ACTIVITY 3

Photosynthesis in sun and shade

Introduction

Several species of plant which grow in the Squares show clear morphological differences between leaves which grow in full sunlight and leaves which grow in the shade. In this investigation, pupils sample sun and shade shoots of the stinging nettle (*Urtica dioica*) and consider differences in leaf size and internode length.

Figure 12. Shoots of stinging nettles in partial shade.

Learning outcomes

Through this activity pupils will:

- use systematic sampling to compare and contrast two morphological differences within a single species of plant
- consider the results of their investigation in relation to photosynthesis and the adaptations of plants to intraspecific competition.

Background information for teachers

It is sometimes difficult to separate out all the biotic and abiotic variables which affect the characteristics of plants. By concentrating on one species in two slightly contrasting habitats, it is possible to collect scientific data to consider the effect of light levels on shoots and leaves. Since nettles spread vegetatively, a large clump of genetically-identical shoots can straddle different light levels.

Leaves which grow in the shade ('shade leaves') are generally larger in area but thinner than leaves which grow in full sunlight ('sun leaves'). Sun leaves become thicker than shade leaves because they have a thicker cuticle and longer palisade cells, and sometimes several layers of palisade cells. The larger shade leaves provide a larger area for absorbing light energy for photosynthesis in a place where light levels are low. In contrast, smaller sun leaves will provide less surface area for the loss of water through transpiration. Transpiration rates will, of course, be higher where leaves are exposed directly to the sun.

Shoots grow more quickly in height where light levels are low. This rapid growth helps the shoot to reach light. The length of the internode (the part of the stem between each leaf) is longer for shade shoots than sun shoots.

A final variable which is less straightforward to measure in the field is leaf colour. Sun leaves tend to be a lighter green than shade leaves and they may also be tinged in red. Shade leaves generally contain a greater mass of chlorophyll and are darker green in colour. In shade leaves, the chloroplasts move within the cells to take up a position where they will absorb the maximum light without shading other chloroplasts below them. The chloroplasts are evenly distributed between the palisade and spongy mesophyll layers. By contrast, in sun leaves, the chloroplasts take turns in the bright light and then shelter in the shade of others whilst they make use of the light they have absorbed. Too much bright light would destroy the chlorophyll. In sun leaves, most of the chloroplasts are found in the palisade layer. There may also be a difference in the amounts of different pigments in the leaf. Anthocyanin pigments are produced in the stems and leaves of the sun shoots. These red pigments help to protect the chlorophyll from excess ultra-violet radiation.

Most of these adaptations take place during leaf development - there is little a leaf can do if its light conditions change. Shade leaves can be up to five times more efficient in harvesting the same amount of sunlight as sun leaves. But shade leaves lose water by transpiration quicker than sun leaves given the same temperature and humidity conditions.

Other points for discussion

Some surveys have shown that the density of stinging hairs on nettles is higher on shade leaves. Wilting time also varies; leaves on cut sun shoots take much longer to wilt than leaves on cut shade shoots, probably because sun leaves are more effective at limiting transpiration.

Safety

Make sure that the pupils sampling the nettles are wearing rubber gloves and that their arms and legs are covered.

Resources

Worksheets

- 1. Obtaining your results
- 2. Class results sheet
- 3. Analysis and evaluation of results

Accompanying CD

- PowerPoint ‘Sense of Place’
- All photos from this section

Apparatus needed

Rubber gloves
Tape measure or rope
Colour chart
Balance
Graph paper
Scissors
Polythene bags
Clipboard, pens, pencils

Lesson sequence
1. Before fieldwork

Locate a clump of nettles at the edge of trees where one side is more shaded than the other. There is a less frequently mown area under the trees at the northern (Euston station) end of Gordon Square which is a particularly useful place to look. Using one clump of nettles spread by rhizomes from a single plant helps to control genetic variation and improves the reliability of the method.

Introducing the investigation to pupils

From KS3, pupils will have been introduced to the process of photosynthesis and have some knowledge and understanding of the structure of the leaf (including the role of palisade cells, chloroplasts and air holes).

If there is time show pupils a nettle plant which has been dug up so that they can see the rhizome system and appreciate that the shoots all belong to one plant. Using live specimens of a sun shoot and a shade shoot, or use the photographs on the CD, ask the pupils to list the differences that they notice and to suggest what the two shoots might look like if they are left in the sun for 15 minutes. Live specimens wilt very quickly, particularly of shade shoots, so you may need to rest the shoots in water. Write the differences on the board and discuss how these modifications might help the plant.

Fieldwork

Divide the class into groups of 3–5 pupils. Each group lays a tape measure across the part of the nettle clump being sampled (see Fig. 13) so that one end is in the shade and the other end is in the sun. Select the two largest shoots touching the first half metre of the tape (a shade shoot) and the two largest shoots touching the last half metre of the tape (a sun shoot). If possible all the shoots should be flowering or non-flowering as variation in leaf size can occur between flowering and non-flowering shoots. In total the class should sample a minimum of 10 shade and 10 sun shoots.

Figure 13. Transect of a single clump of nettles from sun to shade.

For each shoot sampled, pupils measure the length of the third and fourth internodes. The third internode is the distance between the third and fourth leaves down the stem, the fourth internode is the length between the fourth and fifth leaves.

