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A SURVEY OF THE SOIL ALGAE OF TWO VEGETATION TYPES IN CENTRAL OKLAHOMA

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CHAPTER I

HISTORICAL INTRODUCTION

Dorn (15) in 1650 defined Nostoc, a common inhabitant of the soil, as being "a kind of jelly or slime found oftentimes in the summer in the fields and meadowes."

During the 17th and 18th centuries botanists placed representatives of algae, mosses, lichens, and fungi within the same genus, and few species of soil algae were distinguished from these groups (59).

Early in the 19th century considerable interest developed in these plants, and a comprehensive literature on the algae arose. By the middle of the century botanists had distinguished soil algae from other groups of cryptogams, some of the earlier generic names disappeared, and many new species were described. At the close of the 19th century the monographers were beginning to bring order out of chaos and succeeded in attaining a taxonomic clarity for many of the species (59).

Petersen (59) reports that Ehrenberg in 1843 was the first to point out the presence of diatoms on and in the soil. In his examination of numerous soil samples from various parts of America he found a number of algae. Notably he found and described the two chief soil

diatoms, Hantzschia amphioxys[1] and Pinnularia borealis. Later, in his Microgeology (17) he has figured these and other diatoms found in cultivated soils from different parts of the world.

The close of the 19th century saw the rise of ecological viewpoints in systematic literature. Subsequent works have, as a rule, contained more complete information regarding habitats. Since the information is scattered throughout the literature it is difficult to form any general idea of the soil algal flora.

Graebner (32) made an attempt to list completely the flora of a plant community when he described the heaths of northern Germany. He included the algae, to which he ascribed considerable importance as the first invaders on new soil, causing the first formation of humus in the poor soil. Fritsch (25) discussed the importance of the algae as the first colonists on new soil and their significance in the subsequent establishment of higher plants. Other studies (5, 28, 60, 74) have related algae to other plants with reference to succession or competition.

Many investigators (7, 8, 9, 10, 11, 13, 18, 19, 32, 38, 43, 44, 45, 51, 52, 59, 64, 67, 79) have tried to approximate the growth of algae in natural environment by means of enrichment cultures. The use of enrichment cultures has increased considerably the list of algae found on and in the soil. It is now known that Chlorophyceae, Cyanophyceae, and Bacillariophyceae are found on the surface of the soil, both on cultivated land and uncultivated soils.

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[1]The manuals (6, 12, 23, 24, 29, 30, 31, 33, 34, 35, 36, 37, 42, 49, 53, 54, 55, 56, 62, 69, 71, 72, 73, 77, 78) used in the classification are listed under "Literature." Authors of taxa, if not in text, are listed in table 2.

During the present century there have been several studies of soil algae, but only Fehér's (21) could be called a broad survey. He examined soil from Africa, Asia, North America, and Australia. Less extensive ecological and taxonomic studies have been published for Africa (18), Germany (19, 46), England (7, 8, 10, 27, 39, 40, 43, 45), India (50), Denmark (59), and the United States (13, 47, 51, 52, 64, 67, 68, 79). There have been also some morphological and physiological investigations. In 1928 Drewes (16) observed the phenomenon of nitrogen-fixation for species of Anabaena and Nostoc. His discovery was confirmed by Allison and Morris (2). Allison, Hoover, and Morris (1), De (14), Fritsch and De (26), and Stokes (70) have also contributed to the knowledge of algal fixation of atmospheric nitrogen. Soil algae also add humus (23, 65, pp. 160-164) to soils and play a very important part in the stabilization of soils by crust formation (5, 23, 66).

Although culturing of soil algae has been practiced since the latter part of the 19th century, no standard procedure has been established in the techniques of collecting and culturing. Graebner (32) obtained Chlorophyceae and Cyanophyceae when soils from heaths were added to flasks containing sterile, washed sand moistened with sterile water. Later, Jacobsen (38) grew several green organisms from soil introduced into various liquid nutrient media of fibrin, albumin, wheat starch, sugars, mineral-salts, or milk. He also studied the influence of the hydrogen-ion concentration on the growth of certain green soil-inhabiting algae.

A different method was adopted by Esmarch (18) for his study of the Cyanophyceae in the soils of German African colonies. He placed

1 cm. samples of the soil in sterile Petri dishes. The samples were moistened with sterile tap water; then the soil surface was covered with a sterile filter paper firmly pressed to the surface with a sterile spatula. The cultures were incubated at approximately 19-21° C. in the diffused light of a greenhouse. The algae grew through the pores of the filter paper forming blue-green and brownish-green spots. After the first appearance of algae the cultures were retained from two to six weeks before the filter papers were removed and preserved. Most of the soil samples used in the study were taken at depths of 1 to 50 cm. (1-25 cm. and 25-50 cm.) with a few samples being collected to a depth of 120 cm. From the 90 soil samples 33 species of blue-green algae were recorded.

Esmarch (19) investigated the distribution of algae in surface samples and at depths of 10 to 50 cm. in cultivated and uncultivated soils of Germany. He sampled sandy, clay, and marshy cultivated soils. The uncultivated soils sampled were sandy heathland, marshy soil, forest humus, and moist sand. Culturing procedures were the same as those used in his studies of 1910 except that he moistened the soil samples with sterile distilled water. He was primarily interested in the blue-greens, but he also mentioned that other algae (greens and diatoms) grew through the filter paper, as well as mosses, molds, and bacteria. Forty-five species of blue-green algae were identified in the study.

Robbins (64) cultured algae from 22 soil samples collected from a variety of Colorado soil types (sandy loam, clay loam, heavy clay, hard gravelly clay, heavy adobe, and river bottom silt) to see if the quantity of algae present in the soil would be sufficient to supply a

large part of the energy for the nitrogen-fixing Azotobacter. After removal of the surface debris he collected the first 3 or 4 inches of the soil. The samples were cultured in sterile 500 ml. Florence flasks filled to their greatest diameter with well-washed quartz sand. Twenty-two flasks were inoculated with 25 ml. of the different soil suspensions, made by shaking 20 gm. of the soil sample in 50 ml. of sterile distilled water for 5 minutes. The culture flasks were tipped to form both a solid and an aqueous surface for growth. Incubation was started in a sunny place in the greenhouse and then continued in a shady place in a laboratory. Under these conditions algal growth appeared in all flasks after one to two months of incubation. Robbins subcultured some of the species on a 1% agar medium of a soil extract solution. Twenty-one different species of algae were found in the soil examined; 19 blue-greens, 1 green, and 1 diatom.

Bristol (7) used an aqueous mineral-salt solution (now known as Bristol's solution) to culture 13 different samples of British soils which had been stored from 22 to 70 years. The samples after being partially air-dried were passed through a sieve having 1/4-inch meshes. They were then placed in large bottles and sealed to prevent infection from outside and evaporation of the contained soil moisture. However, some of the containers were opened and moistened to bring the water-content up to 18%. About 0.5 inch of sterile culture solution and 3-4 gm. of the soil were then introduced into sterile small glass boxes or into small flasks, which were plugged with cotton-wool. The vessels were kept under glass bell jars until growth appeared. As evaporation occurred in the liquid cultures, sterile culture solution diluted one-

quarter to one-half was added. Sixteen species, including 12 blue-greens, 3 greens, and 1 diatom were found to have retained their vitality during very long periods of inactivity. Nostoc muscorum and Nodularia harveyana Thur. resumed growth after desiccation for 70 years.

