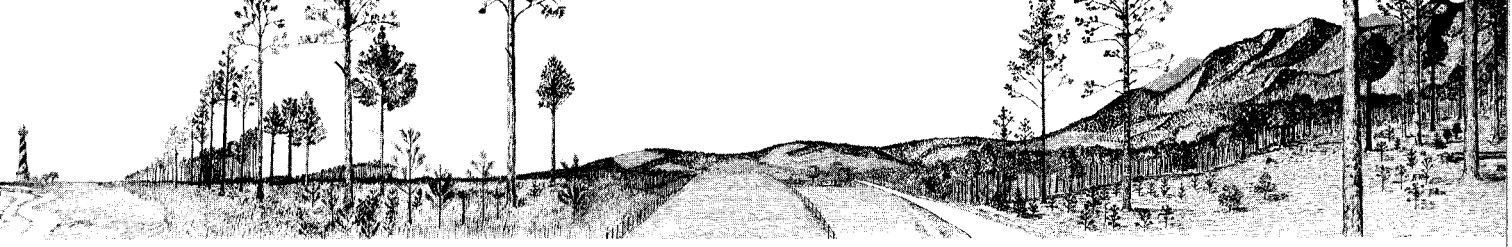

USDA Forest Service Research Note SE-150 February 1971

MICROBIAL POPULATIONS IN TWO SWAMP SOILS OF SOUTH CAROLINA

Abstract.--Microbial populations were counted in agar-plated samples of two swamp soils collected in summer and winter. Number of aerobic and anaerobic microorganisms differed significantly among the soils and between seasons. Alluvial soil from the river swamp was high in organic matter, N, K, Ca, and pH and averaged 88 million microorganisms per gram over the growing season. Nonalluvial soil from the headwater swamp was somewhat lower in organic matter, nutrients, and pH and averaged 75 million microorganisms per gram. During the winter, numbers of microorganisms dropped to less than half the summer population. Numbers of aerobic bacteria and actinomycetes were negatively related to soil moisture; numbers of anaerobic bacteria were positively related.

Microorganisms and their role in the forest soil environment usually are not considered in silvicultural investigations. Although some information is available on the microbiological relations of agricultural and upland forest soils, little is known about the microbial populations in swamp soils. It is likely that microorganisms in these normally anaerobic soils have important effects on accumulation of toxic substances, such as carbon dioxide and organic acids, as well as on the availability of nutrients.

The work described in this Note was undertaken to determine the kinds and numbers of microorganisms in soils from two types of swamps in the South Carolina coastal plain. Data are presented on anaerobic and aerobic populations, and how size of these populations is affected by soil moisture and season of the year is discussed.

METHODS

The soils studied were obtained from the Santee River swamp (Santee soil) and from a nonalluvial headwater swamp (Bluebird soil) on the Francis Marion National Forest in Berkeley County, South Carolina. Each soil was in six growing compartments of the hydroedaphytron[1] located on the Santee Experimental Forest.

Soil in the compartments was a homogeneous mixture taken from the surface layer of each swamp. The soils were serving as growing media for seedlings in a study of the effect of different soil-water regimes on growth

[1] Hook, D. D., and Stubbs, J. Physiographic seed source variation in tupelo gums grown in various water regimes. Ninth South. Conf. Forest Tree Impr. Proc. 1967: 61-64. 1967.

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of swamp tupelo (Nyssa sylvatica var. biflora (Walt.) Sarg.) and water tupelo (N. aquatica L.). During 1968 the compartments were maintained under levels of soil-water stress varying from saturation to 800 millibars (mb.) of moisture tension. Tension was monitored at 6 inches below the soil surface with ceramic-cup tensiometers.

Soil textural class was determined by the hydrometer method. The soils were further analyzed for pH, organic matter content by wet combustion, and total nitrogen (N) by the macro Kjeldahl method; available phosphorus (P) was determined colorimetrically by the Chlorostannous-Reduced Molybdophosphoric Blue color method, using a Bray No. 2 extracting solution.[2] Exchangeable potassium (K) and calcium (Ca) extracted in N ammonium acetate were determined by atomic absorption spectrophotometry.

A tube-type sampler was used to collect soil periodically at 1- to 2-week intervals from early June to September 1968 and once in February 1969. The samples included the surface 3 inches of soil and were taken at eight locations from each growing compartment.

After mixing the eight subsamples from a compartment, 50 grams of soil were transferred to a flask containing a dispersing agent (1 percent "Tween-80" and 0.1 percent agar). Sterile water was added to make 500 ml. of suspension, which was mixed for 10 minutes and allowed to settle.

