12-1974

Some physical properties and cation exchange capacities of soils from greens of four golf courses as compared to USGA Green section specifications

Reginald M. Jellicorse

To the Graduate Council:

I am submitting herewith a thesis written by Reginald M. Jellicorse entitled "Some physical properties and cation exchange capacities of soils from greens of four golf courses as compared to USGA Green section specifications." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Landscape Architecture.

Lloyd M. Callahan, Major Professor

We have read this thesis and recommend its acceptance:

Don B. Williams, W. L. Parks

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Reginald M. Jellicorse entitled "Some Physical Properties and Cation Exchange Capacities of Soils from Greens of Four Golf Courses as Compared to USGA Green Section Specifications." 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.

Lloyd M. Callahan

Lloyd M. Callahan, Major Professor

We have read this thesis and recommend its acceptance:

O B Williams

W L Parks

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

SOME PHYSICAL PROPERTIES AND CATION EXCHANGE CAPACITIES OF SOILS FROM GREENS OF FOUR GOLF COURSES AS COMPARED TO USGA GREEN SECTION SPECIFICATIONS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Reginald M. Jellicorse

December 1974

ACKNOWLEDGMENTS

The author wishes to express his appreciation to the following:

Dr. Lloyd M. Callahan for directing this thesis and the author's course of study, and for serving as committee chairman.

Dr. Don B. Williams for assistance throughout the author's course of study and for being a member of the author's committee.

Dr. W. L. Parks for his friendship, for his assistance with laboratory procedures and for being a member of the author's committee.

In addition the author wishes to express appreciation to Alan R. McDaniel for his assistance in the statistical analysis of these data.

Finally the author wishes to express his gratitude to Glenda Sue, his wife, for her encouragement and assistance throughout this course of study.

ABSTRACT

The purpose of this investigation was to determine and compare certain physical properties and cation exchange capacities at various depths of putting green soils from four golf courses in the Knoxville, Tennessee area. These golf courses were of different ages and types of green construction. This study also included a comparison of these same physical properties and CEC with a laboratory soil mixture of sand, silt, clay and organic matter prepared in accordance with USGA Green Section specifications which served as a standard of known and currently accepted soil property responses.

The experimental data for this investigation were obtained by laboratory analysis of particle size distribution, organic matter content, bulk density, aeration porosity, total porosity, percolation rates, available moisture holding capacity and cation exchange capacity.

It was found that based on particle size distribution only Cobbly Nob golf course green soils were similar to the USGA standard. Fox Den golf course, although built with the aid of the USGA laboratory recommendations on components for putting green soil mixture, had putting green soils similar to those found in greens on Deane Hill and Cherokee golf course greens which were built without the aid of USGA laboratory recommendations. These three golf courses had putting green soils with much greater amounts of silt and clay and less total sand than the USGA standard or Cobbly Nob putting green soils.

It was found that in the older greens on Deane Hill and Cherokee golf courses fine and very fine sand, silt and clay increased with increasing depth. Furthermore, the top few cm of all putting green soils were somewhat different to soil taken from lower depths, indicating the use of different textured topdressing materials.

Organic matter content tended to increase in the upper soil levels in all greens and with the greatest increase in the older greens. The USGA standard mixture was exceeded in organic matter content by the upper levels of the oldest greens only.

Variations in particle size distribution and organic matter content among the soil samples were reflected in variations in aeration porosity, total porosity, percolation rate, available moisture holding capacity and CEC. It was found in this study that bulk density was not significantly different among soil samples.

Aeration porosities, total porosities and percolation rates generally decreased as fine and very fine sand, silt and clay increased. The USGA standard and Cobbly Nob putting green soils were within acceptable ranges of aeration porosity, total porosity and percolation rate while all others were considerably lower.

Available moisture holding capacity increased as amounts of organic matter, fine and very fine sand, silt and clay increased, however increases in organic matter caused the greatest increase.

Cation exchange capacity increased as both clay and organic matter content increased although increases in organic matter resulted in the greatest increase.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

In the field of turfgrass research major emphasis in recent years has been on putting green construction. This is understandable since putting greens comprise the largest monetary investment per square foot of sod in the field of turfgrass management. This has prompted considerable investigation into green construction involving top soil mixtures which will withstand heavy traffic use over a period of years.

Through these investigations techniques and standards of physical properties for soil components used in putting greens have evolved and are widely accepted. It is now possible for the practical manager to receive information on the proper amounts of locally available sands, soils, and organic matter for greens top soil mixtures resulting in a desirable and long lasting putting green.

Information is needed on the profile development in putting greens, which could alter some soil properties with depth. Profile development would depend upon soil texture, mixture of soil components, age, and certain management practices.

The objective of this study is to determine and compare physical properties and cation exchange capacities of the top soil of three randomly selected greens on four golf courses in the Knoxville, Tennessee area with a greens soil mixture prepared according to USGA Green Section specifications. Investigations will specifically determine compacted bulk density of disturbed samples, aeration porosity and total porosity, percolation rate of water, available moisture holding capacity, percent of fractional ranges of sand, percent of silt, clay and organic matter, and cation exchange capacities of soil samples from greens at different depths. These greens differ in age and construction.

CHAPTER II

REVIEW OF LITERATURE

The role of any soil is to provide a medium for good root growth, nutrient storage, moisture retention, adequate aeration, and mechanical support for plants (8). Furthermore, soils in putting greens have the additional requirement to withstand compaction forces of constant foot and equipment traffic without losing good physical characteristics (29).

Compaction is referred to by Baver (5) as the moving together of soil particles which results in an increase in soil density. Water can serve as a lubricant to soil particles resulting in ease of particle movement. As moisture content increases, density increases with compaction. Evans and Lemon (14) found that as moisture increases there is a decline in the ability of soil aggregates to withstand traffic.

Investigations by Zimmerman (42) and Shoop (32) showed that compaction reduces total porosity principally at the expense of aeration porosity. Veihmeyer and Hendrickson (36) found that compaction of soil reduced the size of pores which would permit root entry. The reduction of aeration porosity by compaction was found by many researchers to reduce the hydraulic conductivity of soils (18, 24, 32, 41). From work done by Kunze (24) and Howard (18), it appeared that clay content affects the amount of aeration pore space reduction due to compaction. In their work with native Texas soils amended with sand and black sedge peat, aeration porosity and percolation rates were reduced, the magnitude of which was proportional to increases in clay content above 4 percent.

Vanderber et al. (35) states that compaction of soils due to usage occurs at the surface and decreases with depth. This was confirmed by Zimmerman (42) and Shoop (32) who further state that the effects of compaction are greatest at 0 to 2 and 0 to 1 inch depths respectively as determined by increases in bulk densities of homogeneous soils.

The preceding review illustrates the effects of compaction as manifest in physical properties in the soil.

Native soils with satisfactory physical properties for heavily used turfgrass areas are almost nonexistent. Modification of the particle size distribution of fine textured soils with coarse textured materials is often a means of improving the physical properties of soils for use in putting greens (42).

Sand is often used as a coarse textured amendment in soils to help maintain desirable physical properties under compaction. Kunze (24) found that as sand content increases from 60 to 85 percent by volume in a soil mixture the relative change in aeration porosity due to compaction decreased. Shoop (32) studied a coarse sand (80 percent particle size between 1.0 and 0.50 mm), a mortar sand (over 50 percent particle size between 0.50 and 0.25 mm), and a concrete sand (43 percent particle size between 0.50 and 0.25 mm with particle distribution ranging from gravel to silt) in sand-soil-peat mixes. He found that 60 percent or more by volume of each of these sand types is generally required to maintain aeration porosity above 12 percent and hydraulic conductivity greater than 1.0 inch per hour after compaction. However, Zimmerman (41), conducting investigations in the same field plots, found that after five years 70 percent or more sands of the coarse, mortar and concrete types is required to maintain hydraulic conductivities which exceed 1.0 inch per hour.

As sand content increases above 70 percent of soil mixtures, differences in effectiveness of various sands for increasing percolation rates can be noticed (32). Swartz (33) found that a soil mixture with 50 percent or less of a 0.50 to 0.25 mm sand had percolation rates of less than one inch per hour after compaction. However, an increase to 70 percent or greater of this sand fractional range resulted in percolation rates above one inch per hour. It was found by Shoop (32) that a mixture of 90 percent of a coarse sand (80 percent particle size between 1.0 and 0.25 mm) had percolation rates generally in excess of 15 inches per hour in artifically compacted field plots.

Kunze (24) stated that on the basis of weight of clipping yields compacted sand-soil-peat mixtures with ratios of 6-3-1, 7-2-1 and 8-1-1 sands of 1.0 to 0.5 mm size range were more desirable than sands of the 5.0 to 2.0 mm, 2.0 to 1.0 mm and 0.5 to 0.25 mm. These observations were made on T-35A bermudagrass. Howard (18) observed that a brick sand (30 percent particle size between 1.0 to 0.5 mm and 50 percent particle size between 0.5 to 0.25 mm) in 6-3-1, 7-2-1, 8-1-1 and $8^{1}/2-^{1}/2-1$ ratio sand-soil-peat mixtures gave best results based on weight of clippings removed from "cohansey" bentgrass. Both researchers found that a montmorillonite clay soil in the above sand-soil-peat mixes gave better clipping yields than a kaolinite and illite clay soil.

