EXERCISE 9

Soil Temperature and Atmosphere

OBJECTIVES

1. *To observe how soil temperature is affected by soil moisture, soil texture, and organic residue*
2. *To calculate the total energy adsorbed by soils in a given period of time*
3. *To observe how flooding changes the soil atmosphere and the redox potential of a soil*

INTRODUCTION

Soil Temperature

Soil temperature has significant impact on many soil properties, such as chemical reactions, microbial growth, and plant growth. Chemical reaction rates increase as soil temperature increases. The Q_{10} is a rule-of-thumb that says that the rate of a chemical reaction will double for every 10°C increase in temperature. Therefore, soil temperature is important in determining the chemical dynamics of a soil and ultimately, the nutrient supply for plants. Soil temperature also affects which members of the microbial population are active at any given time and the rate of their biochemical reactions. In addition, soil temperature affects the rate of plant root growth and biochemical activity. In the spring, many seeds do not germinate until the soil warms to a certain temperature, and if the seeds do germinate their root systems will tend to grow more slowly in cool soils.

The primary source of heat energy for soils is from solar radiation. Pathways of energy adsorption within the soil are direct and indirect, with most soil heat energy coming from the direct adsorption of solar radiation and diffuse scatter radiation.

Once solar radiation is adsorbed by the soil, the increase in soil temperature is a function of several factors including soil water content, the amount of organic residue on the surface, soil texture and slope aspect. Of these factors, soil water content has the most affect on the rate at which soils warm and cool. The large specific heat of water requires large quantities of energy must be acquired in order to increase the temperature of the water. Therefore, wetter soils are buffered against temperature changes, they will warm up and cool down slower than drier soils. **Specific heat** is defined as the amount of energy (cal) needed to raise 1 g of material 1°C (Eq. 9.1). Soil solids and water have different specific heats. The specific heat for soil minerals and water are 0.2 cal g^{-1} $°C^{-1}$ and 1.0 cal g^{-1} $°C^{-1}$, respectively.

$$\text{Specific Heat} = \frac{\text{cal}}{\text{g }^{\circ}\text{C}} \qquad \textbf{Eq. [9.1]}$$

Therefore, the energy needed to raise 24 g of soil minerals and 5.4 g of water 1°C is given in the following example.

$$\text{Energy} = (\text{mass}_{\text{soil}} * \text{Specific Heat}_{\text{minerals}}) + (\text{mass}_{\text{water}} * \text{Specific Heat}_{\text{water}})$$

$$\text{cal} = \left(24\ \text{g}_{\text{soil}} * \frac{0.2\ \text{cal}}{\text{g}_{\text{soil}}\ {}^{\circ}\text{C}}\right) + \left(5.4\ \text{g}_{\text{water}} * \frac{1.0\ \text{cal}}{\text{g}_{\text{water}} * {}^{\circ}\text{C}}\right) = 10.2\ \text{cal}$$

There are many pathways for heat loss from soils, including reradiation, evaporation transpiration, and reflection.

Soil Atmosphere

The amount of air in the soil has a major effect on biological and chemical reactions in the soil. Soil air contains the same constituents present the atmosphere, but in different concentrations (Table 9.1). In general, soils have lower O_2 and higher CO_2 concentrations than the atmosphere due in part to respiration of plant roots and soil microbes. Respiration can be summarized by the reaction:

$$C_6H_{12}O_6 + 6O_2 \leftrightarrow 6CO_2 + 6H_2O + \text{energy}$$

Table 9.1. Average amount of compounds found in the soil and in the atmosphere

	Air	Soil
Compound	(%)	
N_2	78	78
O_2	21	20
CO_2	0.035	0.5
H_2O	20-90	95-99

Respiration is the conversion of reduced C to oxidized C resulting in the release of energy. During respiration, O_2 is used as the terminal electron acceptor thereby allowing organisms to carry out aerobic respiration. When O_2 is not present, some organisms are capable of using other compounds as an electron acceptor for alternate respiration pathways. To determine if a molecule is being used as an electron acceptor, one can measure the redox potential (Eh) of a soil in voltage (V). Compounds that undergo redox reactions do so at characteristic Eh values. Therefore, by knowing the Eh of a soil we can establish which form (i.e. oxidized or reduced) of an element is present (Table 9.2). If the Eh measurement is more positive than the characteristic Eh value, then the oxidized form of that compound or element is present. If the Eh measurement is more negative than the characteristic Eh value, then the reduced form is present. For example, a soil with a measured Eh of 0.220V would indicate that most of the manganese would be in the Mn^{2+} state but the iron would be in the Fe^{3+} oxidation state.

Table 9.2. Characteristic redox potentials (Eh) for selected compounds which are often present in the soil

Element	Oxidized Form	Reduced Form	Eh (V)
O	O_2	H_2O	0.400
N	NO_3	NH_4	0.300
Mn	Mn^{4+}	Mn^{2+}	0.250
Fe	Fe^{3+}	Fe^{2+}	0.200
S	SO_4^{2-}	H_2S	-0.500
C	CO_2	CH_4	-0.100

Review Questions

1. Why does it take longer to heat a wet soil versus a dry soil?
2. Why is soil temperature important for plant growth?
3. What are the ways heat energy is lost from the soil? Which one is most important?
4. Why does the composition of soil air differ from the atmosphere?

REFERENCES

Jacobs, H.S. and R.M. Reed. 1964. Soils Laboratory Exercise Source Book. American Society of Agronomy. Madison, WI.