Some prickly thoughts: Does holly become more prickly when it’s grazed?

Anne Bebbington

An investigation that introduces plant defence mechanisms and the idea of adaptation

Holly has long been a popular subject for study for all ages of pupils. Exercises at primary level have used counting of the number of prickles both as part of the mathematics curriculum and for thinking about the role of prickles in protecting the tree and introducing the idea of adaptation (see for example Townsend, 2001). At secondary level the emphasis is usually on adaptation. Pupils’ investigations demonstrate that leaves at the top of the tree are less prickly than those at the bottom of the tree, which are more likely to be grazed by large herbivores. (See both the SAPS and FSC websites for descriptions of such an activity and pupil worksheets.) In addition, pupils at this level are taught that some variations are genetically inherited and that environmental differences can also result in variation (NC, Sc2, 4a). The holly tree, as shown below, offers an opportunity to demonstrate this.

Holly (*Ilex aquifolium*) is a native species common throughout most of the British Isles in woodland, scrub and as part of hedgerows. The tree is dioecious, having separate male and female trees (Box 1). It is widely cultivated and a large number of cultivars with different genetically determined characteristics are known. Figure 1 shows the wild species and three common cultivated varieties. These demonstrate the enormous variability in colour and leaf prickliness that can occur between cultivars.

A single tree of the wild type can also show great variability in the number of prickles per leaf, not just in relation to the height of the leaves on the tree. For example, differences occur between leaves of different ages, leaves on shoots of different ages and leaves on flowering and non-flowering shoots. Evidence also suggests that prickliness is increased by grazing – that it is environmentally induced (Ocheso, 1997).

Investigations need to take account of this high degree of variability. The activity proposed here suggests:

- how an unbiased sample of leaves can be collected;
- how variability can be limited by the sampling procedure;
- a new measure of prickliness.

Teacher guidance notes are followed by four pupil worksheets.

ABSTRACT

An investigation into the prickliness of holly leaves is described, which can be adapted for both primary and secondary level pupils. It encourages pupils to consider the role of prickles and introduces the idea of adaptation. A measure of prickliness is described which takes into account both the number of prickles and the angle of the prickle to the leaf surface. Controlling variability and eliminating bias are also taken into account in the sampling procedure. The field work and follow-up work are detailed, with copies of pupil worksheets.

BOX 1 Flowering in the holly, *Ilex aquifolium*

Holly has separate male and female trees. The male tree has flowers with well-developed stamens and an aborted ovary. Flowers of the female tree each have 4 aborted stamens and an ovary that develops into a bright red berry after fertilisation.

Cultivated varieties may be only male or female, e.g. ‘Ferox’, the hedgehog holly, is male and does not produce berries. Some varieties have white, black, yellow or orange berries.

School Science Review, March 2006, 87(320) 83
Figure 1 Holly and three of its cultivated varieties.
(a) Holly, *Ilex aquifolium*, wild type
(b) Variety ‘Argentea Marginata Pendula’
(c) Variety ‘J. C. van Tol’
(d) Variety ‘Ferox Argentea’
The investigation – teacher guidance notes

Preparation
Clipping is used to simulate grazing. Any holly tree or hedge, part of which is left unclipped or clipped less frequently, would provide a suitable subject for study. Absence of grazing (clipping) for one year appears to be sufficient to lead to a decrease in prickliness (Obeso, 1997). Make sure the clipped hedge has had time to develop new shoots before being sampled. Where two trees are being compared it is best to choose trees of the same sex (see Box 1 for differences) and, where a hedge is being used, check that it does not contain a number of different cultivars. Although this exercise can be carried out at most times of year, early summer (June), when the current season’s growth is well-developed, is ideal.

Equipment required
Pupils will need:
- 2 10-metre tape measures
- canes or surveying poles marked at 0.5 m, 1.0 m and 1.5 m
- metre rules
- 30 cm rulers
- polythene bags
- secateurs

Introducing the investigation
Show pupils the illustrations of the different cultivars of holly (Figure 1) to demonstrate genetic variation in this species.

Use the worksheets downloaded from the Science and Plants for Schools (SAPS) website (see end), which show how the number of prickles per leaf varies at different heights on the tree, and discuss why this should be an advantage to the tree. Revise the pupils’ ideas about adaptation.