Lunt and Wyckoff (27) discovered that the more uniform the sand particle size the less it is affected by compaction.

Nelson (30) found that as soil particle size decreased from 0.44 mm to 0.02 mm there was a similar decrease in pore size resulting in reduced percolation rates and increased amounts of retained water. Lutz and Leamer (28) stated that percolation rates of a soil increase exponentially with an increase in particle size. Particle sizes smaller than silt (<0.002 mm) retained considerable moisture in the unavailable state according to Jamison and Kroth (19).

Cation exchange capacity (CEC) is decreased by additions of sand to soil. The coarser the sand the greater is the reduction of CEC. Additions of sand from 0 to 40 percent by volume has the greatest dilution effect on fertility as compared to CEC reduction caused by additions of sand from 40 to 80 percent by volume (41).

Perkins and King (31) stated that CEC was related to particle size of the mineral fraction of soils. As particle size decreases from 0.056 mm to clay (<0.0025 mm), base exchange capacity increased.

Based on these and other research studies the United States Golf Association (USGA) Green Section has recommended acceptable ranges of sand and soil particle sizes for a desirable putting green soil (15). They are as follows:

3 percent or less of >2.0 mm sand
7 percent or less of 2.0 to 1.0 mm sand
65 percent or less of 1.0 to 0.25 mm sand
17 percent or less of 0.25 to 0.05 mm sand
5 percent or less of silt (0.05 to 0.002 mm)
3 percent or less of clay (<0.002 mm)

This soil is mixed in volumetric ratios with organic matter. The ratio of organic matter to sand will vary depending on recommendations made as a result of laboratory analysis of physical and chemical properties of the organic matter and sand-organic matter mixtures.

The importance of organic matter in a soil is expressed by Kohnke (23) by the statement, "organic matter is an integral part of every soil and one that affects its physical and chemical conditions to a much greater extent than its proportional share would indicate."

The incorporation of sphagnum peat moss into grit, sand and clay soils resulted in mixtures less affected by compaction according to Bunt (9). In sand, soil, and peat mixtures Shoop (32) found that in the absence of peat more sand was required to maintain adequate percolation rates after compaction.

Davice (11) stated that in existing putting greens there was a positive correlation between organic matter and total pore space but a negative relationship between organic matter and aeration porosity. Junker and Madison (20) found that when peat is used in soil mixtures there is a wide distribution of pore size but that the soil becomes less dense, holds more water in the available state, and approaches wilting point more gradually.

Shoop (32) reported that a fine textured reed sedge peat incorporated up to 20 percent by volume improves the percolation rates of compacted sand, soil and peat mixtures and at the same time improved the available moisture holding capacity.

Results of a study on fertility of compacted sand, soil and fine textured reed sedge peat mixtures showed that increased peat content increased the fertility but lowered the pH (41). Yuan et al. (40) stated that organic matter correlated directly with CEC as did clay content, however, organic matter caused a greater increase in CEC than did clay on a unit weight basis. Organic matter also assists in plant nutrition through its own decomposition as well as through the exchange capacity of humus (23).

The nature of porosity of a soil depends on the size of particles and the state of aggregation. Total porosity was not as important as pore size distribution, especially the large pores which contribute to aeration porosity (5). Lewis and Powers (26) stated that in addition to particle size distribution, organic matter influenced the pore size distribution.

Aeration porosity is that pore space, usually the large pores, that are drained by tensions of 40 to 100 cm of water and the moisture remaining in the soil is the percent moisture at field capacity (11). Davice (12) observed that the better putting greens had more large pore spaces than did poor greens. Howard (18) observed that aeration porosity was closely related to clipping yields and visual ratings in compacted soil mixtures. Kunze (24) found that aeration porosity of 10 to 15 percent was associated with higher clipping yield of T-35A bermudagrass.

Adequate aeration porosity in putting green soils is important to root and plant growth. Letey et al. (25) stated that grass generally had a very dense fibrous root system and aeration porosity, among other things, was believed to affect root depth of grasses. According to Baver (5) when aeration porosity drops below 10 percent root proliferation was restricted. It was found by Hopkins et al. (17) that under reduced aeration conditions root respiration and growth were retarded, thus reducing nutrient uptake.

The movement of water through a given volume of soil takes place through pore spaces. The nature of the pore space distribution determines the amount of water movement through that soil. Gravity removes water from the aeration pore space. Thus drainage or the percolation of water through a soil is related to the aeration pore size distribution (3). Investigations by Baver (4) showed that hydraulic conductivity varied directly with the content of aeration pore space. Shoop (32) and Kunze (24) found aeration porosity and percolation rates highly positively correlated in their work with putting green soil mixtures.

Bodman and Harradine (6) found that decreased water permeability in soil columns with time appeared to be the result of pore blockage due to dispersed and migrated fine particles, principally clay. Fine silt of 0.02 to 0.002 mm range was found by Wright (39) to move appreciably through fine sand of 0.25 to 0.10 mm range and both coarse silt of 0.05

to 0.02 mm range and fine silt moved readily through medium sand of 0.5 to 0.25 mm range. This could contribute to pore space blockage and reduce percolation rates.

It is therefore evident that the effects of compaction alter the pore space distribution, primarily by reducing the aeration porosity. This in turn reduces percolation rates. Of the soil fractions, clay contributes most to the reduction of aeration porosity with compaction. The soils particle size distribution and organic matter content influence the pore space distribution, fertility levels, and ability of the soil to maintain adequate aeration porosity and percolation rates under compaction.

CHAPTER III

MATERIALS AND METHODS

The top soil mixtures of selected greens on four golf courses in the Knoxville, Tennessee area were evaluated for their physical properties and cation exchange capacities. The golf courses sampled were Deane Hill Country Club, built around 1948, Cherokee Country Club, built about 1904 with greens which had been rebuilt in 1945, Fox Den golf course, built in 1971, and Cobbly Nob golf course, built in 1973. Each golf course had bentgrass putting greens. The Fox Den and Cobbly Nob golf course greens were constructed with the aid of USGA laboratory analysis recommendations. According to the superintendent each course had operating budgets in the \$90,000 to \$100,000 range. Appendix Table VIII contains criteria as to depth of soil core sampling for the greens selected on the four golf courses.

COLLECTION OF SAMPLES

Three greens were analyzed on each of the golf courses. These greens were selected from either the front or back nine holes and were considered by the superintendent to be average as to growth response and playability of the turfgrass cover.

The surface of greens studied were marked off in a grid pattern at 3 m intervals with steel measuring tapes aligned on a compass setting of north-south and east-west to eliminate bias in sampling and for adherence to a randomized block design. Coring samples, 2.25 cm in diameter, were removed with a soil sampling tube from the total depth of the greens at each 3 m grid intersection. The depth of the sample was measured and recorded. After removing the live grass and thatch cover on top of each sample core, the remainder of the soil core was subdivided into 10 cm increments of 0 to 10, 10 to 20 and 20 to 30 cm.

LABORATORY PROCEDURES

Sample Preparation

The soil samples were air-dried at 20° C in the laboratory for four weeks in 15 cm flower pots. The soil samples were frequently stirred to assure more uniform drying. The air-dried samples were crushed with a mortar and pestle and passed through a 2 mm sieve. Approximately one liter of each sample was thoroughly mixed by rotating on a plastic sheet and then stored in a 15 cm flower pot lined with a plastic bag. Soil fragments larger than 2 mm were placed in small paper bags on top of their respective soil samples in the pots.

Mechanical Analysis

Particle size distribution was determined on all samples using the dry sieving method described by Day (13) for sand analysis and the pipette method reported by Kilmer and Alexander (21) for silt and clay analysis. Determinations were made on 10 g samples with most of the organic matter removed by repeated use of 30 percent hydrogen peroxide.

A drop or two of 50 percent hydrochloric acid was added to eliminate manganese and iron oxides. To disperse the fine fractions of the soil 200 ml of a calgon solution (50 g of calgon per 1 of water) was added and the samples agitated occasionally for 48 hours. The soil solutions were then washed through a 300 mesh sieve which retained all sands but allowed the silt and clay to pass through into a one 1 cylinder. The sands were oven dried and analyzed by the dry sieving method (13). Sedimentation in the cylinder and pipette aliquots to determine silt and clay content were performed at 20° C. The nomograph by Tanner and Jackson (34) were used to obtain settling times for aliquot removal to determine silt and clay content.

Organic Matter Analysis

Easily oxidizable organic matter was determined by the Walkley-Black method as described by Allison (1). Finely ground samples of either 0.5 or 1.0 g size were used depending on the estimated organic matter present. The higher percent of organic matter the smaller the sample size used.

Compacted Core Sample Analysis

The following procedures were conducted in accordance with personal communications with Dr. Colman Y. Ward of Mississippi State University as a result of a personal visit to that institution. The USGA Green Section sponsored soil testing laboratory is currently located at Mississippi State University under the direction of Dr. Ward.

