Biochimica et Biophysica Acta (BBA) - Bioenergetics

Volume 180, Issue 2, 24 June 1969, Pages 302-319

Conformational changes of chloroplasts induced by illumination of leaves *in vivo*

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https://doi.org/10.1016/0005-2728(69)90116-9

Abstract

Upon illumination leaves showed both fast absorbance changes and a slow increase in their apparent absorbance (maximum at about 530 mÎ¼) which appeared to be caused by a light-dependent shrinkage reaction of chloroplasts. The extent of shrinkage was strongly influenced by the quality and intensity of exciting light and by the presence or absence of electron acceptors. The following observations pertain to the control of electron flow within the electron transport chain of photosynthesis.

1. 1. In N_2, shrinkage was promoted by either far-red light or low intensity red light which caused a mediated cyclic electron flow to occur in Photosystem I. Shrinkage was inhibited by illumination with high intensity red light.

2. 2. Addition of red to a beam of far-red light illuminating a leaf under N_2

stimulated shrinkage if the intensities of both beams were sufficiently low and led to inhibition of shrinkage if the red beam was intense. A dark period was required to relieve inhibition.

3. 3. In CO_2-free air, O_2 was an electron acceptor and caused shrinkage at higher intensities of red but not at low intensity far-red light. Shrinkage promoted in N_2 by far-red or low intensity red light was strongly suppressed by O_2 which appeared to interrupt cyclic electron transfer by oxidizing an electron acceptor in the pathway between Photosystem I and $NADP^+$. This view was supported by measurements of cytochrome *f* changes at 420 mÎ¼. Action spectra indicated also that shrinkage in N_2 was a Photosystem I reaction, while in the presence of O_2 Photosystems I and II cooperated to produce shrinkage.

4. 4. While shrinkage was greatly stimulated by low concentrations of O_2, when both photosystems were sufficiently excited, increasing O_2 concentrations suppressed shrinkage increasingly in the investigated plant species possibly by inhibiting electron flow.

5. 5. The affinity of the shrinkage reaction for O_2 was high. Half maximal stimulation or inhibition of shrinkage was obtained at an O_2 concn. of about 1.4 Î¼M in the tissue or 1200 ppm in the gas phase. Half maximal fluorescence quenching by O_2 occurred at a similar concentration. The kinetics of shrinkage and of fluorescence during a change in the gas atmosphere from N_2 to CO_2-free air or *vice versa* were similar indicating that the effects of O_2 on the redox state of the quencher and on the shrinkage were indirect and were both mediated by the same reaction of O_2 with a component of the electron transport chain beyond Photosystem I.

6. 6. Shrinkage caused by electron flow to O_2 in air or by the cyclic electron flow in N_2 was effectively suppressed by CO_2. However, CO_2 relieved the inhibition of shrinkage caused by high intensity red light under N_2 probably by stimulating electron flow. The affinity of the system for CO_2 as judged by the ability of CO_2 to act as a fluorescence quencher in N_2 in blue light or as an inhibitor of shrinkage in far-red light was higher than that for O_2. Half maximal response was obtained in leaves capable of high rates of photosynthesis at a CO_2 concn. in the gas phase of 10â€“20 ppm.

7. 7. The results indicate that CO_2 and O_2 *in vivo* both act as electron acceptors of photosynthesis; O_2 reduction probably supplies ATP in a pseudocyclic type of

photo-phosphorylation. Cyclic electron transfer in the presence of O_2 is unlikely to occur except under conditions where the reaction reducing O_2 is saturated. The observations support the series model of photosynthesis and do not seem to fit into a model with separate and independent photoreactions.

Previous article

Next article

Abbreviations

DCMU, 3-(3â€²,4â€²-dichlorophenyl)-1,1-dimethylurea; CCCP, carbonylcyanide *m*-chlorophenylhydrazone; FCCP, carbonylcyanide *p*-trifluorophenylhydrazone

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