To the Graduate Council:

I am submitting herewith a thesis written by Dennis Paul Shepard entitled "Comparison of Physical and Chemical Properties of Commercial and Indigenous Forms of Organic Matter in Golf Green Soil Mixtures." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ornamental Horticulture and Landscape Design.

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COMPARISON OF PHYSICAL AND CHEMICAL PROPERTIES OF COMMERCIAL AND INDIGENOUS FORMS OF ORGANIC MATTER IN GOLF GREEN SOIL MIXTURES

A Thesis
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ABSTRACT

The purpose of this study was to determine the influence and degradation rate of several commercial and indigenous forms of organic matter in soil mixtures for golf greens. The study included both physical and chemical determinations.

A greenhouse study was conducted to compare bentgrass (*Agrostis* sp.) responses and disease incidence, media leachate volumes, pH of leachates, and temperatures of media. Samples were tested in a laboratory to determine particle size distribution, organic matter, porosity, bulk density, percolation rate, and cation exchange capacity.

The indigenous organic materials of pine bark, oak sawdust, sewage sludge, cotton chop, corn chop, and soybean chop compared favorably with the commercial forms of Michigan and sphagnum peats as organic amendments.

There was no apparent serious problems with acidity resulting through the process of decomposition of the media tested.

All of the test media met USGA specifications for porosity and bulk density.

The USGA mix was the only test media to meet USGA recommendations for percolation. All of the other media exceeded the maximum level recommended by the USGA. However, it is known that percolation rates often decrease considerably with time.

No significant amounts of silt and clay were added as a contaminant by the organic amendments tested, except for sewage sludge. Sphagnum

peat and pine bark demonstrated the greatest resistance to decomposition throughout the study. Sewage sludge, corn chop, and cotton chop experienced some decomposition during the first 26 weeks, but tended to resist decomposition thereafter. Michigan peat, soybean chop, and oak sawdust decomposed slightly at 26 and 52 weeks. Corn chop provided only a low amount of easily digestible organic matter.

All of the organic amendments showed an increase in cation exchange capacity with pine bark and oak sawdust showing the greatest increase with time.

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CHAPTER I

INTRODUCTION

The United States Golf Association and numerous universities have conducted considerable research over the years in developing technology toward constructing better golf putting greens. Investigations have been extensive in areas of determining fractional size, proportion and shape of sand, allowable quantities of silt and clay, green depth, and various types of inorganic and organic amendments needed to provide optimum physical and chemical conditions for turfgrass growth. Tests have been made to study such physical conditions as porosity, compaction, bulk density, particle migration, moisture characteristics, and percolation, among others. Cation exchange capacity and pH are two important chemical characteristics that have been studied. Organic matter sources and the proper amount needed to amend soils is an area that has received some attention also.

Cost of current recommended green construction is high and seriously restricts educational programs which encourage desired green mixtures and construction. Availability of low cost indigenous sources of organic materials could lower the overall cost of building golf greens and aid in promoting desired mixtures for green construction. Expense of golf course construction is the biggest argument against following desired guidelines of building greens.

The objective of this study was (1) to determine the influence and degradation rates of several commercial and indigenous forms of organic matter in soil mixtures for golf greens, and (2) to investigate the effects through decomposition of these organic matter sources on root and shoot growth of the turfgrass cover, with special emphasis on their stability, acidulation, persistence, and contributory disease incidence.

CHAPTER II

REVIEW OF LITERATURE

Soil modification by the addition of soil amendments is an important area of study in turfgrass management. A soil amendment is defined as an alteration of the properties of a soil by the addition of substances such as lime, gypsum, sawdust, etc., to the soil for the purpose of making the soil more suitable for the production of plants (17). Soils alone cannot meet the standards set by the United States Golf Association for proper green construction. Both organic and inorganic amendments are added to meet green construction requirements. The proper ratio of these amendments is of extreme importance.

I. INORGANIC AMENDMENTS

Through the years researchers have done considerable work on the use of sand as an inorganic soil amendment for golf putting green construction (27, 35, 50, 64). Results of extensive investigations indicate that rounded silica sands are preferable (to rocky, angular sands) with an ideal particle size distribution of 100 percent below 1.0 mm in diameter, 35 percent below 0.50 mm, 15 percent below 0.25 mm, and 5 percent below 0.05 mm (25). Investigations indicate also the following conditions as being necessary for optimum turfgrass growth and golf green construction: (1) infiltration and transmission of water through the mixture at a rate of 5 to 25 cm per hour with 10 to 15 cm per hour being ideal, (2) total pore space between 40 and 55 percent with at least 15 percent non-capillary porosity, (3) bulk density of 1.20 to 1.60 g/cm^3 with 1.25 to 1.45 g/cm^3 being ideal, and (4) a green depth of 36 cm after settling (25, 27, 35, 50, 64). These investigations showed that a golf green mixture meeting those requirements will reduce the effects of compaction by decreasing bulk density, increasing porosity, and allowing proper water infiltration and percolation. Lunt and Wyckoff (40) found that the more uniform the sand particle size the less compaction affected it.

II. ORGANIC AMENDMENTS

Organic matter affects soil properties by: (1) improving aggregation, (2) influencing aeration porosity and moisture retention, (3) influencing soil temperature through its effects on soil color and moisture content, (4) increasing cation exchange capacity which reduces leaching of cations, and by (5) serving as an essential plant nutrient source and an energy source for soil organisms (59).

Availability, cost, and physical and chemical properties of the different organic amendments have been of interest to researchers in studying their feasibility for use in golf putting greens. Their effectiveness depends on the kind of organic amendment, the amount in which they are added, how uniformly they are mixed, the soil type they are added to, and the various chemical and physical properties of the organic amendment. Desirable properties of an organic amendment include: (1) ease of handling and mixing, (2) good moisture retention, (3) resistance to decomposition, (4) a coarse or fibrous structure with few fines, (5) at least 90 percent organic matter content, and (6) freedom from disease organisms, insects, weed seeds, and toxic compounds (61).

Organic amendments decompose at different rates after they are added to a soil. Chemical composition of the residue, moisture, pH, temperature, available minerals, and the carbon:nitrogen ratio of the plant residue all influence decomposition (1).

Golf green mixtures under practical conditions are mixed on a volume basis. An 8-1-1 mixture is favored with the mixture consisting of eight parts sand, one part soil, and one part organic matter (25).

Previous work with a few types of organic materials has provided some indication of their potential responses in a soil mixture.

Peat

Extensive research has been done on peat and its utilization as an organic amendment for golf green mixtures (30, 36, 41, 50). Peat is defined as an unconsolidated soil material that consists largely of undecomposed, or only slightly decomposed organic matter accumulated under conditions of excessive moisture (17). Lucas et al. (36) reported that peat may bring about a number of desirable improvements such as: (1) increased moisture holding capacity of sandy soils, (2) increased water infiltration of fine textured soils, (3) increased soil friability and aeration, (4) decreased bulk density and improved plant root penetration, (5) increased buffering effect of the soil, (6) increased soil microbial activity, (7) source of slow-release nitrogen, and (8) increased availability of certain elements to plants. Peats should absorb four to five times their dry weight of water, contain at least

90 percent organic matter by weight on a dry-matter basis, and should normally vary in reaction from pH 4.0 to 7.5 or higher. Both raw and cultivated types of peat have been recommended (45).

Numerous studies have determined the physical properties of peat when used as an organic amendment. The addition of peat to a soil mixture has been shown to decrease compaction (14, 50). Swartz and Kardos (54) found that different soil types in sand-soil-peat mixtures reacted differently to compaction. A mixture containing 70 percent sand and a Gilpin silt loam was completely impermeable after compaction. All other mixtures with the same sand content were highly permeable. Several investigators found that the addition of peat increased percolation (48, 50, 53). Furthermore, the addition of peat to a soil mixture increases moisture retention (30, 36, 45, 50, 51). Research has shown that porosity of a soil mixture was increased with the addition of peat (50, 51, 53, 64). Zimmerman (64) found that increasing the peat content at the expense of soil decreased bulk density.

Peat influences the chemical characteristics of a soil mixture. Zimmerman (63) found coarse sand mixtures containing 10 percent peat were less fertile than sand containing 20 percent peat. The pH values were lower with the 20 percent peat also. Peats differ in their chemical nature and volume weight therefore requiring different liming rates if lime is needed. Nitrogen content of different peats varies with the nitrogen releasing slowly as the peat decomposes. Peat humus contains 2.0 to 3.5 percent, and sphagnum moss peat contains 0.6 to 1.4 percent nitrogen (36).

Some researchers found problems with peat. Morgan et al. (44) mixed sphagnum peat on a 33 percent volume basis with a Fallbrook sandy loam. They found if proper irrigation practices are not followed, peat may become excessively compacted. Smally et al. (51) found that peat mixed at a 10 percent by volume basis with an Arredondo loamy fine sand did not effectively increase hydraulic conductivity.

Sprague and Marrero (52) found that New Jersey peat and spent mushroom soil were more satisfactory than raw Michigan peat, manure, or peat moss for sandy soils. Lucas et al. (36) rated peats according to their value of adding stable organic matter as follows: Peat humus decomposed > reed-sedge peat > hypnum moss peat > sphagnum moss peat. Brown and Duble (11) found no significant difference between sand-soil-peat mixtures containing 0, 5, or 10 percent peat moss throughout the mixture as related to rate of bermudagrass cover development. A major disadvantage of peat is it is more expensive than some other types of organic matter.

Sawdust

Sawdust is an inexpensive organic matter source that is readily available in most areas of the country. The primary expense for sawdust is hauling. The ready availability and low cost of sawdust has focused considerable attention on it as a possible organic amendment for golf greens.

Sawdust consists chiefly of organic materials synthesized by the tree from water, and from carbon dioxide and oxygen from the air (3). The ultimate composition in relation to the elements of various woods does not markedly differ. Carbon varies from 48 to 54 percent. Nitrogen usually varies from 0.1 to 0.3 percent. Therefore sawdust has a wide carbon:nitrogen ratio (49). Products with wide carbon:nitrogen ratios decompose slowly (59). Several investigators have recommended that nitrogen be added with sawdust when it is used as a soil organic amendment (3, 33, 38, 41, 49, 56). Studies have shown that the primary harmful effects of sawdust to plants is the depletion of nitrogen, although this depleting effect seldom extends beyond the first season (3, 38). It has been recommended that an addition of one pound of nitrogen per 100 pounds of sawdust will raise the available nitrogen for plant use to a sufficient level of about 1.2 percent (3, 47).

Allison et al (4, 5) and Maas and Adamson (41) found that sawdust of softwoods decomposes more slowly than hardwood sawdust and requires less added nitrogen. Lunt (38) studied several types of sawdusts and found them to have little effect on soil acidity. This was confirmed by Allison and Anderson (3), but they suggested that it would be a good practice to add lime to the sawdust if the soil is not already well supplied with lime.

Principal benefits of using slowly decomposable sawdust are increased moisture retention and greater aeration (8). Sawdust can absorb up to 500 percent of its dry weight of water (23). Maas and Adamson (41) conducted work on the resistance of sawdust to decomposition in the presence of soil and nutrient solution. Over a 36-month period, it was found that particle size was not an important factor, but the presence of soil greatly increased the rate of decomposition.

The addition of a nutrient solution containing low levels of nitrogen, phosphrous, and potassium increased the rate of decomposition greatly in red alder sawdust and moderately in Douglas fir sawdust. Softwoods were found to decay slower than hardwoods.

Waddington et al. (60) tested the effect of sawdust on the germination and seedling growth of several turfgrasses using a mixture ratio of two parts soil to one part fresh sawdust. The effect of 12 fresh sawdust mixtures on Highland and Seaside bentgrass, Pennlawn fescue, and Merion Kentucky bluegrass were studied. Seedling height was reduced on all turfgrasses. Stand was reduced with some of the sawdust types. Softwoods required less nitrogen to restore green color than hardwoods. Results of their investigations concluded that it is best not to use fresh sawdust in seedbeds. This conclusion was supported by Wilde (62), Davey (20) and others. They pointed out that sawdust contains tannins and phenolic compounds injurious to plants and soil microbes. The harmful effects of these chemicals in old sawdust or composted sawdust tends to be much less than with some frest sawdusts.

Bark

Bark, like sawdust, is a waste material of the lumber industry. Bark has been used as a soil amendment in nursery container production (18, 29). The abundance of pine bark in the southern United States could provide a relatively inexpensive source of organic matter for use as an amendment to golf green soils.

Amending fine sand and silt with up to 50 percent by volume of milled pine bark increased vegetative growth and root development of

Tifgreen bermudagrass and delayed the effects of compaction (55). Bermudagrass recovery from low temperature was quickest in soils amended with 50 percent milled pine bark, followed by soil amended with 25 percent milled pine bark, and lastly in unamended soil. Mazur et al. (42) tested physical properties of hardwood bark growth media. Bark-soil mixtures for nursery container production deteriorated significantly after a 13-month incubation period. They further compared bark mixtures to peat mixtures for possible use in golf greens. On the basis of water flow rate and porosity, mixtures containing 60 to 70 percent sand, 15 to 20 percent peat or bark, and 15 to 20 percent soil were quite desirable. They concluded that since golf greens are built to last many years, hardwood bark would decompose too rapidly and be undesirable as an organic amendment for golf green construction.

Allison and Murphy (6) studied decomposition of nine species of pine bark in the presence and absence of additional nitrogen for periods of 63 to 800 days. Pine species studied were white, shortleaf, loblolly, slash, longleaf, ponderosa, western white, lodgepole, and sugar. Rate of decomposition of the barks was not significantly increased by additions of nitrogen. Lodgepole pine was the least resistant to decomposition.

Brown and Pokorny (12) tested the physical and chemical properties of milled pine bark and sand mixtures. Mixing pine bark and sand in proportions of 25, 50, and 75 percent by volume resulted in a bulk density range of 0.22 to 1.56 g/cm^3. Percolation rate decreased as sand increased (91 to 15 cm/15 minutes). The pH of the pine bark and sand mixtures increased as sand percentage increased (pH 4.1 to 5.4). Cation exchange capacity declined linearly as sand increased (11 to 1 m.e./100 cm^3).

Sewage Sludge

Sewage sludge is classified as either activated or digested sewage sludge. Activated sewage sludge is a natural organic nitrogen carrier (26). It has good physical characteristics and contains an average of 4 to 7 percent nitrogen with some of the nitrogen retained in unavailable or slowly released forms (7). It also contains 4 to 6 percent phosphate and 0.4 to 0.7 percent potash. Digested sewage sludge has a lower nutrient content and may be physically suitable for use (24). Sewage sludges may be either acid or alkaline and contain from 25 to over 60 percent organic matter (37).

Lunt (37) and Epstein (22) found that sewage sludge increases soil aggregation. Epstein found that digested sewage sludge added to Beltsville silt loam at 5 percent by weight retained approximately 10 times more water than the soil alone. He also found that available water decreased with time and came to "equilibrium" faster with higher temperatures. Hydraulic conductivity was initially increased but later dropped to that of the original soil. Some sewage sludge may increase the heavy metal content of soils and plants (9). Cornfield et al. (19) found that the overall activity of the organisms that decompose natural and added organic matter was unaffected by any of the types and levels of sludge they applied to a potting soil (loam, pH 6.7, organic matter 4.1 percent) in which barley was planted. Miller (43) used CO_2 evolution to determine decomposition of anaerobically digested sewage sludge in soil. Sewage sludge was rather resistant to further decomposition after a six-month incubation period during which only

20 percent of the carbon evolved as CO_2. Sludge decomposition was not affected by moisture content in a sandy soil. Most of the sludge decomposition occurred in the first month and soil temperature was the main factor influencing decomposition. Lunt (39) reported that about one-third to one-half of the nitrogen in activated sewage sludge is mineralized in four weeks when conditions were favorable.

Research on the effects of sewage sludge on turfgrass is limited. Burns and Boswell (15) compared turfgrass rooting in residential and industrial sludge. Centipedegrass rooting was drastically retarded by both sludges. Bermudagrass rooting was retarded only a little. Industrial sludge reduced rooting more than residential sludge probably because of higher heavy metal concentration. Boswell (9) found that forage yields of tall fescue were increased by about 30 percent over a two-year period in a Davidson clay loam-sludge amended soil as compared to soil alone. Burton et al (16) reported the benefit of good turfgrass growth from a combination of four parts sawdust to one part sludge. Sludge hastened the conversion process of sawdust to humus.

