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STUDIES OF TURFGRASS CULTIVATION

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INTRODUCTION

Turf cultivation is a mechanical procedure that produces a spiking, cutting, or core-removing action on the sod of established turf. It is used in an attempt to reduce surface compaction of the sod; to encourage destruction of "thatch", which is a surface accumulation of leaves, stems, and roots; and to create soil pores in which roots can make better growth.

The development of turf cultivation has taken place mainly on golf courses where special problems are found. Soil compaction is one of the most common problems, and can be very severe where water is used in large amounts, and where heavy traffic occurs on wet soils. The bentgrasses, Agrostis spp., which are popular on golf courses, develop a serious thatch. This accumulation or thatch is associated with excessive water runoff on slopes and high points of small undulations. On such areas the soil may remain dry in spite of an abundance of rainfall. Turf cultivation has been considered useful for reducing soil compaction and runoff. Other factors have encouraged the practice; for example, many turfmen hope to improve soil aeration by creating openings in the sod. Some claim to maintain turf with cultivation in areas where they had failed formerly without cultivation. Not only has the golf course superintendent shown a desire to use turf cultivation, but technical advisors also have encouraged the practice.

The rise in popularity of turf cultivation is shown by the rapid evolution of machinery created for the job. One of the first tools, a potato fork, was used approximately 25 years ago. Now more efficient machines are used such as the "Aerifier" (spoon), "Night-crawler" (hollow tine), and "Turferator" (drill).

In 1948 and 1949, a series of cultivation tests on golf course type of turf were started on the New Jersey Agricultural Experiment Station plots and on a fairway of the Rutgers Golf Course. These first studies were of exploratory nature to determine the general effect of cultivation and to find the most promising leads for further investigation. This paper is a report on information obtained in the study of these turf cultivation tests and related experiments. The results obtained from turf cultivation are recorded by measurements of turf quality; root development; freedom of the grasses from disease; weed population; and penetration into the sod of water, lime, and phosphorus. Greenhouse studies were used to measure the response of Colonial bentgrass, Agrostis tenuis, to oxygen supply and soil compaction.

REVIEW OF LITERATURE

Formal turf cultivation studies are not reported in the literature, but some observations have been recorded. Faulkner (17)[1] reports that "the holes made in the sod are filled with roots breathing in the pure oxygen". Abundant root development has been observed many times in the soil openings created by turf cultivation. This may occur in summer, a season when turf grasses tend to develop short roots which represent only a small part of the total root system (18, 48). The roots found in the holes created by cultivation may be the result of several factors, of which aeration is possibly one of the most important. A number of investigations have shown that corn (5), tomatoes (13), soybeans (4), and oats (19) will develop a larger root system in aerated solutions than in unaerated solutions. Also, a number of soil culture studies have shown that soil aeration gives a marked improvement in root development for hydrophytes (14), barley (3), corn (24, 25), soybeans (26), and sunflower (26). Since these plants which represent a wide range of habitat show a response to increased aeration, there is reason to expect a similar response on the part of the turf grasses.

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[1]Figures in parentheses refer to Literature Cited.

Work with crops other than turf show that soil compaction hinders root development. Lawton (25) found that compaction of the soil in greenhouse cultures reduced the root growth of corn plants. Other workers have shown similar results for barley (37), wheat (37), and sugar beets (46). These studies show that an increase in the ratio of tops to roots is associated with soil compaction. General observations indicate that this same relationship may occur for turf grasses.

Skrdla (43) found that severe soil compaction did not restrict the development of turf grasses nearly as much if adequate nutrients were supplied. This suggests that soil compaction hinders the nutrient supplying power of the soil. Smith and Cook (46) showed a lower rate of nitrate production in compacted soil, despite the presence of nitrogenous organic matter. Hubbell and Gardner (22) have shown on two New Mexico soils that soil compaction reduces the bacterial population. Thus, soil compaction may have influence on the growth of turf grasses as a result of its effect on the nutrient supplying ability of the soil organisms.

Cultivation of other crops has shown increases in yields which have been attributed to the nitrate supplying power of the soil (7, 32). Lyon (28) found less nitrate in uncultivated field soils; and he was able to increase their nitrate content by aeration. The benefits provided by cultivation of field crops suggest that increased growth of grasses may be obtained by turf cultivation.

Pasture studies have shown that soil compaction caused by trampling greatly increases the amount of water runoff (2, 15). Rogers (39) reported that the runoff from a one-inch rainfall on pasture land washed off 9 per cent of a 200-pound per acre application of triple superphosphate. Runoff is another factor that may hinder turf development on compacted soils.

