Experimental method and biological concepts demonstrated using duckweed

G. Robinson, Winchester College

INTRODUCTION

Most biology teachers will have encountered the problems that accompany investigations into the effects of different variables on plant growth. Regular and accurate watering is

required, time-consuming if large numbers are involved, and still the plants contrive to dehydrate over a sunny weekend. They occupy space that is either needed for other purposes or hard to keep under controlled conditions—in many windows light intensity varies much more than expected over a distance of even a few centimetres. Then the regular recording of measurements frequently damages the plants and the time and effort involved seem unprofitable in view of the returns gained. Not surprisingly the desire to perform experiments producing sufficient data from which to draw valid conclusions is often sacrificed for practical considerations. (But then, most biology texts illustrate an experiment where one or two plants have been grown in mineral deficient solutions—alongside a fine table of the effects produced!).

For several weeks I had watched thirteen-year-old GCSE pupils struggling with most of these pitfalls as they pursued individual investigations. Their imagination and perseverance was impressive, even more so their ability to draw uncompromisingly firm conclusions on the basis of very little evidence. I felt it was time to try and convince them that serial repetitions of experiments are a vital component of scientific method, particularly in biology were the material with which we work has inherent variability.

We had been considering the role of producers at the start of food chains. Briefly we discussed the requirement for light and carbon dioxide in primary production. As we had not yet dealt with photosynthesis in detail there was considerable uncertainty about the relative importance of the two requirements. Knowing that in the near future I was going to be tackling population growth it occurred to me that we might use duckweed, *Lemna minor*, to study both things at once. The small size of the plant has made it a favourite subject for population growth studies and it seemed the ideal plant for working with large numbers.

METHOD

Each pair of pupils was given six standard, 10 × 2·5 cm, glass specimen tubes. These were half-filled accurately from a stock solution of Baby Bio made up to the recommended concentration. Into each tube were placed five, single-leaved and healthy duckweed plants with any side 'buds' carefully trimmed off with scissors. The pupils then breathed out into the air spaces of three of the tubes to enrich them with carbon dioxide. The tubes were immediately sealed with polythene stoppers, shaken vigorously and labelled. The three remaining tubes were also stoppered and shaken similarly to act as 'low carbon dioxide' controls.

Light intensity was varied by covering one tube from each group with two layers of plain duplicating paper, one tube from each group with one layer of paper and leaving the last two tubes uncovered. This treatment provided low, medium and high light intensities respectively. All tubes were placed on their sides in a tray in a south-facing window.

Once a week the numbers of (a) live plants, (b) live leaves, and (c) dead leaves were recorded in each tube. Any 'bud' comprising more than a semicircle was considered a new leaf. New plants had to be completely separated from their parents. More air was breathed into the air spaces above the carbon dioxide enriched plants and all tubes shaken vigorously to encourage separation into new plants. With a duplicated record sheet to fill in this only took about fifteen minutes in all. Class totals were accumulated for each week. At the end of five weeks the weekly class totals were summarized and a copy given to the pupils who were asked to present the data as they thought most appropriate.

The investigation was carried out with two different classes of pupils; the results obtained were very similar.