III. OTHER ORGANIC MATTER AMENDMENTS

Hulls of cocoa shells, rice, peanuts, and buckwheat have been tested as soil amendments. Richer et al. (48) found cocoa shells and peats to be equally desirable for use as a golf green amendment when used in amounts by weight of 14 percent or more. However, they found products other than peat generally to be unsatisfactory unless they were composted first. These amendments were fluffy, hard to handle for mixing if not composted first, and they broke down rapidly and generated considerable heat (45). Mushroom soil was found to be unsatisfactory because of its low organic matter content (48, 53). Another disadvantage of these materials is their restricted availability as compared to other organic matter sources.

Considerable research with sand and peat has established their importance as primary beneficial amendments for golf putting greens (27, 30, 35, 36, 48, 50, 54, 63). Research with inexpensive, readily available amendments is limited. Information is greatly lacking concerning the physical and chemical effects that noncommercial organic amendments such as cotton, corn, and soybean stalks have when used as an organic amendment in green mixtures.

CHAPTER III

MATERIALS AND METHODS

A study was conducted to determine the influence and degradation rate of several commercial and indigenous forms of organic matter in soil mixtures for golf greens. The experiments were conducted from January 1976 to January 1977 in greenhouse facilities of the Department of Ornamental Horticulture and Landscape Design on the Agricultural campus of the University of Tennessee, Knoxville.

I. GREENHOUSE PROCEDURE

Equipment Preparation

Wooden frames were constructed on top of four greenhouse benches to support heavy glazed containers holding the test media. Each frame contained 20 glazed containers of approximately 7,100 cm^3 volume (Figure 1). The study consisted of 10 treatments replicated four times with duplicated samples totaling 80 containers of test media. Duplicated samples were needed to permit dismantling a set at six months and again at 12 months following test initiation.

The containers had a drain hole in the bottom of approximately 3 cm diameter (Figure 1). A rubber stopper containing a glass drain tube was mounted in the hole flush with the inside bottom of the containers. Paraffin was poured into the bottom of the containers and tapered toward the center to assure positive flow of effluent to the drain hole. The containers were mounted on the wooden frames with the rubber supported

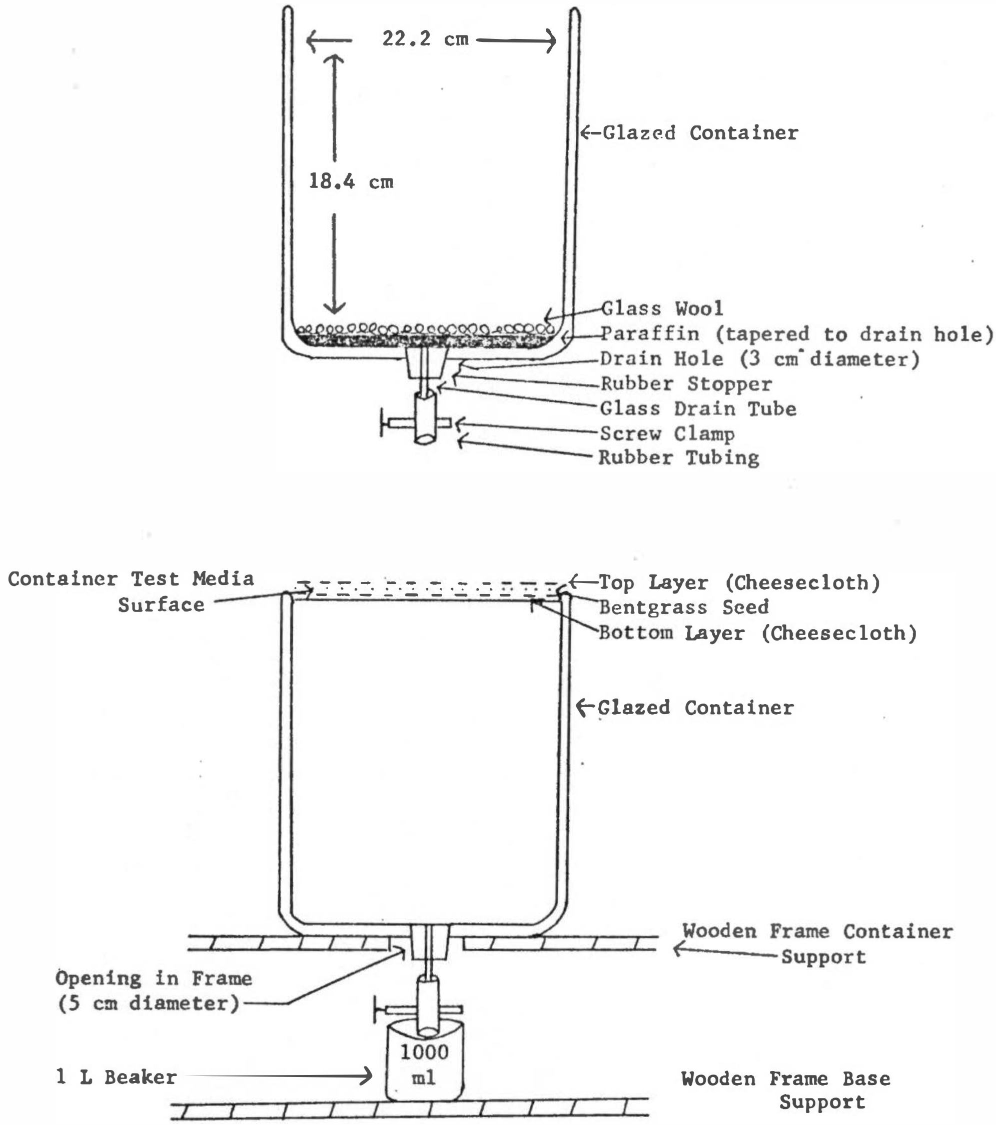

Figure 1. Cross-section diagram of glazed container showing container size and drainage system (top), and container positioned on frame support and leachate collection method (bottom).

glass drain tube suspended through a 5 cm diameter hole. The frame support raised the containers approximately 25 cm above the base support so that a 1 liter beaker could be positioned beneath each container drain tube to collect leachate. A thin layer of glass wool was placed on top of the hardened paraffin and covering the drain hole to prevent loss of test media from the container. Containers were labeled as to the respective test media and completely randomized on the four wooden frames.

Test Media Preparation

A medium grade round river sand was seived through a 2 mm wire mesh screen to remove all gravel. The sand was then thoroughly washed under high water pressure to remove floating debris, silt, clay and some fine sand. A laboratory soil mechanical analysis of the washed sand showed a fractional distribution of sand with a classification of medium coarse.

Three commercial and five indigenous types of organic matter were prepared for mixing with the washed sand. The commercial materials tested were Michigan peat, sphagnum peat, and ground pine bark. Indigenous forms were fresh oak sawdust, sewage sludge, corn stalk chop, cotton stalk chop, and soybean stalk chop. The Michigan peat, sphagnum peat and ground pine bark were obtained from local garden stores in Knoxville. Fresh oak sawdust was acquired from a Knoxville area sawmill. Sewage sludge was donated by the Knoxville Third Creek Waste Disposal Plant. All of the materials were air-dried, ground thoroughly with a mortar and pestal and seived through a 16 mesh wire screen to remove coarse particles. Corn and soybean stalks were obtained from a stockpile located on the University of Tennessee Agricultural Campus at Knoxville. Cotton stalks were removed from a plot on the University of Tennessee Plant Sciences Farm at Knoxville. These three amendments were ground in a hammermill, air-dried, and seived through a 16 mesh wire screen.

The eight organic amendments were mixed at a 10 percent by volume with 90 percent by volume of washed medium coarse sand. A check test media was included consisting of 100 percent washed sand. A "standard" test media was included consisting of a United States Golf Association (USGA) mixture on an 8-1-1 volume basis as recommended (26). The USGA mixture consisted of 80 percent washed medium-coarse sand, 10 percent Michigan peat and 10 percent loam soil by volume. The loam soil analysis showed 34.3 percent sand, 38.3 percent silt, 23.5 percent clay, and 3.9 percent organic matter by weight.

The respective portions of the organic amendments and sand were moistened to aid in their stabilized mixing. The sand and organic amendments were thoroughly blended in a cement mixer. After blending, the mixtures were uniformly hand packed in their respective replicated containers. The containers were then placed in their appropriate position on the greenhouse wooden frames.

Seeding

Each container had a surface media area approximating 387 cm^2. A round double layer of cheesecloth was placed on top of each of the test medias (Figure 1, bottom). Penncross bentgrass (*Agrostis palustris* Huds.) was sowed on the surface of each container at the equivalent rate of 907 g/93 m^2 (2 lb/1,000 square feet) on December 31, 1975. The seeds were placed on one layer of cheesecloth and another added to prevent washing during germination. Distilled water was applied twice daily for two weeks. Most of the bentgrass seed germinated during this two week period, and the test actually began January 14, 1976.

Mechanical and Nutritional Maintenance

Temperature and humidity were recorded during the course of the study using a one-week continuous chart hygrothermograph. The bentgrass growing in the test medias was clipped 3 times weekly at approximately 9 mm height (3/8-inch) using electric clippers. All grass clippings were removed by vacumming to reduce thatch accumulation. The amount of water applied for maintenance irrigation varied through the test period from 400 to 1500 ml in accordance with the plants' apparent needs. However, all test media received the same amount during any respective watering date. The pH of the distilled water averaged 7.5. A modified Hoagland nutrient solution, with average pH of 6.7, was applied once per week at 150 ml per container.

II. GREENHOUSE TESTS

All containers were closely observed for disease and insect activity, and foliage responses to environmental stress. When disease or insect activity was observed, the appropriate fungicide or insecticide was utilized to eliminate the problem.

Container leachates were collected in 1 liter beakers placed beneath the drainage hole (Figure 1, bottom). The volume of leachate was measured weekly. Special leachate collections were taken 9 times during the course of the study, once every six weeks, and pH determined. The nine special leachate collection dates were January 15, March 2, April 14, May 29, July 16, August 28, October 17, November 28, and January 14, 1977.

Temperature measurements were made at four depths in the center of each container at nine recording periods, once every six weeks during the study. A 12-channel YSI Model 44 Telethermometer was used with thermocouple measurement determinations at the surface, and at depths of 5, 10, and 15 cm in each container media.

Air temperature and humidity were recorded in the greenhouse with a one-week continuous chart hygrothermograph positioned 23 cm above the surface of the media containers and 1.5 m above the greenhouse floor.

Sample Collection

Laboratory tests were conducted on media samples for three different sampling periods. Samples were collected from each of the initial media mixtures in which no turfgrass had been grown. Media samples were also collected representing the 0 to 5, 5 to 10, and 10 to 15 cm depths at 26 weeks and 52 weeks after test initiation. One set of the containers, four replications of each test media in which grass was grown, were sampled and dismantled at 26 weeks. The remaining set of test media were sampled and dismantled at 52 weeks.

Aluminum cylinders were cut from electrical conduit pipe to be used for removing media samples from each of the containers. The cylinders were precision cut to provide accurate dimensions of 5.15 cm in depth and 5.27 cm in diameter. Additional cylinders were cut to 2.5 cm in depth to serve as extension retaining rings and so they would accurately fit on top of the sample cylinders.

Undisturbed soil cores were removed from each test media with a sampling tube similar to the one described by Uhland (57), but modified as shown in Figure 2. A special soil sampling tube was constructed to hold three aluminum cylinders so that three undisturbed soil depth samples could be taken with one probing. The three cylinders were stacked on top of one another to remove samples from the 0 to 5, 5 to 10, and 10 to 15 cm depths. The three cylinders were very carefully separated with a very fine wire knife. Thatch and vegetative growth were removed from the top of the 0 to 5 cm cores and excess media material was trimmed off of the bottom cylinder. Muslin cloth was immediately attached to the bottom of each separated cylinder sample and held in place by two rubber bands. A 2.5 cm deep extension retaining ring was attached to the top of each sample cylinder with a 2.5 cm wide piece of bicycle rubber innertube.

III. LABORATORY PROCEDURES

After the sample cylinders were removed from the containers, separated, muslin cloth and extension rings attached, they were taken into the laboratory for analysis. Prior to extensive analysis each sample was placed under an impactor to assure tightness of sample due to the presence of a high percentage of organic matter. The impactor used was similar to the one described by Bruce (13) with slight modifications.

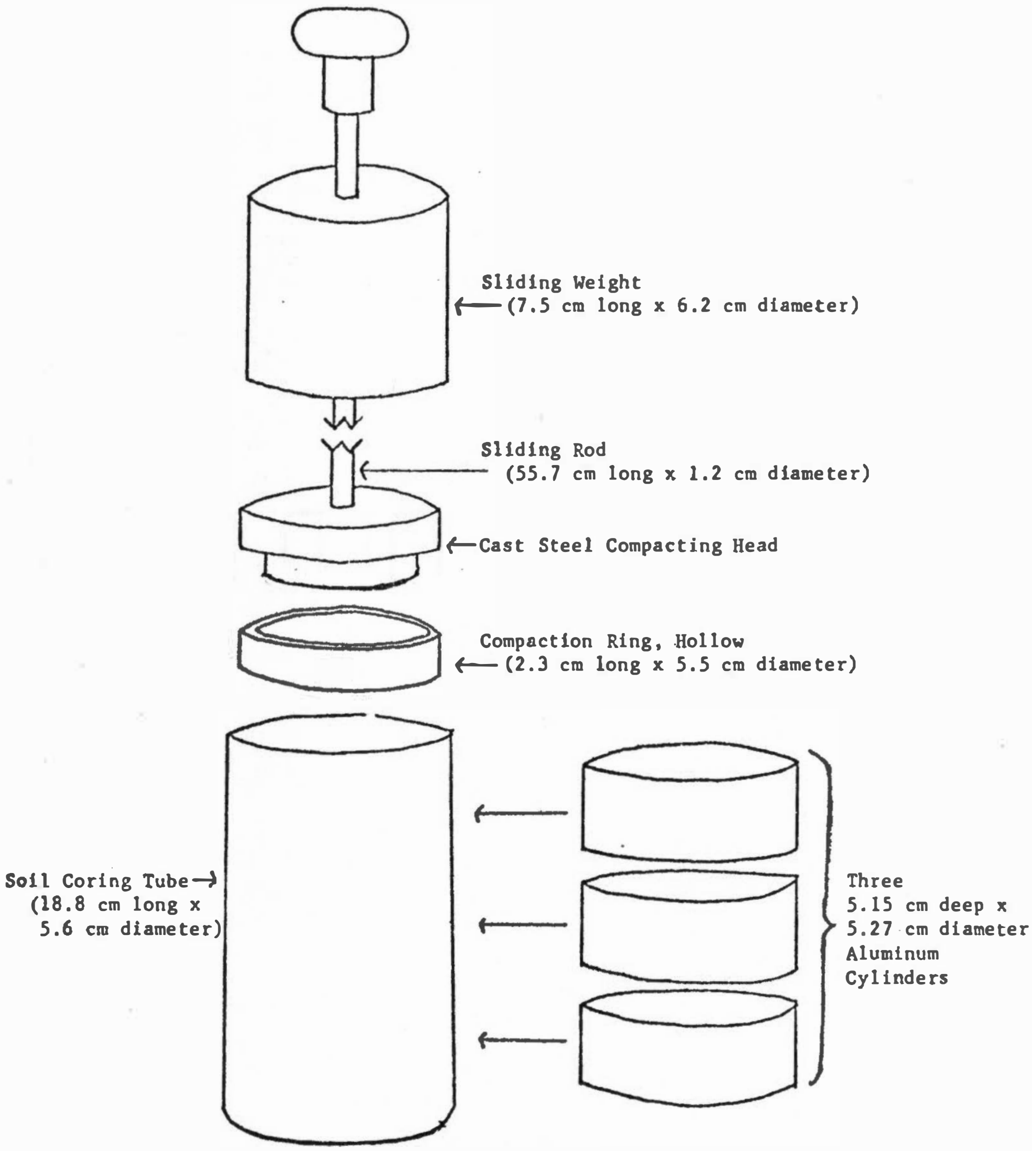

Figure 2. A diagram of the soil core sample tube and cylinders used to remove the undisturbed media samples from the containers.