Moore and Karrer (52) compared the soil algal flora of different regions of the United States. They examined heavy clay, loose clay, sand, sandy alkali, sandy gravel, and humus soil. Collections were taken from the surface and then every 10 cm. to a maximum depth of 120 cm. All subterranean cultures were obtained from places where the soil had not been disturbed for a number of years. Approximately 10-gm. portions of soil taken from various depths were introduced into sterile pint milk bottles containing 1 1/2 inches of sand and 150 ml. of a modified Beyerinck's solution (now known as Moore's solution) diluted to one-half. The bottles were plugged with cotton and the sand was slanted so that part of it was not submerged. As evaporation occurred in the cultures, sterile water was added to replace the loss. A total of 17 species were identified, 9 blue-greens, 5 greens, and 3 diatoms. Three species, Chlorococcum humicola, Hantzschia amphioxys, and Navicula atemoides Grun. were found at a depth of 100 cm.

Coyle (13) endeavored to determine if there was any correlation between the algal species found and the various soil types. She made 89 collections from all seven major soil areas and 28 named soil types in the State of Ohio. After debris or leaf litter had been removed, the soil samples were taken in pairs from the upper 1 inch and at a depth of 12 inches. The samples were collected in sterile tin-coated "salve" boxes 2 3/8 inches in diameter and 7/8 inch deep. The culture procedure

was a modification of that used by Moore and Karrer (52). Each sample was cultured in two different mineral-salt solutions, Bristol's and Moore's, from 9 to 17 months. Her 125-ml. Erlenmeyer culture flasks contained 50 gm. of fine quartz sand, thoroughly washed with distilled water, and 30 ml. of mineral-salt solution. The flasks were plugged with cotton-wool and sterilized for one hour under 15 lbs. pressure. The total identified was 46 genera and 90 species and varieties of algae. The greatest number of species and varieties of algae were members of the blue-greens, followed by diatoms, greens, and yellow-greens in that order. From her study there seems to be no correlation between drainage, soil texture, or the presence or absence of organic matter, and the number of species found in the soil.

John (40) made a detailed study of the microstratification of soil algae in 24 uncultivated British soils; 15 alkaline, 7 acid, and 2 neutral. The pH values of the soils varied between 8.4 and 3.7. The samples were taken with a small rectangular shovel from the top, second, third, and fourth centimeters in depth every month for a period of about two years. Each sample was thoroughly mixed and placed in a waxed tin until culturing was begun. Precautions were taken during sampling to prevent contamination.

About 1 ml. of soil was introduced into sterile half-pint milk bottles filled to a depth of 2 inches with Benecke solution and closed with a plug of cotton-wool. A set of moist cultures was also set up by spreading a layer of soil 1 cm. deep in sterile Petri dishes and moistening them periodically with sterile distilled water. They were then placed in an unheated greenhouse under natural illumination. From these soil

samples the greatest number of species and varieties identified were members of the greens followed by the blue-greens, diatoms and yellow-greens, a red, and a euglenoid. He found that certain algae were characteristic of the surface layers, while others, especially members of the Xanthophyceae, were commoner in the lower layers.

Willson and Forest (79) made a study of different techniques of sampling and culturing soil algae. Samples were taken from a plowed field and two uncultivated plots (protected prairie and a slightly overgrazed pasture) located in central Oklahoma. Three collecting procedures (surface, auger, and solid core) were compared. The core samples were divided into thirds and each portion cultured separately in sterile Petri dishes. Surface and auger samples were amalgamated and teaspoonful-portions were placed in sterile Petri dishes. Series of cultures were moistened with sterile cistern water, Hoagland's #1 solution diluted to one-fourth the original concentration, and an organic nutrient solution. The series of cultures were subjected to different types of fluorescent illumination for 24 hours per day. One of the light banks contained "white" tubes illuminating the plates at 60-204 foot-candles; the other was the "daylight" type and illuminated at 50-204 foot-candles. In the study 14 blue-greens, 7 greens, 3 diatoms, and 1 euglenoid were identified.

Studies on the soil algae of Oklahoma were made by Booth (5), Vinyard (unpublished), Fehér (21), and Willson and Forest (79). Booth was principally interested in the quantity of algae in the soil crust, rather than the species present. Vinyard occasionally collected algae from soil crusts, but neither Vinyard nor Booth attempted culturing to

develop the inconspicuous flora. Soil samples taken from two of the twelve areas studied by Fehér (21) in North America were collected at Ardmore and Eufaula, Oklahoma, probably from black jack-post oak forests. He stated that 21 species of algae were found in North America, but did not break down the findings for each area.

The scope of the present investigation is four-fold: (1) determination of the algal flora in the upper 0.5 inch of soil collected from two black jack-post oak forests and two tall-grass prairies; (2) determination of the seasonal distribution of algae by sampling at the same stations in October, 1956, and January, April, and July in 1957; (3) treatment of samples with mineral-salt solution to develop the inconspicuous flora and subculture for the purpose of studying morphology, anatomy, ecology, and physiology; and (4) comparison of the algal flora of the two vegetation types.

The algae found in this study were collected from forest and prairie soils which in the field had been moistened only by atmospheric water; ecologically they were eu-terrestrial algae.

CHAPTER II

LOCATION AND DESCRIPTION OF AREAS

Four localities near Norman, Oklahoma (fig. 1) were sampled. Availability, relatively undisturbed conditions in the areas, and the supplementary available knowledge (41, 48, 63, 79) of the plots were the criteria used in making the selections. For convenience each of the areas investigated has been assigned a plot number. Plots 1 and 2 represent the black jack-post oak forests, and plots 3 and 4 designate the tall-grass prairies.

Plot 1 (fig. 1) is located approximately 15 miles east of Norman, Oklahoma, in the southwest quarter of section 25, township 9 north, range 1 east, Cleveland County. Rice and Penfound (63) reported that, according to reliable information, this forest had never been cut-over, grazed only slightly, but burned-over periodically. The area sampled has a rolling topography with a gentle west-facing slope. It is open with scattered clumps of grasses, small patches of lichens, liverworts and mosses, and an occasional pile of dead leaves. The dominant trees were Quercus stellata Wang. (post oak) and Quercus marilandica Muenchh. (blackjack oak) (63).

Plot 2 is located 3 1/2 miles west and 1 mile north of Stella, Oklahoma, in section 14, township 10 north, range 1 west, Cleveland County. This forest was fenced, moderately grazed, burned-over

periodically, and firewood had been cut from it until 1945 (Rice and Penfound, unpublished). The area sampled has a rolling topography with gentle north- and south-facing slopes. The forest has a dense woody underbrush with some grasses interspersed in a few clear spots under the dominant tree, blackjack oak (Rice, unpublished). The surface of the soil is matted with dead leaves, roots and other debris.

Plot 3 (fig. 1) located in the University of Oklahoma Grassland Investigations Plots, is located approximately 8 miles southwest of Norman, Oklahoma, along State Highway 9, in section 12, township 8 north, range 4 west, in McClain County. The prairie, with a gentle north-facing slope, had been moderately grazed up until about 1949. This protected prairie, as far as is known, had never been plowed or burned, and the soil was covered with a thick layer of natural mulch and humic mulch. From an extensive study of this plot in 1952, Rice (unpublished) identified 60 species of flowering plants. He found that Andropogon scoparius Michx. (little blue-stem), Panicum virgatum L. (panic grass) and Sorghastrum nutans (L.) Nash (Indian grass) were the dominant plants. In an adjacent virgin prairie Kelting (41) found the same species to be dominant.

Plot 4 (fig. 1) is located 2 miles north and 1/2 mile east of Noble, Oklahoma, in section 14, township 8 north, range 2 west, Cleveland County. This plot has a gentle northeast-facing slope, had been under cultivation until about 1937, and had been burned about 1947. Since its abandonment, about 1937, the cultivated field has reverted to a grassland. In recent years parts of the area have been mowed for hay, but the north end, the area sampled, had not been disturbed for approximately 20

years except for being burned once. The vegetation of this area had not been studied, but the north end has a good grass cover of little blue-stem (Andropogon scoparius) and big blue-stem (Andropogon gerardi Vitman). Also there is a small community of Rhus copallina L. (sumac) which indicates that the area had not been disturbed recently. A small amount of natural mulch was found on the surface with some bare areas between the clumps of grasses.