Many pasture and soil studies have shown that lime (11, 12, 33, 40, 41) and phosphorus (10, 30, 38, 40, 41, 50) penetrate the soil slowly. Longnecker and Sprague (27) showed that surface applications of lime to established turf penetrate the soil very slowly. Midgely (31) found that placing superphosphate in knife grooves at 4-inch intervals gave 57 per cent more topgrowth of Kentucky bluegrass Poa pratensis pasture than surface application. This study suggests that some turf areas might benefit from a cultivation treatment if phosphorus penetration is encouraged.

The possibility of a weed problem arising from cultivation is suggested by viability studies of buried seeds. Goss (20) reported on seed burial studies in which goosegrass, Eleusine indica, gave 0.5 to 3.0 per cent germination after 6 years; white clover, Trifolium repens, gave 3 to 4.5 per cent after 10 years (exclusive of hard seeds); buckhorn, Plantago lanceolata, gave 2.5 to 3.5 per cent after 10 years; broad-leaved plantain, Plantago major, gave 5.5 to 83.5 per cent after 21 years; and red-seeded dandelion, Taraxacum erythrospermum, gave 0.5 to 8.0 per cent after 6 years. Brenchley and Warington (9) reported that seed of grass species, primarily annual bluegrass (Poa annua); chickweed (Stellaria media); and speedwell (Veronica arvensis), survived for 8, 5, and 5 years, respectively. On more recently established areas, cultivation of turf will expose buried seeds to conditions that are favorable for germination, which suggests that cultivation may create or intensify weed problems.

METHODS AND PROCEDURES

Since a review of the literature did not reveal any investigations on turf cultivation, it was not possible to select any one phase to serve as a basis for study. Therefore, the most important need was to measure the response of turf grasses to cultivation, and to obtain information on the relative importance of fundamental factors that might influence the development of the grass. Greenhouse studies were established to measure the response of turf grasses to oxygen level in nutrient solution. Also, greenhouse cultures were used to study the effect of soil compaction on Colonial bentgrass. Three field studies were established on fairway type of turf, and two were established on putting green type of turf. Techniques and descriptions of all individual field and greenhouse tests are given in the following sections.

Greenhouse Tests

Solution Culture Aeration Study--The effect of solution aeration on the growth of Colonial bentgrass, *Agrostis tenuis*, was studied in a series of three tests in 1948, 1949, and 1950. Seedling plants were grown in nutrient solution under uniform conditions for one to two weeks prior to the start of solution aeration. Each culture contained three plants and each treatment was replicated four times. The size of the culture jars was 2650, 2650, and 1893 mls. for the respective tests. The aeration treatments were of 33, 61, and 35 days duration, respectively. The 1948 and 1950 cultures were not clipped, but the 1949 cultures were clipped six times at a height of one inch.

Air was supplied to the treated cultures by capillary tubes that were placed 3 to 5 cms. from the bottom of the individual jars. In all three tests, one set of cultures received no air; a second set received air bubbles at a rate of approximately one per second, and the third set of cultures received a quantity of air that bubbled through the solution at a rate too rapid for counting.

In all tests, the major salts used in solution preparation were $Ca(NO_3)_2$; KH_2PO_4, K_2SO_4, and $MgSo_4$. These salts were used at concentrations of 0.004, 0.001, 0.002, and 0.002 molar, respectively. The concentration of the elements in terms of p.p.m. were Ca 160, N 112, K 200, P 31, S 128, and Mg 49. Also, Fe, B, Mn, and Zn were supplied at the respective rates of 1.0, 0.25, 0.25, and 0.25 p.p.m. In the first test, the solution was changed at 3 to 6-day intervals. Between changes, solution was added as required to replace transpiration loss. In the second test, the solution was changed when any one of the treatments reached a pH of 6.0, and solution was added as required to replace transpiration loss. In the third test, the nutrient solution was introduced by continuous flow from a reservoir through a capillary tube that extended below the surface of the culture solution. In addition, special measures were used in this test to control the amount of oxygen in the nutrient solution. The oxygen content of the fresh solution was reduced by bubbling nitrogen gas through the preparation bottles. The treated solution was then siphoned into reservoirs to avoid any aeration from pouring. The solution in both the reservoir and culture was covered with 4mm. of mineral oil for the purpose of excluding oxygen (23).

The oxygen content of the culture solutions was determined by the Winkler method (29) during various stages of the three tests. Dry weights of roots and tops were determined for the group of three plants grown in each culture. Petroleum ether was used to extract the mineral oil from the dried plants grown in the third test, and the total nitrogen in the tops and roots was determined by the micro-Kjeldahl method of Pepkowitz and Shive (36).