The modified impactor was built by Jellicorse (28) to deliver 6.22 m kg (45 ft/lb) with 15 drops of the 1.36 kg (3 lb) weight, and to accommodate 5.3 cm diameter aluminum core cylinders. The compacted cores thus would have physical properties approximating two-year-old field samples as determined by Howard (27).

Initial media samples contained no turfgrass root growth to stabilize the medium coarse sand and high percentage of organic matter in mixture. To aid in removal of the samples from the containers, the media was moistened with 250 ml of distilled water one day prior to sample removal. The samples were immediately compacted after collection and prior to soaking in water to help prevent the organic matter from floating out of the mixture. After compaction, the samples were placed in a tub of water, soaked for four hours, brought to equilibrium with 40 cm of water for eight hours on a tension table, then subjected to the compaction again. Core samples collected at 26 and 52 weeks were compacted immediately after removal from the crocks also. These samples were not compacted a second time because root growth in the media helped hold them intact during soaking. Compaction compressed the mixture medias from 3 to 5 mm below the top of the aluminum sample cylinders.

After compaction, samples were soaked for 24 hours in water adjusted to 1/2 cm below the top of the sample cylinders, not the retaining ring. Samples were then placed in a vacuum jar with a pneumatic suction device attached. The samples were subjected to a light suction of 12-1/2 cm of mercury for 12 hours to remove trapped air and help in achieving more complete saturation. Following saturation, the samples were removed, wiped with a sponge to remove excess water from the cylinder and weighed to the nearest 0.01 g. The weight of the cores was recorded as saturated weight.

Following weighing, the samples were placed on a tension table and brought to equilibrium with 40 cm of water for eight hours. Because of the very high coarse sand content of the different media mixtures, water was readily removed from the core samples thus only eight hours was needed to bring the samples to equilibrium. Sample weights were again taken to the nearest 0.01 g and recorded as field capacity weights.

Samples were then placed in a tub and soaked for four to six hours in water maintained at 1/2 cm below the soil level in the cylinder. The cylinders of media were then transferred to a percolation rack similar to the one described by Klute (34), and 6.25 mm constant head of water maintained on top of the samples. Water was permitted to drain through the samples for 24 hours before percolation rates were determined. Water percolation through the individual core mixtures were collected for 15 minutes to determine transmitted water in cm^3 per hour. Hydraulic conductivity was measured by Darcy's Law (34). Percolation rates in cm per hour were determined by the formula:

$$\text{cm/hour} = (Q/21.801\ \text{cm}^2 \times 5.15/5.775\ \text{cm})$$

Q = Transmission rate (cm^3/hour).

$21.801\ cm^2$ = Soil surface of the core.

5.15 cm = Height of sample.

5.775 cm = Height of sample plus constant water head.

Core samples were removed from the percolation rack and oven-dried at 105°C for 48 hours and total dry weight recorded to the nearest 0.01 g. Total dry weight included the weight of the cylinder, retaining ring, muslin cloth, rubber bands and innertube section.

Bulk density (BD) of the laboratory compacted core samples was determined by the following formula:

$$BD = \frac{W_A - W_B}{V}$$

BD = Bulk density of compacted core samples.

W_A = Total oven dry weight including soil media mixture, aluminum cylinder, retaining ring, cloth, rubber bands and innertube section.

W_B = Oven dry weight of aluminum cylinder, retaining ring, muslin cloth, rubber bands and innertube section.

V = Volume of 5.15 cm × 21.801 cm^2 aluminum cylinder (112.28 cm^3).

Percent aeration porosity (AP) and total porosity (TP) were determined by the following formula as reported by Vomocil (58):

$$\%\ AP = \frac{\text{Saturated Weight - Field Capacity Weight}}{\text{Volume of Cylinder (112.28 cm}^3\text{)}} \times 100$$

$$\%\ TP = \frac{\text{Saturated Weight - Total Oven Dry Weight}}{\text{Volume of Cylinder (112.28 cm}^3\text{)}} \times 100$$

<u>Mechanical Analysis</u>

Media mixtures were removed from the aluminum cylinders and placed in labeled paper bags. Particle size distribution for sand was determined on 10 g samples by the dry seiving method described by Day (21) after organic matter was removed by repeated additions of 30 percent hydrogen peroxide. Determinations for silt and clay were conducted on 100 g samples according to the method described by Bouyoucos (10). Since the same water washed sand was used for all mixtures, it was not necessary to determine how much silt and clay each individual core sample contained. Silt and clay were analyzed for the sand to determine how much silt and clay each of the mixture medias contained. Silt and clay of the USGA mixture media was determined also because it contained 10 percent by volume loam soil and therefore had more silt and clay than the other mixture medias.

Organic Matter Analysis

The Walkley-Black method described by Allison (2) was used for determining easily oxidizable organic matter. Samples were not ground and passed through a 0.50 mm seive as normally provided in the procedure due to the very high percentage of coarse sand used in the media mixture. An unpredictable portion of organic matter in certain samples was not of an oxidizable type and therefore the percent organic matter value would be less than if all the organic matter was oxidized. A sample size of 1 g was used for the determinations.

Cation Exchange Capacity Determinations

Removal of cations from 50 g air-dry samples was performed by the procedure described by Peech et al. (46), using a neutral normal acetate solution.

After washing the samples with 200 ml of methyl alcohol, the ammonium ions which occupied the cation exchange sites of the samples, as a result of cation removal, were removed by leaching of the samples with 300 ml of 0.005 N acidified 10 percent sodium chloride solution as described by Peech et al. (46). Leachates were then analyzed for the ammonium ion concentration in parts per million (ppm) on a Technicon Autoanalyzer. Cation exchange capacity of each sample was determined by converting the ammonium ion concentration to milliequivalents per 100 g of soil mixture.

CHAPTER IV

RESULTS AND DISCUSSION

Physical and chemical properties were determined for ten golf putting green test media in which Penncross bentgrass was grown. The organic matter materials tested, and their respective abbreviated names and code references in brackets, were Michigan peat (Michigan peat, MP), sphagnum peat (sphagnum peat, SP), ground pine bark (pine bark, PB), oak sawdust (oak sawdust, OS), sewage sludge (sewage sludge, SS), corn stalk chop (corn chop, CC), cotton stalk chop (cotton chop, Cot), and soybean stalk chop (soybean chop, SC). A check (Chk) test of pure sand and a "standard" test media for comparisons of a United States Golf Association (USGA) mixture of 8 parts sand - 1 part organic matter - 1 part loam soil were included also.

I. GREENHOUSE RESPONSES

Bentgrass Responses and Disease Incidence

The seed in the different media germinated at varying rates. The check, sewage sludge, and sphagnum peat media had the slowest rates of seed germination. Bentgrass seed germinated much faster and at a similar rate in media of USGA, Michigan peat, corn chop, soybean chop, cotton chop, pine bark and oak sawdust than in the check, sewage sludge, and sphagnum peat media. Most of the bentgrass had good density within six weeks after seed germination.

Mild saprophytic fungi activity was observed on the surface of some of the test media within three days after the bentgrass seed had germinated. The fungi activity was found only in bentgrass growing in media containing sphagnum peat, Michigan peat, and soybean chop. The fungus was identified as _Peziza ostracoderma_ Korf., which is a type having no known parasitic effects in bentgrass. Thus it was postulated that the activity of this particular organism was the result of the organic materials used not being sterilized with this organism present as a contaminant.

Another fungi identified was a slime mold (_Lycogala epidendrum_ (L) Fries.) which appeared in the bentgrass growing in the media containing soybean chop eight days after seed germination. However, the slime mold growth disappeared within a week and appeared to have no effect on the bentgrass.

A broad spectrum fungicide program was used during the warm months. The chemicals used were Tersan 1991, Dyrene, Daconil 2787, and Acti-dione Thiram, singly and occasionally in combination with Tersan SP. There was no disease observed as a result of the fungicides used.

Bentgrass in all of the media containers was slightly damaged by sod webworms during the first week of June 1976. The insecticide Sevin was applied to all media containers three times during the following four week period with the bentgrass recovering rapidly.

Bentgrass was observed throughout the study to determine which test media resulted in the greatest density, darkest color and fastest rate of growth. Bentgrass rate of growth during the first four months of the study appeared to be faster in medias containing sewage sludge and soybean chop. However, bentgrass rate of growth still appeared good in media containing cotton chop, sphagnum peat, the USGA mix, corn chop, and the check. Oak sawdust and pine bark media resulted in the slowest rate of bentgrass growth and the foliage coloration was a considerably lighter shade of green than the other test medias. By the time bentgrass growth was eight months of age, all of the test media appeared similar in rate of growth, stand density, and general quality appearance except bentgrass growth in oak sawdust which had a slow rate of growth and light-green coloration. Low or deficient levels of nitrogen generally appears in leaves as a light-green to yellow-green color (46). Other investigators have reported a principle harmful effect of sawdust, when used as an organic amendment, to be its depleting effect of nitrogen (3, 38). The nitrogen depletion effect could account for the light-green color of bentgrass growing in the oak sawdust media. There was little change in stand density and general quality appearance of the bentgrass growth for the remainder of the experiment.

Media Leachate Volumes

Leachates were collected continuously throughout the period of the study for each of the test medias. Leachate volumes were measured and recorded weekly. Weekly waterings of the bentgrass varied in volume of irrigation water applied as judged to meet the apparent needs of the plants. However, the variability in volume of irrigation further added to the variability in volume of leachates being collected.

After container media settled and bentgrass roots began developing, some trends could be noted in rate of water movement through certain test media. As greenhouse temperatures increased during the warm months, leachate volumes became more variable. In general, the season of the year and type of media appeared to influence leachate volumes to some extent (Table I and Figure 3). Leachate volumes generally were greater when temperatures were cooler than under high temperatures. Humidity varied more during the cooler periods of the year than during the warm periods. During warm months, humidity reached 100 percent for most days due primarily to heavy watering of other ornamental plants being maintained in the same greenhouse and to the greenhouse cooling system. Where low or no leachate volumes were recorded, water loss was probably due to accelerated transpiration from the bentgrass and evaporation from the collection beakers. The greater volume losses of leachate generally coincided with periods of low air humidity much more than cooler temperatures, although some loss could be associated with cooler air temperatures.

The different types of test media appeared to influence the rate of percolation and eventual volume of leachate collected (Figure 4). The USGA media had the lowest mean leachate volume of 100 ml for the 52 week test period. This was probably due to the presence of very fine sand, silt and clay, plus the 10 percent by volume of Michigan peat. Porosity for the USGA media was significantly lower than the other medias tested (Tables II and III). Mean leachate volumes for the check, Michigan peat, cotton chop, sphagnum peat, corn chop, and pine bark ranged sequentially from 148 to 184 ml (Figure 4). The low volume of leachate for the check was influenced by a longer exposure time of the leachate to evaporation in the collection beakers since percolation was rapid as aided by high porosity (Tables II, III, and IV).

TABLE I

LEACHATE VOLUMES FOR TEST MEDIAS
WEEKLY DETERMINATIONS

Collection Date	Water Applied	Weekly Leachate Volumes (ml)									
		CHK	USGA	MP	SP	CC	SS	CoT	SC	OS	PB
1/13/76	1400	0	0	0	0	99	0	104	63	49	43
1/20	1000	0	0	164	0	64	0	135	85	44	38
1/27	800	0	0	166	0	78	23	352	80	40	34
2/3	700	0	117	368	126	171	188	685	82	272	222
2/10	900	82	468	774	543	382	456	734	171	718	602
2/17	1400	244	444	851	589	427	468	0	200	791	712
2/24	800	166	121	106	231	82	71	0	342	129	132
3/2	850	331	212	164	434	240	371	0	507	250	284
3/9	900	222	133	59	336	192	322	185	447	144	163
3/16	800	401	154	105	519	273	665	0	641	346	252
3/23	1100	353	240	91	480	240	631	0	571	321	240
3/30	1150	307	229	188	328	391	610	235	554	733	435
4/6	1100	288	169	144	243	324	492	152	497	710	352
4/13	1400	235	111	108	220	267	500	44	486	675	319
4/20	1000	14	21	35	34	66	105	420	148	83	63
4/27	900	420	281	303	387	427	491	375	582	501	466
5/4	600	404	242	345	433	443	484	501	661	565	502
5/11	700	508	263	403	538	520	497	744	703	691	585
5/18	800	733	491	600	827	767	695	640	841	865	850
5/25	1000	327	198	451	419	344	401	421	479	319	320
6/1	850	240	201	171	252	218	197	268	241	202	191
6/8	1000	0	0	0	0	0	0	5	11	0	0
6/15	1200	0	0	0	0	0	0	0	0	0	0
6/22	900	0	0	0	0	0	0	0	0	0	0
6/29	950	75	15	103	73	129	76	105	312	306	180
7/6	800	113	19	175	113	138	104	156	363	383	222
7/13	800	217	47	168	189	217	217	219	476	487	319
7/20	900	88	68	77	86	60	197	84	195	39	54
7/27	500	192	66	133	207	110	189	139	187	141	120
8/3	650	0	0	0	0	0	0	0	0	0	0
8/10	1000	0	0	0	0	0	0	0	0	0	0
8/17	750	0	0	0	0	0	0	0	0	0	0
8/24	1250	35	21	0	24	11	23	0	0	24	0
8/31	750	16	13	0	6	0	0	0	44	0	0

TABLE I (continued)

Collection Date	Water Applied	Weekly Leachate Volumes (ml)									
		CHK	USGA	MP	SP	CC	SS	CoT	SC	OS	PB
9/7	450	0	0	0	0	0	0	0	0	0	0
9/14	850	81	0	20	50	15	0	20	251	24	46
9/21	600	90	159	268	84	0	341	118	510	50	71
9/28	700	0	0	0	0	0	0	0	0	0	0
10/5	500	0	0	0	0	0	0	0	0	0	0
10/12	450	0	0	0	0	0	0	0	0	0	0
10/19	600	0	0	0	0	35	35	25	446	33	16
10/26	400	0	0	0	0	0	0	0	0	0	0
11/2	700	0	0	0	0	0	0	0	0	0	0
11/9	700	0	0	0	0	0	0	0	0	0	0
11/16	650	50	0	13	15	10	10	21	584	47	19
11/23	700	0	0	0	0	0	0	0	0	0	0
11/30	450	156	15	91	78	50	51	46	475	126	22
12/7	800	102	16	71	86	142	142	50	386	130	34
12/14	900	119	0	60	77	35	34	19	455	76	50
12/21	700	140	22	111	122	75	75	31	301	85	36
12/28	1000	486	368	551	475	439	439	635	653	418	450
1/4	1500	380	235	325	343	363	363	316	464	413	273
Means	850	148	100	151	157	180	207	154	300	238	184