The systematic seasonal investigation of the soil algae of two vegetation types in central Oklahoma was started in October, 1956, and completed July, 1957. The first collections were taken at the end of a dry season in which the annual precipitation was 20.96 inches of which 1.89 inches were recorded for October, 1956 (75). The following year was an unusually wet season with 56.45 inches of precipitation (76), and the moisture conditions were favorable for good algal growth. The annual precipitation was measured at Norman, Oklahoma, and not at the areas sampled.

CHAPTER III

METHODS

Twenty stations 10 yards apart were established in each plot. In a previous study by Willson and Forest (79), the stations were located every 10 paces. For this work, in order to obtain a more systematic arrangement of the stations, a string marked at 10-yard intervals was used. Each station was identified with a 2-inch square metal tag, cut from a tin can, numbered with black screen paint, and wired to a 10-inch piece of galvanized wire. The tag extended approximately 4 inches above the surface of the soil. Strips of cloth and white marking tags were tied to vegetation near each station to aid in their location.

After removal of the mulch, approximately 0.5 inch of the surface soil was collected with a 1 1/2-inch metal spatula and placed in new No. 1/2, Rock Kraft, paper sacks. Station- and collection-number, vegetation at the station, date, and general soil conditions for each station were recorded on the sacks. Before each collection the spatula was cleaned and heated in the flame of an alcohol burner. This precaution was taken to reduce contamination of samples from different stations and to give a clearer picture of the algal flora for each. Soil collections were taken clockwise around the station marker with some overlapping on the previous collection area. The total area sampled at each station throughout the 4 seasons was approximately 4 sq. ft. The soil samples

were stored in a constant temperature room (21° C.) until cultured.

Twenty samples from each plot per season were collected in October, 1956 (fall), and January, April, and July, 1957 (winter, spring, and summer, respectively). The fall, spring, and summer samples were cultured within 5 days after making collections. The winter collections from the forests were stored for a maximum of 16 days and those from the prairie plots were stored for not more than 28 days, previous to culturing. The station numbers, dates of collections, sample numbers, date cultured, and the periods of examination per plot have been recorded in table 1.

Three 10-gm. portions of each sample, thoroughly mixed, were plated in chemically cleaned, sterile (15 lb. pressure, 20 min.), Petri dishes and moistened with sterile modified Bristol's solution (4) made with pyrex distilled water. Plated samples (moist cultures) were incubated at a constant temperature of 21° C., a relative humidity of 60%, and an illumination, for 16 hours per day, of 150-300 foot-candles provided by Sylvania, white, fluorescent lamps. Occasionally sterile solution was added to the cultures to replace the moisture lost through evaporation. A critical examination of the samples was made after a minimum period of 4 weeks incubation.

Uni-algal cultures were made from liquid cultures of soil collected in the fall and winter. Two 3-gm. portions of a soil sample were added to 45 ml. of sterile modified Bristol's solution in 125-ml. cotton-stoppered Erlenmeyer flasks. These liquid cultures were subjected to the same laboratory conditions as the plated samples, and incubated for a period of 2 to 3 weeks, or until a green ring of growth appeared around

the meniscus of the culture solution. A drop of the green growth was placed in the bottom of sterile Petri dishes and a sterile 2% modified Bristol's agar was added. Isolated colonies picked from the poured plates were streaked on agar slants.

A critical microscopic examination of organisms scraped from plated soil samples was made by the water-mount technique. For a more detailed examination of diatoms, the frustules were cleared by boiling in a liquid mounting medium with a high refractive index, Hyrax, which produces a permanent mount upon cooling (3).

After the final examination of soil samples, duplicate packets of the dried samples were prepared as herbarium specimens. Each packet was identified by station- and sample-number; i.e., 20-260 refers to sample No. 260 taken from station No. 20 in plot 1 of the forest on July 4, 1957 (table 1). One set of the duplicates from the fall collection was sent to Dr. Francis Drouet for verification of the author's determinations of the Myxophyceae and for storage of the specimens in the Chicago Natural History Museum.

Hydrogen-ion concentrations of the fall collections (80 samples) were determined by the method outlined by Piper (61). A Beckman pH meter, model H2, was used in measuring the hydrogen-ion concentration.

CHAPTER IV

RESULTS

A total of 82 species and varieties for the 4 seasons were identified from the plots, 72 from the forests and 58 from the prairies (table 2). In the forests 25 species and varieties occurred in 1 season only, 8 in 2 seasons, 4 in 3 seasons, and 35 in all seasons. Twenty-one species and varieties were found in the prairies for only 1 season, 4 in 2 seasons, 9 in 3 seasons, and 24 in all seasons.

The average percentage of occurrence of each organism per season from the combined forest and prairie plots is shown in table 2. The seasonal distribution of all species and varieties per season and the predominants found in the 4 plots are listed in table 3.

The blue-green algae (Cyanophyceae) compose the greatest percentage of total species and varieties of algae, of all seasons, from both forest and prairie plots (fig. 2). Diatoms (Bacillariophyceae) were the second most numerous with the greatest percentage occurring in the winter. The highest percentage of green algae (Chlorophyceae), the third most numerous group, occurred in the spring. Infrequent groups of algae inhabiting the soil samples were the yellow-greens (Xanthophyceae) and the euglenoids (Euglenophyceae) each of which comprised less than 10% of the total kinds per season.

Approximately three-fourths of the blue-greens and about three-

fifths of the diatoms were found to be common to the forests and prairies for all seasons (table 4). The range in the percentages of the species and varieties in the green algae per season was greater than that for the diatoms and blue-greens. The yellow-greens were encountered in the winter, spring, and summer collections from forest soils, and only one species and variety occurred in a summer collection from a prairie soil sample. A member of the euglenoids occurred in the spring collections from the forest soils and from both vegetation types in the summer collections.

Seasonal differences in the number of species and varieties within the two vegetation types are shown in table 5. The greatest number of kinds was found in the summer collections from the forests, while the greatest number from the prairies occurred in the fall. The least number of species and varieties were found in the winter collections from the forests and prairies. The lowest percentage of kinds that were common to both forests and prairies occurred in the fall and the highest in the spring and summer. The average per cent of total species and varieties common to both vegetation types was 63.4.

In the 4 seasons a total of 24 species and varieties were confined to the forests, 10 present only in the prairies, and 49 were common to both (table 6). The occurrence of a species or variety, present only in one vegetation type per season, was less than 12.5% in the samples, except for Achnanthes coarctata which was found in 20-30% of the collections from the forests. Four species (Achnanthes coarctata, Characium pringsheimii, Oedocladium lewisii, and Stauroneis anceps var. linearis) from the forests, but none from the prairies, were present in all

seasonal collections.

A total of 36 species and varieties were found in all 4 seasonal collections (table 7). Thirty-five of these were present in the forests and 24 in the prairies with 23 being common to both. Eight species from forest soil samples and 7 species from prairie samples occurred in 45-100% of the samples per season. Of these, Chlorococcum humicola, Hantzschia amphioxys, Navicula mutica, Nostoc muscorum, Pinnularia borealis, and Plectonema nostocorum are the species most common in both types of plots. Cylindrospermum licheniforme and Scytonema hofmannii, in the forests only, and Lyngbya aestuarii, in the prairies only, occurred in 45-100% of the samples. The species and varieties that occurred in 45-100% of the soil samples per season have been arbitrarily designated as "predominants" (table 8). The greatest percentage of predominants occurred in the forests from the winter collections and the lowest occurred in the spring collections from the prairies.