Explain that scientific evidence suggests that holly is able to increase the prickliness of its leaves as a response to an environmental factor – grazing. This is variation caused by environmental differences. Ask the pupils to discuss how this might be investigated.

Fieldwork
This should show pupils how to obtain an unbiased sample and to limit variability not due to clipping.

A tape is laid on either sides of the canopy being compared or along the base of the hedge at a distance of 1 m from it (Figure 2). Pairs of pupils stand at regular intervals along this transect line. One pupil holds the marked cane or surveying pole. The other pupil places the metre rule at the 0.5 m mark and at right-angles to the pole. The first shoot that touches the pole is the one selected for sampling (Figure 3). This is repeated at 1.0 m and 1.5 m. By keeping within 1.5 m of the bottom of the tree, variation due to differences in height on the tree should be kept to a minimum.

Flowering shoots (or ones with berries), which often have spineless leaves, are rejected. To obtain leaves of approximately the same age, the current year’s growth (see Figure 4) is removed with secateurs and placed in a polythene bag (teachers may prefer to do this themselves). Pupils then remove leaves from the middle of the cut portion of shoot (say the 3rd and 4th nodes), each pair therefore having a sample of 6 leaves. This method may need to be modified to suit the size of tree or hedge being sampled but in total a sample of 30–40 leaves from each of the clipped and unclipped parts of the tree or hedge should be large enough.

Figure 2 A hedge transect.

Figure 3 Selecting a shoot to sample.
Measuring prickliness

The prickliness of a holly leaf is usually equated to the number of prickles. However, pupils at the Field Centre suggested that leaves where all the prickles were in the same plane were not as prickly as those where the prickles were sharply angled, even where there were fewer prickles. They suggested that multiplying the number of prickles by a measure of the spread of the prickles would give a prickliness factor that could more readily be linked to the palatability of the leaf to a grazing herbivore. The following method was devised to calculate a ‘prickliness factor’.

The number of prickles on the leaf is counted. The leaf stalk is then removed and the leaf blade placed flat on the table surface. The vertical distance from the table surface to the tip of the tallest spine is then measured in mm (Figure 5). The number of spines multiplied by the height of the tallest spine gives the ‘prickliness factor’. For example, in Figure 6, leaf A has 9 spines and the height of the tallest spine is 21 mm. Its ‘prickliness factor’ is therefore $9 \times 21 = 189$. Leaf B has 18 spines and the height of the tallest spine is 9 mm. Its ‘prickliness factor’ is therefore $18 \times 9 = 162$. 

Figure 4. Shoot showing current year’s growth and leaves at the third and fourth nodes.

Figure 5. Measuring the spread of the ‘tallest spine.’

Figure 6. Comparison of prickliness between two leaves.
BOX 2  Calculating a running mean
- Plot the measurement (prickliness) for sample 1.
- Plot the mean for samples 1 and 2.
- Plot the mean for samples 1–3.
- Continue in this way, increasing the size of the sample that contributes to the mean.
- Plot the graph as you go along.

Initially, when the sample size is small the line will fluctuate considerably. As the sample size increases the line will flatten out. The point at which the line begins to lose any fluctuation is the point at which the sample size is large enough to give the true mean.

Follow-up activities
Pupils enter their data into a class recording sheet. There is an opportunity here to introduce the use of simple spreadsheets to collate class results. The pupils calculate the mean prickliness factor for the clipped and unclipped parts of the tree or hedge and choose an appropriate graph to show what they have found. A difference in the mean prickliness factor would suggest that the degree of prickliness in holly can be environmentally induced. The ability to produce spines, however, is genetically inherited (not all plants are able to do this).

Evaluation
Pupils should evaluate what they have done. They might consider:
- Any problems they had in collecting the sample.
- Was their sample big enough? More able pupils could be shown how to calculate a running mean (see Box 2).
- Was the prickliness factor a good measure of prickliness?
- How could the investigation be extended if time allowed?

Possible examples of further investigations are:
- Does prickliness increase at the top of the tree if it is clipped?
- Does leaf size vary with prickliness?
- Will a non-prickly cultivar become prickly if it is clipped?