Soil Compaction Study--Colonial bentgrass was grown in 8.2 liter, bottom-drained jars (8 x 11 inches). Ten jars were filled with a sandy loam soil which was compacted to a volume weight of 1.64; and ten additional jars were filled to a volume weight of 1.36. The plants in five of the compact and five of the loose soil cultures were clipped eight times to approximately one-half inch height. The plants in the remaining ten cultures were clipped three times during the 20-week period to approximately one-half inch height. Equivalent amounts of water were applied to all treatments. At harvest, dry weights of clippings, tops, and roots were determined. The roots were washed free of the soil mass and dried. The dry root samples were ashed and the ash-free dry weight is reported as the dry root weight.

Field Tests

Frequency of Cultivation Study--The Frequency of Cultivation Study was established on a mixed turf, which was predominantly Colonial bentgrass cut to a three-quarter inch height. Treatments of two and six cultivations per season were made during 1949 and 1950, with an Aerifier equipped with one-inch spoons that penetrated 3 to 5 inches. Figure 1 shows an Aerifier model, and Figure 2 shows a section of cultivated turf. The individual plots were 6 x 35 feet, and the test was in quadruplicate. A complete fertilizer containing 25 to 33 per cent organic nitrogen was applied at a rate of 49 pounds of N per acre during April and September of each year. Fertilizer ratios of 1-1-1 and 4-3-2 were used in 1949 and 1950, respectively. Also, Milorganite (6% organic nitrogen) was applied at the rate of 436 pounds per acre in May, 1950.

The soil of the test area had a pH of 6.6, and is a loam consisting of Pensauken gravel and red Brunswick shale. The area is a well-drained site on the New Jersey Experiment Station turf plots.

Data taken on this test include actual counts of crabgrass, Digitaria sanguinalis and Digitaria ischeum, and dandelions, Taraxacum officinale; clipping weights; percentage estimates of annual bluegrass, Poa annua; percentage estimates of Colonial bentgrass; water penetration

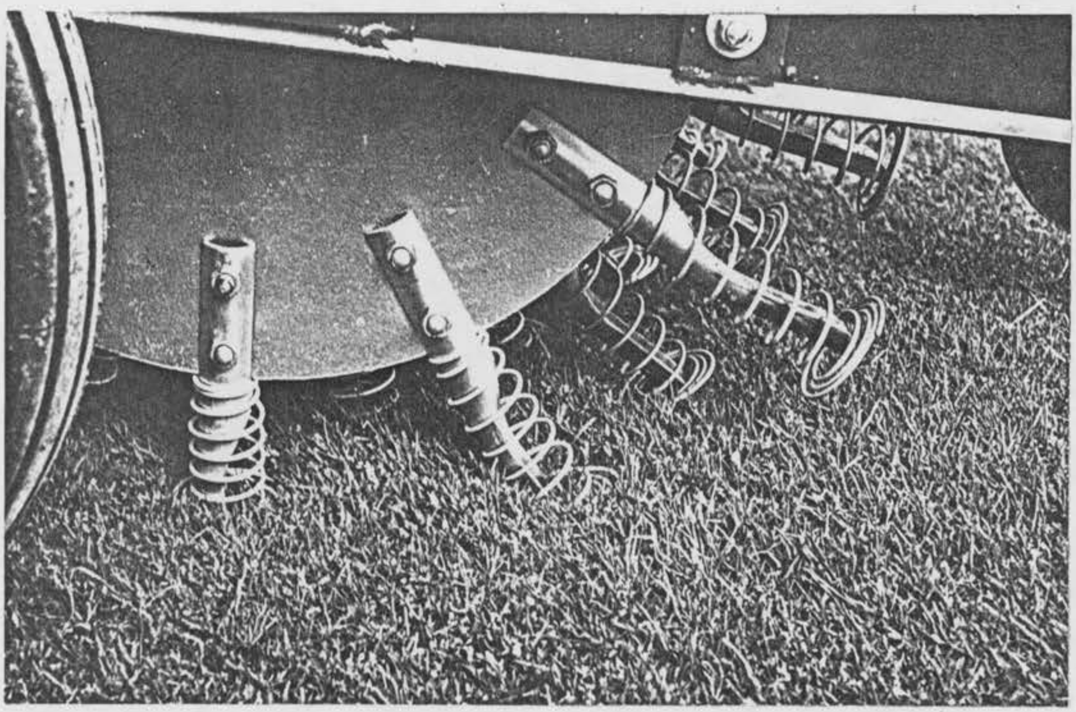

Figure 1. A section of an Aerifier reel, not in operation. The springs serve to break the soil cores and to reduce the tearing action of the spoon. The machine is used with or without the springs.

rates; volume weight of the soil at 1-4 inches[1], and per cent air space porosity at 1-4 inches[1].

