
A Comparison of Chemical Characteristics and Soil Invertebrate Diversities in Coniferous and Deciduous Forest Soils

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Abstract: Levels of phosphorus, potassium, nitrogen, pH, and moisture were measured for soils found under deciduous and conifer trees. Soil invertebrates were sampled from each area and the species diversities calculated. There was a significantly higher diversity and more organisms in the deciduous soil. Earthworms, gastropods, and millipedes were more likely to be found in deciduous soil while mites and springtails were more numerous in coniferous soil. This difference in distribution is related to the pH levels (which were lower in the coniferous soil), the amount of nutrients available, and the vegetation growing in the area.

INTRODUCTION

The soil types, vegetation, and organisms in a soil ecosystem determine the efficiency of the nutrient cycle. The soil type has an effect on the vegetation through its acidic properties, availability of nutrients, and pore size of the soil particles (Birch and Clark 1953). Some vegetation in turn affects soil properties. For example, conifers increase acidity and decrease the amount of available nutrients in the soil where they grow (Spurr and Barnes 1980). Soil organisms sensitive to varied pH and nutrient levels are then dependent on both soil and vegetation types in determining their distribution. It should be stressed that acidity levels alone are not the limiting factor in the distribution of organisms and consequently the species diversity. Wilde (1954) states that pH affects the activity of soil organisms, availability of nutrients, and structure of soils; yet the limiting factor seems to be nutrient availability. Little is known about how nutrients are recycled in a soil ecosystem through the decomposition of litter, though it is acknowledged that soil organisms play a major role in this process. They disintegrate plant tissues, decompose sugar, cellulose and lignin, transform nutrients into humus, and mix organic matter with mineral soil (Edwards 1974). Specific organisms accomplish decomposition at various rates in different soil types. So soil organisms are the machinery that keeps a soil ecosystem recycling its nutrients.

Thus it is important to identify the role of each species in this cycle, and to determine how chemical and physical differences in the soil affect the type and abundance of the organisms inhabiting particular soil types. Deciduous and coniferous forest soil types were analyzed in this study to determine if their chemical and physical properties would affect the amount, type, and diversity of soil invertebrates inhabiting them. The null hypotheses are :

1. There is no difference between the chemical and physical properties of coniferous and deciduous soils.
2. There is no difference between the type, abundance, and diversity of soil invertebrates found in coniferous and deciduous soils.

METHODS

Several physical and chemical properties and soil invertebrate species diversities were measured in coniferous and deciduous soils of the Carleton Arboretum in Rice Co., Minnesota. The two sampling areas were located on level ground just south of the Cannon River. They were about 100 meters apart and were most likely subjected to the same environmental conditions because of their close proximity. Scots pine and cedar dominated the conifer stand, while basswood, elm, and shagbark hickory grew in the deciduous stand.

All sampling of the soils and organisms was done from mid-October to mid-November. Chemical properties of the soils were examined twice (at the beginning and end of study) using the LaMotte soil testing kit. Levels of potassium, nitrogen, phosphorus and pH, as well as moisture content were measured. Only three levels (high, medium, and low) were used in determining potassium, nitrogen, and phosphorus amounts, The pH was determined by mixing equal weights of soil and water and using an electrode for better accuracy (within .5).

Soil organisms were sampled by placing a 1 ft^2 metal frame on the surface of the soil (after clearing the litter) and digging out a square piece of soil 10 cm deep within the grid. These samples were placed in metal pans and brought back to the lab to be analyzed. Ten samples of each forest soil type were randomly taken, Organisms were picked out by hand and stored in ethanol. Ten soil cores were also taken from each site, and the Burlese-Tullgren funnels were used to collect smaller organisms. All of the organisms found in the samples were counted and identified. Both the Shannon and Simpson diversity indexes were calculated for invertebrates from each site. A significance test was done on the Simpson diversity values.

RESULTS

There were some similarities in the chemical levels of the deciduous and coniferous soils (see Table 1). Only pH and phosphorus differed, with lower levels of both in the coniferous soil. Nitrogen, potassium, and moisture content were very similar. On Table 2, pH and phosphorus again differed between the soil types. However, phosphorus was higher in the coniferous soil in this data set and moisture differed also. It is important to note that this set of data was for soils found in the east side of the Arboretum, whereas my samples came from the south. Nutrient levels in the soil are very dynamic and change with the moisture, temperature, and season. For higher accuracy, the chemical levels should have been measured more often, and calcium levels should have been tested since this nutrient is very important in determining species distribution.

