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Studies on the growth and development in *Spirogyra* IV. A close relationship between the diurnal movement pattern and the photosynthetic rates of *Spirogyra* filaments

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A relationship between the pattern of diurnal movement of *Spirogyra* filaments and their photosynthetic activities was quantitatively investigated.

The light type movement occurred at 1500-3600 lux, the intermediate type at 750-850 lux, and the dim light type at 400 lux, with a decline in photosynthetic rates in correspondence to the decrease in light intensities. At 3600 lux, DCMU suppressed the photosynthetic rate and transformed the movement pattern from the light type to the lower light-intensity type depending on the concentrations. These results suggest a close connection between the level of some photosynthetic substance(s) and the determination of the type of movement pattern.

Key Index Words: *DCMU*; *diurnal movement*; *photosynthesis*; Spirogyra.

OJIMA and TANAKA (1970, 1971) found that filaments of *Spirogyra* exhibited their characteristic diurnal movement only under the influence of light-dark cycles. Their movement patterns could be divided into three types—the light type, the intermediate type, and the dim light type—depending upon the light intensity of the light phase part of the cycle. These patterns could also be transformed from the light type to the lower light-intensity types by the application of DCMU (3-(3, 4-dichlorophenyl)-1, 1-dimethylurea), a photosynthetic inhibitor (TANAKA *et al.* 1977).

In this study, to obtain additional information on the correlation between the movement pattern of *Spirogyra* filaments and their photosynthetic processes, *Spirogyra* photosynthetic rates, under the influence of various light conditions and under the effect of various concentrations of DCMU were measured. These measurements were then compared with *Spirogyra* movement patterns observed under the same conditions.

Materials and Methods

Filaments of *Spirogyra* sp. were cultured in a growth room under a constant temperature (17±1°C) and with a 14 hr light period (8 : 00-22 : 00).

Light irradiation was provided by white fluorescent tubes (NATIONAL FL-40 SW) positioned above the alga. Tap water was used as the culture medium, but 0.06% ethanol/tap water[1)] was chosen as the control medium for the DCMU experiments. Containers used for culture and movement observation were glass aquaria (12×10×2 cm). WINKLER's oxygen bottles were used for

1) This mixture had been proved in preliminary tests to have no effect on either the movement or oxygen evolution of *Spirogyra* filaments.

the measurement of oxygen content changes in the media.

The photosynthetic rate was calculated by measuring oxygen content changes in the media during a 3 hr incubaton period (10 : 20-13 : 20) after about 18 hr preincubation under the respective culture conditions. These changes were measured according to the WINKLER method using $MnCl_2$, KI-NaOH, HCl, and $Na_2S_2O_3$ solutions.

Results and Discussion

Movement pattern and photosynthetic rates of Spirogyra under various light conditions: Filaments were cultured at intensities of 3600, 2000, 1500, 850, 750, and 400 lux, and their movements at each intensity were recorded. As shown in Fig. 1, the light type, intermediate type, and dim light type movements occurred at intensities of 1500-3600 lux, 750-850 lux, and 400 lux, respectively[2]. Photosynthetic rates at the respective light intensities were then measured (Fig. 2). These results, presented in Figs. 1 and 2, reveal that a change in movement pattern from the light type to the intermediate type or the dim light type was accompanied by a decrease in the photosynthetic rate.

Effect of DCMU upon the movement pattern and photosynthetic rates of Spirogyra under the light type condition: Filaments were cultured under the light type condition in media containing various concentrations of

2) Detailed explanations of the characteristics of each type were presented in Table 1 of our previous paper (TANAKA *et al.* 1977).