Soil from each sample was placed in 5.3 cm diameter aluminum cylinders which were 5.15 cm deep. A 2.5 cm deep retaining ring made of the same diameter aluminum cylinder was attached to the top of the 5.3 by 5.15 cm cylinder with a 2.5 cm section of bicycle innertube. The base of each cylinder was covered with a piece of muslin cloth held in place with a rubber band. The cylinders were filled to the top of the retainer ring with soil then tapped on the table five times to settle the soil. The samples were then placed in a tub and filled with water to just below the soil level in the cylinder and allowed to soak for 24 hours. After the soil core samples were saturated with water they were transferred to a tension table and brought to equilibrium at 40 cm of water tension for 24 hours. The samples were then removed from the tension table and subjected to a compacting force of 6.22 m kg (45 ft lb) pressure with an impactor of the type described by Bruce (7). The impactor was built to deliver 6.22 m kg with 15 drops of the 1.36 kg (3 lb) weight and to accommodate 5 cm diameter cores. The resulting force of compaction gives the disturbed core samples physical properties approximating two year old field compacted soil as determined by Howard (18).

After compaction the retaining rings were removed and cores were trimmed even to the top of the 5.3 by 5.15 cm cylinders. The retaining rings were then placed back on top of the cylinders.

The compacted core samples were then saturated by placing in vacuum jars and water added to slightly below the soil level in the cylinders. The samples were subjected to light suction provided by a pneumatic suction device for 12 hours to remove trapped air to achieve more complete saturation. The saturated samples were removed from the vacuum jars, wiped with a sponge to remove excess water in the cloth covering, and weighed to the nearest 0.001 g. The resulting weights were recorded as saturated weight.

Following weighing the samples were again placed on the tension table and brought to equilibrium with 40 cm of water for another 24 hours. Weights were then taken to the nearest 0.001 g and recorded as field capacity weights.

The cylinders of soil were then transferred to a tub and soaked in water maintained at a level of 1/2 cm below the soil level for 4 to 6 hours. The samples were then placed on a percolation rack for draining as described by Klute (22). The percolation rack provided a 6.25 mm constant head of water on top of the core samples in the cylinders. Water was allowed to drain through the cores for 24 hours before water transmission rates were determined. Samples of water percolating through the cores were collected for 15 to 60 minutes to determine transmitted water in ml per hour. Darcy'a Law was used to determine hydraulic conductivity (22). Percolation rates in cm per hour was calculated by the formula:

$$\text{cm/hour} = [Q/19.625\ \text{cm}^2 \times 5\ \text{cm}/5.625\ \text{cm}]$$

Q = Transmission rate

$19.625\ \text{cm}^2$ = Soil Surface of Core

5 cm = Height of Sample

5.625 cm = Height of Sample plus constant water head

The cores were then oven dried at 105° C for 48 hours and total dry weight of the cores was recorded to the nearest 0.001 g. Total dry weight included the cylinder, retaining ring, cloth, rubber band and innertube section.

Bulk density (BD) of the laboratory compacted cores was calculated by the following formula:

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

BD = Bulk density of compacted cores

W_A = Total oven dry weight including soil, aluminum cylinder, retaining ring, cloth, rubber band and innertube section

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

V = Volume of 5.3 x 5.15 aluminum cylinder (113.51 cu cm)

Percent aeration porosity (AP) and total porosity (TP) were calculated using the following formulas as reported by Vomocil (38).

$$\%AP = \frac{\text{Saturated Weight - Field Capacity Weight}}{\text{Volume of (113.51 cu cm) cylinder}} \times 100$$

$$\%TP = \frac{\text{Saturated Weight - Total Oven Dry Weight}}{\text{Volume of (113.51 cu cm) cylinder}} \times 100$$

Available Moisture Determinations

Available moisture holding capacity is the water held between field capacity and 15 bars tension (11). Soil samples were placed in a pressure membrane apparatus, saturated for 24 hours, subjected to 15.82 kg/cu cm of pressure for 24 hours and weighed. Percent moisture was determined following oven drying at 105° C for 24 hours (37). Available moisture holding capacity was calculated by the formula:

Volume % Available Moisture = Volume % Moisture at 40 cm tension - (Weight % Moisture at 15 bars tension x compacted Bulk Density)

Cation Exchange Capacity Determinations

Cation removal from 20 g soil samples was conducted following the procedure described by Chapman and Pratt (10) using a 250 ml neutral normal ammonium acetate solution.

The ammonium ions which occupied the soil samples cation exchange sites as a result of cation removal were removed by use of the procedure described by Banwart et al. (2) using 200 ml of 2 molar potassium chloride solution. The filtrate of this procedure was then analyzed for the ammonium ion concentration in parts per million on a Technicon Autoanalyzer. Ammonium ion concentration was converted to milliequivalents per 100 g of soil which represent cation exchange capacity of the soil sample.

USGA Standard Core Samples

An artificial soil mixture was prepared in accordance with the 1973 revision of the USGA Green Section specifications (15) for particle size distribution of a putting green soil. Sand fractions were obtained by sieving a washed river sand using the procedure described by Day (13). Clay and silt fractions were obtained by removing the organic matter and sand from a soil obtained from the University of Tennessee Ornamental Horticulture and Landscaping Design Research Park. Particle size distribution analysis of this soil indicated there was 41.7 percent sand, 33.3 percent silt, and 23.7 percent clay and contained 1.31 percent organic matter by weight. The proper proportion by weight of each soil fraction were combined to give a soil with the following percent particle size distribution:

0.0% of >2.0 mm sand

9.5% of 2.0 to 1.0 mm sand

25.0% of 1.0 to 0.5 mm sand

40.0% of 0.5 to 0.25 mm sand

13.0% of 0.25 to 0.1 mm sand

5.0% of 0.1 to 0.05 mm sand

4.45% silt

3.05% clay

This soil was combined with 20 percent by volume of sewage sludge, well rotted sawdust, sphagnum peat and Michigan peat. These four soil mixtures were subjected to the same compacted core and cation exchange capacity analysis procedure as the putting green soil samples collected from the four golf courses. The results of these analysis were averaged to reflect means of the four organic matter types and served as a standard for comparison of the soil samples taken from the four golf courses. Appendix Table IX contains individual mixture analysis values.

STATISTICAL ANALYSIS

The experimental design was a randomized complete block over four locations (four golf courses) with three replications per location (three greens per golf course). The design is comparable to a split plot design where locations were main effects and split treatments were depth of sampling which were compared to the USGA standard samples.

CHAPTER IV

RESULTS AND DISCUSSION

The soils of bentgrass putting greens on four golf courses of similar operating budgets in the Knoxville, Tennessee area were analyzed and compared on the basis of physical properties and cation exchange capacities to a mean soil mixture prepared in the laboratory according to specifications by the U. S. Golf Association Green Section and established as the standard. Comparisons were made within each green tested according to depth also.

Physical properties and cation exchange capacities were determined on each 10 cm subsample increment. Physical properties investigated were particle size distribution, organic matter (Appendix Table X), bulk density, aeration porosity, total porosity, percolation rates and available moisture holding capacity (Appendix Table XI). Cation exchange capacities were determined by using the neutral normal ammonium acetate method (Appendix Table XII).

PARTICLE SIZE DISTRIBUTION

The laboratory prepared USGA standard soil mixture did not contain gravel (particles >2.0 mm) (Table I). Soil samples analyzed from the greens on all four golf courses contained some gravel. The USGA specifications for putting green soil mixtures allow only a maximum of 3

TABLE I

COMPARISON OF PERCENTAGE MEANS OF GRAVEL AND SAND FRACTIONS OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Location and Depth	Gravel[a] (mm) >2.0	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
Standard	0.00 a	9.09 e	23.93 g	38.28 e	12.44 d	4.79 b
Deane Hill						
0-10 cm	2.50 c	4.57 bc	20.21 e	21.81 ab	7.50 b	4.86 b
10-22 cm	2.55 c	3.11 ab	12.32 c	21.10 ab	9.30 c	7.77 c
Cherokee						
0-10 cm	1.61 bc	4.48 bc	18.21 d	31.66 d	10.02 c	5.01 b
10-20 cm	0.68 ab	2.70 a	10.44 b	26.68 c	12.56 d	7.14 c
20-25 cm	0.54 ab	1.55 a	7.62 a	20.44 a	13.10 d	9.24 d
Fox Den						
0-10 cm	5.08 e	4.48 bc	26.41 h	22.59 b	4.03 a	2.79 a
10-20 cm	5.11 e	5.01 c	22.31 f	21.82 ab	3.78 a	2.63 a
20-30 cm	3.97 de	5.19 c	22.32 f	22.44 b	4.19 a	2.95 a
Cobbly Nob						
0-10 cm	2.85 cd	7.10 d	42.96 i	25.09 c	8.82 bc	4.76 b
10-20 cm	2.34 c	10.51 e	50.72 j	25.45 c	3.66 a	1.56 a
20-30 cm	2.04 c	10.19 e	49.46 j	26.31 c	4.12 a	1.80 a

[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.

percent gravel in the sand used. However, higher amounts of gravel were found only in the greens on the Fox Den golf course. In general, there was no significant difference in the amount of gravel within greens on the same golf course. In most cases gravel content tended to decrease with increasing depth of the greens.