The number of species and varieties varied in the 4 plots sampled (table 3). Samples taken from plot 1 produced the greatest number per season with a total of 61 different kinds for the 4 seasons. Fifty-one species and varieties were found in plots 2 and 4 and 46 in plot 3. In the forests 21 species and varieties were present only in plot 1 and 11 in plot 2. Two of the species, Oedocladium lewisii and Stauroneis anceps var. linearis, occurred in all seasons in plot 1. Eleven species and varieties were confined to plot 4 of the prairie and 7 in plot 3. Nitzschia ignorata was the only species present in plot 4 that occurred in all seasonal collections.

Chlorococcum humicola was found to be the most common organism

in the liquid cultures. Others that were frequently observed were Achnanthes coarctata, Microcoleus vaginatus, Navicula mutica, and Ulothrix flaccida.

The pH values of the fall soil collections were lower in those soil samples taken from the forest plots (table 9). The range of the hydrogen-ion concentrations of the soil samples was greater in the forests than in the prairies, and the mean of the hydrogen-ion concentration of the forest soils was lower than that of the prairies. No attempt was made to establish a correlation between the pH of the soil samples and the species and varieties present.

CHAPTER V

DISCUSSION

Several methods of culturing algae from soil have been used, but no procedure has been generally accepted. Liquid cultures (7, 13, 32, 38, 40, 52, 64) have been used extensively, but are subject to criticism since the algae are subjected to obviously artificial conditions. It seems that aquatic forms that thrive on the soil would be favored, and the development of terrestrial forms would be inhibited.

The moist soil culture methods used by Esmarch (18, 19), John (40), and Willson and Forest (79) seems to be the best method in culturing soil algae. By this method the habitat of the organisms is not completely altered, hence, one should derive a clearer picture of the species that exist in eu-terrestrial soils. Moist cultures are easy to set up, maintain, and study for an extensive period.

The moist culture method does not solve all the problems involved in the culturing of soil algae, but more species were observed when using this method than in the liquid cultures. It is felt that a comparative study of the two methods warrants investigation, using both procedures. John (40) found that almost all of the Cyanophyceae, most of the Bacillariophyceae, and some of the Chlorophyceae, develop better in moist cultures, whereas almost all the Xanthophyceae and the remainder of the Chlorophyceae were more abundant in liquid cultures.

The poured plate method is decidedly favorable to the development of a limited number of species, especially some of those that grow and/or reproduce rapidly. On the other hand agar cultures of soil algae are completely destroyed by bacteria and fungi within a period of ten days to two weeks. Furthermore, the agar sometimes becomes dehydrated before the slower growing algae develop.

One of the most serious problems that must be solved is the classification of algae grown under artificial conditions. The habit of a number of these organisms was variable in different culture conditions. Scytonema hofmannii showed several forms in the same culture. If grown on partially flooded soils, it may resemble Tolypothrix or Microchaete.

There was a moderate variation in the number of species and varieties in all seasons in the soils of both vegetation types. This was primarily due to the occurrence of the sporadic representatives. The greatest number of kinds occurred in the summer from the forests and in the fall from the prairies (table 5). The smallest number of species and varieties for both vegetation types was in the winter. The winter decrease might have been caused by the longer period of storage of these soil samples before culturing.

From the forest and prairie plots in central Oklahoma the greatest number of species and varieties of algae occurred in those plots (1 and 4) that had the least accumulation of mulch covering the surface. This confirms the findings of Petersen (64, 65) in his investigations of the algae in soil samples taken from various plant formations in Iceland and Denmark. He found that the algal flora was richest in species on naked ground, and poorer on soil covered with withered leaves, moss, or

a dense phanerogam vegetation.

No definite analytical method has been devised to describe accurately the algal flora of a community. The various techniques used in sampling the higher forms of vegetation are not applicable in the analysis of algal populations, since the organisms involved are microscopic. When dealing with soil algae it is difficult to determine the frequency and percentage of cover of each species, due to the size, numbers, diversity, and polymorphism of forms. In this study only the presence of a species or variety, not the frequency, in a sample was recorded. Since coverage was not involved, and since only the percentage of occurrence per sample was used, the term "dominant" had little or no meaning in a study of this type. In order to categorize those species and varieties of algae that were encountered in 45-100% of the samples per season the term "predominant" was employed.

Previous investigators have, as a rule, taken a small number of soil samples from a variety of localities. Those (8, 20, 40, 43, 45) that were concerned with seasonal studies made collections from general areas; only Fehér (20) had designated stations. He took forest soil samples from 30 stations located in central and northern Europe.

In this study conducted in central Oklahoma, a large number of samples from each plot per season were taken from designated stations. With the extensive sampling in the forest and prairie plots, and the adoption of the moist culture method, it is felt that most of the algae present were probably observed. However, it is difficult to be sure of this since these organisms are microscopic and most of them did not form conspicuous growths.

The appearance of Volvox sp. in a soil sample taken from plot 4 of the prairie in the fall collections was of interest, since this organism has been considered to be an aquatic inhabitant. However, there is a large farm pond about 300 yards north of the plot from which it might have been transported.

About 59% of the species and varieties identified in this study were present in both the forest and prairie soils. From this evidence the algal populations of these two vegetation types in central Oklahoma appeared to be similar.

CHAPTER VI

SUMMARY

This investigation concerns the comparison of the seasonal algal flora in the upper 0.5 inch of soil collected from two black jack-post oak forests (plots 1 and 2), and two tall-grass prairies (plots 3 and 4) in central Oklahoma.

Seasonal (fall, winter, spring, and summer) surface soil samples were collected from 20 stations 10 yards apart in each of the 4 plots. After removal of the mulch, the samples were deposited in new paper sacks with a clean metal spatula which had been flamed with an alcohol burner. Three 10-gm. portions of each sample, thoroughly mixed, were placed in sterile Petri dishes and moistened with sterile modified Bristol's solution containing pyrex distilled water. The cultures were incubated at a constant temperature of 21° C., a relative humidity of 60%, and an illumination, for 16 hours per day, of 150-300 foot-candles provided by Sylvania, white, fluorescent lamps. Cultures were examined after a minimum of 4 weeks incubation. Some sub-cultures were made with Bristol's 2% agar.

From 960 moist soil cultures made from 320 samples collected and cultured, 82 species and varieties were identified; 35 blue-greens (Myxophyceae), 23 diatoms (Bacillariophyceae), 18 greens (Chlorophyceae), 5 yellow-greens (Xanthophyceae), and 1 euglenoid (Euglenophyceae).

Thirty-six of these species and varieties were present in all seasonal collections; 35 in forests and 24 in prairies, 23 being common to both. The greatest number of species and varieties occurred in the forests. Of the 72 different kinds in forest soil samples, 24 were confined to that area as compared to 10 of the total of 58 species and varieties found in the prairies. Forty-eight were common to both vegetation types.

Only the occurrence of an organism, not the frequency, in a sample was recorded. The algae that occurred in 45-100% of the soil samples per season were arbitrarily designated as "predominants." There were six predominants common to both vegetation types: Chlorococcum humicola, Hantzschia amphioxys, Navicula mutica, Nostoc muscorum, Pinnularia borealis, and Plectonema nostocorum. Two predominants, Cylindrospermum licheniforme and Scytonema hofmannii, were from the forests only, and one only, Lyngbya aestuarii, from the prairies. The greatest number of predominants occurred in the forests from the winter collections and the lowest occurred in the spring collections from the prairies.

A greater number of species and varieties occurred in the open forest (plot 1) than in the forest with dense woody underbrush (plot 2). The prairie which had been under cultivation (plot 4) yielded more species and varieties than the protected prairie (plot 3).

From the evidence in this study it appears that the seasonal variation in the number of species and varieties was primarily due to the occurrence of the sporadic representatives.