Learning outcomes
This exercise emphasises the importance of unbiased sampling. It can also lead to interesting discussion about how genetically inherited characteristics can be modified by environmental differences. Pupils can be encouraged to think of other ways in which plants might protect themselves from being eaten both by large herbivores and smaller animals such as insects; for example, stinging hairs in the nettle (Urtica dioica), the production of strongly aromatic oils in many members of the mint family (Lamiaceae). Many of these plant defence mechanisms are now known to be environmentally induced.

Defence mechanisms may involve fascinating and complex interactions; for example, some plants when grazed give off volatile chemicals that act as airborne SOS signals, revealing the presence of an insect herbivore to its predators and parasites. The possibility of enhancing some of these plant defence mechanisms in crop plants by genetic modification is an important area of research that more able pupils may wish to explore.

Pupil worksheets
Four worksheets are provided for the pupils (see pages 88–90):
- Planning (Pupil worksheet 1)
- Obtaining results (Pupil worksheet 2)
- A class recording sheet (Pupil worksheet 3)
- Comparing your results (Pupil worksheet 4)

Curriculum slot

English Science National Curriculum

Key stage 2 (pupils aged 7–11): Sc2: 4a 4c 5b.
Key stage 3 (pupils aged 11–14): 7c 7d and 9A (QCA, 2004)
Pupil worksheet 1: Planning

Figure A holly stem with leaves and berries.

You are going to investigate whether the prickliness of holly leaves is affected by clipping. Choose one of the following questions to investigate:

- Are leaves more prickly on holly that has been regularly clipped than on holly not clipped for at least a year?
- Will there be no difference in prickliness of leaves on clipped and unclipped holly?

What will your prediction be?

Variables

Which is the variable that you are changing?

Which variables will you try and control?

Are there any variables that you cannot control?

On a separate sheet of paper write a plan for your investigation

You need to:

- list the equipment that you need
- explain how you will select which leaves to measure
- describe how you will measure prickliness
- explain how you will make sure that your test is fair.

Pupil worksheet 2: Obtaining results

You are investigating whether the prickliness of holly leaves is affected by clipping.

Collecting a sample of leaves

1. Place a tape measure along the bottom of the clipped part of the hedge and 1m away from it.

2. Find your position along this transect line.

3. Place the metre rule on the 0.5 metre mark at right angles to the cane. The first shoot touching the cane or the shoot nearest to the end of the cane is the one that you are going to sample.

4. Using secateurs remove this season’s growth from the shoot.

5. Remove the 2 leaves nearest the middle of this piece of shoot.

6. Repeat this for the unclipped part of the hedge.

Measuring prickliness of the leaves

1. Count the number of prickles on the leaf.

2. Remove the leaf stalk with scissors and place the leaf on a flat surface.

3. Measure the vertical distance from the flat surface to the tip of the tallest prickle.

4. Calculate the prickliness factor as follows:

   \[ \text{The number of spines} \times \text{the height of the tallest prickle} \]

   \[ = \text{the ‘prickliness factor’}. \]

Enter your results into the class recording sheet.
## Pupil worksheet 3: Class recording sheet

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Mean prickliness (no. of prickles x height of tallest prickles)
Pupil worksheet 4: Comparing your results

You are investigating whether the prickliness of holly leaves is affected by clipping.

- Calculate the mean ‘prickliness factor’ for the clipped and unclipped part of the hedge.
- Draw a bar chart to show what you have found. Make sure you label the y-axis.

Conclusions

1. What does your bar chart show?
2. Do these results agree with your prediction?
3. Do you think the prickliness of holly is likely to be affected by grazing?
4. Can you think of any other ways in which plants protect themselves from grazing?

Evaluation

1. Did any part of the investigation not work out as you thought it would?
2. Suggest ways in which you could improve your investigation.
3. Suggest how you could extend the investigation if you had more time.

References


Websites

For pupil activities looking at variability in the number of prickles of leaves at different heights on holly trees:
Field Studies Council (FSC):
www.field-studies-council.org
Science and Plants for Schools (SAPS) (also gives links to photocopies of holly leaves taken from different heights on a tree):
www-saps.plantsci.cam.ac.uk/worksheets/active/prac3.htm

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