The populations of aerobic bacteria and actinomycetes were determined by culturing 1:100,000 dilutions of the soil suspensions at room temperature (24° C.) in Thornton's Medium.[3] Brewer's Medium was used with a 1:100,000 dilution to determine populations of anaerobic bacteria. Fungi populations were determined from a 1:2,000 dilution cultured in Martin's Medium.[4] Population counts were made on three plates of each culture from each medium. All data were expressed as numbers per gram of ovendry soil.

RESULTS

Soil properties.--Selected physical and chemical properties of the soils are presented in table 1. The differences between the soils are largely due to their origin. Soil in the Santee River swamp is composed of alluvial material carried downstream from the Piedmont and mountains. Except during extremely dry periods, there is surface water in the swamp throughout the year. The Bluebird soil has developed in a nonalluvial swamp that drains neighboring pine lands. Water levels in this swamp are governed by rainfall; consequently, there are periods when the water table may be several inches below the surface.

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[2] Jackson, M. L. Soil chemical analysis. Ed. 14, 498 pp. Englewood Cliffs, N. J.: Prentice-Hall, Inc. 1958.

[3] Thornton, H. C. On the development of a standardizing agar medium for counting soil bacteria with especial regard to the repression of spreading colonies. Ann. Appl. Biol. 9: 241-274. 1922.

[4] Martin, J. P. Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. Soil Sci. 69: 215-232. 1950.

Table 1.--Physical and chemical properties of soils from Santee River swamp and Bluebird swamp

Soil	Soil property								
	Sand	Silt	Clay	pH	Organic Matter	N	P	K	Ca
	- - Percent - -				- Percent -		- - p.p.m. - -		
Santee (mucky clay)	35	20	45	6.4	22	0.85	29	251	3,275
Bluebird (loam)	50	30	20	5.8	18	.57	42	156	801

Effects of soil and season.--Microbial populations by season and soil are summarized in table 2. The winter data consist of a single sample taken in February 1969; summer data are the average of seven samples collected in June, July, August, and September 1968. Both season of the year and soil type had statistically significant effects on total populations. The greatest population change from summer to winter was a reduction of 75 percent in the actinomycetes group. Aerobic bacteria declined 67 percent and anaerobic bacteria decreased 30 percent in both soils. The fungi remained unchanged throughout the year in both soils.

Table 2.--Summer and winter microbial populations in Santee and Bluebird soils

Microorganism	Summer		Winter	
	Santee	Bluebird	Santee	Bluebird
	- - - - - - - Millions per gram of ovendry soil - - - - - - -			
Aerobic bacteria	77.8	67.5	26.1	20.8
Anaerobic bacteria	3.4	2.8	2.6	1.8
Actinomycetes	6.2	4.4	1.6	1.1
Fungi	.6	.6	.6	.5
Total[1]	88.0	75.3	30.9	24.2

[1]The differences among soils and between seasons are significant at the 1-percent level.

Greatest microbial populations were found in the Santee soil regardless of season. The actinomycetes were most influenced by soil type; Bluebird soil had 30 percent fewer of these organisms than did Santee soil. Anaerobic bacteria averaged 25 percent and aerobic bacteria 16 percent less in Bluebird soil than in Santee soil.

Effects of soil moisture.--The relationship between the summer microbial populations and moisture content of the soil was tested for both soils by fitting a regression of the form $Y = a + bx$, where Y is

the population in millions per gram of ovendry soil, and x is the soil moisture content expressed as a percentage of ovendry weight. Moisture content was determined at the time soil was collected for plating. Separate regressions were fitted to the counts of the aerobic and anaerobic bacteria, the actinomycetes, and the fungi. A statistically significant relationship (1-percent level) was found for all organisms except anaerobic bacteria in the Bluebird soil and fungi in the Santee soil. Numbers of aerobic bacteria, fungi, and actinomycetes were negatively related to soil moisture; numbers of anaerobic bacteria were positively related (figures 1 and 2).