The USGA standard contained 9.1 percent sand in the very coarse fractional range of 2.0 to 1.0 mm, which is within acceptable limits. Very coarse sand in the greens of all four golf courses was found to be significantly lower than the USGA standard, except for the two lower depths in greens on Cobbly Nob. Percentages of sand in the 2.0 to 1.0 mm range was found to be uniform within sampling depth in greens on Deane Hill and Fox Den golf courses. The upper sampling depths in greens on the Cherokee golf course showed a significantly higher percent of very coarse sand than the two deeper depths. The sampling depth of 0 to 10 cm in greens on Cobbly Nob contained significantly less 2.0 to 1.0 mm sand than the two lower depths.

The USGA standard contained 23.9 percent coarse sand of the 1.0 to 0.5 mm fractional range (Table I). The percentage of coarse sand was significantly lower than the USGA standard for all depths in greens on Deane Hill and Cherokee and the two lower depths in greens on Fox Den. Coarse sand percentages were very high for all three depths in greens on Cobbly Nob. In general, as sampling depth increased percentages of coarse sand decreased, except on Cobbly Nob. There was no significant difference in percent of coarse sand in the two deeper depths within greens on Fox Den and Cobbly Nob.

The medium sand fractional range of 0.5 to 0.25 mm for the USGA standard was 38.3 percent (Table I). Percentages of medium sand in greens on all four golf courses were significantly lower than the USGA standard. Medium sand decreased significantly with increasing depth in greens on Cherokee but no significance in this trend was noted in greens on the other three golf courses.

Fine sand of 0.25 to 0.1 mm size range for the USGA standard was 12.4 percent (Table I). Sand in this fractional range from all sampling depths in greens on Deane Hill, Fox Den and Cobbly Nob, and the top sampling depth in greens on Cherokee, were significantly lower than the USGA standard. Only the two deeper depths of Cherokee were not significantly different than the USGA standard. There was an increase in fine sand with increasing sampling depth in greens on Deane Hill and Cherokee, although this increase was not significant in the two deeper depths of Cherokee. This increase was from 8 to 9 percent in greens on Deane Hill and from 10 to 13 percent in greens on Cherokee. Fox Den putting green soils had a uniform distribution of sand of the fine fractional range throughout all sampling depths. The upper sampling depth of Cobbly Nob had almost 9 percent fine sand which was significantly greater than the two lower depths with approximately 4 percent.

The USGA standard contained 4.8 percent of very fine sand of the 0.1 to 0.05 mm fractional range (Table I). The 0 to 10 cm sampling depth in greens on Deane Hill, Cherokee and Cobbly Nob were not significantly different than the USGA standard. Sampling depths below 10 cm in greens on Deane Hill and Cherokee golf courses were considerably higher than the USGA standard. Sand of the very fine fractional range was significantly lower in all sampling depths in greens on Fox Den and the two deeper depths on Cobbly Nob. Very fine sand in greens on Deane Hill and Cherokee golf courses increased significantly with increasing depth. This increase in Deane Hill was from 5 to 8 percent and in Cherokee from 5 to 9 percent. There was no significant difference in very fine sand in Fox Den greens with respect to sampling depth. The 0 to 10 cm depth in Cobbly Nob greens contained considerably greater amounts of very fine sand than the two lower depths, which were not significantly different.

In general, none of the golf course putting green soils had sand fraction distribution similar to the USGA standard. Deane Hill and Cherokee soils had little uniformity within greens. Generally, very coarse to medium sand fractions decreased with increasing depth while fine and very fine sand increased with increasing depth. Fox Den putting green soil had fairly uniform sand fraction distributions. The only deviation from uniformity was in the upper sampling depth which contained somewhat more coarse size sand than the lower depths. The lower two sampling depths of Cobbly Nob had very uniform sand fraction distributions. The upper sampling depth differed by having a somewhat finer sand than the two lower depths.

The USGA laboratory prepared soil standard contained total sand in the amount of 88.7 percent by weight (Table II). Total sand in the soil samples from greens on Deane Hill, Cherokee and Fox Den golf courses was considerably lower than the USGA standard, ranging from a high of 69

TABLE II

COMPARISON OF PERCENTAGE MEANS OF SOIL FRACTIONS OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Location and Depth	Soil Fractions (mm)[a] Gravel >2.0	Sand 2.0-0.05	Silt 0.05-0.002	Clay <0.002	O. M. (% by wt.)
Standard	0.00 a	88.71 b	4.26 a	2.92 b	4.31 c
Deane Hill					
0-10 cm	2.50 c	58.96 d	18.81 c	13.72 d	6.01 a
10-22 cm	2.55 c	53.61 f	23.98 d	16.80 e	3.06 d
Cherokee					
0-10 cm	1.61 bc	69.38 c	12.21 b	11.64 c	5.17 b
10-20 cm	0.68 ab	59.53 d	27.20 e	10.59 c	2.00 ef
20-25 cm	0.54 ab	51.94 g	32.00 f	13.75 d	1.77 ef
Fox Den					
0-10 cm	5.08 e	60.29 d	18.62 c	12.85 d	3.16 d
10-20 cm	5.11 e	55.54 e	23.80 d	13.85 d	1.70 ef
20-30 cm	3.97 de	57.09 e	23.57 d	13.85 d	1.52 f
Cobbly Nob					
0-10 cm	2.85 cd	88.73 b	4.65 a	1.55 a	2.22 e
10-20 cm	2.34 c	91.89 a	3.50 a	0.66 a	1.61 ef
20-30 cm	2.04 c	91.88 a	2.92 a	1.49 a	1.67 ef

[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.

percent to a low of 52 percent. However, sand totals of 92 percent from the two deeper sampling depths in greens on Cobbly Nob golf course were significantly higher than the USGA standard. Only the 0 to 10 cm depth of Cobbly Nob was not significantly different than the USGA standard. As sampling depth increased in greens on Deane Hill and Cherokee sand percentages decreased significantly. The only correlation with sampling depth in greens on the Fox Den golf course was a significantly higher sand content in the top depth as compared to the two deeper depths, although there was no significant difference between percentage means in the two deeper depths. Total sand percentages in the top sampling depth from Cobbly Nob was significantly less than the two deeper depths.

Silt content in greens on the four golf courses was of particular interest. Where the USGA standard contained 4.3 percent silt, significantly greater quantities were found in greens on Deane Hill, Cherokee and Fox Den golf courses (Table II). Green soils from Deane Hill and Fox Den contained silt in the amount of 19 to 24 percent and Cherokee containing 12 to 32 percent. These silt contents greatly exceed the five percent recommended for green soil mixtures as stated in the USGA specifications. Silt content in greens on Cobbly Nob were from 3 to 5 percent which was not significantly different from the USGA standard. In general, silt content increased significantly with increasing sampling depth in greens on Deane Hill and Cherokee golf courses. An increase in silt content was found in the depths below 10 cm in greens on Fox Den while the lower two depths were relatively uniform. Silt content in greens on Cobbly Nob was not significantly different with respect to sampling depth.

Clay content of the putting green soils followed similar trends observed with silt content (Table II). The USGA standard mixture contained 2.9 percent clay which was significantly less than that found in all sampling depths of greens on Deane Hill, Cherokee and Fox Den golf courses. The percent clay in these three courses ranged from a high of 17 percent to a low of 11 percent, all of which exceed the maximum allowable of three percent as specified by USGA recommendations. Cobbly Nob putting green soil samples had significantly less clay in all depths than the USGA standard. Clay content in greens on Deane Hill and Cherokee golf courses were significantly greater in the deepest depth. There was no significant difference in clay content between sampling depths in greens on Fox Den and Cobbly Nob golf courses.

Organic matter content of the USGA standard was 4.3 percent by weight which was significantly greater than organic matter content in greens on all golf courses, with the exception of the 0 to 10 cm depth in greens on Deane Hill and Cherokee (Table II). The organic matter in the USGA standard was fresh and undecomposed due to preparation in the laboratory shortly prior to analysis. However, organic matter content in samples from greens on the four golf courses reflected organic matter incorporations and root growth remaining after decomposition with time. In all greens sampled organic matter content generally decreased with increasing depth. Organic matter content in the two lower depths in greens on Cherokee, Fox Den and Cobbly Nob showed no significant difference. The higher means in the 0 to 10 cm sampling depth for all the golf courses tends to reflect the amount of organic matter additions to the sod surface in the form of soil topdressing applied from two to four times annually.

COMPACTED CORE ANALYSIS

Researchers in Texas (24) stated that 15 drops of an impactor type compactor would provide 6.22 m kg of pressure to a 5 cm diameter core sample and was approximately equal to undisturbed field compacted soil. In these investigations the same compacting procedure was followed.

Bulk density comparisons between the USGA standard and all sampling depths in greens on all four golf courses were not significantly different (Table III). The results of this phase of the investigations tend to support the statement by Howard (18) that, "bulk density determinations were of little value in appraising the fitness of any soil mixture for putting green use."

