BUFFERING ACTION OF HYDRILLA VERTICILLATA ON THE AQUATIC pH AND THE EFFECT OF CADMIUM IONS ON THIS PLANT

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ABSTRACT

During photosynthesis on Hydrilla verticillata, the pH of the surrounding water is rendered slightly alkaline and in the absence of light the pH is brought back to near neutral condition. However, if the habitat pH is acidic or alkaline due to the effluents present, this plant has a remarkable buffering capacity to bring the habitat pH to optimum, which is near-neutral. The ability of the plant to raise the pH of the habitat from 7 to slightly alkalinity under illumination is lost when cadmium ions are present in water. The buffering action of the plant has been studied in (a) acidic and alkaline conditions (b) natural and distilled water and (c) nutrient solutions under normal and artificial illumination. A typical electrophytogram of a twig is also included.

Key words: Buffering action, Hydrille verticillata, removal of Cd^{++}

INTRODUCTION

Hydrilla verticillata is a slender, branched, leafy, submerged aquatic weed that grows up to 45 cm in length and has fibrous roots. It grows as dense mass in ponds, lakes and in slow-running water all over India and is eaten by some fishes and aquatic birds. It is an excellent oxygen generator. The present paper describes the inlfuence of this plant on its aquatic environment, and to find the effect of the toxic heavy metal cadmium ions on this plant, since the industrial effluents from many industries containing cadmium are let out on agricultural land or into water resources, thereby affecting the flora [1-9].

EXPERIMENTAL

Influence of the plant on the habitat pH

Weighed amounts of H.vertillata were kept in known quantities of (i) distilled water (ii) natural water (a) as such (b) with dissolved carbon dioxide (c) slightly acidified with nitric acid (d) slightly aklalified with sodium hydroxide (iii) dilute solutions of potassium nitrate (iv) diluted Hoagland's nutrient solution ($NH_4H_2PO_4$ = 75 ppm + KNO_3 = 303 ppm + $Ca(NO_3)_2$ = 328 ppm + $MgSO_4$ = 120 ppm + ferrous gluconate = 6 ppm initial pH = 6.25) (a) as such (b) with dissolved carbon dioxide (c) slightly acidified with dilute nitric acid (d) slightly alkalified with dilute sodium carbonate. Changes in habitat pH under different intensities of light with time was monitored using a digital Research pH meter (Model 1400 R). Atomic absorption spectrophotometer (AAS), Perkin-Elmer (Model 380) was used to estimate sodium. potassium and calcium ions given out by the plant, when kept in conductivity water, under daylight of about 46.5 lm/m^2 for about 6 hrs.

Measurement of oxygen liberated

A one litre beaker having 1000 g of aquatic medium, with an inverted funnel of 10 cm dia, within which the plant twigs were kept constituted a simple arrangement for the oxygen measurement studies. The volume of gas liberated during photosynthesis was collected in inverted burettes by the downward displacement of the aqueous media. Studies were carried out in almost all the media described earlier.

Effect of cadmium ions

Weighed amounts of this plant were kept in known quantities of very dilute solutions of cadmium sulphate, in distilled water and in natural water for different periods. Cadmium content of the habitat was analysed by AAS. Changes in pH of the media, the physical changes undergone by the plant and its habitat were monitored.

Electrochemical studies

The electrophytogram for the plant was obtained by Gensler's method [10] using 0.25 mm thick platinum electrode SCE and a high impedance electrometer (Keithley 610 B Model). The plant was kept in natural water, in shade, where the maximum light intensity was about 325 lm/m^2. The average pH of the habitat was 8.1. The minimum and maximum temperature recorded were 28°C and 40°C respectively.

RESULTS AND DISCUSSION

H. verticillata when kept in natural water developed alkalinity even at a light intensity of 7.4 lm/m^2. As the intensity increased the rate of alkalification also increased. However, a limiting rate was attained at an intensity of about 55.7 lm/m^2 light. Direct sunlight of very high intensity 464.5 – 1858 lm/m^2 resulted in the bleaching of the plant when the quantity of habitat was limited. At night, the fall in pH was due to respiratory carbon dioxide. Plant-water ratio, the effective utilisation of light and rate of respiration have determined the upper and lower limits of the pH, which were 8.15 and 6.85 under field conditions at 6 PM and 6 AM respectively. The variation was rhythmic. The remarkable behaviour of H. verticillata consists in the neutralisation of acidic habitat even in the absence of light. When placed in acidified natural water the neutralisation continued in darkness too. Similarly, under the influence of light, an opposite reaction also occurred on placing the plant in alkaline habitat. Neutralisation occurred in day time. It may perhaps be due to photorespiration that sets in if the habitat is alkaline.