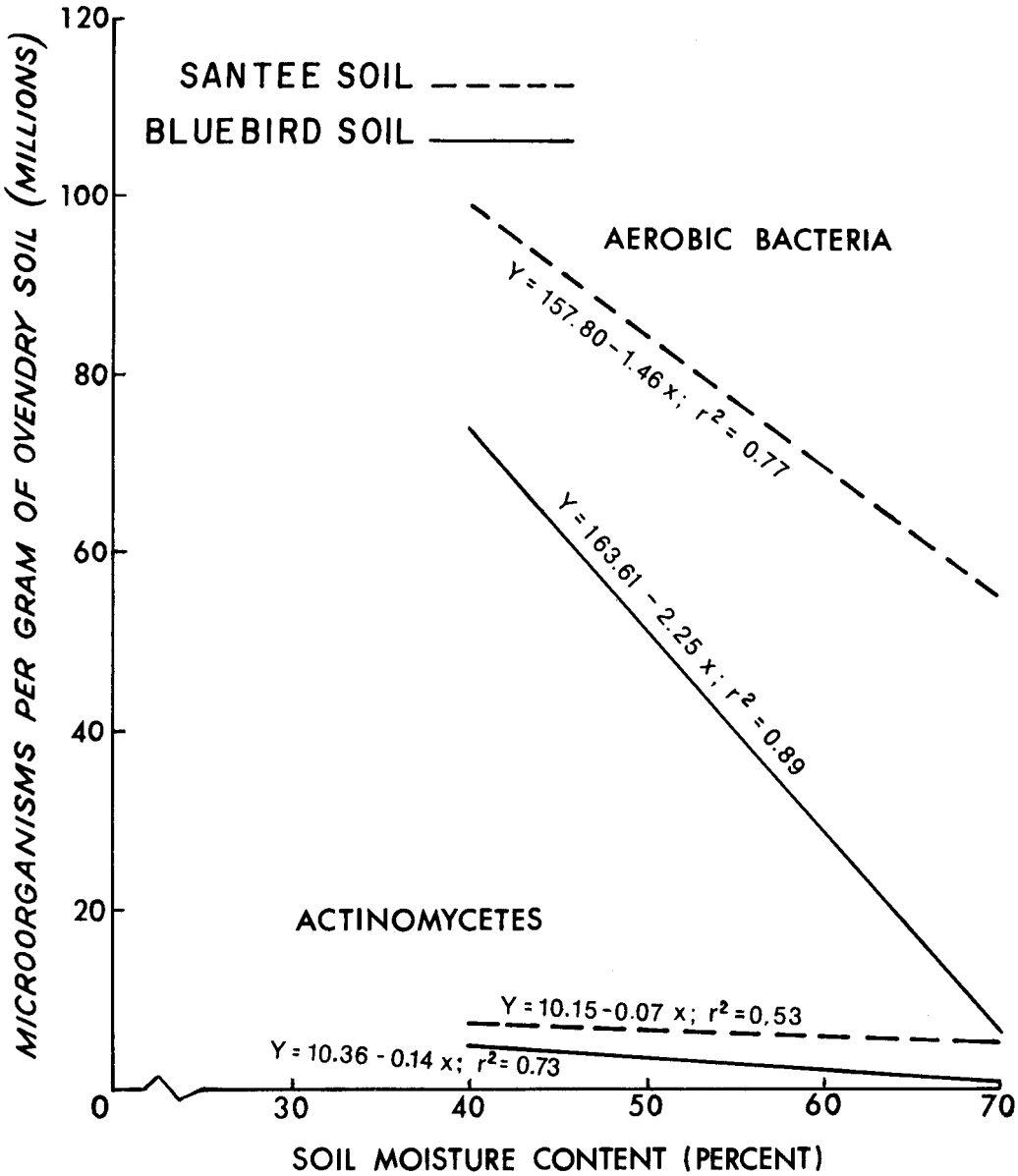

Figure 1.--Relationship between numbers of aerobic bacteria and actinomycetes and soil moisture in Santee and Bluebird soils.