Aeration porosity, or noncapillary porosity, of the USGA standard was 15 percent which is the precise minimum recommended by the USGA specifications (Table III). Only the two lower sampling depths in greens on Cobbly Nob were not significantly different than the USGA standard. Aeration porosity of the compacted cores for all sampling depths in greens on Deane Hill, Cherokee and Fox Den golf courses were significantly lower than the USGA standard, ranging from 5 to 8 percent. Aeration porosity decreased significantly below the 10 cm sampling depth in greens on Deane Hill, Cherokee and Fox Den golf courses. However,

TABLE III

COMPARISON OF MEANS OF BULK DENSITY, AERATION POROSITY AND TOTAL POROSITY OF COMPACTED CORE ANALYSIS OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Location and Depth	Bulk Density[a] (g/cu cm)	Aeration Porosity (%)	Total Porosity (%)
Standard	1.50 a	14.99 a	49.24 ab
Deane Hill			
0-10 cm	1.49 a	7.33 cd	46.69 c
10-22 cm	1.51 a	5.20 ef	44.42 d
Cherokee			
0-10 cm	1.49 a	8.00 c	46.73 c
10-20 cm	1.49 a	5.02 f	40.26 f
20-25 cm	1.50 a	5.15 ef	42.12 e
Fox Den			
0-10 cm	1.48 a	7.76 c	39.69 g
10-20 cm	1.49 a	6.86 cd	35.02 h
20-30 cm	1.49 a	6.41 de	32.56 i
Cobbly Nob			
0-10 cm	1.50 a	12.46 b	48.04 bc
10-20 cm	1.51 a	14.71 a	50.41 a
20-30 cm	1.51 a	15.56 a	50.26 a

[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.

results of the two lower depths for these three golf courses showed no significant difference within green sampling depths. This trend reversed in greens on Cobbly Nob which showed an increase in aeration porosities with increasing depth.

Specifications by the USGA Green Section recommended that compacted top soil mixes should have a total pore space volume between 40 and 55 percent (15). Total porosity of the USGA laboratory standard in these investigations was 49.2 percent which was significantly greater than total pore space of all sampling depths in greens on Deane Hill, Cherokee and Fox Den golf courses (Table III). However, total porosity in greens on Deane Hill and Cherokee were within the recommended pore space range as specified by the USGA, ranging from 40 to 47 percent. Total porosity in greens on Cobbly Nob were not significantly different than the USGA standard. Total porosities in samples from Fox Den greens only were lower than USGA specifications, although only slightly. In greens on Deane Hill, Cherokee and Fox Den total porosity decreased significantly with sampling below the 10 cm depth. Total pore space in the top and deepest sampling depths in greens on Cherokee were significantly higher than the middle depth. Fox Den green porosities decreased as sampling depth increased. Total porosity of the two deeper sampling depths of Cobbly Nob increased significantly over that of the top depth.

Percolation rates (infiltration and transmission) of water through compacted core samples as recommended by the USGA are from 5 to 25 cm per hour (2 to 10 inches per hour). Ideal rates of percolation are suggested to be from 10 to 15 cm per hour (4 to 6 inches per hour)

(15). The USGA standard in these studies had a percolation rate of 14.1 cm per hour, well within the ideal recommended range (Table IV). Percolation rates for greens on the Cobbly Nob golf course not only fell within the ideal range, with rates of 12 to 15.8 cm per hour, but were the only greens sampled of the four golf courses to meet even the minimum recommendations. Percolation for greens on the Deane Hill, Cherokee and Fox Den golf courses showed extremely low rates of from 0.25 to 1.1 cm per hour. For these same three golf courses, as sampling depth increased percolation rates decreased exhibiting a correlation between particle size migration to progressively deeper depths of soil fractions of the fine and very fine sands (Table I), and clay and silt (Table II). These results support similar observations by Howard (18) and Kunze (24). The reverse of this trend was evident in greens on the Cobbly Nob golf course. As sampling depth increased percolation rates increased, reflecting increases in very coarse to medium sand fractions with increasing depth, and decreases in fine and very fine sands and silt and clay with increasing depth (Tables I and II). Results of aeration porosity and total porosity further support these trends (Table III).

Available moisture holding capacity of the USGA standard, reported as cm of water per cm of soil, was 0.32 and was not significantly different to the top sampling depth of greens on Deane Hill and Fox Den (Table IV). Only the top sampling depth of greens on Cherokee had significantly greater available moisture holding capacity than the USGA standard. Depths below 10 cm in greens on Deane Hill, Cherokee and Fox Den and all sampling depths of Cobbly Nob were significantly less than the USGA

TABLE IV

COMPARISON OF MEANS OF PERCOLATION RATES AND AVAILABLE MOISTURE HOLDING CAPACITY OF COMPACTED CORE ANALYSIS OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Location and Depth	Percolation Rates[a] (cm/hr)	Available Moisture Holding Capacity (cm of H_2O/cm of Soil Depth)
Standard	14.05 b	0.322 b
Deane Hill		
0-10 cm	0.87 de	0.329 b
10-22 cm	0.25 e	0.276 c
Cherokee		
0-10 cm	1.05 d	0.343 a
10-20 cm	0.33 de	0.302 c
20-25 cm	0.25 e	0.299 cd
Fox Den		
0-10 cm	0.98 de	0.320 b
10-20 cm	0.57 de	0.285 de
20-30 cm	0.31 e	0.281 e
Cobbly Nob		
0-10 cm	12.02 c	0.256 f
10-20 cm	13.74 b	0.236 g
20-30 cm	15.75 a	0.235 g

[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.

standard. In all greens investigated available moisture holding capacity was highest in the top sampling depth and decreased significantly in the lower depths. The trends in this study show a much stronger influence of organic matter content on available moisture holding capacity of the soil than with other soil fractions, such as fine and very fine sand, silt and clay.

Correlation coefficients were determined between physical properties of the various compacted core analysis to determine the interrelationships that one property may have upon another (Table V). Aeration porosity had a highly significant positive correlation of 0.681 with total porosity and an even higher significant correlation of 0.950 with percolation rates. In this study, as aeration porosities decreased total porosity and percolation rates decreased. However, percolation rates followed more closely the decreasing trend with aeration porosity than did total porosity. Correlation between aeration porosity and available moisture holding capacity showed a negative relationship of -0.655 and was significant only at the 0.05 level. This was expected since aeration porosity and available moisture holding capacity are influenced by different ranges of particle size distribution. Aeration porosity showed no significant relationship with bulk density analysis due to the very close range of bulk densities determined in this study.

Total porosity had a highly significant positive correlation coefficient of 0.697 with percolation rates but an even lower negative correlation coefficient of -0.437 at the 0.05 level of probability, with available moisture holding capacity (Table V). Indications are, as total

TABLE V

CORRELATION COEFFICIENTS BETWEEN PHYSICAL PROPERTIES OF COMPACTED CORE ANALYSIS OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Aeration Porosity	vs	Total Porosity	= 0.681**
" "	vs	Percolation Rate	= 0.950**
" "	vs	Av. Moist. Hold. Cap.	=-0.655*
" "	vs	Bulk Density	= 0.307 ns
Total Porosity	vs	Percolation Rate	= 0.697**
" "	vs	Av. Moist. Hold. Cap.	=-0.437*
" "	vs	Bulk Density	= 0.353 ns
Bulk Density	vs	Percolation Rate	= 0.360 ns
" "	vs	Av. Moist. Hold. Cap.	=-0.265 ns
Percolation Rate	vs	Av. Moist. Hold. Cap.	=-0.675*

**Correlation coefficients significant at the 0.01 level of probability.

*Correlation coefficients significant at the 0.05 level of probability.

ns = Not significant.

porosity decreased percolation rates decreased while available moisture holding capacity tended to increase. The trend between total porosity and available moisture holding capacity in this study is a reflection of differences in these properties among greens on golf courses rather than between depth within greens. Correlations between total porosity and bulk density were not significant.

Bulk density was not found to be significantly correlated to any other compacted core physical property, further supporting the opinion by Howard (18) of the little value of bulk density determinations (Table V).

Percolation rates and available moisture holding capacity were negatively correlated with a coefficient of -0.675 and only at the 0.05 level of probability (Table V). This would indicate that in this study as percolation rates of greens on golf courses increased available moisture holding capacity generally decreased.

CATION EXCHANGE CAPACITY

Cation exchange capacity (CEC) was used as a basis of comparison between the potential cation availability level of the USGA standard and the sampling depths of the greens on the four golf courses. The USGA standard had a mean CEC of 4.8 milliequivalents per 100 grams of oven-dry soil (Table VI). All depths of sampling on Deane Hill and the upper and lowest depths on Cherokee were significantly higher than the USGA standard. The middle sampling depth on Cherokee was not significantly different than the USGA standard. All depths in greens on Fox Den and

TABLE VI

COMPARISON OF MEANS OF CATION EXCHANGE CAPACITY OF A USGA LABORATORY PREPARED STANDARD AND SAMPLES FROM GREENS ON FOUR GOLF COURSES

Location and Depth	Cation Exchange Capacities (meq/100 g of Soil)
USGA Standard	4.80 d
Deane Hill	
0-10 cm	13,85 a
10-22 cm	10.90 b
Cherokee	
0-10 cm	10.32 b
10-20 cm	4.88 d
20-25 cm	5.88 c
Fox Den	
0-10 cm	4.11 e
10-20 cm	2.61 fg
20-30 cm	2.34 gh
Cobbly Nob	
0-10 cm	3.20 f
10-20 cm	2.86 fg
20-30 cm	1.80 h

[a]Means not having the same letter differ significantly at the 0.05 level of probability according to Duncan's Multiple Range Test.

