LIGHT-INDUCED GAS EXCHANGES IN SHORTLY ILLUMINATED INTACT ETIOLATED LEAVES MEASURED BY MASS SPECTROMETRY

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The synthesis and organization of active photosynthetic units upon the illumination of etiolated leaves involve light and dark reactions which can be studied by alternating short light periods with longer periods of darkness. Under such conditions it has been shown (1,2) that photosynthetic O_2 evolution occurred in etiolated leaves provided they had been first illuminated by 2 short (5 min) periods separated by a 2 hours dark interval. We have investigated this phenomenon on intact barley leaves (6 day-old) by measuring gas exchanges by mass spectrometry. The detection and calculation methods have been described elsewhere (3).

Upon the first illumination of etiolated leaves (fig.1A), O_2 production could not be detected. Only a slight variation of the baseline (also present in the control without leaves) was observed. Both O_2 uptake and CO_2 production were enhanced by about 30%. This effect was only partly reversed in darkness. We ascribe this result to a stimulation of respiration by light.

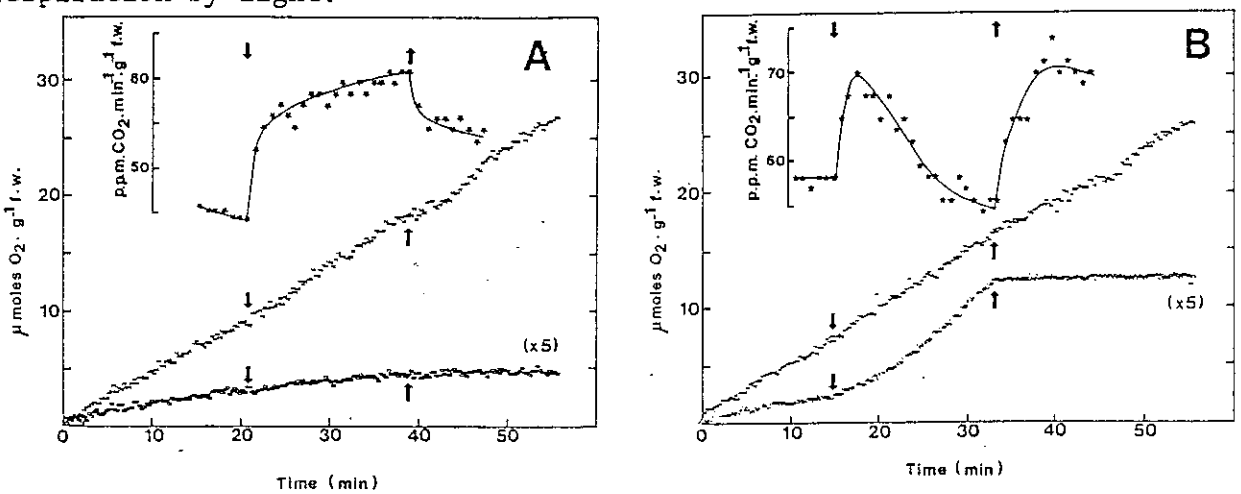
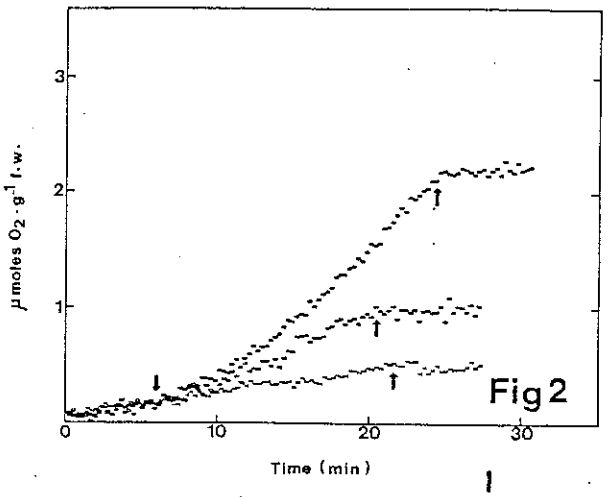


Figure 1: Variations of O_2 evolution (○), O_2 uptake (x) and first derivative of CO_2 concentration (★) during a dark to light transition. Pre-treatment of the leaves : none (etiolated) (A), 5 min white light + 150 min darkness (B) ; (↓) light on, (↑) light off ; light intensity was 500 $\mu E.m^{-2}.s^{-1}$.

