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Impact of the Herbicide Magnacide-H (2-Propenal) on Algae

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2-Propenal, the active ingredient of Magnacide-H[1], is used as an herbicide to control submerged aquatic plants in irrigation canals. The increased use of overhead sprinklers has generally paralleled the employment of Magnacide-H formulation because xylene, a commonly employed herbicide, causes plants to float free and to collect in the water pump filters, whereas Magnacide-H causes in situ disintegration of the plant material.

Magnacide-H is a liquid, volatile unsaturated aldehyde that derives its herbicidal activity by reacting with sulfhydryl-containing enzymes (IZARD & LIEBERMANN 1978). This characteristic makes it also lethal to non-target organisms such as algae, insects, and fishes in the aquatic ecosystem. This chemical was responsible for a major fish-kill on the Beaverhead River located in southwestern Montana. All fish were killed in a 2.5 mile stretch of river, with another 1.5 miles experiencing lower mortality. Trout are regarded as indicators of high water quality, and they are relatively sensitive to Magnacide-H. BARTLEY and HATTRUP (1975) showed that rainbow trout exposed to a concentration of 500 ppb of this chemical for 4.8 h exhibited 100% mortality and 410 ppb, 70% mortality in the same exposure period. Zero mortality was recorded for exposure to 240 ppb for 4.8 h and 48 ppb for 48 h.

This investigation was undertaken to determine the relationship between Magnacide-H concentration and rate of photosynthesis in several ubiquitous fresh-water algae primary producer communities.

MATERIALS AND METHODS

Algal species employed were Enteromorpha intestinalis and Cladophora glomerata. Both are members of the Division Chlorophyta and were collected near Missoula, MT in Rattlesnake Creek and the Clark Fork River, respectively. The blue-green alga Anabaena sp. was purchased from Carolina Biological Supply. C. glomerata and

[1]Magnacide-H is the registered trademark of Magna Corporation, 11808 South Bloomfield Ave., Santa Fe Springs, CA, and carries EPA Registration Number 10707-0 issued November 25, 1975.

0007-4861/82/0028-0245 $01.00

E. intestinalis were collected just prior to treatment and suspended in Bristol's solution (NICHOLS & BOLD 1965), whereas Anabaena was both grown and suspended in Bristol's solution. Anabaena was grown at 25°C using a light intensity of 550 ft-c. (cool white; fluorescent) in 125 mL Erlenmeyer flasks. Anabaena was harvested from the growth medium by centrifugation at 4000x g. The experimental cells or thalli were suspended in Bristol's solution to which Magnacide-H was added at various concentrations ranging from 0 (control), 10, 100, 250, 500, 750, 1000, and 5000 ppb. Concentrations represent the formulation of 92% acrolein and 8% inert ingredients. Incubation times were usually 24 or 48 h at constant temperatures of either 15, 20, 25 or 30°C at 550 ft-c. light intensity. Following incubation in Magnacide-H, cell material was placed in manometric flasks with 2.7 mL of the treatment solution plus a carbonate-bicarbonate Warburg #11 mixture to yield a 0.2 M buffer solution (UMBREIT et al. 1964). Photosynthesis (1500 ft-c.) and respiration (darkness) rates were determined at 25°C using a Gilson Respirometer (model GRP-20).

Dry weights were determined by heating the algae in a forced-air oven at 85°C for 24 h in small aluminum crucibles followed by equilibration over Drierite ($CaCO_3$).

RESULTS

The effect of Magnacide-H on photosynthesis was different for each algal species tested. Figure 1 presents data for C. glomerata tested over a range of herbicide concentrations from 0 to 5 ppm at four different growth temperatures. The onset of inhibition to oxygen production was at 500 ppb (15°C), 750 ppb (20°C), 500 ppb (25°C) and 100 ppb (30°C). A second measure of toxicity, in which the concentration of herbicide effected a 50% reduction in photosynthesis rate, can be used (Photosynthesis Inhibition, PI_{50}). The PI_{50} for cells exposed to Magnacide-H was 680 ppb at 15°C, 1070 ppb at 20°C, 1000 ppb at 25°C and 760 ppb at 30°C. The results show that cells treated at 15 and 30°C had similar PI_{50} values, whereas the 20 and 25°C treatments formed a second group with higher concentrations required to elicit a PI_{50}.

Figure 2 shows the results of experiments using Enteromorpha. The PI_{50} for thalli exposed to Magnacide-H at 25°C for 24 h was 1.8 ppm and 2.5 ppm when the exposure temperature was 20°C. In experiments at 15°C, the rate of photosynthesis was not reduced by 50%.