To measure water penetration, a galvanized metal cylinder, 4.5 inches in diameter was driven into the turf to a depth of 1.5 inches. A total of 700 ml. of water was poured into the cylinder, making a head of 2.7 inches. The time required for this quantity of water to percolate into the soil was measured. In this and in all other water penetration tests, the individual readings for each plot are based on a minimum of twenty readings.

Twenty natural structure soil cores (3 inches in diameter and 3 inches in depth) were taken from each treatment to determine volume weight of the soil and per cent air space. These were analyzed for air space by the use of the pycnometer technique (35, 49). Following this, the samples were oven dried for determination of volume weight.

Methods of Cultivation Study--Three different methods of cultivation were used on a mixed turf, which was predominantly Colonial bentgrass, cut to a three-quarter inch height. In the first and second methods, the Aerifier was used to cultivate to depths of approximately 2 and 5

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[1]Determinations made in cooperation with Dr. George R. Blake, Assistant Research Specialist in Soil Physics, New Jersey Agricultural Experiment Station.

Figure 2. A section of turf cultivated with the Aerifier, without the spring attachment on the spoons. Springs were not used in the present study. The cores were broken and spread with a steel mat or by the subsequent mowing.

inches, respectively. For the third method, a disk drill was used to cut the turf at intervals of 7 inches. Quadruplicate treatments were started on plots 6 x 26 feet in October, 1948, and were repeated each spring and fall in 1949 and 1950. After each cultivation, a complete fertilizer was used to supply a minimum of 64 pounds of nitrogen per acre. The soil had a pH of 6.4, and is a loam consisting of Pensauken gravel and red Brunswick shale. The test site is located on a gentle slope on the New Jersey Experiment Station turf plots. The plots were rated for turf quality; presence of clover, crabgrass, and dandelions; and rate of water infiltration. Turf quality was rated on a scale of 1, 2, 3, 4, etc., the lowest value representing the best quality. Clover ratings represent estimated percentages. Crabgrass and dandelion ratings were determined by actual plant counts.

Time of Cultivation Study--Time of cultivation treatments were established on seaside creeping bentgrass, *Agrostis palustris*, cut at a height of four-sixteenths to five-sixteenths inch. The dates of cultivation for the different treatments were spring, summer, fall, spring and summer, spring and fall, summer and fall, and a combination of all three seasons.

All cultivation treatments were made with the Aerifier equipped with one-half inch diameter spoons. The entire test area was topdressed with improved topsoil after each cultivation treatment. The soil used for topdressing was a sandy loam that contained 12 to 14 per cent organic matter. In addition, a minimum of 3.5 pounds of actual nitrogen was applied per 1,000 square feet each season. The treatments were in triplicate, and the cultivation plots were 5 x 20 feet in size. The treatments were started in the fall of 1948, and were continued through 1949 and 1950. During the 1948 and 1949 seasons, all crabgrass plants were removed before they set seed. In August, 1950, counts of individual plants were made for each plot at the time of hand-weeding. Water penetration readings were taken in November, 1950. The test is located on the turf plots of the New Jersey Experiment Station. The soil had a pH of 6.6, and is a loam consisting of Pensauken gravel and red Brunswick shale. The area received less traffic than the typical putting green, but this was partially offset by the fact that the soil texture is heavier and contains less organic matter than most golf greens.

<u>Bentgrass Cultivation-Rate of Nitrogen Study</u>--A seaside creeping bentgrass turf cut to a height of four to five-sixteenths of an inch was used for the test area. The treatment included three rates of nitrogen on cultivated

and non-cultivated turf. The nitrogen treatments used were 3.2, 4.8, and 6.4 pounds of actual N per 1,000 square feet each season. Each nitrogen plot was split into sub-plots of cultivated and non-cultivated turf. The treatments were in triplicate, and the cultivation plots were 9 x 30 feet. The Aerifier was used with one-half inch spoons each spring and fall. The entire test area was topdressed with improved topsoil after each cultivation treatment. The test was established on a loam soil, consisting of Pensauken gravel and red Brunswick shale. The treatments were made during the 1949 and 1950 seasons. In 1950, the actual number of crabgrass plants and the amount of large brownpatch, Rhizoctonia solani, were recorded for cultivated and non-cultivated plots. Large brownpatch was rated by percentage estimates, and the total area of individual infections was determined by diameter measurements.