Cobbly Nob were significantly lower than the USGA standard. In all greens CEC was greatest in the top 10 cm sampling depth and generally decreased with increasing depth. Higher CEC can be accounted for in part in the top 10 cm depth since this level normally contains the highest percentage of root growth and receives high organic matter soil top dressing incorporations into surface core aerification holes.

Correlation coefficients of the separate soil fractions compared with the physical properties and cation exchange capacities of the various soils provide a more accurate means of determining interrelationships (Table VII). Although, bulk density determinations showed no significant relationship to any of the soil fractions or components.

Aeration porosity showed a highly significant positive correlation with sand fractions of the 2.0 to 0.25 mm range (Table VII). Correlations with 0.25 to 0.1 mm sand were not significant but highly significant negative interrelationships resulted with very fine sand of 0.1 to 0.05 mm size, and gravel, silt and clay. Aeration porosity showed no significant correlation with organic matter. Results of this study indicated that as amounts of sand of 0.25 mm and larger increased aeration porosity increased, but as gravel, sand of 0.1 mm and smaller, silt, and clay increased aeration porosity decreased

Total porosity was found to have a highly significant positive correlation with sand in the 2.0 to 0.25 mm fractional range and with organic matter (Table VII). Sand of the fractional range 0.25 to 0.1 mm was also positively correlated to total porosity but only at the 0.05 level of probability. No significance was found to exist between total

TABLE VII

CORRELATION COEFFICIENTS AMONG SOIL FRACTIONS OF A USGA LABORATORY PREPARED STANDARD AND PHYSICAL PROPERTIES AND CATION EXCHANGE CAPACITIES FROM GREENS ON FOUR GOLF COURSES

Soil Fractions		Bulk Density	Aeration Porosity	Total Porosity	Percolation Rate	Available Moisture Holding Capacity	Cation Exchange Capacity
Gravel	>2.0	-0.279 ns	-0.425**	-0.606**	-0.487**	-0.014 ns	-0.137 ns
Sand	2.0-1.0	0.238 ns	0.921 **	0.611**	0.899**	-0.695**	-0.411*
	1.0-0.5	0.194 ns	0.669**	0.440**	0.647**	-0.876**	-0.491**
	0.5-0.25	0.140 ns	0.698**	0.550**	0.676**	-0.033 ns	-0.104 ns
	0.25-0.1	0.078 ns	0.090 ns	0.344*	0.173 ns	0.380**	0.280 ns
	0.1-0.05	0.210 ns	-0.422**	-0.006 ns	-0.324*	0.571**	0.242 ns
Silt	0.05-0.002	-0.247 ns	-0.940**	-0.778**	-0.910**	0.585**	0.444*
Clay	<0.002	-0.285 ns	-0.929**	-0.719**	-0.950**	0.407**	0.490**
Organic Matter		-0.174 ns	0.185 ns	0.439**	0.099 ns	0.705 **	0.700**

**Correlation coefficients significant at the 0.01 level of probability.

*Correlation coefficients significant at the 0.05 level of probability.

ns = Not significant.

porosity and the 0.1 to 0.05 mm sand fractional range. Gravel, silt and clay were found to be negatively correlated to total porosity with highly significant coefficients. Total porosity of the putting green soils analyzed decreased as the amount of gravel, silt and clay increased, and increased as the amount of 0.1 mm sand size and larger increased.

Percolation rates were found to be related to the various soil fractional ranges in virtually the same manner as aeration porosity (Table VII). The relationship between percolation rate and sand of the 2.0 to 0.25 mm fractional range was positive and at a highly significant level. Percolation rates were found to have highly significant negative correlation coefficients with gravel, silt and clay. Sand in the 0.1 to 0.05 mm range was also found to be negatively correlated to percolation rates but only at the 0.05 level of significance. Neither 0.25 to 0.1 mm sand nor organic matter were significantly related to percolation rates. Again, as with aeration porosity, as the amount of sand of the 2.0 to 0.25 mm range increased, percolation rates increased. As very fine sand, silt and clay content increased percolation rates decreased.

Available moisture holding capacity was found to have a highly significant positive relationship with fine and very fine sand, silt, clay and organic matter (Table VII). Of these soil fractions, organic matter had the highest coefficient. Gravel and medium sand showed no significant relationship to available moisture holding capacity. Only coarse and very coarse sand were negatively related to available moisture holding capacity and at a highly significant level. In the putting green soils investigated it appeared that fine and very fine sand, silt, clay and organic matter all influence increases in available moisture as quantities of these soil fractions increased. The coarser components of the soil, such as coarse and very coarse sand, had no influence on available moisture holding capacity.

Cation exchange capacity showed a highly significant positive correlation with clay and organic matter (Table VII). The coefficients for clay and organic matter were 0.490 and 0.700 respectively, indicating organic matter as having the greatest influence on cation exchange capacity. Silt was found to be positively correlated to CEC but only at the 0.05 level of probability, while very fine, fine and medium sand and gravel were not significantly related. CEC and coarse and very coarse sand were found to be negatively correlated but only coarse sand was highly significant. As would be expected, as clay and organic matter increased CEC increased but with organic matter having the greatest increase. As coarse and very coarse sand content increased, CEC decreased.

Hill and Cherokee golf course putting green soils would not be consistent with USGA recommendations and were in fact found to be higher in percent silt and clay and less total sand. In this respect these soils were similar to putting green soils from the Fox Den golf course.

It appears that only Cobbly Nob had greens of similar particle size distribution to the USGA standard, although the lower two sampling depths had higher percentages of total sand which was of a somewhat coarser texture.

Comparisons of particle size distribution within greens reveal that the older greens on Deane Hill and Cherokee had an increase in fine and very fine sand, silt and clay and a decrease in total sand with increasing depth. Greens on Fox Den had greater amounts of total sand and somewhat less silt and clay in the top sampling depth than lower depths. In part this was probably the result of the greens being core aerified and topdressed with very high sand content soil several times yearly in an attempt to alleviate compaction and improve porosity and water percolation. Cobbly Nob greens were found to be generally uniform with depth with the exception of a finer sand found in the upper sampling depth.

In all greens examined organic matter decreased with increasing depth. These higher percentages of organic matter could be attributed to soil modification techniques and the increased volume of root growth normally occurring in shallow depths than in deeper depths.

Results from analysis of particle size distribution and organic matter content indicate that, (1) downward migration of fine and very fine sand, silt and clay had occurred with time, (2) the top few cm of all putting greens analyzed have been modified after construction, probably by use of different textured topdressing materials, and (3) organic matter content tended to increase in the upper soil levels in the older greens. Better utilization of USGA laboratory recommendations was reflected in the particle size distribution in green soils on the Cobbly Nob golf course.

The variations in particle size distribution among the soil samples were reflected in the variations in aeration porosity, total porosity, percolation rate, available moisture holding capacity and CEC. From these relationships a more critical evaluation of the different soil fractional ranges which make up these putting green soils can be made. In this study bulk densities of green soil samples on the four golf courses were not significantly different. Furthermore, bulk density values were not considered desirable factors for use in comparison of suitable soil components for green top soil mixtures.

All depths of soils in greens on Deane Hill, Cherokee and Fox Den golf courses were significantly lower in aeration porosity, total porosity, and percolation rates than the USGA standard, and were generally lower than acceptable ranges for putting green soils. All depths of Cobbly Nob putting green soils were similar to or exceeded the USGA standard and were within acceptable ranges.

Aeration porosity, total porosity, and percolation rates exhibited the trend of decreasing with increasing depth in greens on Deane Hill, Cherokee and Fox Den golf courses. This trend shows a close correlation also between increases in fine and very fine sand, silt and clay with increasing depth for these same three golf courses. In greens on Cobbly Nob the trend tended to reverse showing an increase with increasing depth for aeration porosity, total porosity and percolation rates. Total sand in greens on Cobbly Nob was very high showing a predominance of the very coarse to medium sand fractions which tended to increase with increasing depth. The fine sands and silt and clay were very low.

Available moisture holding capacity of the upper sampling depth of Deane Hill and Fox Den putting green soils were the same as the USGA standard while the upper sampling depth of Cherokee was somewhat higher. Depths below 10 cm on these golf course green soil samples, and all depths of Cobbly Nob greens, was less than the USGA standard. In all green soils available moisture holding capacity decreased with increasing depth, as did organic matter content, indicating the strong influence of organic matter on this particular physical property. In greens which had high amounts of organic matter, fine and very fine sand, silt and clay, available moisture holding capacities were high. Where low amounts of these soil fractions occurred available moisture holding capacity was greatly reduced, as exhibited in greens on Cobbly Nob. The very high available moisture values exhibited by the USGA standard soil mixtures appear to be influenced strongly by the very high organic matter content since silt and clay were very low.

Cation exchange capacities showed a trend somewhat similar to available moisture holding capacity. It was expected that CEC would be greatest in greens where clay and organic matter were highest. However the trend in all putting green soils of decreasing CEC with increasing depth showed the stronger influence of organic matter content over that of clay.

LITERATURE CITED

LITERATURE CITED

1. Allison, L. E. 1965. Organic Carbon. In C. A. Black (Ed.). Methods of soil analysis. Part 2. Amer. Soc. Agron., Inc. Madison, Wis. p. 1372-1376.