Anabaena sp., a member of the Division Cyanophyta, was tested at only 25°C and exhibited a PI_{50} of 690 ppb (Fig. 3). This alga is characterized by having only chlorophyll a and the blue-colored accessory pigment phycocyanin. The appearance of phycocyanin in the test solution at Magnacide-H concentrations of 2.5 ppm and higher shows that the cell's plasma membrane had disintegrated, allowing this pigment to diffuse out of the cell. Cells exposed

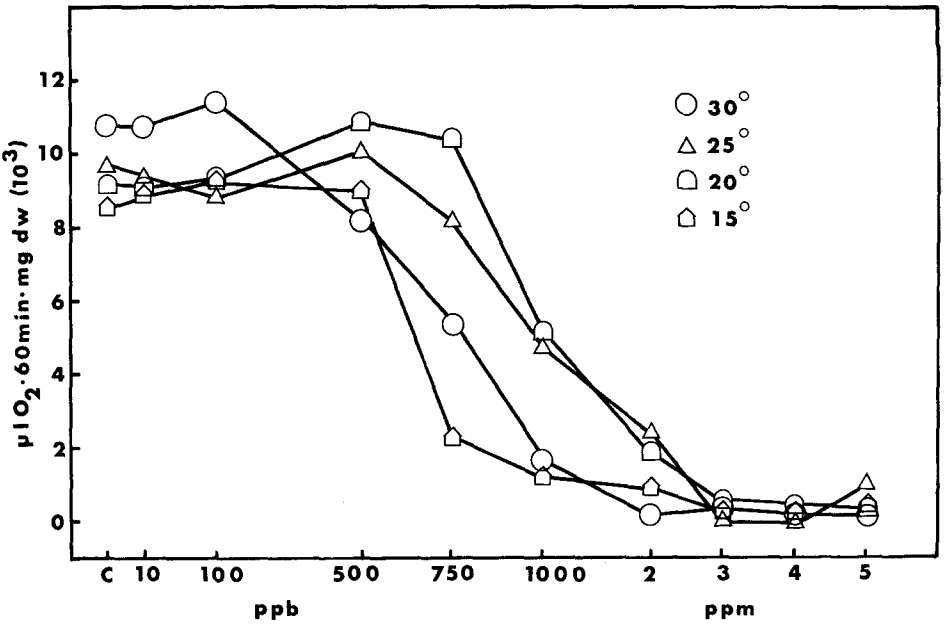

Fig. 1--Rate of photosynthesis for C. glomerata grown at four temperatures and in various concentrations of Magnacide-H for 24 h. Photosynthesis was measured at the growth temperature at a light intensity of 1500 ft-c. Points are the mean of four trials.

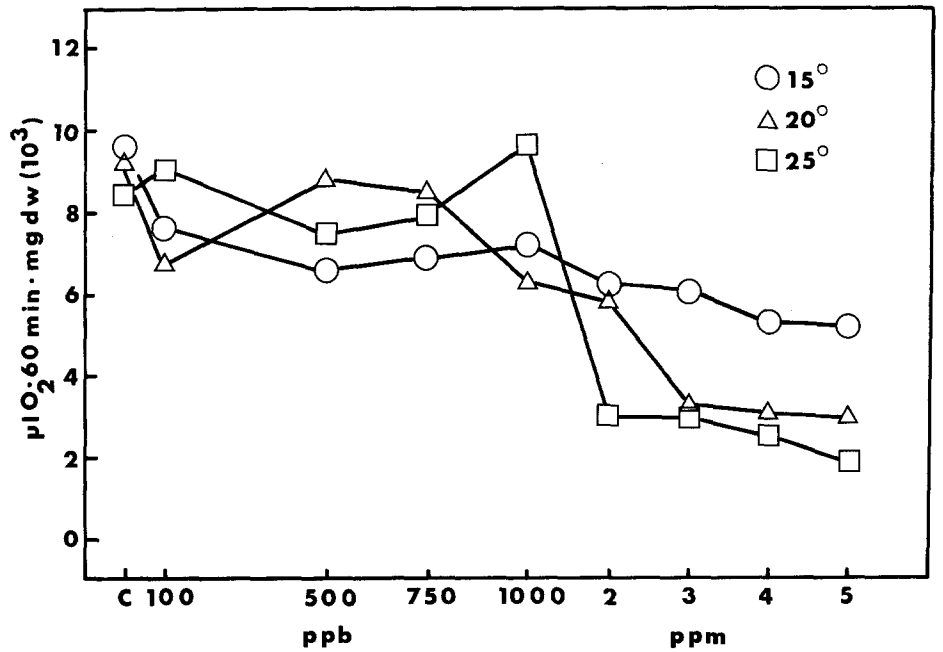

Fig. 2--Rate of O_2 production for Enteromorpha grown in the presence of Magnacide-H at various concentrations for 24 h. Measurement was at the growth temperature and a light intensity of 1500 ft-c. Points are the mean of three trials.

