AN EXAMINATION OF THERMAL METHODS FOR FOLLOWING MICROBIOLOGICAL ACTIVITY IN SOIL

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When energy materials are utilized by microorganisms, the main end-products are carbon dioxide and water, but at the same time some heat is liberated. The determination of CO₂ evolution has been widely used as an index of microbiological activity, but the measurement of amount of heat evolved, or rise in temperature of the substrate, is theoretically a more satisfactory index. The soil population is ordinarily not confronted with an excess of readily available energy material, and therefore the amount of heat that may be expected to be produced is small. Moreover, the specific heat of moist soil is high so that only small changes in temperature are likely to occur. With sufficiently sensitive equipment, however, these should be readily detectable. Readings taken by such a thermal method would be considerably more rapid than determinations of CO₂.

There have been numerous studies of heat evolution by vigorous bacterial cultures in liquid media, and sensitive microcalorimeters have been devised for this purpose. Neither these, nor the equipment used in the investigation of thermogenesis by decomposing plant materials, are well suited for use with soil. Of direct application to this problem is the work of such authors as van Suchtelen (1, 2) on the energetics of soil microbiological processes. His papers are largely theoretical, and experimental details are scanty. He employed Dewar flasks as containers for soil, and measured temperature changes with Beckmann thermometers, expressing them both as degrees rise and calories per hour. Recently, Reinau (3) has employed the same procedure in attempting to arrive at a basis for prediction of the fertilizer requirements of soil. In his “thermo-kinetic” test sucrose is added to soil, with and without N, P, and K sources, alone or in combination. Temperature changes are measured by a Beckmann thermometer every few hours for two days, and from comparisons of the time-temperature curves obtained from the variously treated samples, recommendations of fertilizer requirements are made. Although the claim is not specifically made, nevertheless the principle involved appears to be that fertility is directly related to microbial activity, or at least that a soil of high fertility is one in which intense microbial activity is always present.

EXPERIMENTAL PROCEDURE

Containers.—Containers for the soil samples must be uniform and low thermal loss. Dewar flasks, pieces of approximately uniform heat loss ratings were used. These provide a more satisfactory surface/volume ratio than the bottle type of equal volume. The internal dimensions approximately 2¾ x 6 inches.

Measurement of temperature changes.—Inasmuch as the amount of heat evolved by microorganisms in soil is small, temperature changes must be determined by means of small thermocouples. Beckmann differential thermometers or electrically are preferable both on the grounds of accuracy and the considerable number of samples that are under study. In order that external temperature changes shall not interfere with the results the Dewar flasks must be maintained at constant temperature for both the reference and the sample.

The simplest electrical method of determining temperature change involves the use only of a sensitive galvanometer or a potentiometer. The determination of the difference in e.m.f. between two thermocouples, one of which is maintained at constant temperature as reference. Water in a sealed flask in equilibrium with the room temperature will serve as the reference. Copper-constantan thermocouples of wire were enclosed in thin-walled glass tubing and placed in the soil and a reference liquid. One thermocouple was led to a multiple switch to facilitate consecutive measurements of a number of samples. A Leeds and Northrup type potentiometer of low resistance was employed (critical damping resistance — 18 ohms, period — 5.8 sec; resistance — 15 ohms). By incorporation of appropriate resistances in the circuit the scale deflection can be made independent of zero point shift. The insertion of a 40-ohm resistance in parallel and 150-ohm resistance in series was found desirable. Calibration was carried out by means of Beckmann thermometers. Difficulties arose, however, from zero point shift. With deflections of moderate amplitude, this was probably unimportant, but all attempts to secure a stable reading were unsuccessful. This difficulty may have been inherent in this particular galvanometer. A more satisfactory reading is obtained from a number of samples giving deflection amplitudes, because the degree of zero point shift is affected by the magnitude of the previous deflection. This difficulty may have been inherent in this particular instrument.

Accordingly, the temperature changes were measured potentiometrically, using the galvanometer as a null point indicator. The potentiometer was a Leeds and Northrup type instrument, and a melting ice cold-junction was used as the reference. The thermoelectric power of a copper-constantan thermocouple in the range of 20° to 30° C is 39.6 microvolts per degree. This system was found entirely satisfactory. The galvanometer was highly sensitive.

RESULTS

Non-biological causes of thermal changes...