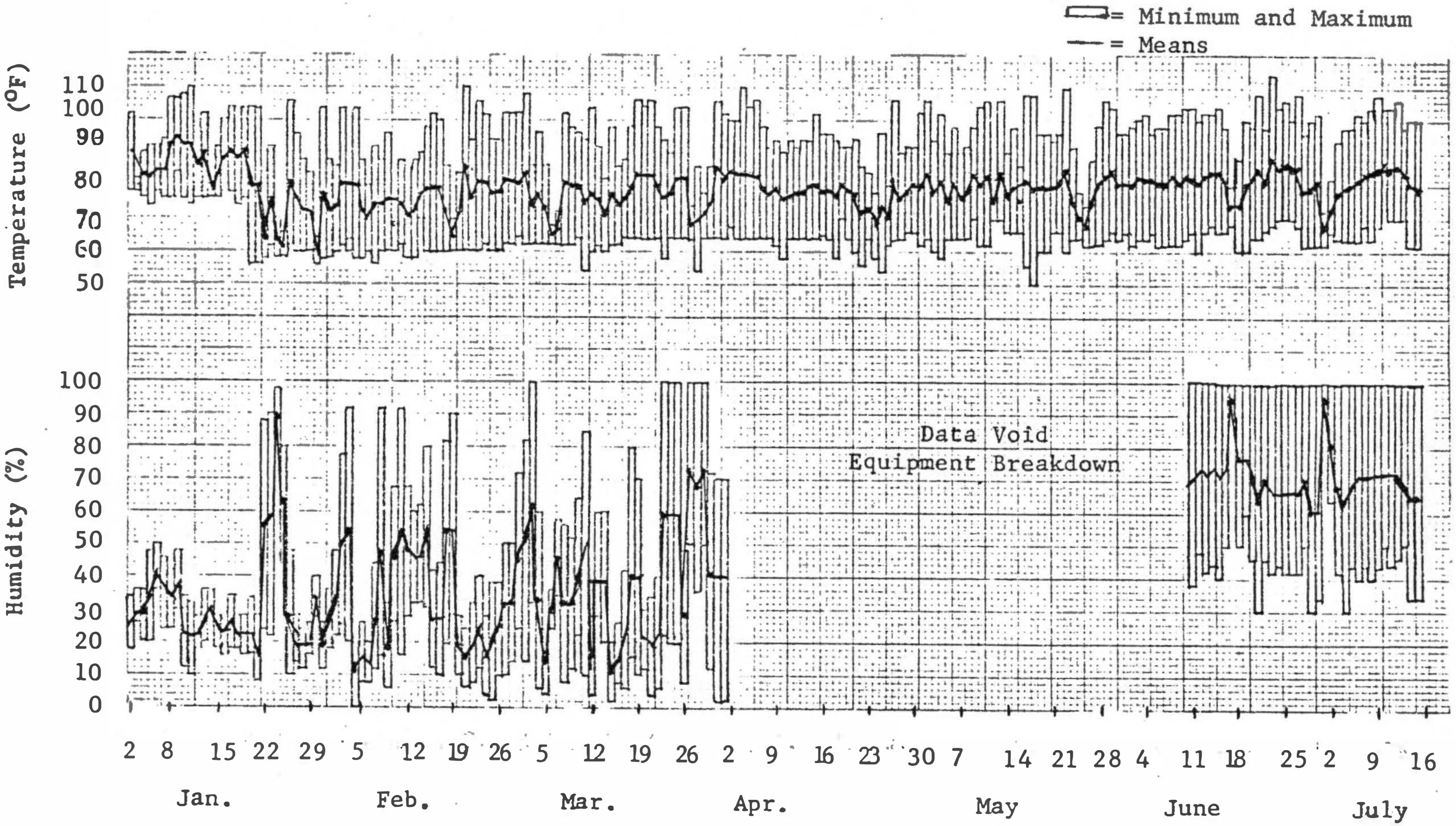

Figure 3. Temperature and humidity data for 52 weeks.

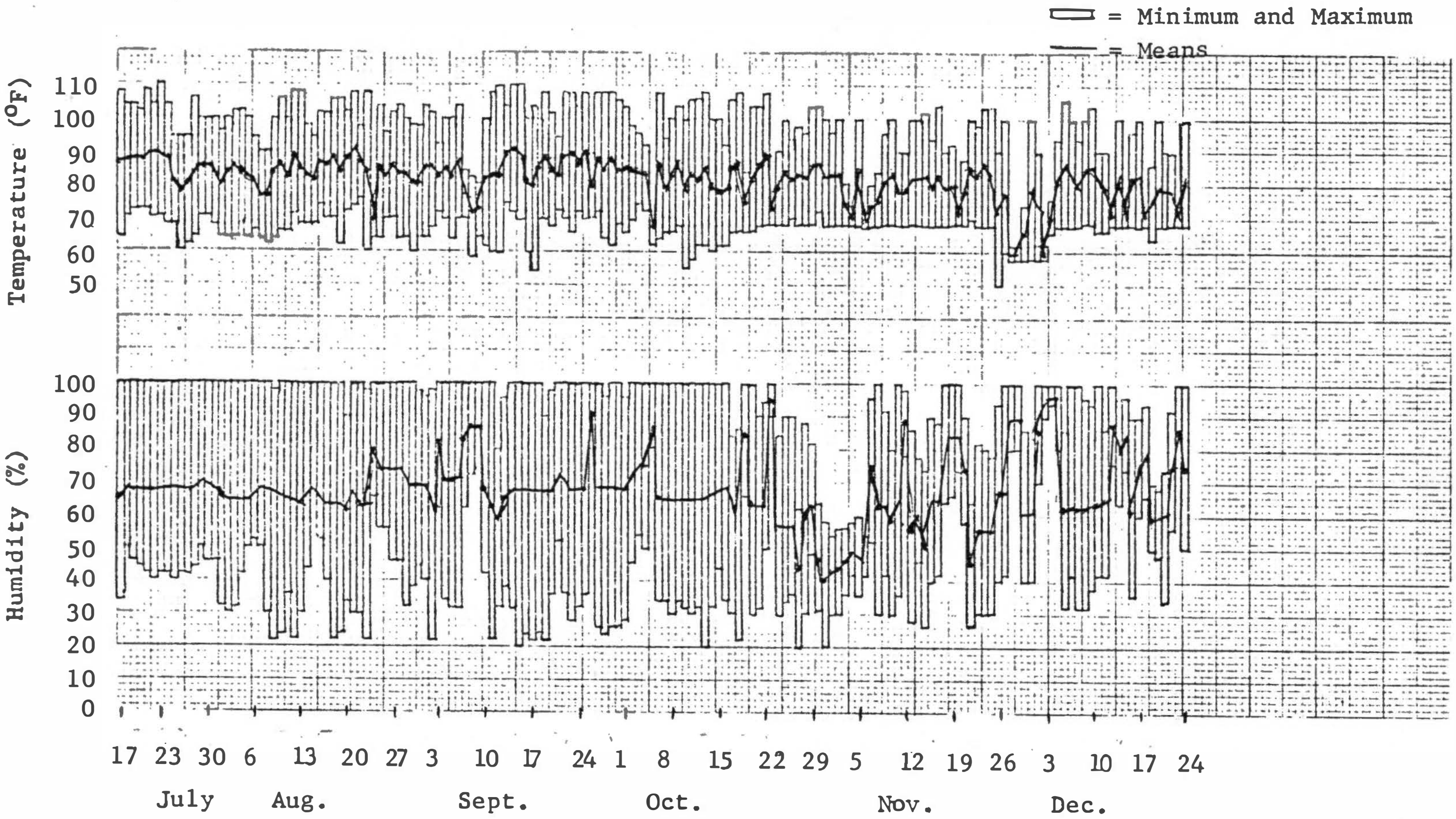

Figure 3 (continued)

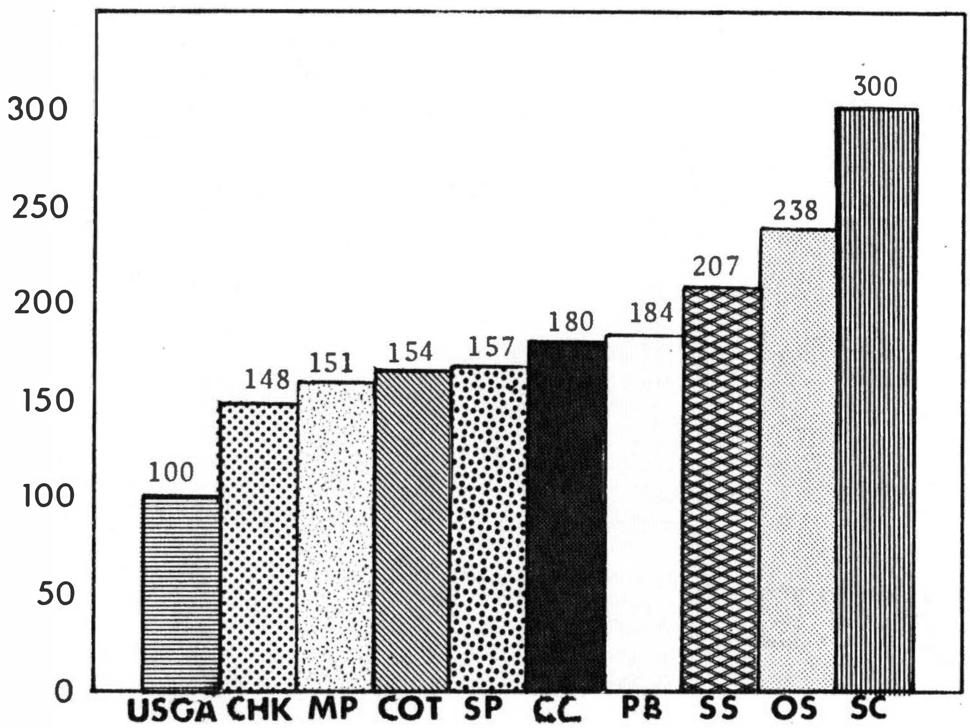

Figure 4. Mean volumes of 52 leachate collections for the 10 test media.

TABLE II

AERATION POROSITY DETERMINATIONS (%)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	30.13 ab	34.38 cdefg	33.65 de
	5-10	30.13 ab	33.63 efgh	34.80 bcde
	10-15	30.13 ab	32.90 ghij	34.70 bcde
USGA	0-5	21.58 e	31.10 kl	30.00 f
	5-10	21.58 e	31.48 kl	28.93 f
	10-15	21.58 e	29.98 l	25.63 g
MP	0-5	28.20 d	34.00 cdefgh	35.33 abcd
	5-10	28.20 d	34.15 cdefgh	34.08 cde
	10-15	28.20 d	33.35 fghi	33.93 cde
SP	0-5	29.50 bc	35.65 abc	36.70 ab
	5-10	29.50 bc	35.50 abcd	35.93 abc
	10-15	29.50 bc	34.95 bcdef	35.98 abc
CC	0-5	30.33 ab	36.13 ab	33.10 e
	5-10	30.33 ab	35.08 bcde	35.28 abcde
	10-15	30.33 ab	35.03 bcdef	34.98 bcde
SS	0-5	28.50 d	33.43 efghi	35.60 abcd
	5-10	28.50 d	35.05 bcdef	36.10 abc
	10-15	28.50 d	34.85 bcdef	35.83 abcd
CoT	0-5	30.23 ab	35.53 abcd	36.25 ab
	5-10	30.23 ab	32.73 hij	36.45 ab
	10-15	30.23 ab	31.95 ijk	36.50 ab
SC	0-5	30.78 a	35.55 abcd	36.93 ab
	5-10	30.78 a	35.55 abcd	36.53 ab
	10-15	30.78 a	34.43 cdefg	36.08 abc
OS	0-5	29.03 cd	33.93 defgh	35.03 bcde
	5-10	29.03 cd	35.00 bcdef	35.80 abcd
	10-15	29.03 cd	35.07 bcdef	36.28 ab
PB	0-5	28.95 cd	37.03 a	37.30 a
	5-10	28.95 cd	34.98 bcdef	34.80 bcde
	10-15	28.95 cd	35.40 bcd	36.23 bcd

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

TABLE III

TOTAL POROSITY DETERMINATIONS (%)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	39.10 ab	42.48 defg	43.73 bcdefg
	5-10	39.10 ab	41.13 fg	42.00 fg
	10-15	39.10 ab	40.55 g	41.53 g
USGA	0-5	33.58 d	42.93 bcdef	42.03 fg
	5-10	33.58 d	43.50 bcde	51.15 g
	10-15	33.58 d	43.25 bcde	40.93 g
MP	0-5	37.90 bc	44.18 abcde	45.53 abcd
	5-10	37.90 bc	43.68 bcde	43.28 defg
	10-15	37.90 bc	43.23 bcde	43.30 cdefg
SP	0-5	39.58 a	45.03 ab	46.13 abc
	5-10	39.58 a	45.15 ab	44.38 abcdef
	10-15	39.58 a	45.20 ab	43.80 bcdefg
CC	0-5	39.38 a	44.58 abcd	44.90 abcdef
	5-10	39.38 a	43.33 bcde	45.83 abcd
	10-15	39.30 a	43.45 bcde	42.65 efg
SS	0-5	38.90 ab	43.85 bcde	44.63 abcdef
	5-10	38.90 ab	45.20 ab	45.47 abcde
	10-15	38.90 ab	43.93 bcde	45.50 abcde
CoT	0-5	39.70 a	45.08 ab	44.60 abcdef
	5-10	39.70 a	42.13 efg	44.58 abcdef
	10-15	39.70 a	41.15 fg	45.13 abcde
SC	0-5	39.13 ab	44.05 bcde	44.63 abcdef
	5-10	39.13 ab	44.30 abcde	44.33 abcdef
	10-15	39.13 ab	42.80 cdef	43.80 bcdefg
OS	0-5	39.00 ab	44.95 abc	45.83 abcde
	5-10	39.00 ab	44.35 abcd	45.15 abcde
	10-15	39.00 ab	45.23 ab	46.25 ab
PB	0-5	37.53 c	46.33 a	47.10 a
	5-10	37.53 c	44.73 abc	44.48 abcdef
	10-15	37.53 c	44.40 abcd	45.15 abcde

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

TABLE IV

BULK DENSITY DETERMINATIONS (g/cm^3)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	1.36 a	1.39 abcde	1.45 ab
	5-10	1.36 a	1.42 abc	1.49 a
	10-15	1.36 a	1.45 a	1.49 a
USGA	0-5	1.35 ab	1.31 efgh	1.34 ghij
	5-10	1.35 ab	1.38 abcdef	1.39 cdefgh
	10-15	1.35 ab	1.40 abcd	1.41 bcde
MP	0-5	1.25 f	1.39 abcde	1.42 bcd
	5-10	1.25 f	1.43 ab	1.46 ab
	10-15	1.25 f	1.43 ab	1.44 abc
SP	0-5	1.30 cde	1.27 h	1.36 defghij
	5-10	1.30 cde	1.30 fgh	1.38 defghi
	10-15	1.30 cde	1.32 defgh	1.33 ij
CC	0-5	1.33 abc	1.36 bcdefg	1.39 cdefgh
	5-10	1.33 abc	1.38 abcdef	1.39 cdefgh
	10-15	1.33 abc	1.37 abcdefg	1.38 defghi
SS	0-5	1.29 e	1.32 defgh	1.36 defghi
	5-10	1.29 e	1.35 bcdefgh	1.42 bcd
	10-15	1.29 e	1.31 efgh	1.41 bcde
CoT	0-5	1.28 ef	1.35 bcdefgh	1.35 fghij
	5-10	1.28 ef	1.37 abcdefg	1.41 bcde
	10-15	1.28 ef	1.37 abcdefg	1.42 bcd
SC	0-5	1.30 cde	1.32 defgh	1.39 cdefgh
	5-10	1.30 cde	1.35 bcdefgh	1.40 cdefg
	10-15	1.30 cde	1.29 gh	1.38 defghi
OS	0-5	1.28 ef	1.30 fgh	1.31 j
	5-10	1.28 ef	1.32 defgh	1.37 defghi
	10-15	1.28 ef	1.31 efgh	1.37 defghi
PB	0-5	1.32 bcd	1.28 h	1.38 defghi
	5-10	1.32 bcd	1.35 cdefgh	1.37 defghi
	10-15	1.32 bcd	1.35 cdefgh	1.36 hij

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

Sewage sludge and oak sawdust mean leachate volumes for 52 weeks were very high, at 207 and 238 ml, respectively (Figure 4, page 35). The organic matter content of both was high by the end of 52 weeks (Table V), thus providing a restriction to rapid percolation. Furthermore, leachate did not begin collecting in the beakers until late in the collection period thus less leachate was present for loss to evaporation.

The highest leachate volumes occurred in the media of soybean chop with a 52 week mean of 300 ml (Figure 4). Soybean chop tended to hold water and release it shortly before collection leachate measurements were made; thus exposure time to evaporation from the beakers was at a minimum.

pH of Leachates

All test medias were irrigated weekly with distilled water which averaged a pH of 7.5. Bentgrass growing in each media received nutrient feeding in the form of weekly applications of a modified Hoagland solution with an average pH of 6.7. Special leachate collections were taken every six weeks and pH determined as an indicator of the acidulation potential of each organic matter type. Research has indicated that increased acidity can be injurious to root growth of turfgrasses (31).

The media comprising Group I showed pH responses beginning with low pH values and evolving into a slight sigmoid type curve that increased with time (Figure 5). Test media comprising this curve response were Michigan peat, sphagnum peat and the USGA mix. The pH for peats has been reported to vary from 4.0 to 7.5 or higher (45).

