Cabomba Tricolour

Anne Adams 1950-2011

Many of you reading this will have known Anne Adams and it is with heavy hearts and great sadness that we have to let you know that Anne died on February 15th 2011. Anne joined SSERC in 2001 having worked previously at Stevenson College and in industry. Anne was without exception thoughtful, supportive and caring of others and, despite many sadnesses in her life, she brought much joy and laughter to all of those with whom she had contact.

Anne was a consummate professional. 'Let's make those practicals work' was the title Anne chose for technician workshops and this could have been her mantra. She worked tirelessly to develop reliable and practicable experimental work, much of which is currently in use in classrooms across Scotland. Nothing was too much trouble for Anne whose technical expertise and friendly manner contributed significantly to SSERC's advisory service. Many teachers, technicians and senior pupils have benefited from her wise advice and huge sense of fun.

We at SSERC have enjoyed Anne's company for ten years and feel privileged to have worked alongside her and to be able to count Anne as a wonderful colleague and friend.

Whilst the Biology Group has responsibility for the contents of this article the practical work described would not have been possible the contribution of Anne.

Background

A significant proportion of the Biology Group in SSERC is old enough to remember using the textbook by McKean [1] when studying biology in their early years. One of the experiments recommended by McKean is the use of *Elodea* (Canadian pondweed) to investigate factors which affect the rate of photosynthesis. Some 40 years later, the same experimental system is still recommended in more contemporary texts. Whilst we do not subscribe to the view that one needs 'green fingers' to be successful when it comes to practical work in the classroom, we do recognise that experiments with *Elodea* often fall into the 'unreliable' category. Despite the difficulties often associated often with *Elodea*, many schools and colleges continue to use it with varying degrees of success. In a recent publication [2] we explored how *Cabomba* might be used as a reliable alternative to *Elodea* and we wish to extend these observations in the experiments described here. In the experiments that follow (described in more detail in a related publication [3]) we present an experimental set-up which provides a stimulating way of engaging students and we contend that this will lead to greater understanding that plants respire continuously and of the effect of light intensity on the rate of photosynthesis.

Materials and Methods

The aquatic plant *Cabomba* is available from most tropical fish suppliers as well as on-line [4, 5]; see the Science3-18 website for more information on maintaining your stock of *Cabomba* [6].

The light source used in these experiments was a 35 W fluorescent tube (product number 56427) purchased from Focus DIY although similar results can be obtained with a variety of light sources likely to be available in the school laboratory. We would recommend that you avoid lamps which might lead to significant changes in the temperature of the solutions. Transmission filters were obtained from Lee Filters [7].

A stock solution of hydrogencarbonate indicator is prepared as follows:

1. Cresol red (0.10 g) and thymol blue (0.20 g) are dissolved in ethanol (20 cm^3).

2. Sodium hydrogencarbonate (0.85 g) is dissolved in freshly boiled, cooled distilled water (approximately 200 cm^3) and combined with the ethanolic solution of cresol red/thymol blue and made up to 1.0 dm^3 with distilled water.

For routine use 100 cm^3 of the stock solution is diluted to 1.0 dm^3 with freshly boiled, cooled distilled water.

Results and Discussion

The use of hydrogencarbonate indicator to monitor CO_2 levels in aqueous solutions is well established [8].

Figure 1 shows how the colour of the indicator solution changes over the pH range 6.8 to 9.2.

One might predict that if some *Cabomba* were introduced into a solution of hydrogencarbonate indicator and irradiated for a sufficient period of time then one would see a colour change in the indicator as CO_2 is removed from solution. To test this hypothesis we set up 2 measuring cylinders containing a single strand of *Cabomba* and hydrogencarbonate indicator. Prior to illumination, the pH of these solutions was approximately 7.4 (orange) as shown in Figure 2A. Both cylinders were placed in front of the lamp for 4 hours of illumination. The photograph shown in Figure 2B is of a cylinder which was covered with black paper (and, therefore, received no light) during the illumination period whereas the cylinder shown in Figure 2C received 100% of the incident light.

The cylinder in Figure 2C has turned a purple colour because photosynthesis has taken place with a consequent reduction in the concentration of CO_2.

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The cylinder in Figure 2B also shows a colour change from its starting point but in this case there has been a lowering of pH indicating a rise in CO_2 concentration (the pH after 4 hours in the dark has fallen to approximately 6.8). This is an interesting observation which can stimulate much discussion. The explanation for this observation is that the *Cabomba* in cylinder B is not photosynthesising but that it is producing CO_2 through respiration and this gives rise to the colour change.