Fairway Cultivation Study--A cultivation study was started in October, 1948, on the outer curve of fairway #2 on the Rutgers Golf Course. The Aerifier, equipped with one-inch spoons, was used each spring and fall prior to any chemical topdressing. In the fall of 1948, and in the spring and fall of 1949, two simultaneous cultivations were made on each treatment date. These treatments which accounted for six cultivations, plus two more made in 1950, gave a total of eight for the test period. The average penetration of the spoons varied from 2.5 to 5.0 inches. The cultivation plots were divided into four subplots which received different chemical topdressings. One subplot received inorganic fertilizer only; a second received ground limestone plus fertilizer; a third received gypsum plus ground limestone plus fertilizer; and the fourth served as a check. For each of the spring and fall seasons, the rates of chemical application per acre were 44 to 52 pounds of nitrogen, 87 pounds of P_2O_5, an average of 1,100 pounds of ground limestone, and an average of 825 pounds of gypsum. The cultivation treatments and the subplot treatments were in quadruplicate. Kentucky bluegrass and annual bluegrass formed the greater part of the turf, which was cut at an average height of one inch. The soil of the test area has a clay loam texture and is a shallow red shale of the Penn series. The treatments were rated in 1950 for percentages of turf cover, clover, annual bluegrass, and crabgrass. Water penetration rates were determined on cultivated and non-cultivated turf in October, 1950.

Eighty plant samples including surface thatch were obtained in October, 1950, by use of a 3 x 6 inch cylinder. Forty samples were collected from the cultivated treatments and forty samples were collected from the non-cultivated treatments made on limed and fertilized turf. The soil was washed from the roots with a gentle stream of water. The washed samples were separated into tops; stems, roots, and leaves found in the 0-1.25 inch soil horizon; and the roots found in the 1.25-6 inch soil horizon. The washed and dried samples from the 0-1.25 inch depth and the 1.25-6 inch depth were ashed with a 600° C temperature. The weight loss by combustion gave an ash-free dry weight which is reported as dry weight.

Soil samples were collected twice per year in 1949 and 1950. A total of six one-inch soil cores were collected from each plot and divided into 0-2, 2-4, and 4-6 inch depths. The composite samples representing the three depths were dried, and screened for testing. Tests were made for pH and available phosphorus[1]. A one:one ratio of soil and water was used for determination of the pH with a glass electrode. The phosphorus extraction was made by electrodialysis in a 0.05M boric acid solution. The phosphorus determination was made colorimetrically, using a photoelectric colorimeter.

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[1] The samples were tested by the soil testing laboratory of the New Jersey Experiment Station under the supervision of W. J. Hanna and E. R. Purvis.

RESULTS

Solution Aeration of Bentgrass Cultures--Table 1 shows the influence of solution aeration on the development of Colonial bentgrass as measured in three different tests. In the first test, aerated solutions, compared with unaerated solutions, gave significant increases[1] in rootgrowth and topgrowth of Colonial bentgrass, *Agrostis tenuis*. A severe attack of aphids terminated the test earlier than planned. Only one test for oxygen content of the solutions had been made at the time of harvest, and the value of 3.5 p.p.m. recorded for the unaerated solution probably is not indicative of the oxygen tension maintained for this check treatment. At no time did the unaerated cultures appear to suffer from a lack of oxygen, nor did the visual appearance of the plants noticeably indicate the differences shown by the dry weights. The failure of the plants in the unaerated cultures to show marked deficiencies indicated the desirability of running a second test of longer duration.

In spite of the longer duration of the second test, the plants showed far less response to aeration than in the first test (Table 1, Tests A and B). The topgrowth and

[1] The significance of all differences was determined by analysis of variance (47). Throughout the context of this thesis, the term significance refers to statistical significance at the 5 per cent level; and the term highly significant refers to statistical significance at the 1 per cent level.

Table 1. The influence of nutrient solutions differing in oxygen content on the development of Colonial bentgrass, *Agrostis tenuis*.