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TABLE 1

SOIL SAMPLE COLLECTION DATA PER PLOT PER SEASON.
DATE CULTURED AND PERIOD OF EXAMINATION

Plots	Station No.	Date of Collection	Sample No.	Date Cultured	Period of Examination
Forest					
Plot 1	1-20	Oct. 23, 1956	1-20	Oct. 28, 1956	Dec. 5-9, 1956
		Jan. 2, 1957	81-100	Jan. 18, 1957	Feb. 11-Mar. 1, 1957
		April 6, 1957	161-180	April 10, 1957	May 10-15, 1957
		July 4, 1957	241-260	July 4, 1957	Aug. 6-9, 1957
Plot 2	21-40	Oct. 26, 1956	21-40	Oct. 30, 1956	Dec. 17-31, 1956
		Jan. 2, 1957	101-120	Jan. 17, 1957	Mar. 4-13, 1957
		April 6, 1957	181-200	April 10, 1957	May 17-19, 1957
		July 4, 1957	261-280	July 4, 1957	Aug. 13-15, 1957
Prairie					
Plot 3	41-60	Oct. 27, 1956	41-60	Oct. 31, 1956	Dec. 31-Jan. 1, 1957
		Jan. 12, 1957	121-140	Feb. 9, 1957	Mar. 13-20, 1957
		April 13, 1957	201-220	April 14, 1957	May 20-22, 1957
		July 5, 1957	281-300	July 5, 1957	Aug. 9-13, 1957
Plot 4	61-80	Oct. 30, 1956	61-80	Oct. 31, 1956	Nov. 25-Dec. 2, 1956
		Jan. 12, 1957	141-160	Feb. 9, 1957	Mar. 22-27, 1957
		April 13, 1957	221-240	April 14, 1957	May 24-25, 1957
		July 5, 1957	301-320	July 5, 1957	Aug. 16-18, 1957

TABLE 2

SEASONAL DISTRIBUTION AND PERCENTAGE OF OCCURRENCE OF ALL SPECIES IN FOREST AND PRAIRIE PLOTS (PERCENTAGE BASED ON 40 SAMPLES PER SEASON)
(F-FALL, W-WINTER, SP-SPRING, SU-SUMMER)

Genera, Species and Varieties	Forests				Prairies			
	F	W	Sp	Su	F	W	Sp	Su
Achnanthes coarctata (Breb.) Grun.	20.0	30.0	20.0	20.0	...	...	...	...
Anabaena inaequalis (Kuetz.) Born. & Flah.	...	...	...	2.5	2.5	...	...	...
A. oscillarioides Bory	...	5.0	10.0	10.0	...	5.0	10.0	30.0
Aphanothece stagnina (Spreng.) A. Br.	57.5	45.0	30.0	42.5	65.0	42.5	32.5	47.5
Borzia trilocularis Cohn	...	...	5.0	...	...	12.5	2.5	...
Carteria cordiformis (Carter) Dill	...	...	...	...	5.0	...	...	...
C. crucifera Korschikov	7.5	...	...	...	2.5	...	...	...
C. globosa Korschikov	2.5	...	...	...	...	...	...	...
Characiopsis pyriformis (A. Br.) Borzi	...	5.0	22.5	15.0	...	...	...	...
C. pyriformis var. subsessilis Lemm.	...	...	...	5.0	...	...	...	2.5
Characium ambiguum Herm.	...	...	...	2.5	...	...	...	...
C. operculum Ackley	2.5	...	...	...	...	...	...	...
C. pringsheimii A. Br.	5.0	2.5	2.5	2.5	...	...	...	...
Chlamydomonas sp.	...	...	55.0	...	...	...	20.0	...
Chlorella variegatus Beyer.	...	...	...	...	5.0	...	...	...
C. vulgaris Beyer.	...	...	27.5	20.0	...	...	22.5	...
Chlorococcum humicola (Naeg.) Rabh.	92.5	100.0	65.0	95.0	92.5	100.0	45.0	77.5
Chroococcus minimus (Keissl.) Lemm.	2.5	...	...	...	2.5	...	...	...
C. minutus (Kuetz.) Naeg.	5.0	...	...	...	...	...	...	...
Cosmarium pokornyanum (Grun.) West & G. S. West	2.5	15.0	12.5	17.5	...	5.0	2.5	10.0
Cylindrospermum licheniforme (Bory) Kuetz.	77.5	80.0	57.5	65.0	67.5	40.0	15.0	25.0
C. majus Kuetz.	10.0	5.0	2.5	10.0	2.5	...	2.5	2.5
C. muscicola Kuetz.	2.5	...	...	...	...	...	...	...
C. stagnale (Kuetz.) Born. and Flah.	7.5	2.5	17.5	2.5	...	...	5.0	2.5
Euastrum sp.	...	...	...	...	...	...	10.0	7.5

TABLE 2--Continued

Genera, Species and Varieties	Forests				Prairies			
	F	W	Sp	Su	F	W	Sp	Su
Euglena sp.	...	...	15.0	22.5	...	...	...	2.5
Gloeothece rupestris (Lyngb.) Born.	2.5	...	...	...	...	...	...	7.5
Hantzschia amphioxys (Ehr.) Grun.	100.0	100.0	90.0	97.5	90.0	77.5	92.5	100.0
Lyngbya aestuarii (Mert.) Lieb.	30.0	25.0	10.0	17.5	67.5	75.0	70.0	75.0
Microcoleus lacustris (Rabh.) Farlow	2.5	...	...	5.0	...	...	...	...
M. paludosus (Kuetz.) Gom.	35.0	57.5	40.0	55.0	37.5	22.5	12.5	32.5
M. rupicola (Tild.) Dr.	42.5	10.0	5.0	2.5	30.0	7.5	...	2.5
M. vaginatus (Vauch.) Gom.	15.0	35.0	17.5	7.5	20.0	...	2.5	...
Navicula (?) cincta (Ehr.) Kuetz.	...	...	...	...	...	2.5	...	...
N. fritschii Lund	40.0	22.5	20.0	65.0	20.0	15.0	25.0	55.0
N. grimmei Krasske	...	2.5	2.5	...	...	...	...	...
N. (?) muralis Grun.	5.0	...	...	...	...	...	...	...
N. mutica Kuetz.	100.0	97.5	95.0	100.0	90.0	95.0	100.0	97.5
N. mutica var. cohnii (Hilse) Grun.	72.5	17.5	12.5	10.0	35.0	17.5	10.0	...
N. mutica var. nivalis (Ehr.) Hust.	...	2.5	2.5	...	5.0	5.0	...	2.5
N. mutica var. ventricosa (Kuetz.) Cleve	2.5	5.0	12.5	...	5.0	...	...	...
N. pseudatomus Lund	27.5	65.0	12.5	60.0	12.5	42.5	10.0	22.5
N. seminulum Grun.	7.5	5.0	...	...	...	...	...	...
Nitzschia (?) communis Rabh.	...	...	...	...	2.5	...	...	...
N. ignorata Krasske	5.0	2.5	...	...	2.5	2.5	10.0	7.5
N. palea (Kuetz.) W. Smith	...	...	...	10.0	...	...	...	52.5
Nostoc commune Vauch.	35.0	50.0	10.0	2.5	12.5	2.5	...	2.5
N. ellipsosporum (Desmaz.) Rabh.	7.5	5.0	...	...	7.5	...	...	...
N. muscorum Ag.	70.0	85.0	72.5	80.0	97.5	82.5	57.5	85.0
Oedocladium lewisii L. Whitford	2.5	2.5	2.5	5.0	...	...	...	...
Oocystis lacustris Chodat	...	...	...	...	...	...	2.5	...
Oscillatoria splendida Grev.	...	...	...	2.5	...	...	...	...
Phormidium sp.	...	...	...	12.5	...	...	...	5.0
P. autumnale (Ag.) Gom.	2.5	...	25.0	30.0	...	7.5	22.5	35.0

