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AN EXPERIMENTAL SYSTEM TO STUDY THE EFFECTS OF PRESSURE, LIGHT AND TEMPERATURE ON MACROPHYTE PRODUCTION*

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ABSTRACT

A new experimental system was developed for measuring photosynthesis, respiration and growth of macrophytes under different conditions of hydrostatic pressure, light and temperature in order to elucidate the effect of hydrostatic pressure on the depth distribution of macrophytes in lakes. The system consists of six incubation vessels that can be exposed to different photon flux densities, temperatures and pressures. Production is measured by changes in oxygen concentration, pH, conductivity, and in growth, morphology and pigments of the plants.

1. INTRODUCTION

There is an important controversy over the role of hydrostatic pressure, apart from that of light and temperature, in the distribution of macrophytes in lakes. Most authors (Spence 1982, Dale 1984) only consider light and temperature as determinants, but the absence of higher plants below 8–10 m depth in many lakes, where the light and the temperature are more than enough, makes the hydrostatic pressure a plausible determinant factor (Peñuelas 1988). The hydrostatic pressure is directly depth dependent and increases linearly 1 atm per 10 m depth. In addition to the distributional evidence there is also some experimental evidence on its inhibitory effects (Gessner 1952, 1961, Ferling 1957).

It is important to control light, temperature, pH and nutrients in experimental designs because all these factors affect photosynthetic activity. The aim of this paper is to present a new system (Fig. 1) in which experimental conditions are controlled.

2. THE EXPERIMENTAL SYSTEM

The system consists of six 1 dm³ incubation vessels (iv), made of teflon cylinders and stainless antimagnetic steel with glass window lids. The lid of each vessel can be tightly screwed down and the vessel is made pressure-tight.

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Fig. 1. The experimental system. A — the general scheme; B — the overall view. dv — distribution vessel, f — faucets. Hg — mercury column, iv — incubation vessel, kt — kryostat and thermostat, l — lamps, mc — measurement chamber, md — metal detector, ms — magnetic stirring device, ns — nutrient solution, ox — oxygen meter, phe — pH meter conductimeter, pp — peristaltic pump, r — relay, sd — stirring device, t — thermometer.
by an "0" ring and some silicone grease. There is a magnetic stirring bar at the bottom with a rotation speed high enough to maintain complete mixing. The glass window allow 85% transmission of photosynthetically active radiation (PAR = 400 – 700 nm). There are two faucets, one that allows the entrance of medium and another as outlet.

The incident photon flux density ranges between 0 and 1000 $\mu$E m$^{-2}$ s$^{-1}$ depending on the neutral filters put on the windows, the distance of the lamps (l) which can be modified, and the different kinds of lamps (e.g. daylight fluorescents, halogen OSRAM, Exzel). Spectral light quality can be chosen by using different lamps. The neutral filters and glass windows do not affect PAR light quality, but they absorb U.V. light, as has been proven by spectro-photometric analysis. The irradiance in each experiment and each vessel is measured with the spherical probe of a Licor-L photometer.

The temperature ranges between 5 and 35°C by immersion of incubation vessels in water metacrilate containers where the temperature is regulated ($\pm 1^\circ$C) by kryostats and thermostats (kt).

All the incubation vessels are connected through a distribution vessel (dv) to a Gilson peristaltic pump (pp) that supplies pressure, and to a mercury column (Hg) that serves as manometer and barostat. When height of the mercury in the column corresponds with the desired experimental pressure, a metal detector (md) fires a relay (r) and the peristaltic pump stops running. Likewise, when there is a decrease in pressure, the barostat switches on the pump until the desired pressure is reestablished. Pressure can also be supplied applying compressed air directly to each incubation vessel. This method is used to test the effect of atmospheres with different oxygen concentrations, and in order to avoid the possible toxicity problems caused by the mercury poisoning (Dale 1984). Poisoning by mercury in aging cultures was avoided by the long and thin tubes with difficult diffusion that connected the mercury column with the growth vessels, and by an air lock separating the mercury from the growth solution. The pressure used in each experiment and each vessel is checked using a manometer applied to the faucets.

All incubation vessels are also connected by thin stainless steel tubes to a small (10 cm$^3$) measurement chamber (mc) made of glass and teflon, that contains oxygen, pH, temperature and conductivity sensors, and a magnetic stirring bar to obtain a correct oxygen measurement (ms). The pH electrode is Orion, the conductivity and temperature probes are DTI and the oxygen electrode is Syland. The metabolic activity of plants in each incubation vessel is measured by operating its faucets so as the medium enters the measurement chamber twice, the first time in order to rinse it, and the second one to provide measurements of oxygen, pH, conductivity and temperature.

The nutritive solution (ns) is pumped from stock to the incubation vessels by a peristaltic pump. The ns composition can be varied in each experiment. Some experiments on carbon sources can be carried out by changing the pH by introducing sodium hydroxide in the incubation vessels (Peñuelas 1985).

In this experimental system the responses of bryophytes, large algae and higher plants to different pressure, irradiance and temperature conditions have been compared. The oxygen method was used to assess photosynthetic and
respiratory activities. The two methods most widely used for determining the photosynthetic activity of macrophytes are the $^{14}$C and the oxygen techniques. Advantages and disadvantages of both systems are discussed in Zevenboom et al. (1983) and in the references there quoted. The oxygen method, although less sensitive, enables continual registration and dark respiration measurements. It did not show any special behaviour of higher plants — plants with gaseous lacunae — in relation to the hydrostatic pressure. However, it turned out to be inappropriate because of methodological problems with air spaces and the effect of pressure. Long term experiments (11 days) and growth, morphological and pigment parameters showed that growth was inhibited by pressure at an excess of 1 atm. In this experimental system it has also been proved that the increase in oxygen partial pressure in lacunae is an important damaging factor that limits the depth distribution of higher plants (Peñuelas 1988).

3. REFERENCES


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