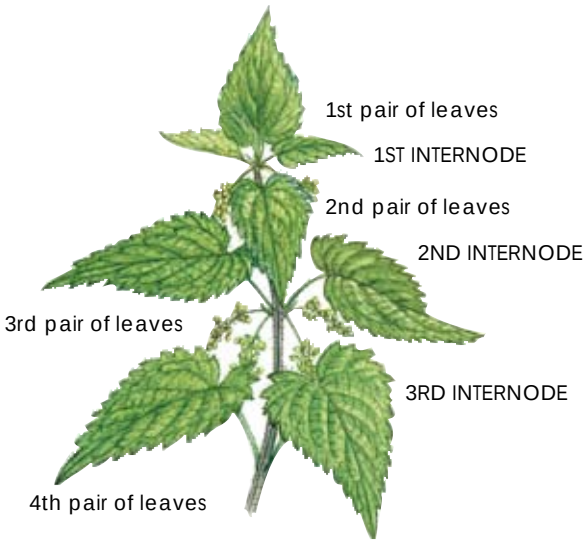

Figure 14. Numbering of leaves and internodes.

It is important that, when sampling to find leaf area, that all the leaves used are of the same maturity and are fully formed. Any side shoots should be avoided. Once the internodes have been measured, pupils remove the fifth and sixth leaves with scissors and place them into polythene bags. Each group should collect at least two shade leaves and at least two sun leaves.

3. After fieldwork

Analysis and evaluation

Although pupils can measure the length and width of leaves as a surrogate for leaf area, more meaningful results can be obtained by weighing the leaves. Photocopy the leaves from each group onto a sheet of graph paper (use a light toner setting so that the lines on the graph paper show). Ask the pupils to trace round the edge of their leaves. Ignore the toothed edge of the leaf (see Fig. 15). Alternatively, if a photocopier is not available, pupils can trace directly around the outline of the leaf, but plastic gloves should be worn.

Cut out the leaf shape and weigh this piece of paper. Then weigh 1cm^2 of graph paper. A balance with a sensitivity of at least tenths of a gram is needed. Use these two figures to calculate the area of the leaf.

$$\frac{\text{The mass of the leaf outline}}{\text{The mass of 1cm}^2\text{ of graph paper}} = \text{area of the leaf in cm}^2$$

Figure 15. Outline of a nettle leaf.

If a balance is not available students can count the 2 mm squares. Squares more than half covered should be counted as a whole square and those less than half covered not counted.

Assuming that 1cm^2 of graph paper contains 25 x 2 mm squares,

$$\frac{\text{The number of squares}}{25} = \text{area of the leaf in cm}^2$$

Pupils can use the prompt questions (Sheet 3) to link the data they have collected to what they know about photosynthesis, and to consider how appropriate the methods were.

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SHEET 1 - OBTAINING YOUR RESULTS

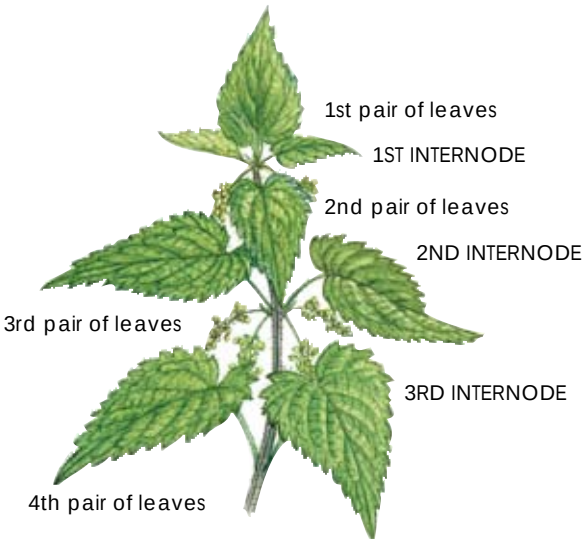
In the field

1. Put a tape measure across the clump of nettles you are investigating running from the shade to the open sunlight.

2. Look at the first half metre of tape in the shade and select the tallest shoot touching the tape.

   (a) Measure the length of the 3rd and 4th internodes.

   (b) Carefully remove the 4th and 5th pairs of leaves with scissors and put them into a polythene bag (labelled SHADE).



3. Choose the next tallest shoot from the first half metre of the tape and repeat 2 (a) and (b).

4. Take the same measurements from two shoots from the first half metre of the tape in the sun. Label the polythene bag SUN.

In the laboratory

On a piece of 2mm graph paper draw round the photocopy of each leaf shape. Cut out the leaf shape.

Find the mass of the leaf shape.

$$\frac{\text{The mass of the leaf outline}}{\text{The mass of 1cm}^2\text{ of graph paper}} = \text{area of the leaf in cm}^2$$

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SHEET 2 - CLASS RESULTS SHEET

Group	Shade shoot				Sun shoot			
	Surface area of leaf (cm^2)		Internode length (cm)		Surface area of leaf (cm^2)		Internode length (cm)	
	4th leaf	5th leaf	3rd inter-node	4th inter-node	4th leaf	5th leaf	3rd inter-node	4th inter-node
1								
2								
3								
4								
5								
6								
7								
8								
Mean								

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SHEET 3 - ANALYSIS AND EVALUATION OF RESULTS

Conclusions

1. Describe the differences that your results show in leaf size and internode length between sun shoots and shade shoots.

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2. Suggest why there are diffferences between sun and shade shoots in
   (a) leaf area

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   (b) internode length

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Evaluation

3. Can you think of any other reasons why nettle leaves vary in size?

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4. Suggest one way you could extend the investigation if you had more time.

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