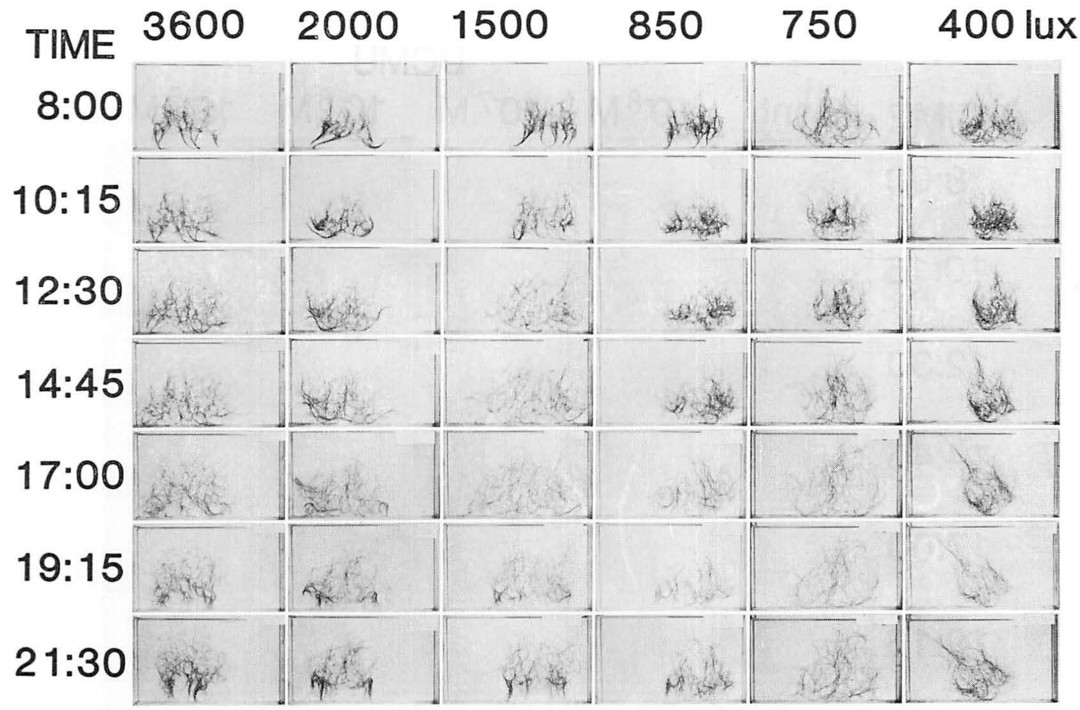
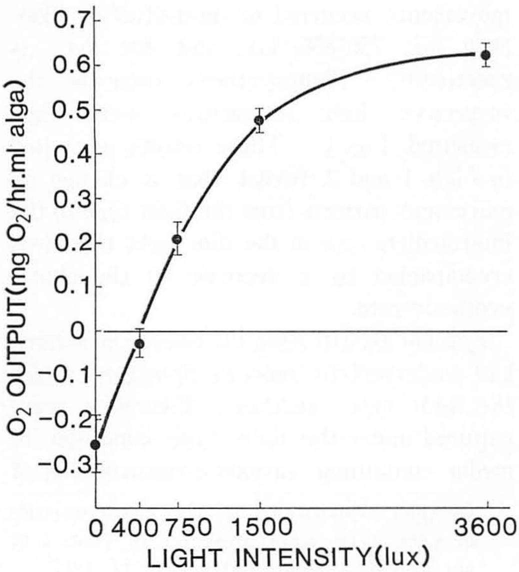


Fig. 1. Filament movements under various light conditions. Light period: 14 hr (8 : 00-22 : 00). Temperature: 17±1°C. Photographs: movements on the 3 rd day (18 Dec. 1980) of incubation (one of three replicates with identical results). At 1500-3600 lux: light type movement—a group of filaments spreads in the first half of light period, but filament tips bend downwards to form a mountain-shape in the second half[2]. At 400 lux: dim light type movement—a group of filaments shrinks in the first half of light period, but spreads again in the second half, and filament tips direct almost upwards all the day[2]. At 750 and 850 lux: intermediate type movement—the dim light type in the first half of light period, but the light type in the second half[2].



DCMU, and their movement patterns were then recorded (Fig. 3). The results were as follows: light type movement in both the control medium and 10^{-8} M of DCMU; intermediate type in 10^{-7} M; and continuous dark type movement[3] in 10^{-6}–10^{-5} M. Photo-

3) Characteristics of the continuous dark type movement: lack of periodical movement, lack of shrinking phase and upwardly directed filament tips all day.

Fig. 2. Photosynthetic activities of filaments under various light conditions. Light period: 14 hr (8 : 00–22 : 00). Temperature: 17±1°C. After an approximate 18 hr preincubation period under the respective light conditions, oxygen measurements were taken using WINKLER's bottles. Incubation period in WINKLER's bottle: 3 hr (10 : 20–13 : 20, 20 Dec. 1980). Points indicate mean values of three replicates, vertical bars show the SD.

