Effects of Previous Light Exposure on Respiration Rate and Dry Weight of Sugar Beet Leaves[1]

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Introduction

Previous attempts to relate respiration rates of sugar beet leaves to variety or ploidy level have been unsuccessful because of extreme variation among samples. Considerable variation was found between different leaves of the same plant sampled at the same time, but much greater variation occurred between samples taken at different periods of the day. Attempts by McNulty[3] to relate respiration rates of sugar beet leaves to variety or salinity of the culture solution were unsuccessful because of the same erratic behavior. Went (1)[4] suggested that translocation of sugars from leaves to the roots may be a limiting factor in photosynthesis of sugar beets. The present studies were undertaken to investigate some of the causes of this extreme variation among samples, and to determine if translocation of substrate might be related to the erratic respiratory behavior.

Material and Methods

Sugar beets growing in a large soil bed in the greenhouse were used. Half-leaf covers were placed on the leaves during daylight. During the later part of the study, in which half-leaves were exposed following 16 to 20 hours of darkness, potted plants of the hybrid variety SL202H9 were used. The half-leaf covers shown in Figure 1 were made from cardboard boxes 10 inches long, 6 inches wide, and 4 inches deep. A piece of stiff cardboard was stapled along the front bottom half of the box about 1 inch from the top and extended slightly beyond each end. The box was cut along this heavier piece to within about 1 inch of each end. The top half of the box was then hinged at the back, level with the front piece on the bottom half. Lip-perforations were made in the bottom of the box to allow air circulation while excluding light.

A small rubber band was placed around a petiole and inserted through a small hole in the box to hold the petiole firmly. The

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[3] Private Communication.

[4] Numbers in parentheses refer to literature cited.

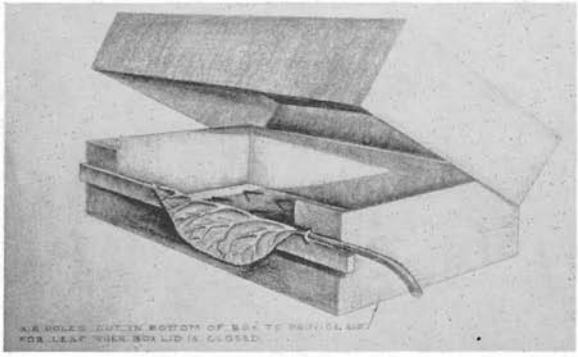

Figure 1.—Half-leaf covers used to keep one side of leaf in darkness while exposing the other side to sunlight.

top half of the box was then closed along the midrib of the leaf and held in place by a large rubber band.

Following unilateral exposure, uniform samples of 19 × 66 mm were cut from each side of each leaf by means of a sharpened, rectangular metal cutter. The samples were loosely rolled and inserted into Warburg vessels. Following a 15-minute equilibrium period at 20° C, manometers were closed and readings taken for a period of 1 hour. The samples were then removed, dried overnight at 65° to 70° C, and weighed. All data are reported as percentages of the respiration rate or dry weight of the unexposed or darkened halves of the same leaves. Each point on the figures represents the average of six, single-leaf comparisons.

Experimental Results

The data in Figure 2 show the response of half-leaves left in sunlight in relation to similar halves of the same leaves that were covered for varying periods before testing. Although the data show considerable variation in dry weight and respiration rate, all showed the same trends resulting from shading. Light intensity was not measured, but tests were run only in bright sunlight. The data indicate a progressive increase in respiration rate and dry weight of half-leaves left exposed to sunlight for more than 1 hour. The correlation value between respiration rate and dry weight was positive ($r = +.331$). This was not significant at the 5% level, possibly due to the small number of observations.

