

DIVISION S-7—FOREST AND RANGE SOILS

Oxidation-Reduction Potential of Saturated Forest Soils

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ABSTRACT

Large decreases in redox potentials of saturated soil over a 25-day incubation period were favored by high temperature and the addition of sucrose, loblolly pine needles (*Pinus taeda* L.), or yellow-poplar leaves (*Liriodendron tulipifera* L.). The addition of a complete nutrient solution had no effect in soils incubated with sucrose, but it reduced the drop in potential in soils incubated with tree litter at 21-27°C. The data suggest the need for care when evaluating soil aeration by means of redox potentials and the dominant role of soil microorganisms in activating redox systems.

Additional Key Words for Indexing: anaerobic, microorganisms.

A POPULAR METHOD of characterizing soil aeration is measurement of the oxidation-reduction (redox) potential of the system. Established by Gillespie (4), the method has been useful in investigations of forest soils and

humus (3, 6, 8, 9). The study described here measured the influences of substrate, temperature, and nutrient status on redox potentials in saturated soils.

PROCEDURE

Subsoil from an undetermined depth was collected in November from a fresh construction grading on the Duke Forest at Durham, North Carolina. The yellow-red coloration suggested an oxidized state. Organic-matter content was low (0.70%).

Freshly fallen needles of loblolly pine (*Pinus taeda* L.) and leaves of yellow-poplar (*Liriodendron tulipifera* L.) were collected in November, air-dried, and ground. Yellow-poplar leaf particles were not over 3 mm² in area, and the loblolly needle particles were not over 20 mm in length.

Approximately 80 g of soil that had been air-dried and passed through a 2-mm screen was placed in each of 32 small screw-top jars. The designated substrate (5% by weight) was then mixed with the soil. Substrates were sucrose, loblolly pine needles, yellow-poplar leaves, and check (no additive). Half of the jars received 80 ml of distilled water, and half received 80 ml of a complete nutrient solution. Two incubation temperatures were tested: 21-27°C and 5°C.

The design was a split-split plot with 2 replications. Major plot treatments were temperatures, subplot treatments were nutrient levels, and the sub-subplots were substrate differences.

Immediately after the substrate had been mixed in, redox potentials were measured with a Photovolt pH meter, model 115, with calomel and platinum wire electrodes. To avoid formation of platinum oxide, the platinum electrode (5) was

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washed between each reading with 2N HNO₃, distilled water, 2N NH₄OH, and distilled water again (1).

After potentials had been measured, the pH of each sample was determined. Redox values were then adjusted to a common pH of 5.0 (the original pH of the soil) with a correction factor of 0.06 volt per pH unit (5). Redox potential and pH were read at 2, 4, 6, 9, 13, and 25 days after the start of incubation.

RESULTS

Total changes in redox potential for the entire incubation period, rather than absolute values, are shown in Table 1. Decreases were favored by the higher temperature and the addition of organic substrate. In general, incubation with sucrose led to lower potentials than were obtained with ground needles or leaves (the differences probably would have been less with a longer incubation period, since then the litter might have broken down more completely). The potentials of soil incubated with yellow-poplar leaves decreased faster than did those of the soil incubated with pine needles, but the difference was small.

At 21-27C, the addition of nutrients decreased the drop in redox potential of soil to which plant organic matter had been added, but did not affect potentials of soil incubated with sucrose. At 5C, reducing potentials developed slowly and were small.

An analysis of variance indicated highly significant effects (0.01 level of confidence) of all treatments and their interactions.

The data suggested that anaerobic microorganisms had greatly influenced the changes in redox potential. To test this hypothesis, 4 bottles were each filled with 150 g of soil saturated with distilled water, to which sucrose (5% by weight) was then added. Two bottles were autoclaved for 1 hour at 15 lb/in² and 121C, and all four were then stored at room temperature. After 4 days the autoclaved soil showed a slight increase in potential (+40 and +27 mv), while the untreated soil had decreased considerably in potential (-129 and -106 mv). These results support the statement by Stephenson et al. (10) that organic matter alone does not cause a change in potential.

DISCUSSION

The data demonstrate a vital role of anaerobic microorganisms in the activation of redox systems in waterlogged soils. In situations favorable to microorganism activity—high temperature and adequate nutrients—redox potentials declined sharply under anaerobic conditions. When proteinaceous or other oxidizable substances constitute the food base under aerobic conditions, positive potentials would be expected (2).

Although redox potentials should be regarded primarily as measures of the intensity of a system's energy (1, 6, 7), substantial capacitative effects were evident in the most

Table 1—Changes in redox potential in saturated soils incubated for 25 days (average of 2 replicates)

Substrate	21-27C		5C	
	Distilled water	Nutrients	Distilled water	Nutrients
	mV/mv			
No additive	+ 70	- 30	+36	- 6
Sucrose (5%)	-676	-682	-76	- 55
Pine needles (5%)	-608	-106	-60	- 85
Yellow-poplar leaves (5%)	-660	-102	-82	-121

active reducing systems. Total reduction energies developed in samples with organic additives at 21-27C were sufficient to cause substantial gleying of relatively well-oxidized yellow-red subsoil materials during the 25-day incubation period. These gleyed samples had the overall appearance and characteristic displeasing odor of materials freshly drawn from a coastal gum swamp. Saturated soils without organic supplements retained their original bright coloration, as have similar samples stored in a saturated state for more than a year in the junior author's laboratory.

Oxidation-reduction potentials should not be regarded solely as quantitative indices of soil aeration conditions. Soil redox systems reflect complex mixtures of reactants including metals, organic compounds, and gases. Negative potentials are indicative of strong reducing conditions which are characterized not only by oxygen deficiencies but also by increased solubility of iron, aluminum, and manganese, and by accumulation of hydrogen sulfide, methane, and hydrogen. Interpretation of such measurements as responses to oxygen supply alone are apt to be misleading.

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