Composition of Soil-Air

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The obvious approach to a study of soil aeration is first, to analyze soil atmosphere, and, second, to study plant requirements. While simple and straight-forward in theory, the methods of measuring and interpreting are difficult in practice.

The Soil Atmosphere

It is very difficult to obtain a true sample of soil-air. Relatively speaking, the analysis of percent oxygen (O_2) and carbon dioxide (CO_2) in the sample is much easier than obtaining the sample itself. First, it is difficult to obtain a representative sample. Second, it is hard to avoid leakage of air from the atmosphere into the sampling unit. This is particularly true when sampling shallow and loose soils usually encountered in greenhouses. Third, the sample may be extracted from the larger soil pores, leaving the smaller ones untouched and it is reasonable to expect the large soil pores to possess higher oxygen concentrations and lower CO_2 levels than the small ones. Fourth,

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an air-filled pore surrounded on all sides by water would not likely be sampled in any case.

In the last few years, the attempt has been made to surmount the difficulties in sampling soil-air through the use of a "diffusion-equilibrium" technique. This consists essentially of an inverted glass cup placed at an approximate depth in the soil. A tube is connected to the upper part of the cup for purposes of removing the air sample. The cup is left undisturbed for a period of time and the air within the sampling apparatus comes into equilibrium with the soil-air. A sample no larger than the volume of the cup can then be removed and analyzed.

In our studies concerned with the effects of aeration and moisture on the growth and flowering of snapdragons, we have employed a diffusion-equilibrium technique for extraction of soil-air. The size of cup and tube was very small, since, through the use of gas chromatography, the sample size could be less than 0.061 cubic inches (about one cubic centimeter.) This reduced the time required for equilibration as well as the danger of leakage. A one millimeter syringe was inserted into the sampling tube and the following day a 1 cc sample extracted.

Soil-air from 4 different root media was analyzed (Eel silt loam with ¼th sand added, equal parts Eel silt loam, sand and peat moss or leaf mold, and equal parts peat moss and perlite). The moisture content was varied in different plots in the manner described in N.Y.S.F.G. Bulletins 192, 197, and 198. Soil moisture ranged from wet (8 cm water tension) to dry (900 cm water tension). The moisture content varied correspondingly from a high of 50 percent by volume to less than 15 percent, while the free pore space varied from almost zero to about 60 percent. Snapdragons, variety War Admiral, were grown in the plots at a 4 x 5 inch spacing.

The results were quite variable, however, a few important observations were made:

1. There was no evidence of low O_2 or high CO_2 in any of the peat-perlite treatments.
2. Indications of low O_2 or high CO_2 were found only in the media containing soil.
3. The lowest O_2 and highest CO_2 were found in the wettest treatment.
4. In just 3 of the 93 samples taken were O_2 levels found below 10 percent (these were found in the wettest plot of the soil plus ¼th sand).

The Plant

We have compiled from the literature, a summary of some of the results concerning plant response to CO_2 and O_2 levels. It is hard to make any generalization. Part of the difficulty lies in the varying techniques used by different experimentalists, part from the natural variation found between different plants and part from the problem of determining the real gas composition at the roots. Where plant response has been studied by varying CO_2 and O_2 levels in air surrounding roots, about the only conclusions that can be made are that observable effects will not be apparent at oxygen concentrations above 10 percent and CO_2 concentrations below 5 percent. Death of roots in most plants will occur at oxygen concentrations near 1 percent.

In addition to the separate effects of O_2 and CO_2, we must consider the interrelationships existing between them. Reports may be found where inhibition of respiration is greater at high CO_2 and low O_2 concentration. However, if only O_2 is decreased and CO_2 either removed or maintained at a normal level (0.03%), respiration can continue at a constant rate down to low O_2 levels. The possible significance lies in the knowledge that increased CO_2 concentrations reduce the rate of such processes as water uptake to a greater extent than similar decreases in oxygen. On the other hand, oxygen deficiences in soil are considered to occur with greater frequency.

Conclusions

It has been stated by some authors that oxygen concentrations in shallow soils are seldom less than 10 percent. Our data appears to substantiate this conclusion. Based upon what we have said in regard to the plant, we are faced with the necessity of finding an explanation for the plant response that occurred in the various plots, particularly the poorer growth in shallow, very wet and apparently, well aerated peat-perlite treatments. In any case, we do not believe that problems of aeration, in general, can always be attributed to oxygen deficiences and/or CO_2 excesses as determined by soil-aerated analyses. In previous bulletins (192, 197, 198), we have indicated that aeration in greenhouse soils is a function of supply rather than concentrations. The rate of supply is determined by the thickness of the water film about the root and is, therefore, directly related to the moisture content of the particular soil. Results of research on this aspect will be presented in a future article.