2. Banwart, W. L., M. A. Tabatabai and J. M. Bremner. 1972. Determination of ammonium in soil extracts and water samples by ammonium electrode. Comm. in Soil Sci. and Plant Analysis. 3(6) 449-458.

3. Baver, L. E. 1936. Soil characteristics influencing the movement and balance of soil moisture. Soil Sci. Soc. Amer. Proc. 1: 431-437.

4. ________. 1938. Soil permeability in relation to non-capillary porosity. Soil Sci. Soc. Amer. Proc. 3:52-56.

5. ________, W. H. Gardner and W. R. Gardner. 1972. (4th Ed.). Soil physics. John Wiley and Sons, Inc., New York. p. 72-129.

6. Bodman, G. B. and E. F. Harradine. 1938. Mean effective pore size and clay migration during water percolation in soils. Soil Sci. Soc. Amer. Proc. 3:44-51.

7. Bruce, R. R. 1955. An instrument for determination of soil compactibility. Soil Sci. Soc. Amer. Proc. 19:253-257.

8. Buckman, H. O. and N. C. Brady. 1960. The nature and properties of soils. (4th Ed.). The MacMillan Company, New York. p. 1-15.

9. Bunt, A. C. 1961. Some physical characteristics of pot plant compost and their effect on plant growth. Plant and Soil. 13: 322-332.

10. Chapman, H. D. and P. F. Pratt. 1961. Methods of analysis for soils, plants, and waters. Univ. of Calif., Div. of Agric. Sci.

11. Committee on Terminology. 1965. Glossary of soil science terms. Soil Sci. Soc. Amer. Proc. 29:330-351.

12. Davice, R. R. 1952. Physical conditions of putting green soils and the environmental factors affecting greens. USGA J. and Turf Management. 5(1):25-27.

13. Day, P. P. 1956. Particle fractionation and particle-size analysis. In C. A. Black (Ed.). Methods of soil analysis. Part 1. Amer. Soc. Agron. Inc., Madison, Wis. p. 555-556.

14. Evans, C. E. and E. R. Lemon. 1957. Conserving soil moisture. USDA Year Book. p. 340-359.

15. Green Section Staff (Anonymous). 1973. Refining the green section specifications for putting green construction. USGA Green Section Record. 11(3):1-8.

16. Waddington, D. V. 1969. Soil and soil related problems. In Hanson, A. A., and F. V. Juska, (Ed.). Turfgrass science. Amer. Soc. of Agron., Inc., Madison, Wis. p. 80-120.

17. Hopkins, H. T., A. W. Specht and S. B. Hendricks. 1950. Growth and nutrient accumulation as controlled by oxygen supply to plant roots. Plant Physiol. 25:193-209.

18. Howard, H. L. 1959. The response of some putting green soil mixtures to compaction. M. S. Thesis. Texas A & M College.

19. Jamison, V. C. and E. M. Kroth. 1958. Available moisture storage capacity in relation to textural composition and organic matter content of several Missouri soils. Soil Sci. Soc. Amer. Proc. 22:189-192.

20. Juncker, P. H. and J. J. Madison. 1967. Soil moisture characteristics of sand-peat mixes. Soil Sci. Soc. Amer. Proc. 31:5-8.

21. Kilmer, V. J. and L. T. Alexander. 1949. Methods of making mechanical analysis of soils. Soil Sci. 68:15-24.

22. Klute, A. 1965. Laboratory measurements of hydraulic conductivity of saturated soils. In C. A. Black (Ed.). Methods of soil analysis. Part 1. Amer. Soc. Agron., Inc., Madison, Wis. p. 210-220.

23. Kohnke, H. 1968. Soil physics. McGraw-Hill Inc., New York. p. 143-159.

24. Kunze, R. J. 1956. The effects of compaction of different golf green soil mixtures on plant growth. M. S. Thesis. Texas A & M College.

25. Letey, J. W., C. Morgan, S. J. Richards and N. Valoras. 1966. Physical soil amendments, soil compaction, irrigation and wetting agents in turfgrass management. III. Effects on oxygen diffusion rate and root growth. Agron. J. 58(5):531-535.

26. Lewis, M. R. and W. L. Powers. 1938. A study of factors affecting infiltration. Soil Sci. Soc. Amer. Proc. 3:334-339.

27. Lunt, O. R. and C. G. Wyckoff. 1955. Methods for minimizing compaction under turfgrass used for athletic areas. Agron. Abst. 47:75

28. Lutz, J. F. and R. W. Leamer. 1939. Pore size distribution as related to the permeability of soils. Soil Sci. Soc. Amer. Proc. 4:28-31.

29. Madison, John H. 1971. Principles of turfgrass culture. Van Nostrad Reinhold Company, New York. p. 151-198.

30. Nelson, W. L. and L. D. Baver. 1940. Movement of water through soils in relation to the nature of the pores. Soil Sci. Soc. Amer. Proc. 5:69-76.

31. Perkins, A. T. and H. H. King. 1936. Base exchange in soil separates and soil fractions (sand and silt). Soil Sci. 42: 323-326.

32. Shoop, G. J. 1967. The effects of various coarse textured material and peat on the physical properties of Hagerstown soil for turfgrass production. Ph.D. Dissertation. Penn. State Univ.

33. Swartz, W. E. and L. T. Kardos. 1963. Effects of compaction on physical properties of sand-soil-peat mixtures at various moisture contents. Agron. J. 55:7-10.

34. Tanner, C. V. and M. L. Jackson. 1947. Nomographs of sedimentation times for soil particles under gravity or centrifugal acceleration. Soil Sci. Soc. Amer. Proc. 12:60-65.

35. Vanderber, G. E., A. W. Cooper, A. E. Erickson and W. M. Corleton. 1957. Soil pressure distribution under tractor and implement traffic. Agric. Engr. 38(12):854-859.

36. Veihmeyer, F. J. and A. H. Hendrickson. 1948. Soil density and root penetration. Soil Sci. 65:487-493.

37. Veihmeyer, F. J. and A. H. Hendrickson. 1949. Methods of measuring field capacity and permanent wilting percentage of soil. Soil Sci. 68:75-95.

38. Vomocil, J. 1965. Porosity. In C. A. Black (Ed.). Methods of soil analysis. Part 1. Amer. Soc. Agron., Inc., Madison, Wis. p. 299-314.

39. Wright, W. R. and J. E. Foss. 1968. Movement of silt-sized particles in sand columns. Soil Sci. Soc. Amer. Proc. 32: 446-448.

40. Yuan, T. L., G. Nathan, Jr. and R. G. Leighty. 1967. Relative contribution of organic and clay fractions to cation-exchange capacity of sandy soils from several soil groups. Soil Sci. 104:123-128.

41. Zimmerman, T. L. 1969. Infiltration rates and fertility levels of physically amended Hagerstown soil. M. S. Thesis. Penn. State Univ.

42. Zimmerman, T. L. 1973. The effects of amendments, compaction, soil depth, and time on various physical properties of physically modified Hagerstown soil. Ph.D. Dissertation. Penn. State Univ.

APPENDIX

TABLE VIII

DEPTH OF SOIL CORE SAMPLING FOR THE RESPECTIVE GREENS ON FOUR GOLF COURSES

Golf Course	Green Number	Sampling Depth (cm)	Mean Depth (cm)
Deane Hill[a]	10	25.91	22.44
	14	21.34	
	16	20.07	
Cherokee	12	27.18	25.99
	13	25.91	
	15	25.89	
Fox Den	5	31.50	29.89
	7	28.19	
	8	29.97	
Cobbly Nob[b]	3	30.98	30.90
	6	30.23	
	7	31.50	

[a]Soil samples obtained below 20 cm depth at Deane Hill were insufficient to conduct all analyses, therefore, this soil was included in the 10 to 20 cm depth sample.

[b]Soil samples obtained below 30 cm at Cobby Nob were included in the 20 to 30 cm depth.

TABLE IX

PHYSICAL PROPERTIES AND CATION EXCHANGE CAPACITIES OF USGA STANDARD MIXTURES BASED ON THE TYPE OF ORGANIC MATTER USED

Physical Properties and CEC	Types of Organic Matter (20 % by volume)			
	Sawdust	Sphagnum peat	Sewage sludge	Michigan peat
Bulk density (g/cu cm)	1.49	1.51	1.50	1.50
Aeration porosity (%)	15.29	14.94	14.64	15.09
Total porosity (%)	52.47	49.67	49.31	45.52
Percolation rate (cm/hr)	14.28	13.23	12.17	12.50
Available moisture holding capacity (cm/cm)	0.312	0.316	0.328	0.332
Organic matter (% by Wt)	3.92	4.18	4.58	4.56
Cation exchange capacity (meq/100 g)	4.61	4.52	4.97	5.15