Distinct differences occurred in the soil appearances. The coniferous soil was dark, crumbly, and layered, with lots of fungi in it and a large amount of needle litter on top. The deciduous soil was colored more evenly, which indicates a mixture of organic and mineral soil, had lots of earthworms, small green plants, and a relatively thin layer of leaves and twigs on top.

Table 3 shows the classification of all organisms found in both coniferous and deciduous soil samples. The common name is given for those organisms that were identified and counted. Insecta is the class represented by the most species, although chilopods, diplopods, crustaceans, ogliochaetes, nematodes, and arachnids were also found.

Table 4 shows the distribution of these organism types as they were found in coniferous and deciduous soils. Many more individuals (299) were found in the deciduous as compared to 188 in the coniferous. Over twice as many "species" were recognized in the deciduous soil. Both had nematodes, but these organisms were too numerous and small to count. The Shannon and Simpson diversity indexes were both higher for the deciduous organisms than the coniferous. The significance test done for the Simpson index resulted in a t value of 10.82 which far exceeds the critical value of $t=1.92$ at $p < .05$. In fact, $p < .001$, indicating a significantly more diverse group of organisms in the deciduous soils.

DISCUSSION

Although it is generally accepted that conifers are found growing in soils with a lower pH, they are not limited to this type of soil. However, they are more acid-tolerant than other trees, so they grow there more often in order to avoid competition with hardwoods on a less acidic soil (Spurr and Barnes 1980). Conifers do have an influence on the soil in which they grow by lowering the pH and amount of available nutrients. While all leaves are slightly acidic, needles are much more so than deciduous leaves (Spurr and Barnes 1980). When they form litter on the soil and decompose, soil acidity is increased. They also decompose more slowly, so nutrients remain in the needles and are not available for use. Since the soil in my two sampling sites most likely had the same characteristics before the conifers were planted. the conifers must have increased the acidity in the time since they were planted would account for the pH difference of 5.6 in the coniferous soil and a pH of 7.5 just 100 meters away in the deciduous area.

Differences in phosphorus levels for the two areas probably resulted from the more rapid cycling of nutrients in the deciduous soils. Conifer needles take 3-5 years to decay, while deciduous litter decays in 6-12 months (Ovington 1962 as cited by Spurr and Barnes 1980). Nutrients such as phosphorus, or nitrogen might be held up in the litter, or leached out by rain and not be detected in the soil tests. This probably happened for both soil types when considering the low nitrogen levels. Pines cause the soil to be lower in pH, nitrogen, exchangeable bases, and cation exchange capacity as found in a study done by Zinke (1962) where all these properties increased as the distance from the tree in which they were measured increased. Conifers also take up less nutrients from the soil and usually live in nutrient poor soils to begin with (Spurr and Barnes 1980). In this table adapted from Rennie (1955) we see how many more nutrients deciduous trees take up than the conifers (numbers are in kg/ha) :

	Ca	K	P
Pines	502	225	52
Non-pine conifers	1082	578	101
Deciduous	2172	556	124

P.E.Muller, a Danish pedologist, defined two general soil types which he identified as the mor and the mull soils. Mor soil is more acidic, has more fungi, less bacteria, and distinct layers of decomposition including leaves and twigs, decomposing litter, and humus. Mull decomposes much more rapidly, contains lots of earthworms and bacteria, and mixed layers of organic and mineral soil (Brown 1978). Judging from my physical observations of the soils, the coniferous soil tends towards the mor type while the deciduous soil tends towards the mull. When considering this difference and the differences in pH and phosphorus, my null hypothesis stating that the soils would be the same can be rejected.