Grass Treatment	Aeration level	Dissolved Oxygen	Av. Dry Wt. per 3 plants: Tops	Av. Dry Wt. per 3 plants: Roots	Ratio of tops to roots
		p.p.m.	gms.	gms.	
		Test A, 1948			
Unclipped	none	3.50[1]	7.73	1.32	5.93
Unclipped	medium	2.55	9.38	1.48	6.39
Unclipped	high	4.63	11.23	2.12	5.38
L.S.D. 5% level[2]			2.32	0.25	n.s.
		Test B, 1949			
Six Clippings	none	1.36[3]	10.88[4]	0.74	14.61
Six Clippings	medium	4.22	11.61	0.98	12.20
Six Clippings	high	6.34	10.29	0.93	11.11
L.S.D. 5% level			n.s.	n.s.	n.s.
		Test C, 1950			
Unclipped	none	0.25[1]	4.64	0.98	4.96
Unclipped	medium	0.70	5.60	1.17	4.77
Unclipped	high	4.60	5.85	1.80	3.24
L.S.D. 5% level			n.s.	0.49	1.20

[1] An average value of three replications based on one analysis per culture.
[2] L.S.D. = difference required for significance.
[3] An average value of three replications based on six analyses per culture.
[4] The values for tops include clipping weights.

rootgrowth weights of the aerated cultures did not differ significantly from those of the unaerated cultures. However, the root weights of the high aeration cultures were consistently greater than those of the check. It was necessary to clip the plants to control the topgrowth during the test period. The average oxygen content of the solution obtained from the six different sampling dates gave 1.36, 4.22, and 6.34 p.p.m. for the low to the high levels of aeration, respectively. The lowest oxygen tension of 1.36 appears to have been too great to produce serious restrictions on the development of the grass plants.

An analysis of the culture solution for the third test of Table 1 showed 0.25, 0.70, and 4.60 p.p.m. of oxygen for the non-aerated, intermediate, and high levels of aeration, respectively. The bentgrass plants grown in the latter solution yielded 26 per cent more topgrowth and 84 per cent more rootgrowth than the plants in the unaerated solutions; the latter difference was significant. As in the previous tests, the ratio of tops to roots was greater for the plants grown in the unaerated solutions than for those grown in the aerated solutions. Table 3 shows that the roots of the plants developed in aerated solutions were longer, and Figure 3 shows that they were more highly branched than the roots developed in the unaerated solutions. The values for topgrowth, rootgrowth, and top to root ratio were intermediate for the plants grown in the solution of medium aeration.

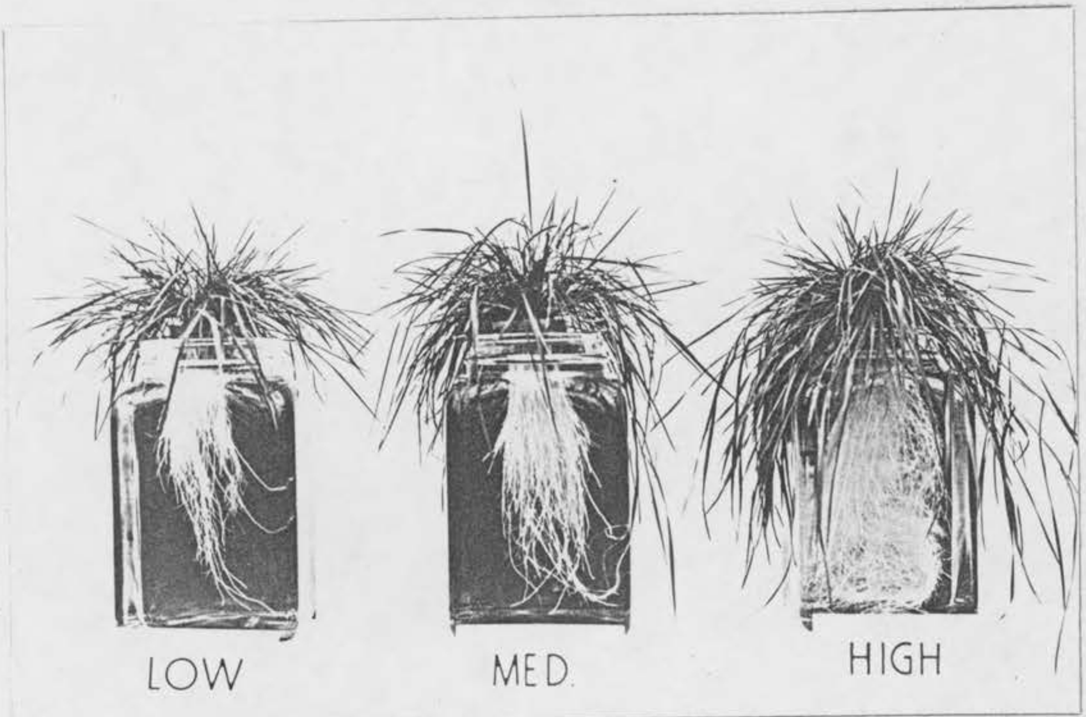

Figure 3. Colonial bentgrass grown in nutrient solution, which received different amounts of aeration (1950 test). From left to right, the aeration treatments were: no aeration, medium aeration, and high aeration.