TABLE 2--Continued

Genera, Species and Varieties	Forests				Prairies			
	F	W	Sp	Su	F	W	Sp	Su
Pinnularia borealis Ehr.	85.0	72.5	80.0	82.5	80.0	60.0	85.0	92.5
P. intermedia Lagerst.	65.0	47.5	12.5	42.5	12.5	45.0	5.0	25.0
P. microstauron (Ehr.) Cleve	47.5	67.5	2.5	30.0	12.5	10.0	7.5	15.0
Plectonama nostocorum Born.	50.0	77.5	65.0	100.0	70.0	70.0	52.5	100.0
P. purpureum Gom.	...	...	...	...	...	...	12.5	...
Porphyrosiphon fuscus Gom.	5.0	5.0	5.0	5.0	2.5	2.5	2.5	2.5
P. notarisii (Menegh.) Kuetz.	15.0	42.5	37.5	42.5	7.5	10.0	10.0	10.0
Raphidiopsis curvata Fritsch & Rich	...	...	5.0	...	...	...	...	...
Schizothrix braunii (A. Br.) Gom.	...	...	...	2.5	...	...	...	...
S. giuseppei Dr.	...	...	...	...	2.5	...	...	...
S. heufleri Grun.	52.5	77.5	25.0	10.0	50.0	27.5	5.0	5.0
S. purpurascens (Kuetz.) Gom.	37.5	2.5	5.0	7.5	25.0	17.5	5.0	17.5
Scytonema hofmannii Ag.	85.0	85.0	75.0	57.5	52.5	35.0	37.5	37.5
Stauroneis anceps Ehr.	...	2.5	...	...	...	...	...	...
S. anceps var. linearis (Ehr.) Cleve	2.5	2.5	2.5	7.5	...	...	...	...
S. (?) borrichii Boye Pet.	...	...	...	...	...	2.5	...	...
S. muriella Lund	37.5	75.0	15.0	2.5	55.0	50.0	25.0	32.5
S. thermicola Boye Pet.	2.5	...	...	...	...	...	...	...
Symploca muralis Kuetz.	2.5	40.0	12.5	25.0	2.5	42.5	12.5	17.5
S. muscorum (Ag.) Gom.	22.5	80.0	52.5	30.0	25.0	55.0	35.0	65.0
Synechococcus aeruginosus Naeg.	5.0	10.0	15.0	5.0	30.0	5.0	...	2.5
Ulothrix bacillaris (Naeg.) For.	...	...	5.0	...	...	...	...	...
U. flaccida Kuetz.	15.0	80.0	70.0	52.5	2.5	35.0	12.5	30.0
U. subtilissima Rabh.	...	...	...	12.5	...	...	...	...
Vaucheria borealis Hirn.	...	...	2.5	...	...	...	...	...
V. hamata (Vauch.) DeC.	...	...	...	2.5	...	...	...	...
V. terrestris (Vauch.) DeC.	...	...	...	2.5	...	...	...	...
Volvox sp.	...	...	...	...	2.5	...	...	...

TABLE 3

SEASONAL DISTRIBUTION OF ALL SPECIES AND VARIETIES IN THE FOUR PLOTS. NUMBERS 1, 2, 3, AND 4 REPRESENT FALL, WINTER, SPRING, AND SUMMER, RESPECTIVELY. NUMBERS UNDERLINED (1, 2, 3, 4) INDICATE THE PREDOMINANTS (OCCURRED IN 45-100 PER CENT OF THE SAMPLES)

Genera, Species and Varieties	Forests		Prairies	
	Plot 1	Plot 2	Plot 3	Plot 4
Achnanthes coarctata	1234	.2..	....	....
Anabaena inaequalis	...4	....	....	....
A. oscillarioides	.234	...4	.234	..34
Aphanothece stagnina	1234	1234	1234	1234
Borzia trilocularis	....	..3.	.23.	.2..
Carteria cordiformis	....	....	1...	....
C. crucifera	1...	....	....	1...
C. globosa	....	1...	....	....
Characiopsis pyriformis	.234	..34	....	....
C. pyriformis var. subsessilis	...4	....	....	...4
Characium ambiguum	...4	....	....	....
C. operculum	....	1...	....	....
C. pringsheimii	12.4	..3.	....	....
Chlamydomonas sp.	..3.	..3.	..3.	..3.
Chlorella variegatus	....	....	1...	....
C. vulgaris	...4	..34	..34	..3.
Chlorococcum humicola	1234	1234	1234	1234
Chroococcus minimus	1...	....	1...	....
C. minutus	....	1...	....	....
Cosmarium pokornyanum	1234	.234	.234	....
Cylindrospermum licheniforme	1234	1234	1234	1234
C. majus	1234	1...	1..4	..3.
C. muscicola	1...	....	....	....
C. stagnale	123.	..34	...4	..3.
Euastrum sp.	....	....	....	..34
Euglena sp.	..34	..34	...4	....
Gloeothece rupestris	1...	....	....	...4
Hantzschia amphioxys	1234	1234	1234	1234
Lyngbya aestuarii	1234	1234	1234	1234
Microcoleus lacustris	1..4	....	....	....
M. paludosus	1234	1234	1234	1234
M. rupicola	1234	123.	12.4	12..
M. vaginatus	1234	1234	1.3.	1...
Navicula (?) cincta	....	....	.2..	....
N. fritschii	1234	1234	1234	1234
N. grimmei	.23.	....	....	....
N. (?) muralis	....	1...	....	....
N. mutica	1234	1234	1234	1234

TABLE 3--Continued

Genera, Species and Varieties	Forests Plot 1	Forests Plot 2	Prairies Plot 3	Prairies Plot 4
N. mutica var. cohnii	1234	123.	123.	123.
N. mutica var. nivalis	.23.	....	1..4	12..
N. mutica var. ventricosa	123.	....	....	1...
N. pseudatomus	1234	1234	1234	12.4
N. seminulum	....	12..	....	....
Nitzschia (?) communis	....	....	1...	....
N. ignorata	12..	....	....	1234
N. palea	....	...4	...4	...4
Nostoc commune	123.	1234	1...	12.4
N. ellipsosporum	12..	12..	1...	1...
N. muscorum	1234	1234	1234	1234
Oedocladium lewisii	1234	....	....	....
Oocystis lacustris	....	....	....	..3.
Oscillatoria splendida	....	...4	....	....
Phormidium sp.	....	...4	....	...4
P. autumnale	1.34	..34	.234	.234
Pinnularia borealis	1234	1234	1234	1234
P. intermedia	1234	1234	1234	.2..
P. microstauron	1234	12.4	12.4	1234
Plectonema nostocorum	1234	1234	1234	1234
P. purpureum	....	....	..3.	..3.
Porphyrosiphon fuscus	.234	12..	.23.	1..4
P. notarisii	1234	1234	12..	1234
Raphidiopsis curvata	..3.	....	....	....
Schizothrix braunii	...4	....	....	....
S. giuseppei	....	....	....	1...
S. heufleri	1234	1234	12.4	123.
S. purpurascens	1.3.	1234	12.4	1234
Scytonema hofmannii	1234	1234	1234	1234
Stauroneis anceps	.2..	....	....	....
S. anceps var. linearis	1234	....	....	....
S. (?) borrichii	....	....	....	.2..
S. muriella	1234	123.	1234	1234
S. thermicola	1...	....	....	....
Symploca muralis	.2.4	1234	.234	12.4
S. muscorum	1234	1234	1234	1234
Synechococcus aeruginosus	1234	.234	12.4	12..
Ulothrix bacillaris	....	..3.	....	....
U. flaccida	1234	1234	1234	.23.
U. subtilissima	....	...4	....	....
Vaucheria borealis	..3.	....	....	....
V. hamata	...4	....	....	....
V. terrestris	...4	....	....	....
Volvox sp.	....	....	....	1...