to 1 ppm were dark green in color and clumped in small colonies, in contrast to control cultures in which the filaments were evenly dispersed and blue-green in color. The appearance of phycocyanin and complete arrestment of photosynthesis both occurred at 2.5 ppm.

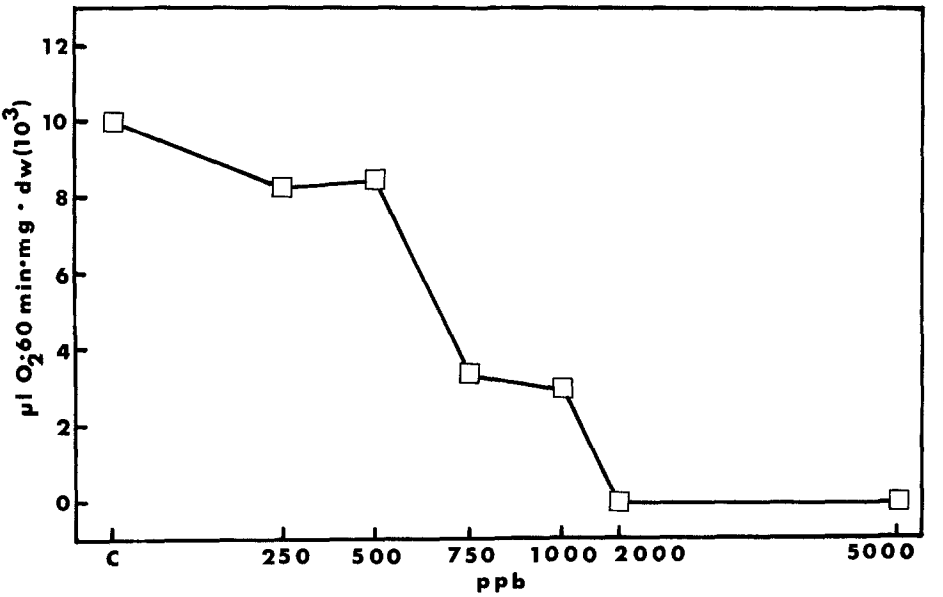

Fig. 3--Oxygen production by Anabaena grown at 25°C. Rates of photosynthesis were at 25°C and a light intensity of 1500 ft-c. Cells were exposed to the herbicide for 24 h. Points are the mean values from five trials.

DISCUSSION

The concentration of Magnacide-H to effect a 50% reduction in photosynthesis was different for each of the three algal species tested and for different temperatures. For cells treated at 25°C Anabaena sp. was the most sensitive (PI_{50} 1000 ppb), and Enteromorpha the least sensitive (PI_{50} 1.8 ppm).

C. glomerata showed increased sensitivity to this herbicide at both lower (15°C, PI_{50} 680 ppb) and higher temperatures (30°C, PI_{50} 100 ppb). Temperature stress was probably additive to herbicidal stress, thus enhancing the toxic effect. Enteromorpha showed the same temperature effect with a PI_{50} of 1.8 ppm at 25°C and PI_{50} 2.5 at 20°C. However, Enteromorpha exhibited reduced sensitivity at 15°C in contrast to C. glomerata.

It is interesting to note the close agreement between 100% inhibition of photosynthesis and the appearance of free-soluble phycocyanin. Because phycocyanin is visually detectable, its appearance in the presence of toxicants could function as a rapid index for the determination of the concentration of toxicant which effects

complete inhibition of metabolism.

BARTLEY and HATTRUP (1975) found that rainbow trout were unaffected by exposure for 4.8 h to Magnacide-H concentrations between 0 and 90 ppb, LD_{50} occurred between 240-410 ppb and 100% mortality at concentrations greater than 500 ppb. In comparison, the PI_{50} for C. glomerata was 1000 ppb (25°C, 24 h) and 690 ppb in Anabaena (25°C, 24 h). Rainbow trout exhibit stress behavior at lower Magnacide-H concentrations than the three algae studied here.

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