So, does respiration occurs in plants which are photosynthesising? Results obtained using the experimental set-up in Figure 3 show this to be the case. We have taken a single strand of *Cabomba* and in 2 places along its length have placed discs cut from the base of a Styrofoam™ cup. The diameter of the disc was such that it was the same size as the internal diameter of the measuring cylinder. A small hole (diameter 2 - 3 mm) was cut in the centre of the polystyrene disc and a further cut made from the centre of the disc to its outer edge. This allows the disc to be placed around the stems of the strands of *Cabomba* and thereby act as a collar. The *Cabomba* and discs were placed in a measuring cylinder containing hydrogencarbonate indicator (pH 7.4).

One third of the measuring cylinder was covered in black paper; one third was covered with a filter which allows 50% of the light to be transmitted and the remaining third was left uncovered. The purpose of the discs is to reduce diffusion of hydrogencarbonate indicator between the 3 regions. The measuring cylinder was then placed in front of the lamp and irradiated for 4 hours. The resultant colour changes are shown in Figure 3. One could of course ask students to predict what they might see before removing the filters to reveal the colour changes which have taken place. In our experience removal of the filters from the measuring cylinder in Figure 3 gives rise to one of those perhaps infrequent yet indulgent moments in teaching when your students say 'wow!' or some such similar remark as they note the variety of colours present in the cylinder.

Figure 1 *– Hydrogencarbonate indicator solutions in the range pH = 6.8 (pale yellow) to pH =9.2 (purple). pH increases in increments of 0.4 units.*

Figure 2 *–*
Effect of irradiation on Cabomba / hydrogencarbonate indicator mixtures.
(A) Prior to irradiation (pH measured to be 7.4)
(B) After 4 hours irradiation during which the cylinder was covered in black paper (pH measured to be 7.0);
(C) After 4 hours irradiation (pH measured to be 8.3)

Figure 3 –
(A) Styrofoam™ fashioned to fit inside a 100 cm³ measuring cylinder
(B) Strand of Cabomba showing 2 collars in place
(C) Effect of irradiation (4 hours) on Cabomba / hydrogencarbonate mixtures. Prior to irradiation the pH was measured to be 7.4.
(i) Upper portion of cylinder covered with black paper during irradiation, (ii) middle portion of cylinder covered with 50% neutral density filter during irradiation, and (iii) lower portion of cylinder uncovered during irradiation after 4 hours irradiation.

It can be seen that both respiration and photosynthesis occur at the same time in the same plant – the bottom one-third, receiving 100% of the light, goes purple (pH has increased to 8.3) implying CO_2 uptake and hence photosynthesis dominates; the middle one-third, receiving 50% of the light, also shows a colour change which implies nett CO_2 uptake (pH has changed to 7.6) and hence photosynthesis dominates; the colour change in the top one-third, receiving no light, shows a reduction in pH (pH has reduced to 6.8) which in turn can be explained by the fact that only respiration is occurring. From the observations shown in Figure 3 we might additionally conclude (i) photosynthesis does not take place in the dark, and (ii) the rate of photosynthesis is greater than the rate of respiration at the light levels used.

A subsequent experiment in which black paper is placed over the top one-third of the measuring cylinder shown in Figure 3, with the bottom one-third uncovered, followed by a period of illumination leads to a reversal of colour change. In theory this reversal process can be repeated many times but in practice diffusion through the pores and gaps in the polystyrene disc eventually make the colour changes less clear.

We believe that the experiments shown here (i) can be used to suggest that both photosynthesis and respiration can occur simultaneously in a single plant, and (ii) can be described as beautiful!

References

[1] Mackean, D.G. (1969), Introduction to Biology (4th Edition), ISBN 7195 1926 8, John Murray (London).
[2] Crawford, K. (2005), *Cabomba* – a reliable alternative to *Elodea*? SSERC Bulletin 215, pp 10-12. See www.sserc.org.uk/members/SafetyNet/bulls/215/Biology.htm
[3] Adams, A., Moore, G., Rutherford, A., Stewart, F., Crawford, K. and Beaumont, P. (2011), *Cabomba* – an exocharmic plant!, School Science Review, in press.
[4] Blades Biological – see www.blades-bio.co.uk/ (accessed March 16th 2011).
[5] Urmston Aquatics – see www.urmstonaquatics.com/ (accessed March 16th 2011).
[6] Science education 3-18 home page – available at http://www.science3-18.org/ (accessed March 16th 2011); please note that to access the full suite of resources on this website a log-in ID is required.
[7] Lee Filters – see www.leefilters.com/ (accessed March 16th 2011).
[8] Nuffield Foundation (1966), Biology: Teachers' Guide III The maintenance of life (Organizer - W.H. Dowdeswell), Longman/Penguin (London & Harmondsworth).