TABLE 3--Continued

Genera, Species and Varieties	Forests		Prairies	
	Plot 1	Plot 2	Plot 3	Plot 4
Total of species and varieties per plot	61	51	46	51
Total of species and varieties per plot per season:				
Fall	43	34	33	34
Winter	42	32	31	31
Spring	43	36	28	30
Summer	44	35	32	29

TABLE 4

NUMBER AND PERCENTAGE OF SPECIES AND VARIETIES OF ALGAE IN FOREST AND PRAIRIE PLOTS PER SEASON PER CLASS

Class and Season	Number of Species			Percentage Total Species in		
	Forest	Prairie	Total	Forest Only	Prairie Only	Both Forests and Prairies
Cyanophyceae						
Fall	26	22	28	21.4	7.2	71.4
Winter	21	19	23	17.4	8.7	73.9
Spring	23	20	24	16.7	4.2	79.1
Summer	26	22	27	18.5	3.7	77.8
Bacillariophyceae						
Fall	16	13	18	27.8	11.1	61.1
Winter	17	13	19	31.6	10.5	57.9
Spring	14	10	15	33.3	6.7	60.0
Summer	12	11	14	21.4	14.3	64.3
Chlorophyceae						
Fall	8	6	11	45.4	27.3	27.3
Winter	5	3	5	40.0	0.0	60.0
Spring	8	7	10	30.0	20.0	50.0
Summer	8	4	9	55.6	11.1	33.3
Xanthophyceae						
Fall	0	0	0	0.0	0.0	0.0
Winter	1	0	1	100.0	0.0	0.0
Spring	2	0	2	100.0	0.0	0.0
Summer	4	1	4	75.0	0.0	25.0
Euglenophyceae						
Fall	0	0	0	0.0	0.0	0.0
Winter	0	0	0	0.0	0.0	0.0
Spring	1	0	1	100.0	0.0	0.0
Summer	1	1	1	0.0	0.0	100.0

TABLE 5

NUMBER AND PERCENTAGE OF SPECIES AND VARIETIES OF ALGAE IN FOREST AND PRAIRIE PLOTS PER SEASON

Season	Number of Species			Percentage Total Species in		
	Forest	Prairie	Total	Forest Only	Prairie Only	Both Forests and Prairies
Fall	50	41	57	28.1	12.3	59.6
Winter	44	35	50	30.0	8.0	62.0
Spring	48	37	50	26.0	8.0	66.0
Summer	51	39	53	26.4	7.6	66.0

TABLE 6

SPECIES AND VARIETIES PRESENT ONLY
IN ONE VEGETATION TYPE

Forests	Prairies
Achnanthes coarctata	Carteria cordiformis
Carteria globosa	Chlorella variegatus
Characium ambiguum	Euastrum sp.
C. operculum	Navicula (?) cincta
C. pringsheimii	Nitzschia (?) communis
Characiopsis pyriformis	Oocystis lacustris
Chroococcus minutus	Plectonema purpureum
Cylindrospermum muscicola	Schizothrix giuseppei
Microcoleus lacustris	Stauroneis (?) borrichii
Navicula grimmei	Volvox sp.
N. (?) muralis	
N. seminulum	
Oedocladium lewisii	
Oscillatoria splendida	
Raphidiopsis curvata	
Schizothrix braunii	
Stauroneis anceps	
S. anceps var. linearis	
S. thermicola	
Ulothrix bacillaris	
U. subtillissima	
Vaucheria borealis	
V. hamata	
V. terrestris	

Percentage of total species and varieties confined to	
Forests	29.3
Prairies	12.2

TABLE 7

SPECIES AND VARIETIES OCCURRING IN ALL SEASONS FROM FOREST AND PRAIRIE PLOTS (X*-PRESENT IN 45-100 PER CENT OF SOIL SAMPLES PER SEASON)

Species and Varieties	Forests	Prairies
Achnanthes coarctata	X	-
Aphanothece stagnina	X	X
Characium ambiguum	X	-
Chlorococcum humicola	X*	X*
Cosmarium pokornyanum	X	-
Cylindrospermum licheniforme	X*	X
C. majus	X	-
C. stagnale	X	-
Hantzschia amphioxys	X*	X*
Lyngbya aestuarii	X	X*
Microcoleus paludosus	X	X
M. rupicola	X	-
M. vaginatus	X	-
Navicula fritschii	X	X
N. mutica	X*	X*
N. mutica var. cohnii	X	-
N. pseudatomus	X	X
Nitzschia ignorata	-	X
Nostoc commune	X	-
N. muscorum	X*	X*
Oedocladium lewisii	X	-
Pinnularia borealis	X*	X*
P. intermedia	X	X
P. microstauron	X	X
Plectonema nostocorum	X*	X*
Porphyrosiphon fuscus	X	X
P. notarisii	X	X
Schizothrix heufleri	X	X
S. purpurascens	X	X
Scytonema hofmannii	X*	X
Stauroneis anceps var. linearis	X	-
S. muriella	X	X
Symploca muralis	X	X
S. muscorum	X	X
Synechococcus aeruginosus	X	-
Ulothrix flaccida	X	X

TABLE 8

PREDOMINANT SPECIES AND VARIETIES IN FOREST AND PRAIRIE PLOTS PER SEASON (F-FALL, W-WINTER, SP-SPRING, SU-SUMMER)

Species and Varieties	Forests				Prairies			
	F	W	Sp	Su	F	W	Sp	Su
Chlorococcum humicola	X	X	X	X	X	X	X	X
Hantzschia amphioxys	X	X	X	X	X	X	X	X
Navicula mutica	X	X	X	X	X	X	X	X
Nostoc muscorum	X	X	X	X	X	X	X	X
Pinnularia borealis	X	X	X	X	X	X	X	X
Plectonema nostocorum	X	X	X	X	X	X	X	X
Cylindrospermum licheniforme	X	X	X	X	X	-	-	-
Scytonema hofmannii	X	X	X	X	X	-	-	-
Lyngbya aestuarii	-	-	-	-	X	X	X	X
Aphanothece stagnina	X	X	-	-	X	-	-	X
Symploca muscorum	-	X	X	-	-	X	-	X
Pinnularia intermedia	X	X	-	-	-	X	-	-
Schizothrix heufleri	X	X	-	-	X	-	-	-
Stauroneis muriella	-	X	-	-	X	X	-	-
Ulothrix flaccida	-	X	X	X	-	-	-	-
Navicula fritschii	-	-	-	X	-	-	-	X
N. pseudatomus	-	X	-	X	-	-	-	-
Pinnularia microstauron	X	X	-	-	-	-	-	-
Chlamydomonas sp.	-	-	X	-	-	-	-	-
Microcoleus paludosus	-	X	-	-	-	-	-	-
Navicula mutica var. cohnii	X	-	-	-	-	-	-	-
Nitzschia palea	-	-	-	-	-	-	-	X
Nostoc commune	-	X	-	-	-	-	-	-

TABLE 9

A COMPARISON OF THE pH OF SOIL OF THE FOREST AND PRAIRIE PLOTS (EACH FIGURE BASED ON AN AVERAGE OF THE HYDROGEN-ION CONCENTRATION OF 20 SAMPLES)

Plots	Date of Collections	Mean	Range
Forests			
Plot 1	October 23, 1956	6.5	5.7 - 7.1
Plot 2	October 26, 1956	6.4	5.9 - 7.2
Prairies			
Plot 3	October 27, 1956	6.7	6.3 - 7.2
Plot 4	October 30, 1956	6.9	6.7 - 7.3