TABLE X

PARTICLE SIZE DISTRIBUTION OF PUTTING GREEN SOILS OF FOUR GOLF COURSES

Location and Depth	Gravel (mm) >2.0	Sand Fractional Ranges (mm)						Silt (mm) 0.05-0.002	Clay (mm) <0.002	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			
Deane Hill										
Green 10										
0-10 cm	2.83	4.07	20.83	25.29	6.76	4.71	61.66	19.18	10.77	5.56
10-25.91 cm	2.14	2.16	10.17	18.75	10.47	9.57	51.12	29.59	14.39	2.76
Green 14										
0-10 cm	2.99	4.09	18.87	19.57	8.62	5.35	56.50	19.03	14.96	6.52
10-21.34 cm	3.86	3.25	12.60	23.97	8.12	6.22	54.16	21.80	16.58	3.60
Green 16										
0-10 cm	1.69	5.54	20.93	20.58	7.13	4.53	58.71	18.22	15.42	5.96
10-20.07 cm	1.65	3.92	14.20	20.59	9.32	7.52	55.55	20.54	19.44	2.82
Cherokee										
Green 12										
0-10 cm	1.26	4.84	18.32	30.11	10.67	4.83	68.77	13.09	11.34	5.54
10-20 cm	0.78	1.18	10.48	29.69	9.99	9.61	60.95	25.95	10.18	2.14
20-27.18 cm	0.35	1.57	6.06	21.00	10.06	13.21	51.90	30.36	15.73	1.66
Green 13										
0-10 cm	1.68	3.58	17.42	31.78	10.38	5.62	68.78	12.66	11.34	5.54
10-20 cm	0.85	3.82	12.11	26.32	12.61	5.37	60.23	26.21	10.57	2.14
20-25.89 cm	0.57	2.00	8.60	19.86	13.62	7.82	51.90	32.25	13.34	1.94
Green 15										
0-10 cm	1.88	5.01	18.89	33.09	9.02	4.57	70.59	10.88	12.24	4.42
10-20 cm	0.41	3.11	8.72	24.04	15.09	6.45	57.42	29.45	11.01	1.72
20-24.89 cm	0.71	1.08	8.19	20.45	15.61	6.68	52.01	33.38	12.19	1.72

TABLE X (continued)

Location and Depth	Gravel (mm) >2.0	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)
Fox Den										
Green 5										
0-10 cm	5.88	5.00	26.15	22.35	4.10	2.30	59.91	17.41	13.54	3.26
10-20 cm	6.55	5.37	24.43	21.63	3.53	2.24	57.20	20.85	13.77	1.63
20-31.50 cm	5.11	5.68	23.33	21.93	3.31	2.00	56.25	22.98	14.19	1.47
Green 7										
0-10 cm	3.66	4.51	26.45	23.86	3.84	2.94	61.60	19.20	12.40	3.14
10-20 cm	4.77	4.83	22.33	21.70	4.21	2.92	55.99	23.02	14.40	1.82
20-31.50 cm	3.61	4.97	22.81	23.43	4.96	3.87	60.04	21.14	13.58	1.63
Green 8										
0-10 cm	5.69	3.93	26.63	21.55	4.14	3.12	59.37	19.24	12.62	3.08
10-20 cm	4.01	4.82	20.16	22.13	3.60	2.72	53.43	27.53	13.37	1.66
20-29.97 cm	3.18	4.91	20.83	21.96	4.30	2.99	54.99	26.58	13.79	1.46
Cobbly Nob										
Green 3										
0-10 cm	2.74	6.30	41.02	27.39	8.37	4.77	87.85	4.76	2.26	2.39
10-20 cm	2.26	7.77	47.80	27.48	4.44	2.33	89.82	4.75	1.44	1.73
20-30.98 cm	2.30	7.85	51.85	27.60	3.75	1.54	92.59	1.97	1.48	1.66
Green 6										
0-10 cm	2.68	8.27	38.23	28.24	9.80	4.81	89.35	4.77	1.02	2.18
10-20 cm	2.77	10.89	47.02	27.79	4.92	1.52	92.14	3.15	0.44	1.50
20-30.23 cm	1.98	11.10	43.51	27.29	5.40	2.67	89.97	4.00	2.51	1.54
Green 7										
0-10 cm	3.14	6.72	49.64	19.64	8.29	4.70	88.99	4.41	1.37	2.09
10-20 cm	1.98	12.86	57.34	21.08	1.61	0.83	93.72	2.60	0.10	1.60
20-31.50 cm	1.83	11.63	53.01	24.04	3.21	1.19	93.07	2.78	0.49	1.82

TABLE XI

BULK DENSITY, AERATION POROSITY, TOTAL POROSITY, PERCOLATION RATES, AND AVAILABLE MOISTURE HOLDING CAPACITY OF COMPACTED CORE ANALYSIS OF PUTTING GREEN SOILS OF FOUR GOLF COURSES

Location and Depth	BD (g/cu cm)	Aeration Porosity (%)	Total Porosity (%)	Percolation rate (cm/hr)	AMHC (cm/cm)
Dean Hill					
Green 10					
0-10 cm	1.48	7.59	44.90	1.02	0.346
10-25.91 cm	1.50	5.01	43.86	0.25	0.261
Green 14					
0-10 cm	1.50	7.79	49.71	0.89	0.324
10-21.34 cm	1.51	5.40	43.85	0.25	0.284
Green 16					
0.10 cm	1.48	6.62	45.45	0.70	0.316
10-20.07 cm	1.52	5.18	45.54	0.25	0.283
Cherokee					
Green 12					
0-10 cm	1.49	8.15	46.86	1.08	0.345
10-20 cm	1.52	5.17	40.74	0.32	0.301
20-27.18 cm	1.51	5.28	42.98	0.25	0.291
Green 13					
0-10 cm	1.50	7.82	46.72	1.21	0.335
10-20 cm	1.48	5.02	39.60	0.42	0.292
20-25.89 cm	1.50	5.50	39.73	0.25	0.303
Green 15					
0-10 cm	1.47	8.04	46.61	0.86	0.347
10-20 cm	1.47	4.87	40.44	0.25	0.313
20.24.89 cm	1.50	4.67	43.64	0.25	0.304
Fox Den					
Green 5					
0-10 cm	1.47	7.61	38.06	1.04	0.312
10-20 cm	1.49	6.72	35.15	0.45	0.282
20.31.50 cm	1.50	6.03	31.07	0.25	0.273
Green 7					
0-10 cm	1.49	7.87	40.16	0.96	0.326
10-20 cm	1.50	6.64	34.74	0.60	0.296
20-28.19 cm	1.50	6.54	34.53	0.25	0.288

TABLE XI (continued)

Location and Depth	BD (g/cu cm)	Aeration Porosity (%)	Total Porosity (%)	Percolation rate (cm/hr)	AMHC (cm/cm)
Fox Den					
Green 8					
0-10 cm	1.47	7.81	40.85	0.95	0.323
10-20 cm	1.49	7.22	35.18	0.68	0.278
20.29.97 cm	1.48	6.65	32.07	0.42	0.282
Cobbly Nob					
Green 3					
0-10 cm	1.49	13.19	48.31	12.32	0.248
10-20 cm	1.50	12.76	49.66	13.27	0.224
20-30.98 cm	1.51	16.95	51.94	15.24	0.236
Green 6					
0-10 cm	1.51	12.38	48.00	11.43	0.262
10-20 cm	1.52	15.99	50.16	14.16	0.241
20-30.23 cm	1.50	13.23	48.24	16.38	0.242
Green 7					
0-10 cm	1.50	11.81	47.81	12.32	0.264
10-20 cm	1.50	15.38	51.42	13.82	0.243
20-31.50 cm	1.51	16.49	50.61	15.62	0.227

TABLE XII

CATION EXCHANGE CAPACITY OF PUTTING GREEN SOILS
OF FOUR GOLF COURSES

Location and Depth	Cation Exchange Capacity (meq/100 g of soil)
Deane Hill	
Green 10	
0-10 cm	12.89
10.25.91 cm	9.89
Green 14	
0-10 cm	14.33
10-21.34 cm	10.18
Green 16	
0-10 cm	14.33
10-20.07 cm	12.62
Cherokee	
Green 12	
0-10 cm	10.89
10-20 cm	4.88
20-27.18 cm	6.17
Green 13	
0-10 cm	10.04
10-20 cm	4.73
20-25.89 cm	5.88
Green 15	
0-10 cm	10.04
10-20 cm	5.02
20-24.89 cm	5.59
Fox Den	
Green 5	
0-10 cm	4.66
10-20 cm	3.15
20-31.50 cm	2.36
Green 7	
0-10 cm	3.87
10-20 cm	2.66
20-28.19 cm	2.51
Green 8	
0-10 cm	3.79
10-20 cm	2.01
20.29.97 cm	2.15

TABLE XII (continued)

Location and Depth	Cation Exchange Capacity (meq/100 g of soil)
Cobbly Nob	
Green 3	
0-10 cm	3.26
10-20 cm	2.82
20-30.98 cm	1.82
Green 6	
0-10 cm	3.15
10-20 cm	2.75
20-30.23 cm	1.50
Green 7	
0-10 cm	3.20
10-20 cm	3.01
20-31.50 cm	2.08

VITA

Reginald Mack Jellicorse was born in Knoxville, Tennessee on December 6, 1943. He attended elementary school in Hamblen County, Tennessee and was graduated from Morristown High School in 1961. He entered the University of Tennessee in the summer of 1962, and in August 1966, received a Bachelor of Science Degree in Education. In the summer of 1972, he entered the University of Tennessee and began study toward a Master's degree in Ornamental Horticulture and Landscape Design. He received this degree in December 1974.

He is married to the former Glenda Sue Howell of Morristown, Tennessee.