The presence of the plant in conductivity water made the habitat distinctly alkaline under the influence of light. However, the build up of alkalinity reached a limiting value of nearly 10 beyond which no further increase was observed. A typical sample of conductivity water which attained a pH of 9.66 in day light of intensity about 46.5 lm/m^2 over a period of 6 hrs, when analysed for K^+, Na^+ and Ca^{++} using AAS showed 0.19, 0.42 and 3.07 $\mu g/ml$ respectively. Presence of Mg^{++} was confirmed but not estimated. The transport of K^+, Ca^{2+}, Na^+, Mg^{2+} and OH^- ions from the plant biofluid into the water medium may be ascribed to a diffusion process (passive transport).

Figure 1 depicts the change of pH brought in by the plant under the influence of 7.4 lm/m^2 light. This neutralisation process has continued in darkness also until the habitat pH became 5.7.

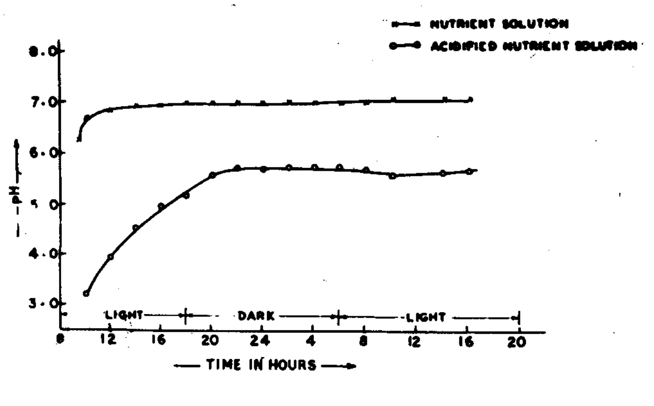

Fig. 1: Change of pH in nutrient solution with time

The secretion of alkali by the plant in very dilute solutions of KNO_3 was normal, whereas the presence of toxic Cd^{++} ions inhibited this process. As the concentration of Cd^{++} ions increased, the habit of rise in pH was largely suppressed. The intake of this toxic metal ion was confirmed by decrease in the metal ion content in the habitat using AAS.

Figure 2 shows the change in pH undergone by the habitat, viz. solutions of Cd^{++} ions, over a period of 5 days. Under normal conditions but in the absence of light, pH of the habitat is brought down by plant respiration. The presence of Cd^{++} ion inhibits this respiration and hence the fall in pH is reduced, when compared to cadmium free aquatic conditions.

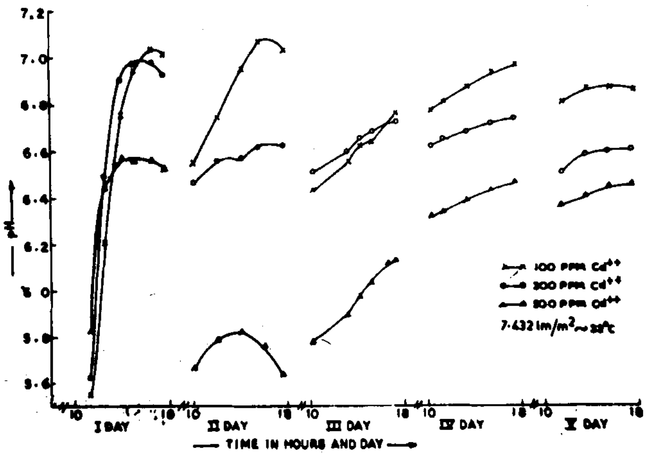

Fig 2: Effect of Cd^{++} ions: change in pH with time

Figure 3 shows the rate of oxygen evolution with time from natural water, acidic water and alkaline water. Near-neutral condition. i.e. pH 7-8 is the best for oxygen evolution. A gram of the plant evolved 0.56 ml of gas at a light intensity of 46.5 lm/m^2 in the temperature range of 28-32°C.