There was a noticeable difference in the species type, abundance, distribution, and diversities of soil invertebrates in the coniferous and deciduous soils, warranting the rejection of my second null hypothesis. ~~From~~ Table 4 ~~it is observed~~ that more earthworms, millipedes, beetles, and snails inhabited the deciduous soil while mites and springtails were more numerous in the coniferous soil. Bornebusch (1930) as cited in Brown (1978) and Raw (1967) found twice as many earthworms and gastropods, and four times the millipedes and centipedes in deciduous soils (with pH of 5.8-6.1). He found more potworms, three times the mites and springtails, and four times the Diptera and elatereid larvae in a spruce forest (with pH 3.6-5.6). In a study done by Kevan (1962) as cited in Brown (1978) there were more potworms and centipedes in coniferous soil, and more earthworms, gastropods, and springtails in the deciduous. Mites were found in the same frequencies. The general trend observed is that there ~~are~~ definitely more earthworms, millipedes, and gastropods in deciduous soils. However, it appears that there should have been more potworms in my coniferous soil. Mites and springtails appear to be well distributed in both types of soil. There are several possibilities for error in my sampling methods. Some of the fast organisms on the surface might have escaped as the litter was cleared off the soil surface. Dark organisms would have been very easy to miss when sorting through the soil. So my sample of organisms is probably biased toward slow, light-colored organisms.

Some of the soil properties that affect organism distributions are pH levels, availability of food, nutrients, moisture, and adequate pore size (Birch and Clark 1953). A low pH limits the amount of available nutrients, especially calcium. The low frequency of earthworms in acidic soil is not so much a result of low acidity tolerance (which does occur in some species of earthworms) but of low availability of calcium and other essential nutrients in the soil. (Satchell 1967). Earthworms have also shown a preference for consuming hardwood leaves that are high in nitrogen, calcium, proteins, and sugar while avoiding conifer needles which are low in these nutrients and sometimes contain distasteful tannins (Schlenker 1971). Earthworms are responsible for adding nutrients such as calcium, potassium, and phosphorus to the soil by consuming leaf litter and excreting casts into the soil (Brown 1978). These casts provide food for bacteria who then breakdown the nutrients further to be mixed with the soil. The bacteria provide food for the protozoans, who then are food for larger carnivorous invertebrates such as centipedes. Large herbivores are also found along with earthworms since they can digest deciduous leaf litter much more efficiently. Earthworms also aerate the soil with their burrowing activities so that more oxygen and water can reach other soil organisms and plant roots. These activities also loosen up dirt and mix the organic humus with mineral soil, speeding up decomposition. All this creates many niches for different organisms to occupy, resulting in higher species diversities wherever earthworms are abundant.

Without as many earthworms in the soil, coniferous soils end up with much slower decomposition and nutrient recycling rates, along with less aeration and mixing which results in layers of organic matter that is separate from the mineral soil. This type of soil is more likely to experience leaching of nutrients. Fewer bacteria inhabit the soil and most decomposition is done by fungi, which thrive in acidic conditions. So the combination of lower pH, less available nutrients, and decreased aeration of the soil limits the abundance of some organisms such as earthworms, gastropods and millipedes in coniferous soils. However, mites and springtails can exist well in these conditions. These organisms essentially take the place of earthworms by releasing nutrients into the soil through their feces. They are small enough to live in more compact, less aerated soils and both feed on fungi (which is why they also can exist well in deciduous soils by filling this niche) that is rich in nutrients (Wallwork 1967, Hale 1967). The mites also distribute fungal spores so the nutrient cycling can continue; springtails also consume the feces of larger arthropods and it is speculated that they are able to break down nutrients and chitin (Millar 1974). Enchytraeidae continue the decomposition process by consuming springtail droppings which may explain why there are more in coniferous soils than deciduous soils(O'Conner 1967).

Soil invertebrates play a major role in the decomposition of forest litter. Certain species with specialized functions occupy niches in different soil types that facilitate this process. So the effect the vegetation has on the soil determines which organisms inhabit the soil; while the organisms allow for the plants to continue their existence by cycling their nutrients back to the soil in available forms. Some of the necessary niches are illustrated in Table 5. "Reducer" organisms are the most important in a soil ecosystem. They must be able to begin the break down of litter into useable nutrients for other organisms and plants. Earthworms and bacteria fill this role in deciduous soil, while mites, springtails, and fungi do so in the coniferous soil. The "mixers" mix the organic matter with mineral soil so nutrients can be taken up by the plant roots. This occurs more efficiently (by the earthworms mainly) in deciduous soil, resulting in faster decomposition and recycling rates. "Channelers" create tunnels in the soil for air and water to reach both plant roots and soil organisms. Larger organisms such as earthworms, millipedes, and beetles occupy this niche.