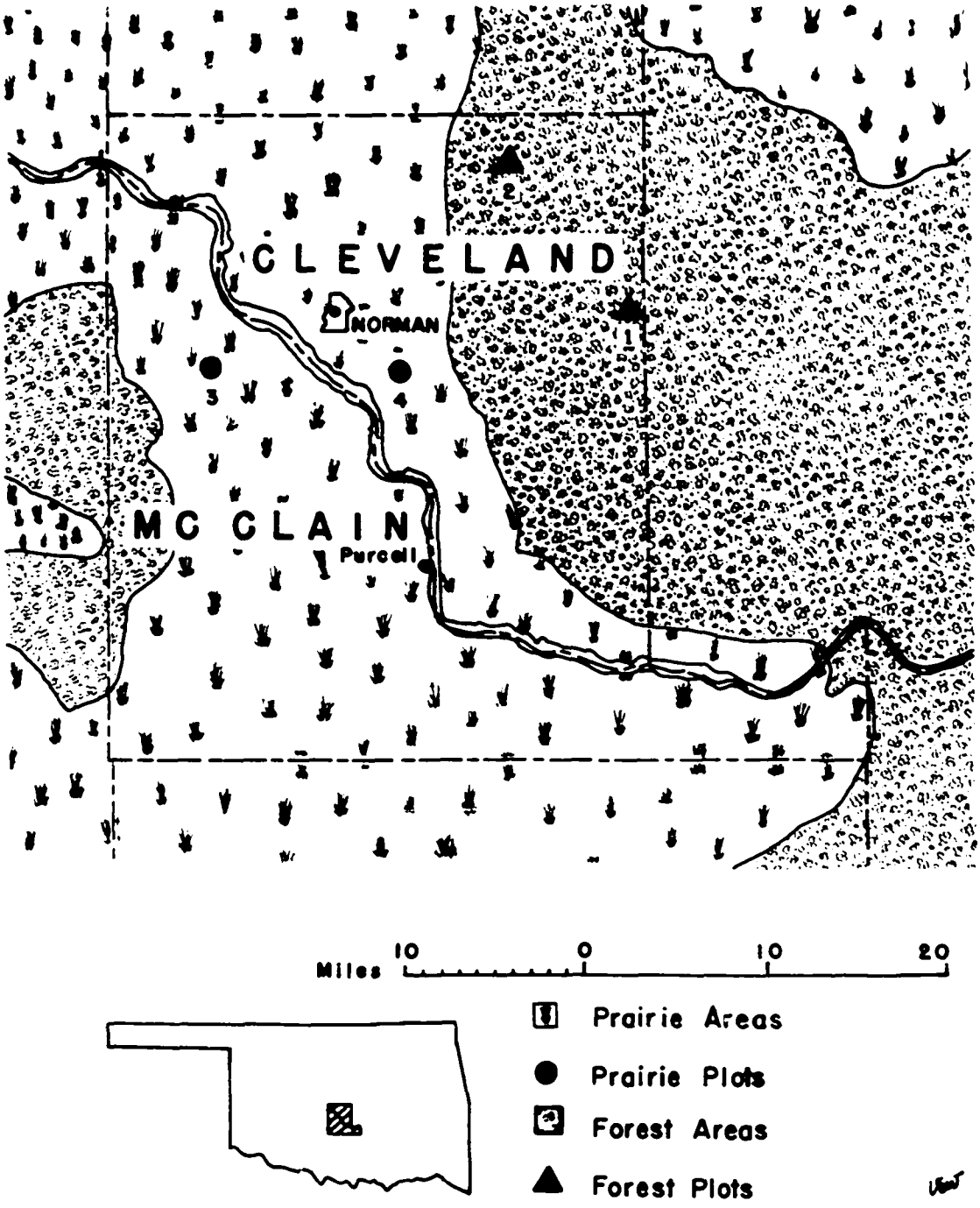

FIG. 1. MAP SHOWING LOCATION OF PLOTS (1, 2, 3, 4) SAMPLED

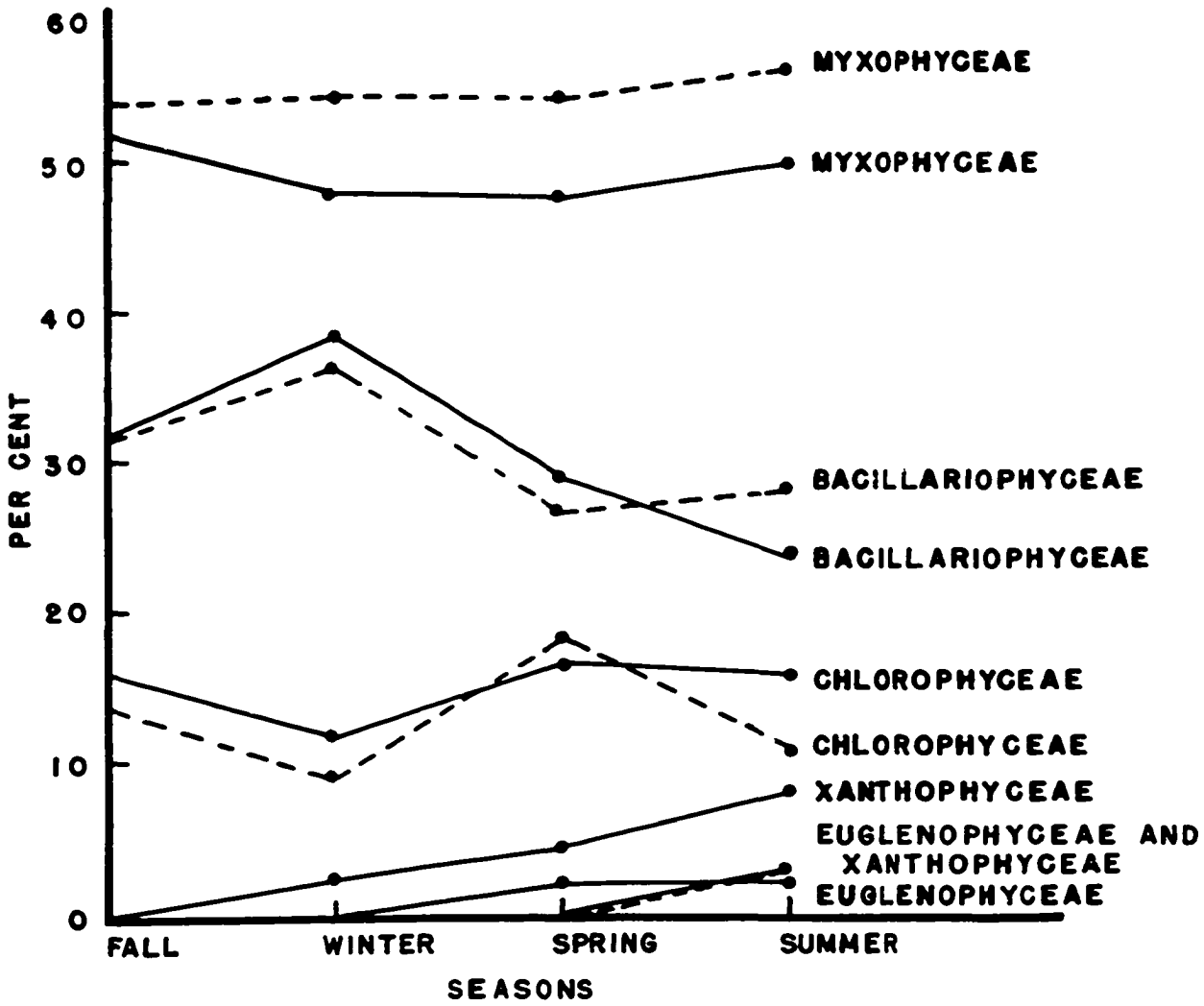

FIG. 2. PERCENTAGE COMPOSITION OF SPECIES AND VARIETIES OF ALGAE PER SEASON FOR EACH VEGETATION TYPE (SOLID LINE, FOREST PLOTS; BROKEN LINE, PRAIRIE PLOTS)