When the leaves had been preilluminated with 5 min white light and then kept in darkness for 150 min, an induction of O_2 evolution with a half-time of approximately 4 min occurred during the 2nd illumination (fig.1B). The stimulation of respiration was also observed in this case, although at a somewhat reduced extent. After a rapid increase during the first 2 min of illumination the rate of net CO_2 production progressively decreased and reached a lower value than in darkness, indicating that CO_2 fixation then occurred.

It was found that the duration of the first illumination had no effect on the gas exchanges patterns at the 2nd illumination. A 40 sec pulse of blue, red or white light (all saturating for pchlide photoreduction) were equally effective. We failed in our attempt to detect a phytochrome effect by red/far-red light experiments.

Absorbance spectroscopy measurements were also carried out during similar treatment of intact leaves. After the first 40 sec illumination, the Shibata shift which is thought to reflect a dissociation of the newly formed chl-protein complexes (4) had a half-time of 5 min, while the regeneration of active pchlide occurred with a half-time of 45 min. In fig.2 we compare the light-induced variation of gas exchanges at different time intervals between the two illuminations. An induction of O_2 evolution could be detected 20 min but not 10 min after a 40 sec light pulse. Therefore the completion of the Shibata shift (which occurred within 10 min) is not a sufficient condition for the induction of a O_2 evolution to occur during a subsequent illumination. Additional measurements would be required to determine accurately the effect of regeneration of pchlide.



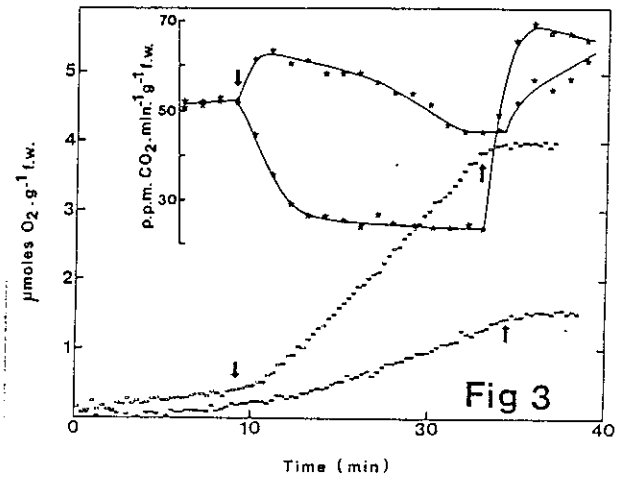


Figure 2: Pre-treatment : 40 sec white light + 10 (x), 20 (●) or 150 (○) min darkness O_2 evolution only.
Figure 3 : Pre-treatment : 40 sec white light + 150 min darkness (●,★) ; same + 40 sec white light + 20 min darkness (○,☆) ; O_2 evolution (●,○) and first derivative of CO_2 concentration (★,☆)

We found that the induction of photosynthetic gas exchanges during the 2nd illumination was strongly accelerated when a 40 sec light pulse was given 20 min before the measuring 15 min illumination (fig.3). Such a light pulse triggers the photoreduction of the regenerated pchlide and the subsequent Shibata shift. This result suggests that the pigment transformations at a 2nd illumination are involved in the process of the induction of photosynthesis.

The rate of O_2 evolution at the end of a 2nd illumination (fig.1B) was about 450 µmoles $O_2.h^{-1}.mg^{-1}$chl, which is about 50% higher than in green leaves.

abbreviations : protochlorophyllide : pchlide ; chlorophylle : chl.

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