The data in Figure 3 show a much more rapid response of leaves kept in the dark for 16 to 20 hours before unilateral light exposure. An exposure of only 3 to 5 minutes caused a rapid increase in respiration rate of half-leaves that were exposed to

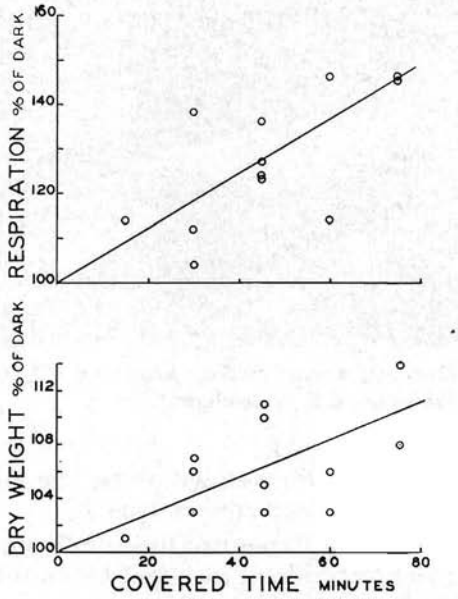

Figure 2.—Respiration rate and dry weight of sugar beet leaves, previously exposed to sunlight, following covering one half of each leaf. Points on figure represent the average of six leaves on separate plants. Data are in percent of the values of the covered part.

sunlight. The data also indicate a possible reduction in the dry weight of half-leaves exposed for only 2 or 3 minutes. The correlation value between respiration rate and dry weight was highly significant ($r = +.716^{**}$).

Discussion

The data indicate a very wide variation in dry weight or respiration rate of leaves, depending on the exposure to light immediately before sampling. Even with carefully matched halves of the same leaves, this variation was large enough to overshadow varietal differences. Variation in age of leaves would further increase the differences observed previously.

Respiration rate appears to be correlated with the concentration of respiratory substrate in the leaves. Leaves kept in the dark before exposure to sunlight were probably quite low in respiratory substrate, but they responded very rapidly as indicated by both respiration rate and increased dry weight. The indicated loss in dry weight due to the first few minutes of exposure probably was caused by the increased respiration rate during the 1½ hours before the leaf tissue was put in the drying oven.

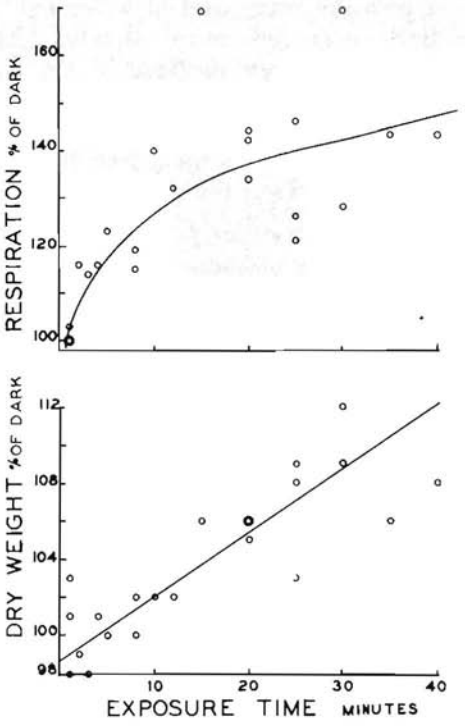

Figure 3.—Respiration rate and dry weight of half-leaves of sugar beets previously kept in darkness, following exposure to sunlight. Data are in percent of the values of the covered part.

Recent studies by the author indicate this rapid photosynthetic response to light to be in sharp contrast to the apparent photosynthetic rate data as measured by carbon dioxide uptake in a sealed chamber. In the sealed chamber, a slight increase in CO_2 concentration of air surrounding the plant was frequently observed when the lights were turned on leaves previously kept in darkness. In the latter case, high concentrations of CO_2 and or partially metabolized substrate in the leaf tissues apparently supplied much of the carbon used in photosynthesis during the first hour or more of illumination at a light intensity of 3800 foot-candles. This study will be reported later in detail.

Summary

Fixation of carbon dioxide by sugar beet leaves previously kept in darkness for several hours occurred very rapidly when the leaves were exposed to sunlight. Respiration rate of the leaves increased rapidly after only a few minutes of exposure.

Reduction in respiration rate and dry weight of half leaves shielded from light occurred more slowly. Respiration rate appears to be stimulated by an increase in the concentration of substrate in the leaves at the time of sampling, although the magnitude of the stimulation may not always be proportional to the concentration of substrate as measured by dry weight. It is evident that other factors also influence leaf respiration.

Literature Cited

(1) WENT, F. W. 1954. The physiology of the growth of sugar beets. Proc. Am. Soc. of Sugar Beet Technol. 8 (2): 319-324.