TABLE V

ORGANIC MATTER DETERMINATIONS (% by wt.)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	0.00 f	0.08 ij	0.16 ij
	5-10	0.00 f	0.03 j	0.07 jk
	10-15	0.00 f	0.00 j	0.00 k
USGA	0-5	1.43 a	1.44 a	1.08 b
	5-10	1.43 a	1.03 bc	1.06 b
	10-15	1.43 a	1.20 b	1.22 a
MP	0-5	1.11 b	1.05 b	1.03 b
	5-10	1.11 b	0.96 cde	0.79 c
	10-15	1.11 b	1.00 cde	0.81 c
SP	0-5	0.23 e	0.39 h	0.51 de
	5-10	0.23 e	0.33 h	0.32 fg
	10-15	0.23 e	0.26 hi	0.29 gh
CC	0-5	0.38 e	0.31 h	0.45 def
	5-10	0.38 e	0.25 hi	0.28 ghi
	10-15	0.38 e	0.27 hi	0.21 ghi
SS	0-5	0.83 c	0.71 fg	0.82 c
	5-10	0.83 c	0.61 g	0.81 c
	10-15	0.83 c	0.76 efg	0.76 c
CoT	0-5	0.59 d	0.38 h	0.42 ef
	5-10	0.59 d	0.26 hi	0.28 ghi
	10-15	0.59 d	0.26 hi	0.26 ghi
SC	0-5	0.60 d	0.37 h	0.31 gh
	5-10	0.60 d	0.32 h	0.21 ghi
	10-15	0.60 d	0.30 h	0.16 hij
OS	0-5	1.08 b	0.76 efg	0.86 c
	5-10	1.08 b	0.80 defg	0.54 def
	10-15	1.08 b	0.79 defg	0.55 d
PB	0-5	0.77 cd	0.89 cdef	0.88 c
	5-10	0.77 cd	0.76 efg	0.85 c
	10-15	0.77 cd	0.77 efg	0.74 c

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

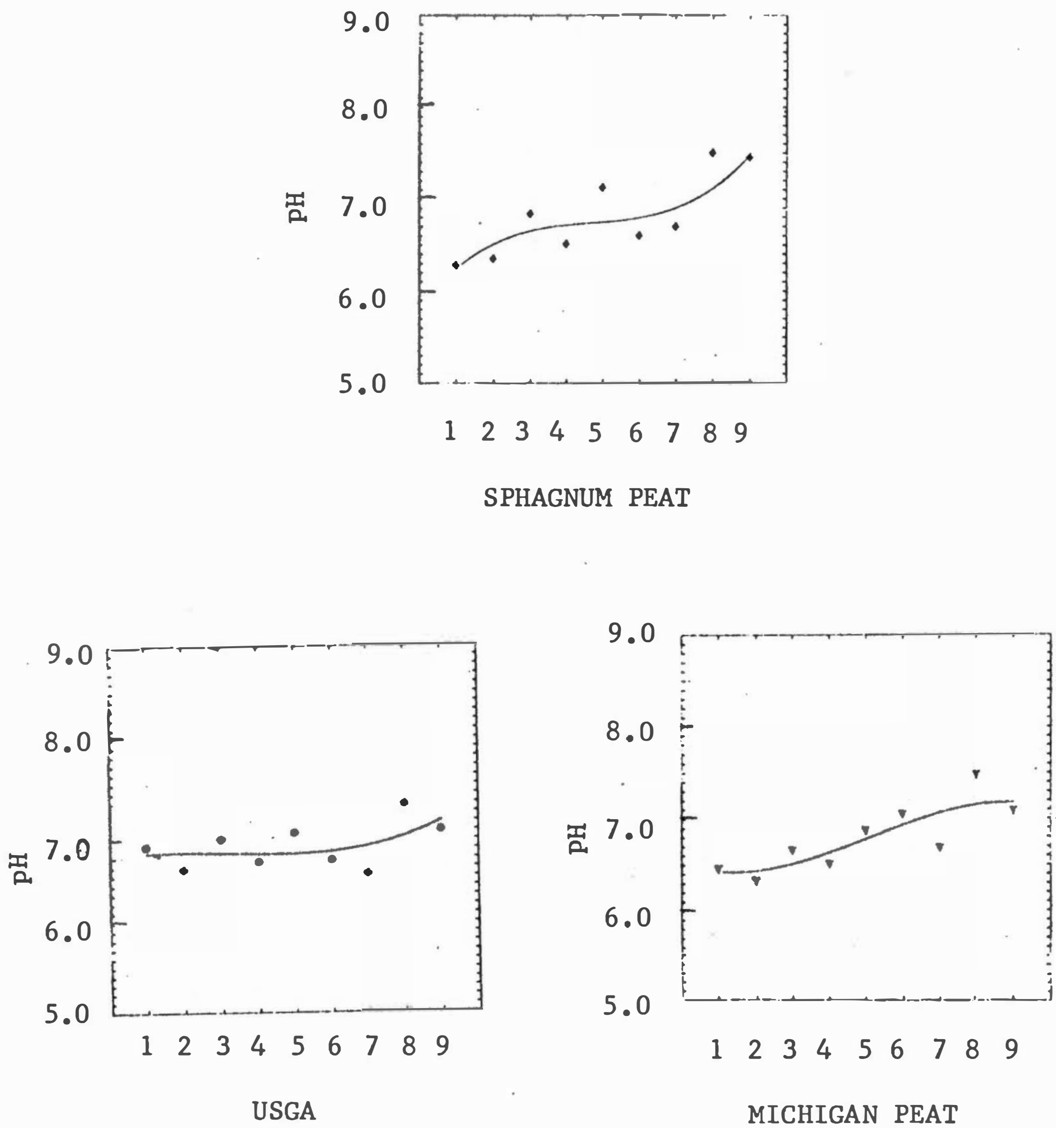

Figure 5. pH values for Group I test media for nine recording periods.

Thus, test media containing peat moss might be expected to show a variety of pH responses. However, the trend of responses appears to be similar. The USGA and Michigan peat media evolved pH values very similar and the pH means for both were identical with a pH of 6.8 (Table VI). Both media contained 10 percent by volume of Michigan peat, differing only in respect to content of other physical materials. The USGA mixture containued silt, clay and fine sand. Sphagnum peat pH varied more between test periods than the USGA and Michigan peat but the trend was the same. Sphagnum peat also had a pH mean of 6.8.

Media comprising Group II showed similar pH responses. Media comprising this group were corn chop, soybean chop, cotton chop, and sewage sludge (Figure 6).

All media in Group II began with high pH values of 8.2 to 8.6. Cotton chop and corn chop pH values increased in acidity exhibiting a moderately steep curve with time but slightly decreasing in acidity for the last two recording periods. Soybean chop and sewage sludge increased in acidity showing a very steep curve with time and a sharp decrease in acidity for the last two or three recording periods. All four media in Group II showed a similar pH mean of 7.5, except soybean chop which was only slightly higher at 7.7 (Table VI). Miller (43) reported that sewage sludge decomposed rapidly for the first several months then tends to resist further decomposition after six months.

Media comprising Group III exhibited pH curve responses which bear little resemblance to each other and to media of Groups I and II (Figure 7). Media comprising the independent pH curve responses of

TABLE VI

pH DETERMINATION OF LEACHATE

Test Media	Test Date and Leachate pH Values									
	1976								1977	
	1/15	3/2	4/14	5/29	7/16	8/28	10/17	11/28	1/14	Means
Group I										
USGA	6.8	6.6	6.9	6.7	7.0	6.7	6.5	7.3	7.0	6.8
MP	6.5	6.3	6.7	6.5	6.9	7.0	6.8	7.5	7.1	6.8
SP	6.3	6.4	6.8	6.5	7.1	6.6	6.7	7.5	7.5	6.8
Group II										
CoT	8.2	7.9	7.9	7.2	7.4	7.3	7.0	7.1	7.2	7.5
CC	8.3	7.9	7.9	7.3	7.4	7.2	6.9	7.4	7.3	7.5
SS	8.2	8.1	8.1	7.7	7.2	6.7	6.9	7.4	7.2	7.5
SC	8.6	8.5	8.3	7.8	7.2	7.0	6.9	7.4	7.3	7.7
Group III										
OS	6.6	6.9	7.4	7.0	7.2	7.2	7.1	7.5	7.1	7.1
PB	7.5	7.5	7.7	7.2	7.1	7.5	7.2	7.8	7.1	7.4
CHK	7.2	7.1	7.0	7.1	7.0	6.6	6.7	7.2	7.3	7.0
Irrigation Water	7.6	7.5	7.4	7.4	7.5	7.3	7.2	7.7	7.7	7.5

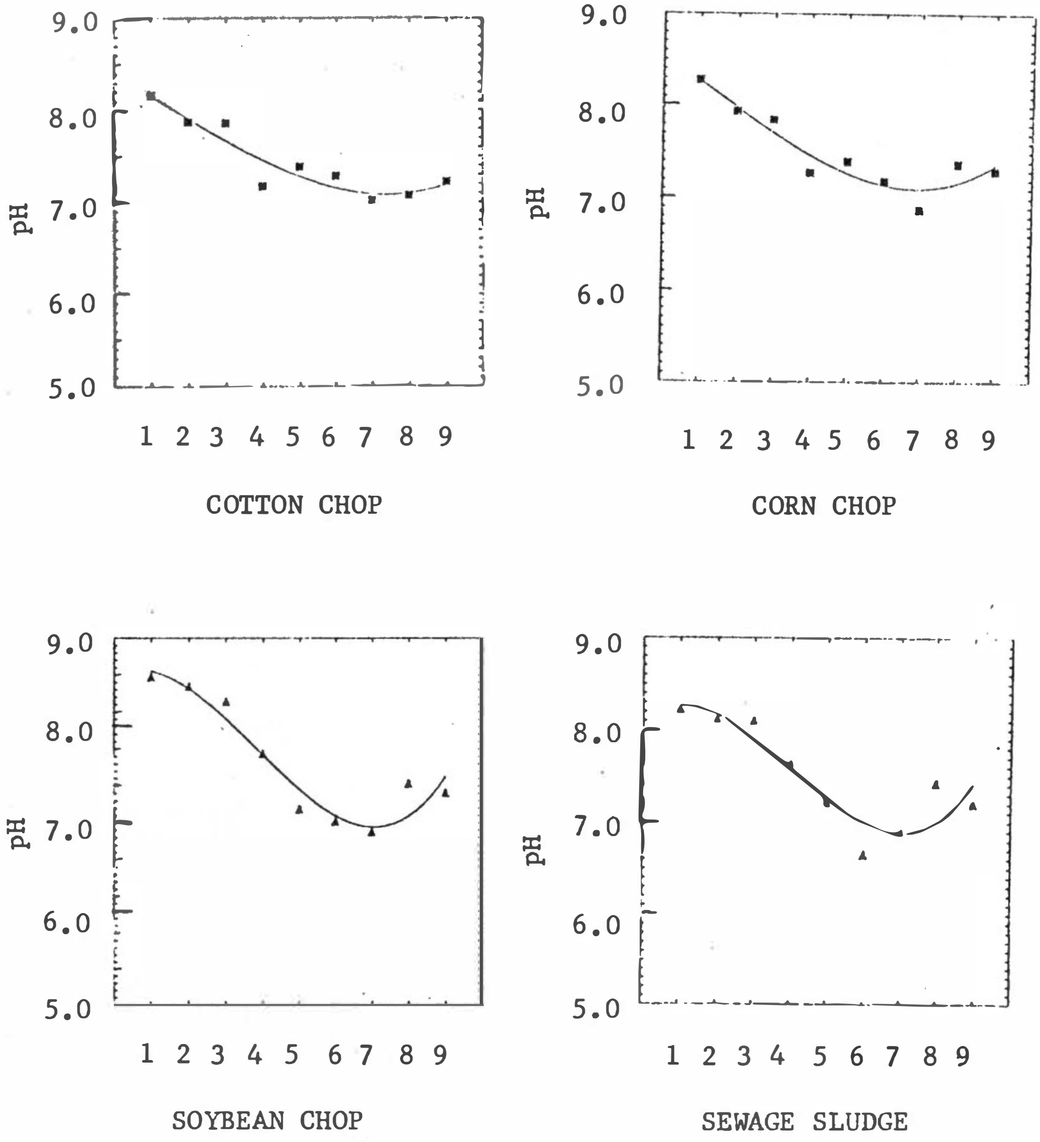

Figure 6. pH values for Group II test media for nine recording periods.

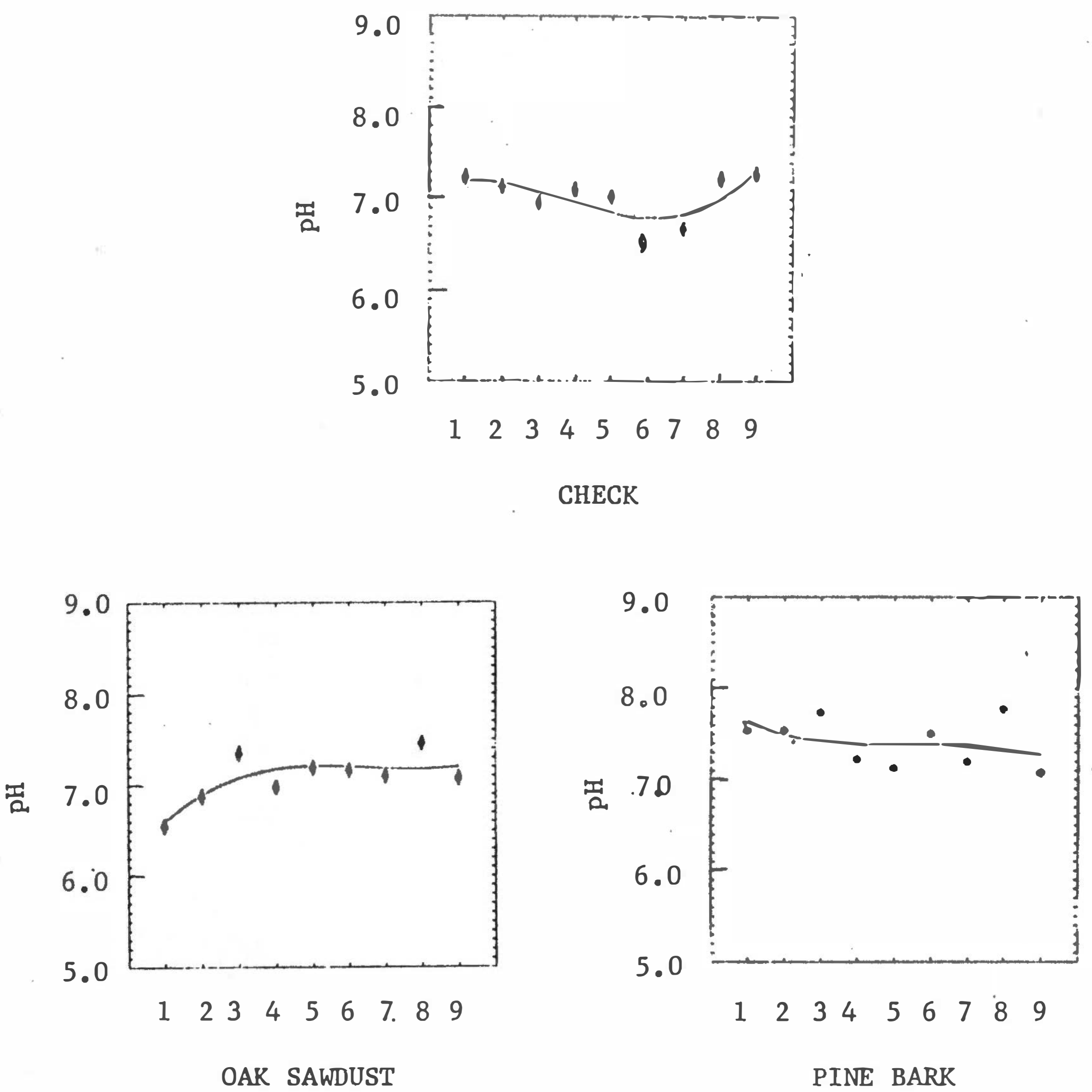

Figure 7. pH values for Group III test media for nine recording periods.

this group were oak sawdust, pine bark, and the check. Oak sawdust started with a low pH of 6.6, decreased in acidity sharply then leveled off. Pine bark exhibited erratic pH plots with time making it unpredictable in pH response. The check media contained no initial incorporation of organic amendment. Therefore, pH values recorded for the check should reflect influences only by the pH of the irrigation distilled water, nutrient solution, root growth of the bentgrass, and possibly of the pesticides applied for diseases and insects control. The pH values for the check showed a slight decline with time but increasing values for the final two recording periods.

