References and Notes

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9 May 1960

"Second Emerson Effect" in the Hill Reaction of Chlorella Cells with Quinone as Oxidant

Abstract. The second Emerson effect can be observed not only in photosynthesis but also in the photoreduction of quinone by *Chlorella* cells. This shows that this effect is not due to respiration and is not associated with the carbon dioxide–reducing phase of photosynthesis. Peaks at 650 and 670 mμ in the action spectra of this effect, in the case of quinone reductions as well as in that of photosynthesis in *Chlorella,* show that light absorbed by chlorophyll *b* as well as that absorbed by chlorophyll *a* 670 can effectively supplement far-red light (> 680 mμ) in both reactions; light absorbed by chlorophyll *a* 680 cannot do so.

The enhancement of the quantum yield of photosynthesis of *Chlorella pyrenoidosa* Chick strain 3 in the far-red region (> 680 mμ) by light of shorter wavelengths was first reported by Emerson and his co-workers (*1*) and was confirmed by Myers and French (*2*). However, there existed no direct evidence that this "second Emerson effect" (so called to distinguish it from the carbon dioxide burst at the beginning of a light period, often designated as the Emerson effect) was not due, at least in part, to light inhibition of respiration rather than to the enhancement of photosynthesis, because the techniques employed (manometry and polarography) could not distinguish positive changes in the rate of photosynthesis from negative changes in the rate of respiration. There was also no evidence as to the localization of the effect, either in the oxygen evolution phase or in the carbon dioxide reduction phase of photosynthesis. It was thought that study of the Hill reaction in quinone-poisoned *Chlorella* cells should provide answers to these two questions.

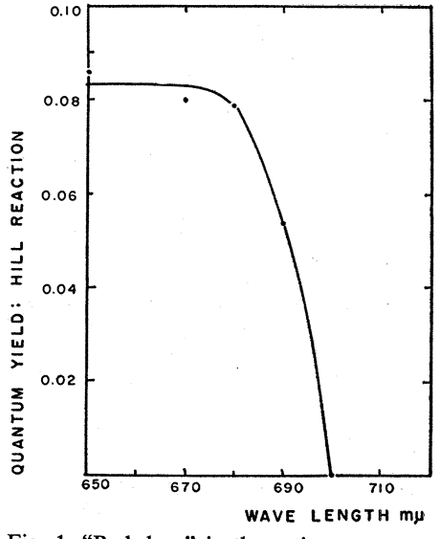

Fig. 1. "Red drop" in the action spectrum of the Hill reaction (photoreduction of quinone) in *Chlorella* cells. Quantum yield is plotted against wavelength of monochromatic light.

Para-benzoquinone (0.2 ml of a solution of 12.5 mg of recrystallized quinone in 5 ml of 0.01*N* sulfuric acid) was added to a thin suspension of *Chlorella* cells. Respiration, as well as capacity for carbon dioxide fixation and reduction, was completely inhibited by the addition of this solution. Nitrogen (99.9 percent N_2) was conducted through the manometer vessel filled with the suspension, for 15 minutes. Manometric measurements of oxygen liberation were then carried out at 10°C. Under these conditions the Hill activity lasted 4 to 5 hours.

Figure 1 shows the "red drop" of the quantum yield of oxygen liberation from quinone solution. The curve strikingly resembles that found for photosynthesis by Emerson *et al.* (*3*).

Figure 2 represents the action spectrum of the second Emerson effect in the quinone-*Chlorella* system. The results were obtained as follows: far-red light was applied to the suspension by placing Schott glass filters (RG8 and RG5, which give a sharp cutoff at 680 mμ) in the beam from an incandescent lamp. The rate of the Hill reaction in this light alone was taken as 100; the rate attributable to this light in the presence of additional shorter-wave light (between 640 and 690 mμ), obtained from the Emerson-Lewis grating monochromator (slit width, 5 mμ) was expressed as a percentage of that in the far-red light alone. In Fig. 2 the results are plotted against the wavelength of the supplementary light.

Govindjee and Rabinowitch (*4*) have demonstrated the existence of (at least) two forms of chlorophyll *a* in *Chlorella*, with different photochemical functions, with absorption peaks around 670 and 680 mμ, respectively. Light absorbed by the first form, like light absorbed by the accessory pigments, can bring about the second Emerson effect; this is revealed by the action spectrum of the second Emerson effect in the photosynthesis of *Chlorella*, which shows two

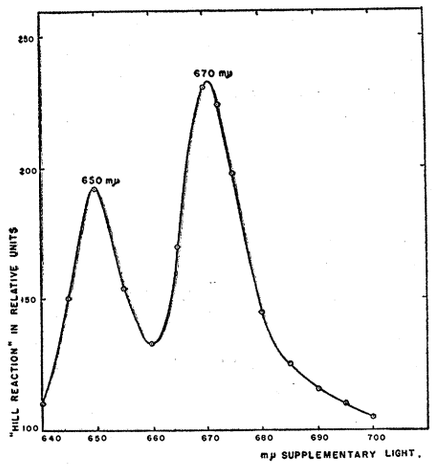

Fig. 2. Action spectrum of the second Emerson effect in the Hill reaction of *Chlorella*. Yield without supplementary light is designated as 100.

peaks in the red region—at 650 mμ (chlorophyll *b*) and at 670 mμ.

In the action spectrum of the second Emerson effect in quinone reduction we find the same two peaks (at 650 and 670 mμ, respectively) as in photosynthesis. This means that in the photoreduction of quinone by *Chlorella* cells, as well as in photosynthesis, the two types of chlorophyll *a* (chlorophyll *a* 670 and chlorophyll *a* 680) play different photochemical roles and that light energy absorbed by chlorophyll *b* probably is transferred to chlorophyll *a* 670.

The complete analogy between photosynthesis and the Hill reaction suggests that the second Emerson effect is not due to the inhibition of respiration and is not associated with the carbon dioxide-reducing mechanism of photosynthesis but with the oxygen-liberating mechanism common to photosynthesis and the Hill reaction (*5*).

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