Table 2. The influence of different levels of aeration on root length and on total nitrogen content of Colonial bentgrass, Agrostis tenuis, grown in solution culture during 1950.

Aeration level	Root length	Solution pH May 6	Average Nitrogen Content: Tops	Average Nitrogen Content: Roots
	cms.		per cent	per cent
None	26.0	6.20	3.18	2.25
Medium	31.3	6.35	4.38	2.68
High	31.5	6.40	4.65	3.60
L.S.D. 5% level	4.1	....	0.52	0.65
L.S.D. 1% level	n.s.	....	0.79	0.98

Table 2 shows that the pH of aerated solutions tended to increase more rapidly than the pH of the unaerated solutions. This indicates that the plants of the aerated cultures probably were absorbing a greater total quantity of nitrate nitrogen than the plants in the unaerated solutions. Analysis of the plants for total nitrogen showed that solution aeration significantly increased the nitrogen content of both tops and roots.

Results Obtained with Soil Compaction Cultures--The effect of soil compaction on the growth of Colonial bentgrass in 8 x 11 inch jars in the greenhouse is shown in Table 3. The roots of Colonial bentgrass grown in soil having a volume weight of 1.36 had a greater total weight and were

Table 3. The effect of soil compaction on Colonial bentgrass, *Agrostis tenuis*, grown in 8 x 11 inch jars from January 28, to June 16, 1950.

Soil Treatment	Soil Density	No. of Clippings	Dry Weight Clippings	Dry Weight Tops	Dry Weight Roots	Ratio Topgrowth to Roots
			gms.	gms.	gms.	
Compact	1.64	8	14.09	14.60	2.61	10.98
Loose	1.36	8	11.31	14.10	3.38	7.81
Compact	1.64	3	18.38	16.80	3.91	9.08
Loose	1.36	3	17.25	17.30	5.76	6.14
L.S.D. 5% level			1.31	2.42	0.95	1.70
L.S.D. 1% level			1.83	3.49	1.33	2.39

more extensive than the roots grown in soil having a volume weight of 1.64, as shown by Table 3 and Figure 4, respectively. When eight clippings were taken, there was a highly significant difference between the clipping weights of plants grown in compact soil and the clipping weights of plants grown in less compact soil; when three clippings were taken, the difference approached significance. The plant tops did not show any significant difference with respect to the volume weight of the soil. The ratio of topgrowth to rootgrowth was significantly greater for the plants grown in the soils with the higher volume weights than for the plants grown in the soils with lower volume weights. Greater frequency of clipping, compared with less frequent clipping, resulted in significant reductions in the dry weights of tops, roots, and clippings.

The Effect of Cultivation on Turf Quality--The effects of cultivation on turf quality are reported in Tables 4, 5, and 6 in terms of turf rank; clipping weights; the quantity of Colonial bentgrass; freedom from clover and annual bluegrass; and the amount of turf cover.

Clipping weight averages determined in August, 1950, for the Frequency of Cultivation Study were similar for the cultivated and uncultivated plots (Table 4). The six per cent lower yield of the plots receiving six cultivations

Figure 4. Colonial bentgrass grown in cultures that received different intensities of soil compaction and clipping. From left to right, the treatments were: (1) compaction - 8 clippings, (2) no compaction - 8 clippings, (3) compaction - 3 clippings, and (4) no compaction - 3 clippings.

Table 4. Turf quality observed on plots receiving two and six cultivations (Aerifier) per season in the Frequency of Cultivation Study. 1950-1951.

Treatment	Clipping Weights[1]	Percentage of Turf Cover: Colonial bentgrass[2]	Percentage of Turf Cover: Annual bluegrass[2]
	gms.	per cent	per cent
No cultivation	68.8	47.5	31.3
Two cultivations	67.8	46.3	33.8
Six cultivations	64.3	50.0	30.0

Differences not significant at the 5% level.

[1]Clipping weights are the average dry weight yield taken from a 24-inch mower swath through the length of the plot, August 21, 1950.
[2]Average of estimates taken March 24, 1951.

compared with that of the uncultivated plots did not represent a significant difference. Estimated percentages of Colonial bentgrass and annual bluegrass on cultivated and uncultivated plots in March, 1951, did not show any significant differences or trends in favor of cultivation.

