PHOTODYNAMIC INJURY TO HEATED LEAVES
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Summary. The leaves of Tradescantia fluminensis Vell, were kept in light and darkness after short-term heating (5 min and 10 min) at different temperatures. In light temperature causing injury was 10⁴ lower than in darkness. A considerable destruction of chlorophyll occurred when the heated leaves were kept in light. If the light intensity was 4,000 lux or even lower the damage to cells was not accompanied by bleaching of chlorophyll. Light produced no effect on unheated leaves. In variegated white-green leaves of Chlorophytum elatum R. Br. light injured only green parts of leaf blades. The minimal light intensity which brought about injury of Tradescantia leaves in experimental conditions was 1,000 lux. Light of the same intensity accelerated death of heated isolated leaves of Cucumis sativus L.

Light damage to Tradescantia leaves occurred when the action of light was accompanied by that of high temperature.

In an atmosphere of nitrogen the injurious effect of light sharply decreased.

It is suggested that the injury of heated leaves in light is caused by photooxydation which is sensitized by chlorophyll and occurs at the expense of photochemical energy which is not used in photosynthesis. Photosynthesis itself is repressed by heating.

Introduction

As early as 1925—1926 NOACK discovered that in the leaves of lower and higher plants in which photosynthesis is inhibited either because of the absence of CO₂ or by the action of phenilureten, tobacco smoke, or sulphur dioxide, light induces destruction of chlorophyll and cell death. He came to the conclusion that in the case of inhibited photosynthesis photochemical energy of chlorophyll is spent on photooxidation of protoplasm and pigments of chloroplasts themselves (NOACK 1925, 1926a, b). In some later works a similar results was obtained when photosynthesis was represses by acids, alkali (WEINER, 1928), or nicotine (MOTHEs and ROMELKE, 1954) or by the removal of CO₂ (FRANCK and FRENCH, 1941). In Chlorella mutants incapable of photosynthesis illumination also results in the destruction of pigments (KANDLER and SCHÖTZ, 1956). Under anaerobic conditions light neither destroys chlorophyll nor causes damage of cells in which photosynthesis has stopped (FRANCK and FRENCH, 1941; KANDLER and SCHÖTZ, 1956). These findings indicate that the mechanism of the destructive effect of light on the cells with inhibited photosynthesis is nothing but photooxydation. Chlorophyll in this case plays the part of a photodynamic agent. In vitro chlorophyll has been known to be a typical photodynamic dye for a long time (HAUSMANN, 1908; HAUSMANN and KOLMER, 1909).
Now there is evidence indicating that the light damage to plant cells may be induced also by low temperatures, both above (Hager, 1957; Kislyuk, 1963, 1964a, b, c, d) and below zero (Riet et and Sagromsky, 1964). Most of the authors also suggest that the rôle of light is that of a photooxydizing agent of living protoplasmic components at the expense of light energy which is not used for photosynthesis under conditions of low temperatures. This energy is rather used by chlorophyll for photooxydation under these conditions.

Rabinowitch (1951) concludes that the inhibition of photosynthesis irrespective of the agent decreases the light resistance of chlorophyll in vivo. Extending this point of view it may be suggested that the stability of chlorophyllous plant cells toward any agent which inhibits photosynthesis must be considerably decreased during illumination. High temperatures can serve to inhibit photosynthesis. It is known that photosynthesis is depressed by lower doses of heating as compared with a number of other functions of the cell (Alexandrov, 1955, 1964a; Rabino-\textit{w}itch, 1959). Hence it may be expected that living and viable plant cells in which photosynthesis is even temporarily repressed by heating can be considerably injured or killed by light as a result of a photodynamic effect. The purpose of the present work was to verify the above suggestion.

**Materials and methods used for estimation of damage**

The leaves of \textit{Tradescantia fluminensis} Veill. were used as the main object of investigation. The leaves of \textit{Cucumis sativus} L. and \textit{Chlorophytum clatum} R. Br. were used in some experiments. Mercury fluorescent lamp DRL-500 served as a light source. A water filter protected leaves and plants from the action of heat.

The following different criteria were used to determine the degree of damage:

1. Calculation of the relation between injured and uninjured area measured by means of a planimeter. The injured area of leaves could be distinguished by its characteristic brown or yellow colour. In doubtful cases the boundaries of the injured area were determined by the presence of plasmolysis in 1 M KNO\textsubscript{3}. 2. The presence or absence of cell protoplasmic streaming as shown by microscopic analysis of the leaves (oc. 7×, ob.W.L.40×). 3. Determination of the chlorophyll content in the leaves, expressed as per cent of fresh leaves content. Chlorophyll was extracted with ethyl alcohol and its solutions were examined by a photometric method in a photoelectrocolorimeter. 4. The capacity to recover photosynthesis in damaged leaves. The measurements of photosynthesis were made radiometrically (Zalesnskii, Semikhatova and Vozenesenskii, 1955) at 22° C and 30,000 lux (10 min exposure).

**Light damage of isolated leaves after heating**

Immediately after cutting the leaves were immersed for 5 min in water heated to a definite temperature in a thermostat. Subsequently one group of leaves were transferred to a moist chamber and exposed to light, while the others were placed in the dark for 48 hr. The air temperature in both cases was the same and ranged from 21° C to 22° C. The