Complex interactions occur between soil and vegetation, soil and organisms, and vegetation and organisms in a soil ecosystem. All are necessary to maintain nutrient cycling in order to ensure that the soil will continue to support life. This study has shown how organisms occupy different niches to carry out the recycling process. Lower pH and nutrient levels caused by conifers inhibit some organisms such as earthworms and gastropods in coniferous soils. The earthworm is a keystone species in the soil communities. The abundance of this organism in the deciduous soils result in more efficient cycling because more diverse species can occupy the niches created by the earthworm while each of their functions contribute to the nutrient cycle. The coniferous ecosystem still functions (while less efficient than the deciduous) because other species such as mites and springtails aid greatly in the breakdown and recycling of nutrients. It is essential for both the plants and organisms for these ecosystems to remain in balance. Further study is needed on the detailed roles that organisms, plants, and soils play in determining how the nutrient recycling process occurs. The effects of pesticides, pollution, and acid rain on this system also need to be examined so we can preserve our forests and agriculture as our ecosystems grow more fragile.

Table 1: Chemical and physical characteristics of deciduous and coniferous soils found in the Carleton Arboretum.

Characteristic	Coniferous	Deciduous
pH	5.6	7.5
Phosphorous	low	high
Nitrogen	very low	very low
Potassium	high	med. high
Moisture content	16.1%	16.2%

Table 2: Data from the 1988 field ecology soil lab (also done in the Carleton Arboretum).

Characteristic	Coniferous	Deciduous
pH	6.0	over 7
Phosphorus	high	low
Nitrogen	very low	very low
Potassium	high	high
Moisture content	9.5%	19.9%
Density (g/cm^3)	1.25	1.08

Table 3: Classification of soil invertebrates

Phylum Annelida
- Class Oligochaeta
    - Suborder Lumbriculidae
        - Family LUMBRICIDAE- earth worms
        - Family ENCHYTRACIDAE - pot worms

Phylum Arthropoda
- Class Arachnida
    - Order ACARI - mites
    - Order ARANEIDA- spiders
    - Order CHLEONETHI - false scorpions
- Class Chilopoda
    - Genus GEOPHILUS - centipedes
    - Genus LITHOBIUS - red centipedes
- Class Crustaceae
    - Order ISOPODA - terrestrial wood lice
- Class DIPLOPODA - millipedes
- Class Insecta
    - Order CLEOPTERA - beetles
        - Family BRUCHIDAE - seed weevils
        - Family ELATRIDAE - wire worms
        - Family TENEBRIONIDAE - darkling beetle
        - Family SCARABEIDAE - scarab beetle
    - Order DIPTERA - flies
        - Family TIPULIDAE - crane flies
    - Order Entotrophi
        - Family IAPYGIDAE - small,white insects
    - Order Hymenoptera
        - Family FORMICIDAE - ants
    - Order Heteroptera
        - Family CYDNIDAE - burrow bug
    - Order Lepidoptera
        - Family NOCTUIDAE - cutworms
    - Subclass Apterygota
        - Order COLLEMBOLA - springtails

Phylum Mollusca
- Class GASTROPODA - snails

Phylum Nematoda

Table 4: Number of individuals in each taxonomic group found in deciduous and coniferous soils. Ph. = Phylum, Cl. = Class, O. = Order, F. = Family, G. = Genus, D.I. = Diversity Index.

Taxonomic Group	Number of individuals Deciduous	Coniferous
F. Lubricidae	34	2
F. Enchytracidae	19	13
O. Acari	65	96
O. Araneida	1	
O. Chleonathi	6	
G. Geophilus		3
G. Lithobius	1	
O. Isopoda	7	
O. Diplopoda	14	
O. Cleoptera (big larvae)	5	11
(small larvae)	2	2
F. Bruchidae		1
F. Elatridae	1	
F. Tenebrionidae	1	
F. Scarabeidae	3	1
O. Diptera (pupa)	5	
F. Tipulidae	1	
F. lapygidae	4	
F. Formicidae	1	
F. Cydnidae	1	
F. Noctuidae (pupa)	1	
O. Collembola	30	59
Cl. Gastropoda	7	
Ph. Nematoda?	yes	yes
total # of individuals	299	188
# of different species	22	10
Shannon D.I.	.77	.58
Simpson D.I.	.92	.64

Table 5: Categories of the function of invertebrates in the soil.

Reducers	Mixers	Channelers
wood lice, springtails, earthworms, pot worms, nematodes, mites, fungi	earthworms, pot worms	millipedes,worms, beetles, larvae

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