able to bind with its specific substrate molecule. The pH in the shaded region was slightly acidic compared to the unshaded habitat. The pH in the shaded region was 6.5 and in the unshaded region it was 7.5. However, the ivy plants are known to be capable of living in adverse soil conditions. Therefore, pH is not likely to have that big an affect on the size of the ivy leaf as light intensity does.

The NPK concentration was measured in both the shaded and unshaded regions. The potassium level was medium in both the regions but, the shaded region had a higher value of 400, compared to the medium value of 200 in the unshaded region. The nitrate level was low in both regions and the phosphorous level was medium (200) in the unshaded region and low (5) in the shaded region. It could be possible that at the time of the investigation, due to a larger amount of plants growing in the unshaded area region (due to more light availability) more plants may have died in the process to survive and compete, for light and nutrients. This could be a second factor which could be investigated in the future to see what, if any, affect it has on the size of the ivy leaves.

Humidity was measured in both areas; my findings showed that the humidity was higher in the shaded region than the unshaded region. The humidity in the shaded region was 80% whereas in the unshaded region the humidity was 60%. The wind speed was slightly higher in the unshaded region (0.4) than the shaded region (0).

Transpiration is the evaporation or loss of water by plants; it occurs chiefly at the leaves while their stomata are open for the passage of $CO_2$ and $O_2$ during photosynthesis.

But air that is not fully saturated with water vapor (100% relative humidity) will dry the surfaces of cells with which it comes in contact. So the photosynthesizing leaf loses substantial amount of water by evaporation. This transpired water must be replaced by the transport of more water from the soil to the leaves through the xylem of the roots and stem. There are various factors which influence (increase of decrease) transpiration these are explained below:

**1. Light -** Plants transpire more rapidly in the light than in the dark. This is largely because light stimulates the opening of the stomata. Light also speeds up transpiration by warming the leaf.

**2. Temperature -** Plants transpire more rapidly at higher temperatures because water evaporates more rapidly as the temperature rises. At 30°C, a leaf may transpire three times as fas t as it does at 20°C.

**3. Humidity -** The rate of diffusion of any substance increases as the difference in concentration of the substances in the two regions increases. When the surrounding air is dry, diffusion of water out of the leaf goes on more rapidly. As humidity increases transpiration decreases.

**4. Wind -** When there is no breeze, the air surrounding a leaf becomes increasingly humid thus reducing the rate of transpiration. When a breeze is present, the humid air is carried away and replaced by drier air. The more wind present the higher transpiration rate.

**5. Soil water -** A plant cannot continue to transpire rapidly if its water loss is not made up by replacement from the soil. When absorption of water by the roots fails to keep up with the rate of transpiration, loss of turgor occurs, and the stomata close. This immediately reduces the rate of transpiration (as well as of photosynthesis). If the loss of turgor extends to the rest of the leaf and stem, the plant wilts.

The volume of water lost in transpiration can be very high. So for plants to survive is important for them to keep the rate of transpiration at a minimal rate. From my experiment it can be seen that the air humidity in the unshaded area was lower compared to the shaded area, moreover the wind speed was also slightly higher in the unshaded region. As a result, transpiration rate will tend to be higher in the unshaded region; this suggests the water potential gradient between the inside and outside of the leaf is steep so water vapour is more likely to evaporate from the leaves. Thus, to reduce this effect, the surface area of the leaves is reduced as opposed to the leaves in the shaded region. Smaller leaves mean a smaller number of stomata, meaning the transpiration can be reduced slightly to a certain degree. Therefore it is necessary to have smaller leaves, with a smaller surface area to help reduce transpiration in unshaded regions.

Overall, this investigation proves my hypothesis that the leaves that are not receiving much light grow bigger in order to absorb as much light as they can, the larger leaf size is almost like compensating for growing at such low ground levels where light is scares.

After analysing my results by the use of a statistical test, the t-test, I can now reject my null hypothesis. The null hypothesis stated: ‘There will be no difference between the sizes of leaves growing in the shaded and unshaded region; any difference in size will be due to chance’. As the t-value I have worked out is greater than the critical value. This suggests that there is a significant difference between the cross-sectional areas of leaves which are growing in a shaded region than those that are growing in an unshaded region. The leaves in the shaded area are larger in size compared to leaves in the unshaded area. Hence, proving my hypothesis.

**Evaluation**

The experimental procedures that were used in this investigation were satisfactory as appropriate results were obtained during the collecting of the data. A firm conclusion can be drawn, that light intensity, as well as other abiotic factors are responsible for the difference in the size of ivy leaves from a shaded and unshaded area of the same woodland. My findings clearly indicate that the size of ivy leaves is greater in the shaded region of the woodland as opposed to the unshaded region. Each abiotic factor was measured individually and taken into account when analysing the results obtained, where several measurements were taken for one abiotic factor an average was deduced.