The general distribution of pH values for the nine recording dates for the three groups tend to suggest a seasonal influence of daylength and temperature response. The recording date plots for most of the media show a similar trend for the 52 week period. The first three recording plots exhibit similarity within groups reflecting organic matter decomposition rate and level of pH emission during the initial three months of the study. The fifth, sixth and seventh plots in most cases showed similarity of organic matter decomposition rate and pH response exhibiting influences possibly of long days and high temperatures. The final two plots tend to reflect conditions of short days, lower temperatures, and the predominance of organic matter fractions more resistant to decomposition.

Temperatures of Media

Research by other investigators indicate that as certain forms of organic matter accelerate in decomposition rate a marked increase in temperature occurs (45). Temperature measurements were made with a thermocouple at the sod surface and at measured depth increments in the containers for each media in this study to record the temperature change phenomena. Temperature measurements were taken with a 12-channel YSI Model 44 Telethermometer every 6 weeks beginning January 21, 1976, and ending January 17, 1977. Recordings were made at the bentgrass sod surface and at three 5 cm depth increments inside of the containers.

The check media contained no organic matter amendment, thus container temperature depth measurements for the check were classified as normal background temperature responses as compared to temperature measurements recorded in containers with an organic amendment incorporated.

Sod surface temperature recordings for the check showed a general increase tending to correspond with increasing daylength and air temperature with season (Table VII). Lower air temperatures were recorded during June, July, and September, as compared with the highest recordings shown in April and October reflecting the influence of a protective covering of "Garland liquid shading compound" applied to the greenhouse glass for the summer months. Sod surface temperatures were higher than any of the depth temperature recordings made inside of the containers throughout the entire 52 week test period. In general, depth temperature measurements following the initial recording date decreased considerably with increasing depth. However, depth temperature measurements for July and September showed no major difference. Considerable depth temperature differences again occurred in the October

TABLE VII

TEMPERATURE MEASUREMENTS OF TEST MEDIA

Test Media		Test Period and Temperature Measurements (°C)								
		1976								1977
		1/21	3/9	4/21	6/3	7/19	9/4	10/20	12/1	1/12
CHK	0	21.5	23.9	31.1	30.9	27.2	28.8	30.7	23.7	22.2
	5 cm	20.9	22.9	27.6	26.4	25.6	26.7	26.1	20.6	20.4
	10 cm	21.1	21.6	26.6	24.9	25.3	26.5	25.3	20.4	20.3
	15 cm	21.2	21.1	25.9	24.2	24.9	26.2	24.8	20.4	20.3
USGA	0	21.4	25.6	31.6	29.6	27.4	28.4	33.0	22.8	22.0
	5 cm	21.0	22.7	28.1	25.9	25.7	26.1	25.9	19.6	19.6
	10 cm	21.3	22.1	26.8	24.7	25.1	25.8	24.1	19.6	19.8
	15 cm	21.5	21.8	26.0	24.1	25.1	25.8	24.1	19.6	19.6
MP	0	21.6	25.5	31.2	30.9	26.8	28.0	31.8	22.2	22.4
	5 cm	21.0	23.4	28.5	26.3	25.6	26.7	26.1	20.0	20.1
	10 cm	21.2	22.2	27.1	27.4	25.4	26.6	25.1	20.0	20.0
	15 cm	21.4	21.9	26.6	24.9	25.1	26.5	24.6	20.0	20.0
SP	0	21.4	26.2	31.4	30.9	27.4	28.4	30.7	23.2	22.3
	5 cm	20.9	23.4	28.3	26.1	25.7	26.3	27.0	20.4	20.1
	10 cm	21.2	21.9	27.1	24.9	25.3	26.2	25.9	20.4	19.8
	15 cm	21.2	21.0	26.4	24.2	25.0	26.1	25.3	20.3	19.8
CC	0	21.3	27.4	29.1	30.6	27.5	27.7	30.6	23.7	21.8
	5 cm	21.6	25.4	27.7	26.1	25.9	25.9	25.8	20.0	19.6
	10 cm	21.9	22.5	26.6	24.6	25.2	25.7	24.7	19.8	19.6
	15 cm	22.1	22.0	26.0	24.2	25.0	25.8	24.4	19.8	19.5
SS	0	21.6	26.9	30.7	28.8	27.2	28.1	31.5	22.7	21.7
	5 cm	22.2	22.6	27.8	25.8	25.6	26.1	25.3	20.6	20.1
	10 cm	22.2	21.2	26.8	24.7	25.2	26.0	24.6	20.4	20.2
	15 cm	22.2	20.8	26.1	23.8	25.0	26.1	24.4	20.3	20.0
CoT	0	21.9	28.1	31.2	29.8	26.6	28.4	30.1	23.0	21.7
	5 cm	21.9	22.6	28.1	25.8	25.4	26.1	25.7	20.0	19.8
	10 cm	22.1	21.4	26.6	24.7	25.0	26.1	24.7	19.8	19.8
	15 cm	22.2	20.9	26.5	23.9	24.8	25.9	24.3	19.8	19.8
SC	0	21.7	26.1	29.9	29.4	27.4	27.6	30.0	22.2	21.5
	5 cm	22.2	23.7	27.7	25.8	25.9	25.9	25.3	20.3	19.9
	10 cm	22.4	22.1	26.7	24.4	25.5	25.8	24.2	20.3	19.9
	15 cm	22.5	21.4	26.1	23.8	25.2	25.7	23.8	20.3	19.8

TABLE VII (continued)

Test Media	Test Period and Temperature Measurements (°C)								
	1976								1977
	1/21	3/9	4/21	6/3	7/19	9/4	10/20	12/1	1/12
OS 0	21.4	26.7	29.8	28.3	27.7	28.2	31.1	20.0	21.8
5 cm	21.8	22.9	28.6	25.9	25.6	26.4	26.2	20.0	19.8
10 cm	22.1	21.6	26.8	24.7	25.2	26.2	24.7	19.5	19.8
15 cm	22.2	21.0	26.0	23.8	24.9	26.0	24.1	20.0	19.9
PB 0	21.8	25.2	30.9	28.8	27.7	28.1	30.3	22.6	21.5
5 cm	22.0	23.3	28.1	26.0	25.8	26.0	26.0	20.3	20.1
10 cm	22.2	21.9	27.0	24.6	25.3	26.0	24.9	20.5	20.1
15 cm	22.2	21.2	26.3	23.8	25.1	25.9	24.3	20.3	20.1

recordings. However, no major difference in depth temperatures occurred during the final two measurements in December and January.

In general, all media containing organic amendments showed a similar trend to that exhibited by the check (Table VII). The trend of temperature variance by depth and time between the check and media containing organic amendments generally were not significant. Organic matter breakdown as reflected in marked heat emission could not be clarified by the recording methods used in this study. It was reported by Miller (43) that most of the sewage sludge decomposition occurred in the first month and soil temperature was the main factor influencing decomposition. Results reported by Miller could not be substantiated on the basis of the media temperature data recordings made in these investigations.

II. LABORATORY RESPONSES

Particle Size Distribution

Core samples were taken from three depths of all replications of each test media for the three sampling periods (Table VIII). A mechanical analysis was conducted on each sample to determine particle size distribution by the method described by Day (21). Although the sand used for mixing the different media had been thoroughly washed to remove all organic matter and most of the silt, clay, and very fine sand fraction, it was recognized that the different organic amendments tested would possibly contain some contamination of these soil inert fractions.

TABLE VIII

PARTICLE SIZE DISTRIBUTION OF THE TEN TEST MEDIA (% by wt.)

Test Media	Time (Weeks)	Depth (cm)	Sand Fractional Ranges (mm) Very Coarse 2.0-1.0	Coarse 1.0-0.5	Medium 0.5-0.25	Fine 0.25-0.1	Very Fine 0.1-0.05	Total	Silt (mm) 0.05-0.002	Clay (mm) < 0.002	O.M. (% by wt.)
Check	0	0-5	4.09	41.00	49.80	3.86	0.31	99.06	0.56	0.38	0.00
		5-10	4.09	41.00	49.80	3.86	0.31	99.06	0.56	0.38	0.00
		10-15	4.09	41.00	49.80	3.86	0.31	99.06	0.56	0.38	0.00
	26	0-5	4.13	40.19	50.25	4.09	0.18	98.84	0.63	0.45	0.08
		5-10	3.33	36.96	53.45	5.27	0.33	99.34	0.45	0.18	0.03
		10-15	2.80	35.16	55.78	5.46	0.17	99.37	0.37	0.26	0.00
	52	0-5	3.61	37.58	52.15	5.45	0.36	99.15	0.42	0.27	0.16
		5-10	3.25	37.91	51.88	5.49	0.50	99.03	0.56	0.34	0.07
		10-15	3.03	34.61	54.12	7.13	0.43	99.32	0.40	0.28	0.00
USGA	0	0-5	5.47	40.44	40.71	4.72	1.34	92.68	3.48	2.41	1.43
		5-10	5.47	40.44	40.71	4.72	1.34	92.68	3.48	2.41	1.43
		10-15	5.47	40.44	40.71	4.72	1.34	92.68	3.48	2.41	1.43
	26	0-5	4.14	41.76	43.01	4.23	1.00	94.14	2.62	1.80	1.44
		5-10	3.49	37.36	46.10	5.40	1.21	93.56	3.23	2.18	1.03
		10-15	3.64	38.15	45.20	5.11	1.28	93.38	3.24	2.18	1.20
	52	0-5	3.-7	33.88	45.29	6.49	2.34	91.17	4.62	3.13	1.08
		5-10	3.74	36.64	44.80	5.65	1.81	92.64	3.77	2.53	1.06
		10-15	3.53	35.41	46.12	5.79	1.90	92.75	3.60	2.43	1.22
MP	0	0-5	4.21	39.54	49.22	4.43	0.35	97.62	0.75	0.52	1.11
		5-10	4.21	29.41	49.22	4.43	0.35	97.62	0.75	0.52	1.11
		10-15	4.21	39.41	49.22	4.43	0.35	97.62	0.75	0.52	1.11
	26	0-5	3.04	38.91	51.96	4.39	0.28	98.58	0.22	0.18	1.02
		5-10	2.58	36.08	54.55	5.11	0.29	98.61	0.24	0.19	0.96
		10-15	2.76	36.02	54.03	5.34	0.28	98.43	0.33	0.23	1.01

TABLE VIII (continued)

Test Media	Time (Weeks)	Depth (cm)	Sand Fractional Ranges (mm) Very Coarse 2.0-1.0	Coarse 1.0-0.5	Medium 0.5-0.25	Fine 0.25-0.1	Very Fine 0.1-0.05	Total	Silt (mm) 0.05-0.002	Clay (mm) < 0.002	O.M. (% by wt.)
	52	0-5	3.01	40.91	49.45	4.46	0.40	98.23	0.43	0.31	1.03
		5-10	2.41	36.75	53.30	5.35	0.48	98.29	0.53	0.39	0.79
		10-15	2.69	39.09	51.32	4.68	0.48	98.26	0.54	0.39	0.81
SP	0	0-5	3.06	35.22	55.12	4.95	0.33	98.68	0.64	0.45	0.23
		5-10	3.06	35.22	55.12	4.95	0.33	98.68	0.64	0.45	0.23
		10-15	3.06	35.22	55.12	4.95	0.33	98.68	0.64	0.45	0.23
	26	0-5	3.14	40.03	50.64	4.66	0.33	98.80	0.46	0.35	0.39
		5-10	3.63	38.84	51.01	5.22	0.27	98.97	0.41	0.29	0.33
		10-15	3.02	37.46	53.94	4.32	0.30	99.04	0.40	0.30	0.26
	52	0-5	3.74	38.70	51.27	4.70	0.40	98.81	0.40	0.28	0.51
		5-10	3.17	37.37	52.40	5.54	0.40	98.88	0.46	0.34	0.32
		10-15	3.40	40.65	49.24	5.24	0.39	98.92	0.45	0.34	0.29
CC	0	0-5	3.45	38.54	51.71	4.67	0.33	98.70	0.54	0.38	0.38
		5-10	3.45	38.54	51.71	4.67	0.33	98.70	0.54	0.38	0.38
		10-15	3.45	38.54	51.71	4.67	0.33	98.70	0.54	0.38	0.38
	26	0-5	3.53	38.63	51.75	4.68	0.36	98.95	0.43	0.31	0.31
		5-10	3.13	36.77	53.35	4.98	0.39	98.62	0.66	0.47	0.25
		10-15	3.22	40.32	50.94	4.22	0.26	98.96	0.45	0.32	0.27
	52	0-5	3.60	41.67	49.49	3.91	0.26	98.93	0.35	0.27	0.45
		5-10	3.00	36.31	53.41	5.62	0.43	98.77	0.56	0.39	0.28
		10-15	2.72	36.90	53.02	5.81	0.45	98.90	0.52	0.37	0.21
SS	0	0-5	4.19	41.78	47.51	4.14	0.36	97.98	0.73	0.46	0.83
		5-10	4.19	41.78	47.51	4.14	0.36	97.98	0.73	0.46	0.83
		10-15	4.19	41.78	47.51	4.14	0.36	97.98	0.73	0.46	0.83
	26	0-5	3.23	36.09	52.15	5.37	0.63	97.47	1.08	0.74	0.71
		5-10	3.45	39.00	50.36	4.38	0.57	97.76	0.96	0.67	0.61
		10-15	3.36	38.85	50.17	4.82	0.53	97.75	0.88	0.61	0.76

TABLE VIII (continued)

Test Media	Time (Weeks)	Depth (cm)	Sand Fractional Ranges (mm) Very Coarse	Coarse	Medium	Fine	Very Fine	Total	Silt (mm)	Clay (mm)	O.M. (% by wt.)
			2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.1	0.1-0.05		0.05-0.002	< 0.002	
	52	0-5	3.34	34.59	53.35	5.60	0.56	97.44	1.03	0.71	0.82
		5-10	3.43	38.27	49.87	5.32	0.69	97.58	0.96	0.65	0.81
		10-15	2.83	37.32	51.00	5.67	0.55	97.37	1.10	0.77	0.76
Cot	0	0-5	4.13	42.55	48.02	3.60	0.38	98.68	0.49	0.24	0.59
		5-10	4.13	42.55	48.02	3.60	0.38	98.68	0.49	0.24	0.59
		10-15	4.13	42.55	48.02	3.60	0.38	98.68	0.49	0.24	0.59
	26	0-5	3.01	38.48	52.54	4.69	0.28	99.00	0.36	0.26	0.38
		5-10	2.90	36.03	53.63	5.87	0.42	98.85	0.51	0.38	0.26
		10-15	3.13	37.81	53.27	4.64	0.28	99.13	0.35	0.26	0.26
	52	0-5	2.33	34.85	55.40	5.93	0.35	98.86	0.42	0.30	0.42
		5-10	2.47	36.10	53.61	6.48	0.36	99.02	0.40	0.30	0.28
		10-15	2.47	35.77	54.09	6.27	0.33	98.93	0.47	0.34	0.26
SC	0	0-5	3.74	41.42	48.81	4.40	0.30	98.67	0.41	0.32	0.60
		5-10	3.74	41.42	48.81	4.40	0.30	98.67	0.41	0.32	0.60
		10-15	3.74	41.42	48.81	4.40	0.30	98.67	0.41	0.32	0.60
	26	0-5	3.30	39.83	50.36	4.82	0.37	98.68	0.55	0.40	0.37
		5-10	3.13	39.33	51.78	4.33	0.30	98.87	0.46	0.35	0.32
		10-15	3.78	38.21	51.88	4.73	0.32	98.92	0.45	0.33	0.30
	52	0-5	3.54	39.64	50.78	4.77	0.25	98.98	0.40	0.31	0.31
		5-10	3.14	34.72	54.55	5.91	0.34	98.66	0.65	0.48	0.21
		10-15	2.43	35.25	54.55	6.37	0.28	98.88	0.54	0.42	0.16
OS	0	0-5	3.48	40.93	49.55	4.10	0.20	98.26	0.38	0.28	1.08
		5-10	3.48	40.93	49.55	4.10	0.20	98.26	0.38	0.28	1.08
		10-15	3.48	40.93	49.55	4.10	0.20	98.26	0.38	0.28	1.08
	26	0-5	3.53	38.33	51.39	5.00	0.46	98.71	0.30	0.23	0.76
		5-10	3.32	38.97	51.24	4.94	0.36	98.83	0.20	0.17	0.80
		10-15	3.01	34.62	55.87	5.13	0.28	98.91	0.17	0.13	0.79