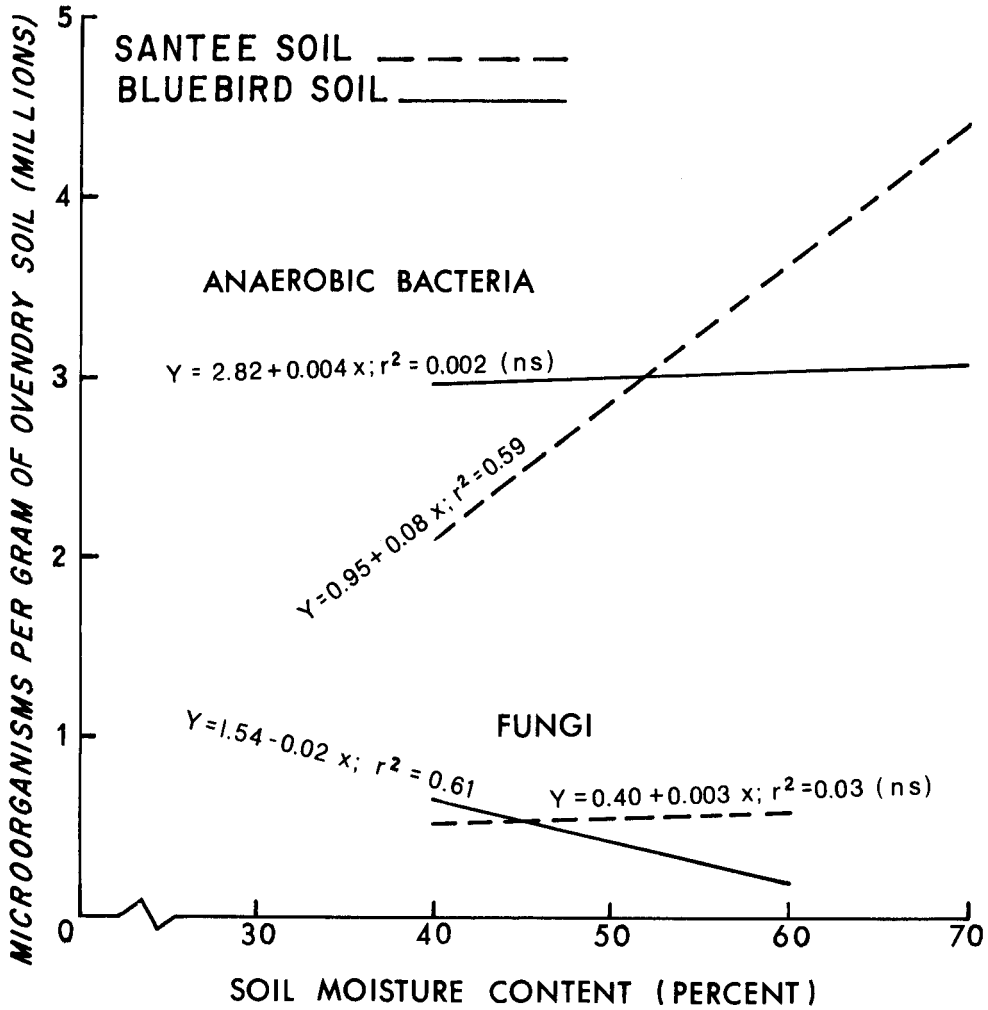

Figure 2.--Relationship between numbers of anaerobic bacteria and fungi and soil moisture in Santee and Bluebird soils.

DISCUSSION

The presence and abundance of microorganisms in the soil are governed primarily by the amount of organic matter, the activity of plant roots, soil temperature and moisture, and the availability of nutrients.[5] The differences in kinds and numbers found in the two swamp soils logically can be attributed to variation in one or more of these environmental factors.

Organic matter content, nutrient levels, and pH undoubtedly were the major factors governing the marked population differences between the Santee and Bluebird soils. Except for P, Bluebird soil was lower than Santee soil in all of the nutrients that

[5] Alexander, M. Introduction to soil microbiology. Ed. 7, 472 pp. New York: John Wiley and Sons, Inc. 1961.

were determined. Organic matter content and pH were lower in Bluebird soil. Also, tree growth, and consequently the contribution of the products of root activity essential to microbial development, was lower in Bluebird soil.

The marked reduction in bacteria and actinomycetes in the winter sample probably resulted from low temperature and the absence of excretion products and sloughed-off tissue from growing roots. The soil temperature at the time of the winter sampling was 2° C., while the average during summer months was 30° C.

The influence of soil moisture on population numbers is an effect of soil aeration rather than water stress. Soil moisture tensions remained low (rarely exceeding 200 mb.) throughout the study. As moisture content of the soil increased, the amount of air in the soil necessarily decreased. This was accompanied by a decrease in numbers of aerobic bacteria and actinomycetes in both soils and in fungi in the Bluebird soil. The anaerobic bacteria in the Bluebird soil responded to increasing soil moisture by increasing their numbers. These are the responses we would expect of aerobic and anaerobic organisms if soil aeration rather than moisture content of the soil was a limiting factor. We have no explanation for the apparent lack of response to soil moisture by the anaerobic bacteria in the Bluebird soil and the fungi in the Santee soil.

Population counts reported here do not necessarily include all viable organisms nor all those that were active at the time of sampling. Many organisms are in a resting state in the soil and become active when cultured and incubated at room temperature and, conversely, many active organisms may go into a resting state. Furthermore, because no one culturing medium, nor even two, would be adequate for all organisms, the counts probably represent only a small fraction of the total. We believe, however, that the sampling intensity and culturing techniques were adequate to establish differences among the bacteria and actinomycetes in the two soils and to provide a basis for assessing their relative abundance.

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