I thought that the method of collecting my data was quite reliable and appropriate for this experiment. However for future experiments I should look to collect a much larger sample size. Due to time restraints, I was able to collect 60 leaves from each region; this is too small a sample size to base a conclusion on. Nevertheless we are able to see a clear observation that the size of the ivy leaves tends to be smaller in unshaded areas, and larger in shaded areas. Moreover a greater section of each area may have been taken into consideration, to help make the results more reflective and reliable. The ivy leaves themselves were measured to $mm^2$, which I believe was fairly accurate, yet mistakes may have been made when trying to trace around the ivy leaves. This is another method which would need to be improved on for future experiments, to help give a more accurate result.

As light intensity was the main abiotic factor being investigated, three light intensities were measured in each area at different distances from the ground (50cm, 100cm and 150cm above ground level). This way the best possible value for light intensity in the area overall can be measured. When light intensity was measured using the light probe, the probe was directed towards a clipboard from each height. This was to ensure a consistent, reliable and reflection is detected by the light meter. Whilst light intensity is the only abiotic factor which was being investigated, it would have been ideal if all other abiotic factors remained the same in both areas, throughout the experiment. However this was not the case as we cannot control them, but any differences were be taken into account. To minimise the effect of each variable, the investigation took place on the same day, to ensure a certain degree of fair testing.

Soil and air temperature, humidity, and wind speed were all measured, one reading was taken of each from the shaded and unshaded area, and to ensure further reliability however; more reading could have been taken and over a greater region of the area of the ivy leaves. pH and NPK test was also carried out on a sample of soil, from both regions. In the future if I carry out this experiment again I would take more than two samples at least of the soil from both regions, and from different areas within each region, to give a more accurate result.

There were no anomalous results, but if there had been any anomalous results they would have been most likely due to human error more than anything else. All precautions were taken while carrying out this experiment. Safety Goggles and gloves were worn when carrying out the pH and NPK test, the equipment was used in an orderly and responsible manner and any spillage was cleaned up quickly and disposed of.

The statistical test (t-test) was a suitable and reliable way of analysing my results compare to the $Chi^2$ test as the t-test is applied to continuous data, and it requires a sample size greater than fifteen; therefore it makes more sense to use the t-test. After analysing my results by the use of a statistical test, the t-test, I can now reject my null hypothesis. The null hypothesis stated: 'There will be no difference between the sizes of leaves growing in the shaded and unshaded region; any difference in size will be due to chance'. As the t-value I have worked out is greater than the critical value. This suggests that there is a significant difference between the cross-sectional areas of leaves which are growing in a shaded region than those that are growing in an unshaded region. The leaves in the shaded area are larger in size compared to leaves in the unshaded area. Hence, proving my hypothesis.

Generally my experiment was a success, my reading were fairly accurate and reliable. From my finding I can now say that there is a significant difference between the size of ivy leaves in an unshaded region and a shaded region. It is clear that the leaves are larger in size in the shaded region as oppose to the leaves from the unshaded region. This is primarily affected by the different light intensity which was measured in both areas. The light intensity was higher in the unshaded region and lower in the shaded, which in affect caused the difference in size of the leaf. Other abiotic factors were also taken into

consideration: humidity, soil and air temperature, wind speed, pH and NPK concentration. These did vary between the two regions, they were abiotic variable which were uncontrollable and therefore could have affected the results obtained. Despite this, it can still be firmly concluded that light intensity has an apparent affect on the size and shade of grebe of ivy leaves from unshaded and shaded areas. For future experiments I would look to use a larger sample size, take more reading for light intensity, and for other abiotic factors. Moreover I would investigate the other abiotic factors which could influence the size of ivy leaves, and take biotic factors into consideration as well. By carrying out the experiment in both areas on several days, or doing several experiments simultaneously, may help me to make a more generalised conclusion.

# Appendix 1

**Bibliography**

Below is a list of secondary resources I have used, which provided me with information on various aspects of my coursework:

1. Biology 1Cambridge
   Endorsed by OCR

2. Biology 2 Cambridge
   Endorsed by OCR

3. Heineman Advanced Science Biology
   By Ann Fullick

4. Third Edition Advanced Biology
   By J.Simpkins and J.I.Williams

5. Understanding Biology For Advanced Level – Second Edition
   By Glenn Toole and Susan Toole

6. World Book Millennium 2000 – Premier reference library