TABLE VIII (continued)

Test Media	Time (Weeks)	Depth (cm)	Sand Fractional Ranges (mm)						Silt (mm)	Clay (mm)	O.M. (% by wt.)
			Very Coarse 2.0-1.0	Coarse 1.0-0.5	Medium 0.5-0.25	Fine 0.25-0.1	Very Fine 0.1-0.05	Total	0.05-0.002	< 0.002	
	52	0-5	3.10	36.13	54.24	4.89	0.25	98.61	0.30	0.23	0.86
		5-10	2.65	38.41	53.02	4.75	0.20	99.03	0.24	0.19	0.54
		10-15	3.33	32.99	56.52	5.85	0.33	99.02	0.24	0.19	0.55
PB	0	0-5	3.40	36.81	52.50	5.34	0.39	98.44	0.46	0.33	0.77
		5-10	3.40	36.81	52.50	5.34	0.39	98.44	0.46	0.33	0.77
		10-15	3.40	36.81	52.50	5.34	0.39	98.44	0.46	0.33	0.77
	26	0-5	3.12	37.72	51.00	5.23	0.51	97.58	0.90	0.63	0.89
		5-10	3-24	37.74	51.10	5.08	0.51	97.67	0.93	0.64	0.76
		10-15	2.53	34.78	54.25	5.59	0.56	97.71	0.89	0.63	0.77
	52	0-5	2.82	35.12	53.04	6.08	0.49	97.55	0.93	0.64	0.88
		5-10	2.63	36.06	53.81	5.09	0.33	97.92	0.75	0.48	0.85
		10-15	2.63	35.53	53.28	5.85	0.44	97.73	0.91	0.62	0.74

Some problems were encountered in applying the standard analysis methods by Day (21) and Kilmer and Alexander (32). Determinations were made on the recommended sample size of 10 g. Sampling error was normal but to what degree became unpredictable due to interactions of several factors. Errors may occur as a result of the very high percentage of organic matter (10 percent by volume) being studied in the test media, the variation in particle size of the different organic matter types, and the presence of unknown proportions of organic fractions within each organic matter type which is resistant to the digestion process used.

In the Kilmer and Alexander process supposedly most of the organic matter was removed by repeated additions of 30 percent hydrogen peroxide. A minimum of 40 ml of 30 percent hydrogen perioxide was added to each sample. This amount still did not appear sufficient to remove some of the coarse and/or resistant forms of organic particles. When pipette samples were removed and put in the drying oven, the silt and clay determination appeared much higher than it should have been. In many of the samples where it was already known that the sand constituted 97 to 99 percent by weight, silt and clay measured 5 to 10 percent by weight. It was theorized that the high silt and clay percentages were caused by salt buildup in the weighing dish during drying due to the large amounts of 30 percent hydrogen peroxide added during organic matter removal. Thus, it was decided to reanalyze samples by the hydrometer method described by Bouyoucos (10), using 100 g samples. Although it was difficult to obtain an accurate measurement of silt and clay by the Bouyoucos method when such very small amounts were present, this method did provide much better agreement in comparison with the known amounts of sand present.

It is known that in repeatedly taking a fixed sample weight over a period of time, such as a 10 g sample, that the percent proportionment of coarse and possibly medium fractions of sand will appear to gradually decrease and a gradual increase will appear in percent of fine particles and organic matter. Root growth adds to organic matter content and occupies an increasing portion of the volume of fixed weight of the 10 g sample. The check media analysis shows this very gradual reproportionment over the 52 week period as organic matter percent increase due to progressive root growth (Table VIII, pages 51-54).

The check contained no initial organic amendment. All other test media, except the USGA mix, initially combined 90 percent medium-coarse sand and 10 percent organic amendment by weight. The USGA mix was proportioned as 80 percent medium coarse sand, 10 percent Michigan peat, and 10 percent loam soil by volume. Generally, total sand content varied less than 1 percent by weight with each organic amendment for the three sampling dates and by depth (Table VIII). The final mechanical analysis at 52 weeks showed the check media contained the highest total sand with an average of 99.17 percent by weight, reflecting the addition of some organic matter to the media as bentgrass root growth. Most of the remaining media showed only slightly less proportions of total percent sand than the check. Media containing sphagnum peat, corn chop, cotton chop, soybean chop, and oak sawdust contained a combined depth average of 0.28 to 0.33 percent less proportionment of sand than the check. Media of Michigan peat contained 0.91 percent, and media of pine bark and sewage sludge contained 1.44 and 1.71 percent, respectively, less proportionment of sand than the check. The initial analysis showed the USGA mix to contain an average of 6.38 percent total sand less than the check, and by 52 weeks 6.98 percent less sand than the check.

Analysis for silt and clay revealed check samples to contain less than 1 percent indicating that some did escape the sand washing process (Table VIII, pages 51-54). Comparing the check initial samples with initial samples of the other test media showed little difference in silt and clay content for Michigan peat, sphagnum peat, corn chop, cotton chop, soybean chop, and oak sawdust. Indications are that these organic amendments contained no significant amounts of silt and clay as a contaminant. However, initial samples of the pine bark media showed a slight, although not significant, increase in silt and clay, with sewage sludge showing a higher increase which was significant. The significantly high amount of silt and clay in the USGA mix of 5.08 to 6.70 percent was the apparent result of the 10 percent by volume addition of loam soil to this particular media.

Evaluations of the data were made to determine the occurrence of particle migration of fine fractions of sand, silt and clay. The occurrence of particle migration could not be clearly defined due probably to factors such as: prewashing the sand to remove most of the find particulate matter, only very small amounts of the fine fractional elements were present, a high percentage of organic matter was used, and normal sampling error.

Organic Matter

The Walkley-Black method described by Allison (2) was used to determine theoretically easily oxidizable organic matter. An unpredictable portion of the organic matter was of a non-oxidizable type and the percentages of organic matter found were probably lower than their true value. The type of sand used in the media also presented some problems. A medium-coarse river sand was selected which contained mica and other non-silica particulate matter. Some of the mica and other particulate matter was not removed in the sand washing process. The presence of non-sand fractions appear to have created problems in establishing true values for organic matter.

The check media contained no organic matter initially (Table V, page 40), thus values shown for organic matter should reflect only bentgrass root growth for the 26 and 52 week samples. Root weights at 52 weeks were more than twice that occurring at 26 weeks.

The test media initially containing an organic amendment indicate considerable variability in the portion of the amendment which actually could be shown to be organic matter (Table V). The USGA mix, which included organic matter contributed by the loam soil and 10 percent by volume Michigan peat, contained 1.43 percent by weight of organic matter which was the highest of the media studied. Media of sand mixed with Michigan peat and oak sawdust contained the next highest amount of organic matter at 1.11 and 1.08 percent, respectively, which was significantly less than the USGA mix. Significantly lower amounts were shown for sewage sludge, at 0.83 percent, pine bark, at 0.77 percent, soybean chop, at 0.60 percent, and cotton chop, at 0.59 percent by weight. The lowest organic matter content of media tested were corn chop, at 0.38 percent, and sphagnum peat at 0.23 percent by weight, which were significant.

Rate of decomposition of the different organic amendments generally showed that most tended to decrease in percent organic matter with time, especially for the first 26 week period (Table V, page 40). The USGA, Michigan peat, and corn chop medias showed a slight rate of decomposition during the 52 week period. Oak sawdust showed a moderate rate of decrease for the first 26 weeks but only slightly decreased between 26 and 52 weeks. The pine bark media showed an increase in organic matter for the first 26 weeks with little change for the remaining period. The increase in organic matter for pine bark likely reflects resistance to breakdown and added organic matter due to bentgrass root growth. Oak sawdust is a hardwood and pine bark a softwood tree product. These results tend to support findings by Allison et al. (4, 5, 6) that hardwood particles breakdown in the soil faster than softwood particles.

Organic matter levels for cotton chop and soybean chop showed a rapid decrease by 26 weeks with a slight decrease thereafter for soybean chop and little change for cotton chop (Table V). After an initial rapid decomposition cotton chop appeared to show resistance to breakdown. Sphagnum peat showed similarities to pine bark with the same trend of increase in organic matter for 26 weeks and only a slight increase thereafter to 52 weeks. Again a resistance to breakdown appeared evident with increased organic matter levels due to bentgrass root growth. The results with sewage sludge follows the same trend reported by Miller (43) that after an initial decomposition there is a resistance to further degradation. Resistance was indicated here by increases in the organic matter during 52 weeks reflecting the probable additions of bentgrass root growth.

Decomposition of organic matter is generally faster under conditions of good aeration (7). Therefore, decomposition of the organic amendments studied should have been better in the top 5 cm media depth than in deeper depths. Root growth in the check media concentrated in the surface 5 cm depth with time and was more than twice that occurring in the 5 to 10 cm depth, suggesting better aeration in the surface 5 cm (Table V, page 40). No measurable quantity of roots occurred in the 10 to 15 cm depth during the 52 week period, suggesting even less favorable aeration.

Organic matter content by depth of amended medias of the USGA mix and Michigan peat showed the same trend (Table V). Root growth of bentgrass contributed heavily in the surface 5 cm depth. Lower values in the 5 to 10 cm depth reflect reduced root growth but still conditions favoring some organic amendment decomposition. The 10 to 15 cm depth show increased organic matter values suggesting conditions were poor for root growth and little breakdown of the organic amendment.

Sphagnum peat and soybean chop show a similar trend in organic matter content by media depth and time (Table V). At both 26 and 52 weeks organic matter content of the media gradually decreased with increasing depth. Bentgrass root growth should be contributing significantly to the organic matter content in the surface 5 cm zone and decreasing with increasing depth.

Corn chop, cotton chop, and sewage sludge can be grouped as similar trends in organic matter content by media depth and time (Table V, page 40). Corn chop and cotton chop, for the first 26 weeks, show a decrease in organic matter content from the 0 to 5 to the 5 to 10 cm depths, then little difference between the 5 to 10 and 10 to 15 cm depths. At this point sewage sludge showed an increase in organic matter content. All these organic amendments showed a decreasing organic matter content with increasing depth for the period between 26 and 52 weeks.

Porosity Determinations

Aeration porosity is defined as the proportion of the bulk volume of soil that is filled with air at any given time or under a given condition such as a specified moisture tension. It is usually the large pores; that is, those drained by a tension of less than approximately 100 cm of water (17).

Aeration porosity values shown for the initial samples ranged from a high of 30.78 percent for soybean chop to a low of 21.58 percent for the USGA. The USGA mix porosity was significantly lower than the other test medias. All of the media studied had aeration porosity values well above 15 percent which is the minimum recommended to meet USGA specifications.

All of the media showed a considerable increase in aeration porosity with time following the initial determinations (Table VIII, pages 51-54). The USGA mix had the greatest overall increase in porosity. The check and cotton chop media had the lowest overall increase. There was considerable variation in aeration porosity increases at the different depths. Except for the USGA media, aeration porosity for all the 26 week test medias ranged from 30 to 37 percent which again was sufficient to meet USGA standards.

Aeration porosity values for the 52 week samples varied considerably between media (Table II, page 36). The USGA mix had a small decrease in aeration porosity for all three depths as compared to 26 weeks. The greatest increase in porosity occurred in the cotton chop media, although only 3 percent. Most of the remaining media showed only a slight increase from 0.3 to 1.4 percent. An increase in aeration porosity with increasing depth occurred in media of corn chop, sewage sludge, oak sawdust, pine bark, and the check. Aeration porosity values for the 52 week samples ranged from 25.6 to 37.3 percent, but the combined depth means for the media varied from only 28 to 36.5 percent.

The USGA recommends that compacted media should have a total porosity of 40 to 55 percent. Total porosity for all the initial media, except the USGA mix, was from 37 to 40 percent, which is still adequate (Table III, page 37). Media with total porosity of 40 percent were sphagnum peat and corn chop. The lowest initial total porosity was shown by the USGA mix with 34 percent, which was significantly lower than the rest.

Total porosity values increased for all depths for all the test media at 26 weeks (Table III). The USGA mix had the largest increase with 10 percent. The check had the lowest increase in total porosity.

Pine bark had the second highest total porosity increase with about 9 percent in the 0 to 5 cm depth and 7 percent in the two lower depths. Total porosity for the 26 week samples ranged from 41 to 46 percent which met USGA standards.

Total porosity values for the 52 week samples varied considerably between media and within media depths (Table III, page 37). Some of the media had slight increases and some slight decreases in total porosity as compared to 26 weeks. The total porosity values for the 52 week samples ranged from 40 to 47 percent which was sufficient to meet USGA Green Section specifications.

Bulk Density

Bulk density of a soil is defined as the mass of dry soil per unit bulk volume. The bulk volume is determined before drying to constant weight at 105°C (17). The USGA Green Section recommends that an acceptable compacted soil mix should have a bulk density between 1.20 to 1.60 g/cm^3, but an ideal range between 1.25 to 1.45 g/cm^3. Bulk density values for the initial media determinations in this study ranged from 1.25 to 1.36 g/cm^3, which is within the ideal range recommended by the USGA (Table IV, page 38). The check had the highest bulk density of 1.36 g/cm^3, which is almost midpoint in the ideal range recommended by the USGA. Michigan peat had the lowest value of 1.25, which was significantly lower than all other media. This supports findings by Lucas et al. (36) that peat may reduce bulk density. The USGA mix had the next highest value at 1.35, which was not significantly different from the check. The remaining media showed values ranging from 1.28 to 1.33 g/cm^3.

Bulk density values for sample determinations at 26 weeks generally increased (Table IV, page 38). The only decreases occurred in the 0 to 5 cm depth samples of the USGA, sphagnum peat, and pine bark, and in the 10 to 15 cm depth of soybean chop. The greatest increase occurred in the Michigan peat media. Increases were only small in media of the check, USGA, corn chop, sewage sludge, cotton chop, and oak sawdust. In general, bulk density values at 26 weeks ranged from 1.27 to 1.45 g/cm^3, which still is in the ideal range recommended by the USGA. The only significant depth difference within a test media was the 0 to 5 cm depth of the USGA mix, which was significantly less than its 10 to 15 cm depth.

All of the 52 week media samples had bulk density values that were equal to or higher than the 26 week samples (Table IV). The check continued to have the highest overall values at all three determination periods for the three depths from 26 to 52 weeks. Sewage sludge had a substantial increase and cotton chop had a slight increase for their two lower sampling depths. Soybean chop, oak sawdust, and pine bark values all increased moderately for all three depths. The 0 to 5 cm depth bulk density of the USGA mix was significantly lower than its 10 to 15 cm depths. The 52 week samples for all media ranged from 1.31 to 1.49 g/cm^3 which continued to meet USGA Green Section specifications.

<u>Percolation Rate</u>

The USGA recommends that when top soil mix is compacted at field capacity moisture content, and maintained under a constant head flow of water for 24 hours at 20.2°C, the laboratory infiltration and transmission rate for water should be from 5 to 25 cm per hour (2 to 10 inches per hour) (25). The USGA initial test mixture had the lowest percolation rate of 8.23 cm per hour which meets USGA Green Section specifications (Table IX). Sewage sludge had the second lowest initial percolation rate of 38 cm per hour. Oak sawdust and cotton chop had the highest initial percolation rates of approximately 64 cm per hour. Corn chop had an initial percolation rate of 57 cm per hour which was not significantly different from oak sawdust. The check, Michigan peat, sphagnum peat, soybean chop, and pine bark media had initial percolation rates of 49 to 55 cm per hour, which were not significantly different.