Total alkalinity of natural water estimated by standard sulphuric acid was 141.8 ppm of $CaCO_3$. In a litre of natural water this alkalinity was reduced to 103.2, 77.4 and 64.5 ppm of $CaCO_3$ by 2.5, 5 and 15 g of plants respectively. The amounts removed were not in proportion to the quantities of plants, since the effective area of the plant that comes in direct contact with sunlight does not increase proportionately with the increase in the quantity of plant due to crampness.

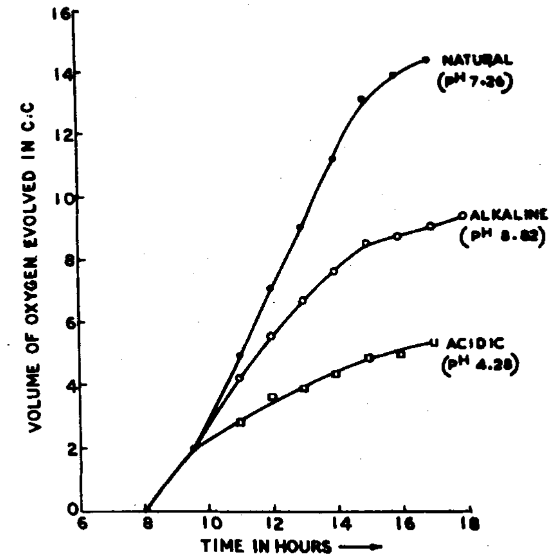

Fig. 3: Rate of evolution of oxygen with time in natural water, alkalified and acidified

The consumption of bicarbonate and release of hydroxyl ion by chara corallina, another submerged plant found in Indian waters, is an established fact. In this plant, the long established alkaline banding phenomenon has been found to be due to light-dependent bicarbonate uptake and OH^- ion efflux. Bicarbonate ion and hydroxyl ion transporters are said to exist at spacially different sites within the plasma lemma.

All carbon in photosynthesis of submerged marine and fresh water plants is fixed by RuP_2 carboxylase. Since this enzyme uses free carbon dioxide, HCO_3^- has to be dehydroxylated inside the cell before the CO_2 can be used by RuP_2 carboxylase [11].

The pH of the natural water was 7.5. When analysed for K^+, Mg^{++}, Na^+ and Ca^{++} by AAS their contents were 2, 9.7, 43 and 50 μg/ml respectively. After keeping the plant in it (ratio 1 : 2000 by wt) over a period of 6 hrs at an intensity of about 46.5 lm/m^2 the pH had increased to 8.87. While the amounts of K^+, Mg^{++} and Ca^{++} remained same, an increase in the amount of sodium to 61 μg/ml was observed. Hence the rise in pH is attributed to sodium hydroxide secreted by the plant.

The Electrophytogram measurements

The potential-time curve obtained for this plant was circadian in nature. This is shown in figure 4. From 4 AM onwards, there was a rise in potential reaching a maximum at 9 AM when the evolution of oxygen reached a steady state. Afternoon, there was a slight fall in potential. After 16 hrs the potential decreased to +140 mV around mid-night and remained almost constant till 4 AM.

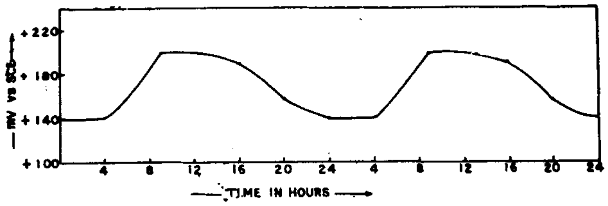

Fig. 4: Electrophytogram of Hydrilla verticillata

28-40°C; Max. light intensity 325 lm/m^2; Habitat pH ~ 8

H. verticillata has air chambers in its body. The electrode inserted is in contact with the plant biofluid and the gas as well. The potential measured may correspond to the O_2/OH^- redox couple. The maximum and minimum values seem to reflect the (i) maximum concentration of oxygen in the air chamber and (ii) its depletion at night in the absence of photosynthesis. The presence or absence of any other redox system in the biofluid remains to be confirmed.

CONCLUSIONS

H. verticillata serves as an environmental protector by maintaining the pH of its aquatic environment at near neutral levels.

Bicarbonate ions are essential for the liberation of oxygen. The ideal pH for the same is 8.25, when the HCO_3^- content reaches maximum.

Cadmium acts as a potential poison to the plant.

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