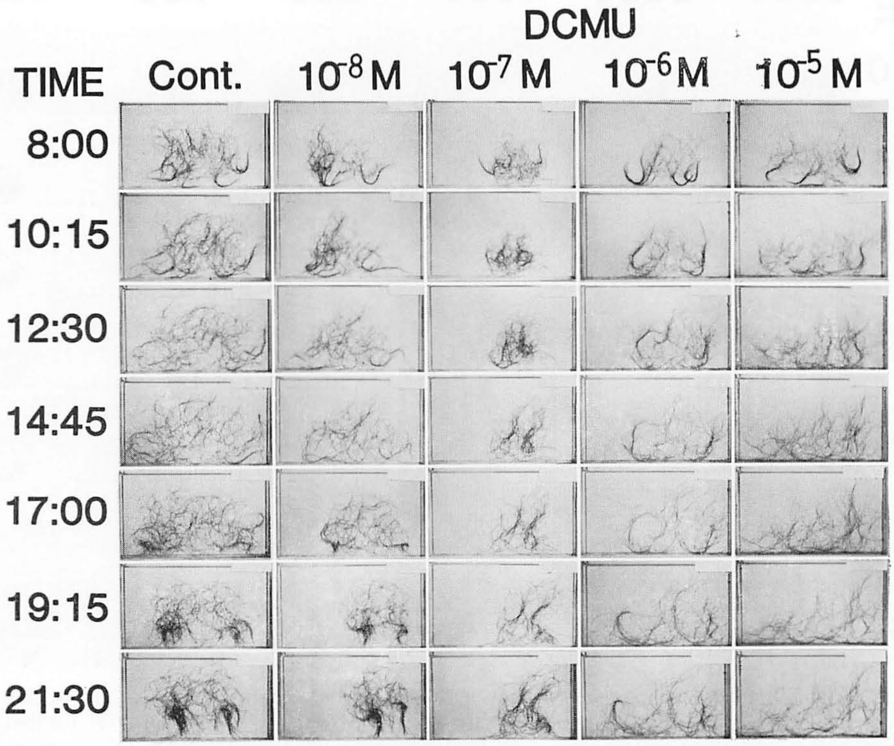


Fig. 3. Effect of DCMU on filament movements under the light type condition. Light period: 14 hr (8 : 00–22 : 00), 3600 lux. Temperature: 17±1°C. Photographs: movements on the 3rd day (19 Dec. 1980) of incubation (one of three replicates with identical results). Cont. and at 10^{-8} M: light type movement[2]. At 10^{-7} M: intermediate type movement[2]. At 10^{-6} and 10^{-5} M: continuous dark type movement[3].

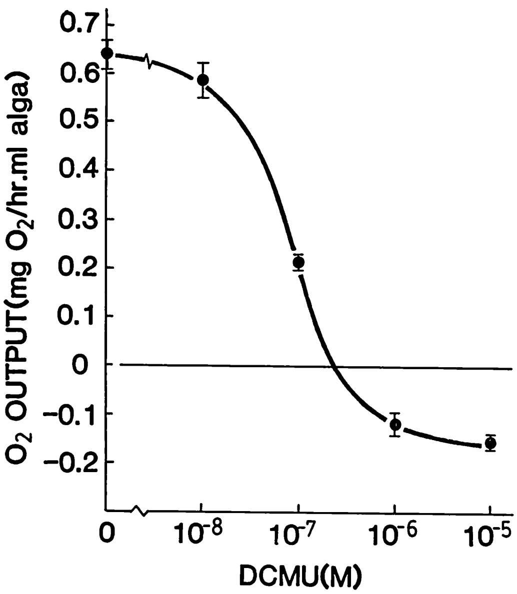


Fig. 4. Effect of DCMU on filament photosynthetic activities under the light type condition. Light period: 14 hr (8 : 00-22 : 00), 3600 lux. Temperature: 17±1°C. After an approximate 18 hr preincubation period in the respective concentrations of DCMU, oxygen measurements were taken using WINKLER's bottles. Incubation period in WINKLER's bottles: 3 hr (10 : 20-13 : 20, 22 Dec. 1980). Points indicate mean values of three replicates, vertical bars show the SD.

synthetic inhibition caused by the presense of DCMU in the media was then measured. As shown in Fig. 4, filament oxygen evolution was barely affected by 10^{-8} M of DCMU; slightly reduced by 10^{-7} M; and markedly reduced by 10^{-6}-10^{-5} M to a rate less than that obtained under 400 lux illuminance without DCMU where dim light type movement occurred (Figs. 1 and 2). Since DCMU at 10^{-8}-10^{-5} M, had no effect upon *Spirogyra* dark respiration (data not shown), the observed reduction in oxygen evolution (Fig. 4) could be accredited to DCMU's ability to suppress photosynthetic activity.

Thus, by comparing the effects of DCMU (Figs. 3 and 4) with the effects of various light conditions (Figs. 1 and 2) upon the diurnal movement and photosynthetic activity of *Spirogyra* filaments, it becomes obvious that there is a precise relationship between the movement patterns and photosynthetic rates. The existence of such a relationship suggests the possibility that the movement patterns of *Spirogyra* filaments are intimately related with some substance(s) of the photosynthetic process. Measurements of diurnal changes in the levels of the photosynthetic products under various culture conditions are now in progress.

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田中　清・松浦正明：アオミドロにおける生長と分化に関する研究
IV. アオミドロ糸状体の日周期運動の型と光合成速度との密接な関係

前報で推定した「日周期運動の型と光合成の関係」を量的に確めるために，14時間明期で，(1) 種々の強さの光 (3600-400 lux) の下での運動を記録するとともに，その光合成速度を測定し，また，(2) 3600 lux の明型条件（明型の運動をする光条件）の下で，種々の濃度 (10^{-8}—10^{-5} M) の DCMU を与えて，同じく，運動の型を記録し，光合成速度を測定した。その結果，(1) 及び (2) の両実験を通して，光合成速度の高い順から，明型，中間型，薄明型，連続暗黒型の運動を示し，その対応関係は，きわめて精密であった。このことは，糸状体の運動の型の決定に，ある光合成関連物質の消長が比較的密接に関係している可能性を推定させる。(036 弘前市文京町 3，弘前大学理学部生物学科)