Photosynthesis Under Field Conditions. I. A Portable, Closed System for Determining Net Assimilation and Respiration of Corn

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THERE are numerous combinations of environmental factors affecting crop yield which occur during the season and vary from day to day or from season to season. It is extremely difficult to evaluate the effect of a particular factor or combination of factors occurring during any specific short period of the season unless data are available describing environments and yields for many years. Harvests before and after short-term treatments of observed combinations of environmental factors have not been successful in measuring the net assimilation of corn during such periods. On the other hand, assimilation or respiration of corn growing under field conditions can be determined accurately and almost instantaneously by measuring the amount of carbon dioxide absorbed or released by the plants. The summation of net assimilation over the season should be very nearly equal to total yield and should be related to the economic component of total yield. Therefore, it seemed desirable to measure daytime assimilation and night respiration over short periods. A system capable of determining minute amounts of assimilation or respiration in the field is described in this paper and its accuracy and utility are discussed.

In order to determine the change in carbon dioxide concentration within a field plot, it is necessary to isolate the plot in some way. Previously two notable attempts have been made to determine the rate of photosynthesis of growing plants on a field plot scale by a gas exchange technique. Both of these attempts were made in the early 1930s. Heinicke and Childers (1) enclosed an apple tree of bearing age in a glass covered, wood-framed chamber which measured 7 by 7 by 11.5 feet and determined the rate of photosynthesis during the growing season for periods as short as 5 hours during the day and respiration for a 12-hour period at night. Thomas and Hill (3) determined the rate of photosynthesis and respiration of alfalfa, sugar beets, and wheat at 64-minute intervals growing in 6- by 6-foot field plots beneath celluloid-covered iron-framework chambers. The same principle of operation was used in both of these studies. Air was continuously drawn into the assimilation chambers, mixed inside the chamber and exhausted through an outlet pipe. A measured subsample was taken of the air at the intake and from the exhaust stream and the difference in concentration of carbon dioxide determined at these two sampling points. The volume of air passing through the chambers was calculated from data on the air stream velocity as measured by an anemometer in the exhaust stream.

The carbon dioxide was absorbed in basic solution and determined by titration (Heinicke and Childers) or electrical conductance (Thomas and Hill). In recent years the development of infrared gas analyzers suitable for analyzing for carbon dioxide have opened entirely new possibilities in this type of research by allowing rapid and accurate determination of carbon dioxide without the need of elaborate sampling arrangements and laboratory facilities. In the system described in this paper, the analyses for carbon dioxide were made with a Liston Becker Model 15A Infra-red gas analyzer. These data were recorded directly by means of an Esterline-Angus Model AW single trace recorder.

PROCEDURE

Construction and Use of Chambers

The assimilation chambers were designed as a tool to study the effect of various climatic factors on the growth of field corn. It was recognized that placing a chamber over the corn imposed a somewhat artificial environment upon the crop. It was desired to make the environment inside the chamber as nearly as possible like the environment outside the chamber. To prevent any accumulative effects from the chambers themselves required that the chambers be portable so they could be periodically moved to "fresh" corn. Therefore, bulky equipment could not be used in constructing the assimilation chambers. The fairly large fans and air ducts necessary to draw a continuous air stream through the assimilation chambers could not be easily adapted to a portable enclosure. For this reason, a "closed system" was designed in which the air remaining during periods of active photosynthesis and the CO₂ supply was manually replenished at a rate equal to the rate at which it was used by the plants. The measure of assimilation was then the metered amount of CO₂ necessary to keep the concentration at the desired level.

Data for respiration at night were obtained by periodically replacing the air in the chambers with outside air. As the plants respired, the concentration of CO₂ increased in the chambers. By recording this increasing concentration during the interim periods between replacements, the necessary data to calculate respiration were obtained.

Two identical assimilation chambers were designed for this work. Two-inch by two-inch lumber was used for the frame. This was covered by a three-mil thickness transparent film sold under the trade name "Weatherable Mylar". "Mylar" has an extremely low permeability to CO₂ and a high resistance to puncture and tearing. The film was attached to the frame to form a gas tight seal. The chambers were 9 feet long, 5 feet wide, and 12 feet high to the center of the roof. When placed over 2 rows of corn 29 inches apart, the chambers enclosed 1/1000 of an acre and contained approximately 30 corn plants.

The chambers weighed approximately 250 pounds and could be easily carried by 4 men. The end panels, to a height of five feet, were removable to facilitate moving the chambers in mature corn. Each chamber had a hinged door in one end for easy access to the inside.

A motor-operated flap was built into one end at the top of each chamber as an air intake for exchanging the air in the chambers during respiration studies. This intake was 11 feet above the ground, placing it above the tassels of the mature corn. At one side on the bottom of each chamber an exhaust opening and flap were constructed. This was controlled by the same motor which operated the intake flap. A fan was installed in the exhaust opening and the combination wired so that the exhaust fan was in operation whenever the flaps were in the open position.

Before the chambers were placed over the corn a rib floor was placed between the corn rows and covered with polyethylene film. The edge of the film was slit for each corn stalk and then drawn tightly around the stalks and attached to the rib floor on the opposite side of the row of corn. When this was done from both sides of the row and the two sheets of film cemented together around the stalks, a seal was obtained which prevented the CO₂ produced in the soil from entering the growth chambers.

1 A contribution of the Department of Agronomy of Cornell University, Ithaca, New York, Department Series Paper 501.
2 Professor and former Assistant (now Assistant Scientist at The Connecticut Agricultural Experiment Station, New Haven, Conn.), respectively.
3 Contributed by E. I. Dupont de Nemours & Co., Wilmington, Delaware.