Media samples at 26 weeks had much higher percolation rates than the initial or 52 week samples (Table IX). Percolation values for the three depths of the ten media ranged from a low of 133 cm per hour to a high of 407 cm per hour. Percolation rates for all of the test media at 26 weeks were much higher than rates recommended by the USGA. The USGA mix again had the lowest percolation rates of all the test media, which was significant. The highest percolation values occurred in media of the check, corn chop, and soybean chop which generally were not significantly different. There was a significant difference within depths for a few medias. The 10 to 15 cm depth of sewage sludge, soybean chop, oak sawdust, and pine bark had significantly greater percolation rates than their respective 0 to 5 cm depths. Percolation rate for sphagnum peat was much higher in the 0 to 5 cm depth than in the two lower depths.

TABLE IX

PERCOLATION RATE DETERMINATIONS (cm/hr)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	53.68 c	337.23 bcdef	69.78 cdefgh
	5-10	53.68 c	353.70 bcde	69.25 cdefgh
	10-15	53.68 c	351.93 bcde	85.94 ab
USGA	0-5	8.23 e	141.35 k	24.04 n
	5-10	8.23 e	159.58 k	21.89 n
	10-15	8.23 e	132.95 k	16.08 n
MP	0-5	51.72 c	278.96 hij	44.64 klm
	5-10	51.72 c	248.38 j	40.22 m
	10-15	51.72 c	254.70 j	42.37 lm
SP	0-5	55.98 c	387.63 ab	60.76 ghij
	5-10	55.98 c	306.48 efghi	65.72 ghij
	10-15	55.98 c	308.78 efgh	79.02 abcde
CC	0-5	56.51 bc	357.70 abcde	56.85 hijk
	5-10	56.51 bc	374.18 abc	66.01 efghi
	10-15	56.51 bc	373-28 abc	70.58 cdefgh
SS	0-5	38.18 d	258.10 ij	63.70 fghij
	5-10	38.18 d	274.15 hij	53.79 ijkl
	10-15	38.18 d	315.15 defgh	56.65 hijk
CoT	0-5	64.93 a	343.80 bcde	74.87 bcdef
	5-10	64.93 a	341.00 bcdef	72.03 cdefg
	10-15	64.93 a	355.23 bcde	70.47 cdefgh
SC	0-5	49.22 c	354.33 bcde	89.20 a
	5-10	49.22 c	361.35 abcd	87.31 ab
	10-15	49.22 c	407.13 a	87.51 ab
OS	0-5	64.12 ab	291.13 fghij	46.35 klm
	5-10	64.12 ab	369.30 abc	52.84 jkl
	10-15	64.12 ab	376.80 abc	67.35 defghi
PB	0-5	49.39 c	281.35 ghij	72.94 cdefg
	5-10	49.39 c	282.48 ghij	79.92 abcd
	10-15	49.39 c	330.98 cdefg	80.57 abc

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

Percolation rates for all media decreased substantially between the 26 week and 52 week sampling dates (Table IX). Percolation rates for the USGA mix samples for 52 weeks were significantly lower than all other media, but the USGA mix was the only media with percolation within rates recommended by the USGA. Michigan peat had the second lowest percolation rates which generally were significantly higher than the USGA mix. The highest percolation rates occurred in the soybean chop although not significantly higher than pine bark. Surprisingly, percolation values for the check were only third highest. A few media showed some significant difference within depths. The 10 to 15 cm depth of the check, sphagnum peat, and oak sawdust had significantly higher percolation rates than their respective shallower depths.

Several possible explanations can be advanced for the variability of percolation rates for the different media at the different sampling periods. All of the media showed an increase in porosity from the initial to the 26 week samplings (Tables II, page 36, and III, page 37). The 26 week samples may possibly be reflecting percolation values resulting from compaction at different moisture levels. Swartz and Kardos (54) found in sand-soil-peat mixtures that as the amount of moisture at the time of compaction increased, the percolation rate decreased. They found that in some 70 percent sand mixtures at equal compaction levels, percolation was 4 to 5 times higher when the samples were compacted at one-half depletion of available moisture than when compacted at field capacity.

In this study the 26 week samples were compacted 48 hours after removal from the test containers during which time the samples probably lost moisture. Initial and 52 week samples were compacted immediately after removal from the test containers. Further contributory factors helping to lower percolation rates from 26 to 52 week samplings could be increased root growth shown as organic matter content (Table V, page 40), increased bulk density reflecting increased root growth (Table IV, page 38), and little change in porosity with root growth replacing decomposed organic amendment (Tables II, page 36, and III, page 37).

Cation Exchange Capacity

Cation exchange capacity (CEC) is defined as the sum total of exchangeable cations that a soil can absorb. It is expressed in milliequivalents per 100 grams of soil, or of other absorbing material such as clay (17). Organic matter contributes many benefits to the improvement of a soil including an increase in CEC and helping to reduce leaching of cations (59).

The check had the lowest CEC values which was significantly lower than all other media except corn chop (Table X). The USGA mix had significantly higher CEC values than all test media. This would be expected due to the USGA mix containing 10 percent Michigan peat, 10 percent loam soil, and only 80 percent sand. All other media, except the check, contained 90 percent sand. Michigan peat had the second highest CEC, which was significant, followed by pine bark and sewage sludge, which were not significantly different. There was no significant difference in CEC values between the remaining medias.

All media decreased in CEC between the initial and 26 week samples except oak sawdust and pine bark which showed an increase (Table X).

TABLE X

CATION EXCHANGE CAPACITY DETERMINATIONS (m.e./100 g)

Test Media	Depth cm	Initial[a]	26 Weeks	52 Weeks
CHK	0-5	1.37 f	1.19 m	1.47 l
	5-10	1.37 f	1.20 m	1.54 kl
	10-15	1.37 f	1.18 m	1.80 jkl
USGA	0-5	3.95 a	3.31 bc	4.16 ab
	5-10	3.95 a	3.53 b	3.75 bc
	10-15	3.95 a	3.89 a	3.74 bc
MP	0-5	3.12 b	2.37 e	2.91 de
	5-10	3.12 b	2.44 e	2.68 defg
	10-15	3.12 b	2.27 ef	3.06 d
SP	0-5	1.80 e	1.59 jkl	2.55 efgh
	5-10	1.80 e	1.82 ghijkl	2.11 hij
	10-15	1.80 e	1.79 hijkl	2.46 efghi
CC	0-5	1.68 ef	1.49 lm	2.30 fghij
	5-10	1.68 ef	1.54 kl	1.88 jkl
	10-15	1.68 ef	1.63 ijkl	1.87 jkl
SS	0-5	2.23 cd	2.16 efg	2.43 efghi
	5-10	2.23 cd	2.12 efg	2.55 efgh
	10-15	2.23 cd	2.33 e	2.32 fghij
CoT	0-5	1.95 de	1.83 ghijkl	2.20 ghij
	5-10	1.95 de	1.88 ghijk	1.95 ijkl
	10-15	1.95 de	1.94 fghij	1.87 jkl
SC	0-5	1.92 de	1.76 ijkl	2.01 ijk
	5-10	1.92 de	1.69 ijkl	1.95 ijkl
	10-15	1.92 de	1.74 ijkl	2.14 hij
OS	0-5	1.78 e	1.81 ghijkl	3.58 e
	5-10	1.78 e	1.74 ijkl	3.07 d
	10-15	1.78 e	1.97 fghi	2.78 def
PB	0-5	2.46 c	2.97 d	4.31 a
	5-10	2.46 c	3.13 cd	4.07 ab
	10-15	2.46 c	2.86 d	4.08 ab

[a]Means within columns followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

The decrease in CEC shown for the 26 week sample period is supported by a general decrease found for organic matter content for these same samples (Table V, page 40). The results suggest a reduction in volume of the organic amendment between the initial to the 26 week period due to decomposition. Check media CEC values were again significantly lower than all other medias, followed by corn chop. CEC values for the USGA mix were significantly higher than the other medias. The only significant difference within depths occurred in the USGA mix in which the 10 to 15 cm depth was significantly higher than the two shallower depths.

In general, CEC values for the test media increased between the 26 week to 52 week sample period (Table X). Again this trend is supported by an increase in organic matter content for this same period (Table V). The CEC and organic matter increase would be expected to reflect increased root growth in the test containers. The check continued to show the lowest CEC values. Pine bark replaced the USGA mix as having the overall highest CEC values, except only significantly higher at the 5 to 10 and 10 to 15 cm depths. This may possibly reflect the resistance of pine bark to decomposition with increased CEC values attributable to increased root growth. Oak sawdust CEC values increased greatly from 26 to 52 weeks followed by Michigan peat. The 0 to 5 cm depth for oak sawdust showed a significant increase in CEC than values shown for the two deeper depths.

In general, CEC values over the 52 week period showed an increase from the start of the test, except for the USGA and Michigan peat media which slightly decreased (Table X, page 69). However, the two tree products, oak sawdust and pine bark, showed a substantial increase in CEC from the initial to 52 weeks.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine physical and chemical properties of several commercial and indigenous forms of organic matter in soil mixtures for golf greens. The investigations included determinations of the effect of the test media on the roots and foliage of bentgrass used as a sod cover. Some of the organic matter amendments exhibited similar response trends but, in general, each developed certain peculiar characteristics.

I. CHECK

The check media of pure, washed medium-coarse sand compared favorably with the other test medias which contained an organic amendment. Bentgrass growth and density were good throughout the study. This media had the second lowest leachate volumes but an irregular trend of leachate pH values with an average of 7.0. Percent sand content was the highest and percent organic matter the lowest. Organic matter content of the check resulted entirely from bentgrass root growth. CEC was the lowest of all the test media.

Aeration and total porosity were high with very high capillary porosity. Bulk density was the highest of the media tested. The check had rapid percolation that exceeded the USGA specifications. Most of the results found for the check were expected.

II. USGA

The USGA mix generally complied with specifications recommended by the U.S. Golf Association for green construction. Bentgrass growth and density were good throughout the study. This media had the lowest leachate volumes, and the leachate pH values with time developed a regular increasing pH trend with an average pH of 6.8. The percent of silt, clay and very fine sand was highest in this media as a result of incorporating 10 percent by volume of loam soil. Percent of total sand was the lowest of media tested. Organic matter was the highest, possibly due to the organic matter added as Michigan peat and the organic matter content of the loam soil. CEC was the highest in the USGA mix also.

Porosity was good as a result of high aeration and total porosity, and very high capillary porosity. Thus, available pore space for good bentgrass root growth was present. Initial bulk density was high and decreased with time. Very good root growth occurred in the 0 to 5 cm depth indicating very favorable conditions for root growth. Percolation rate was lowest of all the medias tested, but percolation values met USGA recommendations for the initial and 52 week samplings.

III. MICHIGAN PEAT

The Michigan peat test media supported a good, dense stand of bentgrass throughout the test. The media had the third lowest leachate volumes with leachate pH values exhibiting a regular increasing trend, with an average of 6.8. Sand content was high with no significant addition of very fine particulate matter as a contaminant. Percent organic matter was second highest initially, with a slight decrease by 26 weeks, and a slight increase from 26 to 52 weeks. CEC values were high in comparison with other media.

Aeration and total porosity values were high and capillary porosity medium. Bulk density was lowest initially, but second highest at 26 and 52 weeks. Root growth was excellent in the 0 to 5 cm depth. Michigan peat had a medium percolation rate initially, but was lower than most of the other media at 26 and 52 weeks. The percolation rate was well above USGA recommendations.

IV. SPHAGNUM PEAT

Bentgrass grew well in this media during the entire test period. Media leachate volumes ranked medium. The leachate pH values developed a regular increasing trend, averaging 6.8, similar to media of the USGA and Michigan peat. Sand content was high. Organic matter content was second lowest initially, but ranked medium at 26 and 52 weeks due to a slight increase in organic matter with time. CEC values were medium to low.

Aeration and total porosity were medium initially, but low at the 52 week sampling period. Capillary porosity was low also. Bulk density values were medium initially and low at 26 and 52 weeks, but all values were in the ideal range recommended by the USGA. Percolation rate was medium for the initial, 26 and 52 week sampling periods but exceeded USGA maximum specifications.

V. CORN STALK CHOP

Bentgrass growth was generally good throughout the study in the corn stalk chop media. Leachate volumes were medium, and the leachate pH values developed a regular decreasing sigmoid-type curve response averaging 7.5. Sand content was high for this media. Organic matter content was low throughout the study with only a slight increasing trend with time. CEC was low, probably resulting from the very low content of easily digestible organic matter of this material.

Aeration, total, and capillary porosity were all high for this media, which helps account for the percolation rates being high initially and at 26 weeks. Percolation rates at 52 weeks increased slightly, but still they exceeded USGA specifications. Bulk density values at all sampling dates were high, but all were within the ideal range recommended by the USGA.

VI. SEWAGE SLUDGE

Bentgrass growth was very good in this media. Leachate volumes were medium to high, and the leachate pH responses followed a regular decreasing sigmoid-type curve trend with an average of 7.5. Sand content was high, but this media material contributed significant amounts of silt and clay as a contaminant. Organic matter content was medium to high for all the sampling periods, with a slight decrease at 26 weeks, and a slight increase at 52 weeks. CEC values were medium.

Aeration and total porosity were medium and capillary porosity was low. Bulk density values were medium initially and at 26 weeks, and high at 52 weeks, but all values were within the ideal recommended range. Percolation rates were lower than most of the other test media but were still above the USGA specifications.

VII. COTTON STALK CHOP

Bentgrass growth was good in this media throughout the study. Leachate volumes were medium to low with the leachate pH values following a regular decreasing sigmoid-type curve, averaging 7.5. Sand content was high. The organic matter content was medium to low with a rapid decrease at 26 weeks, but a slight increase occurring from 26 to 52 weeks.

Aeration and total porosity were medium with capillary porosity medium to high in comparison to the other test media. Bulk density values were low initially and medium at 26 and 52 weeks. Root growth was very good in the 0 to 5 cm depth. Percolation rate values were the highest initially and medium-high at 26 and 52 weeks.

VIII. SOYBEAN STALK CHOP

Bentgrass growth was very good in the soybean stalk chop media. This media had the highest leachate volumes and the highest average leachate pH value of 7.7. The pH values for the leachates followed a regular decreasing sigmoid-type curve. Sand content was high in this media. Organic matter content was medium initially and at 26 weeks, and low at 52 weeks. Organic matter decreased rapidly during the first 26 weeks but decreased slightly from 26 to 52 weeks.

Aeration, total, and capillary porosity values were all very high. Bulk density values were medium initially, medium-low at 26 weeks, and medium at 52 weeks. Percolation rates were medium-low initially, but were the highest of all test media at 26 and 52 weeks. Percolation rates exceeded USGA specifications.

IX. OAK SAWDUST

Bentgrass growth and density were poor in this media throughout the entire study. Grass foliage showed the lightest green coloration in this media also. The leachate volumes were high, with the leachate pH responses exhibiting an irregular type of curve averaging 7.1. Sand content was high but no silt or clay was contributed as a contaminant. Organic matter content was generally high initially, decreasing moderately at 26 weeks, and decreasing slightly at 52 weeks. CEC values were medium-low initially, and increased to medium at 26 weeks, and medium-high by 52 weeks.

Aeration, total, and capillary porosity values were medium in comparison with the other medias. Bulk density values were low initially, decreasing to very low by 52 weeks, but were still within USGA specifications. However, bentgrass root growth was very good in the 0 to 5 cm media depth. Percolation rate was high initially, medium at 26 weeks, and medium-low at 52 weeks. All percolation values were above the maximum recommendations by the USGA.

X. PINE BARK

Bentgrass growth was slow initially, but improved with time. This test media had medium leachate volumes, and an irregular leachate pH response, averaging 7.4. Sand content was high but a small amount of silt and clay was added as a contaminant, although it was not significant. Organic matter content was medium to high. CEC values were high to highest of all test medias from the initial to 52 weeks.

Aeration porosity was medium initially, highest of all test medias at 26 weeks, and medium-low at 52 weeks. Capillary porosity was low, however. Bulk density values were medium-high initially, medium at 26 weeks, and medium-low at 52 weeks. Percolation rate was medium-low initially and at 26 weeks, and high at 52 weeks.

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