RESULTS AND DISCUSSION

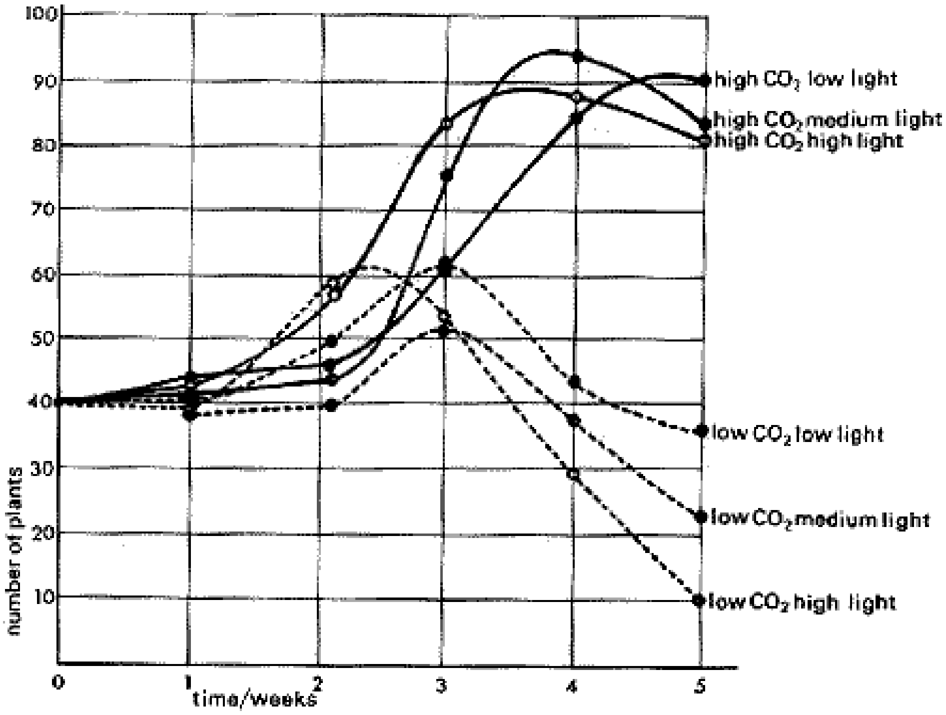
From the outset pupils had been encouraged to record their predictions of what would happen in each tube. Nearly all were of the opinion that more light and carbon dioxide would produce more or better growth, but apart from this there was little real agreement. As data was collected it soon emerged that there were differences in the readings of different pairs of pupils. In a few cases plants in carbon dioxide enriched tubes were growing very poorly compared with others. From pupils whose expectations were thus confounded came that all too familiar comment: 'The experiment isn't working'. As is the way of things, the disenchanted were far noisier than the others and at this stage it was not hard to imagine that the exercise was going to be—at least in the eyes of the pupils—a failure. It came, then, as a considerable surprise to them that the class totals confirmed most, if not all, of their expectations, and were anyway perfectly explicable. Certainly it had been a convincing demonstration of the folly of attaching too much significance to results obtained from single, unrepeated experiments which can so easily be unrepresentative.

One set of class data is reproduced here. Pupils analysed it in many different ways but a plot of plant numbers against time proved most interesting. The graph indicates clearly that increasing the carbon dioxide content of tubes greatly enhances productivity as measured by changes in plant numbers. What was interesting to the pupils was that light intensity had very little effect on the *maximum* population reached. It made the concept of carbon dioxide acting as a *limiting factor* immediately comprehensible. However, it did

Table 1. The effect of varying light intensity and carbon dioxide concentration on populations of duckweed. All figures are totals of eight replicates (class data)

	High carbon dioxide									Low carbon dioxide								
	High light			Medium light			Low light			High light			Medium light			Low light		
Date	P	L	D	P	L	D	P	L	D	P	L	D	P	L	D	P	L	D
3.2.87	40	40	0	40	40	0	40	40	0	40	40	0	40	40	0	40	40	0
10.2.87	42	106	0	41	83	1	43	80	1	40	98	7	39	94	3	44	80	5
18.2.87	57	143	9	44	134	6	46	135	6	59	109	14	40	102	9	50	105	10
24.2.87	84	179	18	76	166	12	62	154	17	54	95	31	52	89	19	62	112	21
3.3.87	88	139	55	96	139	55	85	158	34	18	30	68	38	61	50	44	73	64
10.3.87	82	115	60	83	116	44	91	155	34	10	18	69	23	36	57	37	59	44

P = number of live plants
L = number of live leaves
D = number of dead leaves



Changes in duckweed populations

not take them long to notice that while maximum population was unaffected by light intensity the *rate* at which the maximum was reached appeared to be directly related: the population peaked first in high light intensity and last in low. This brought home the important difference between the roles of energy and raw materials in primary production: by analogy—if the number of bricks for constructing a house is fixed, a larger team of workers cannot build a larger house but they can complete it sooner.

The data and the characteristic growth curves should provide invaluable material to illustrate the various phases of population growth and relative rates of generation and mortality, as well as indicating the restrictions placed on carrying capacity by an environment with finite resources.

The space-saving duckweed and specimen tube admirably served my purpose in emphasizing the need for repetition of experiments in good practical design. That they also produced such excellent data was a largely unexpected bonus, but one that has earned them a niche in my teaching ecosystem.