Numerical ratings were given for turf quality and clover percentage in 1950, for the Methods of Cultivation Study (Table 5). The plots cultivated with the Aerifier and the disk received a lower average rating for turf quality than the non-cultivated plots; the differences between the plots on which the Aerifier was used and the plots on which it was not used were statistically significant. The percentage of clover-infested turf was greater,

Table 5. Turf quality and per cent clover on plots receiving different cultivation treatments in the Methods of Cultivation Study. September, 28, 1950.

Cultivation Treatment	Turf Rating[1]	Clover Rating[2]
		per cent
No cultivation	2.9	20
Aerifier - 2 inches	3.5	15
Aerifier - 5 inches	3.3	16
Disk drill	3.1	18
L.S.D. 5% level	0.34	n.s.

[1]Plots were rated on the amount of good turf. A value of 1.0 indicates the best quality.
[2]The clover rating is based on the per cent of the plot in which clover was established.

but not significantly greater, on the non-cultivated plots than on the cultivated plots.

The Fairway Cultivation Study was rated for the percentage of turf cover, clover, and annual bluegrass (Table 6). The cultivated plots had 8 per cent more turf cover, 3 per cent more clover, and 10 per cent more annual bluegrass than the uncultivated plots. However, the differences were not significant. The increase in turf cover may have been associated with the higher annual bluegrass rating given the cultivated plots.

Turf quality ratings were not given for the creeping bentgrass studies. Except for the openings created in

Table 6. Turf cover, per cent clover, and per cent annual bluegrass on cultivated (Aerifier) and on non-cultivated plots of the Fairway Cultivation Study. October 8, 1950.

Cultivation Treatment	Turf Cover[1]	Clover[2]	Annual bluegrass[3]
	per cent	per cent	per cent
Cultivation, Spring & Fall	83	18.1	46
No Cultivation	77	17.5	42

Differences not significant at 5% level.

[1]Turf cover was estimated on the basis of the percentage area covered with grasses.
[2]The clover ratings are estimates of the per cent of the plot in which clover was established.
[3]The ratings are estimates of the percentage of the plot occupied by annual bluegrass.

the turf by cultivation, no visual differences were observed between the cultivated and the uncultivated plots. The results obtained from three attacks of large brownpatch, Rhizoctonia solani, on this test are reported in Table 7. Disease ratings from cultivated and uncultivated plots did not show any consistent or significant differences in the incidence of large brownpatch. An increased rate of nitrogen fertilization appeared to increase the amount of disease on both cultivated and uncultivated plots; however, none of the results differed significantly.

With regard to all tests, estimates of the quantity of annual bluegrass and clover failed to show significant

Table 7. The amount of large brownpatch, <u>Rhizoctonia solani</u>, occurring under different nitrogen and cultivation treatments of the Bentgrass Cultivation--Rate of Nitrogen Test. 1950

Treatment	Estimated Infection July	Estimated Infection Sept.	Infected Area Sept. 5
	per cent	per cent	sq. in.
No Cultivation (6.4 lbs. N)	33	29	2656
Cultivation (6.4 lbs. N)	32	27	3109
No Cultivation (4.8 lbs. N)	23	21	1450
Cultivation (4.8 lbs. N)	18	23	2480
No Cultivation (3.2 lbs. N)	3	24	2120
Cultivation (3.2 lbs. N)	7	20	1678

Differences not significant at the 5% level.

or consistent reductions for these undesired plants as a result of cultivation. No significant improvement in turf quality was produced by cultivation on any of the field tests. In fact, in the Methods of Cultivation Study, the turf ratings for two of the cultivation treatments were significantly lower than the turf ratings for the no-cultivation treatment.

Results Pertaining to the Effect of Cultivation on Weed Populations--All of the test areas were virtually free of dandelions when the tests were started in the fall of 1948, and the spring of 1949. Plant counts taken in 1950, on cultivated and uncultivated plots, failed to show that cultivation had encouraged a significant increase in the number of dandelions (Table 8). A heavy population of buckhorn plants developed on the Fairway Cultivation Test during the test period. The cultivated plots had 11 per cent more buckhorn plants than the uncultivated plots; however, this difference is not significant (Table 8).

The quantity of crabgrass in the cultivated and non-cultivated plots of fairway type of turf did not differ significantly for any of the tests (Table 8).

Table 8. Quantities of dandelions, crabgrass, and buckhorn observed in cultivated and non-cultivated plots of fairway type of turf. 1950.

Treatment	Average number of dandelions	Average amount of crabgrass[1]	Average number of buckhorn
	Frequency of Cultivation Study		
No Cultivation	17.8	326	...
Two Cultivations/year	15.5	435	...
Six Cultivations/year	16.8	323	...
	Methods of Cultivation Study		
No Cultivation	1.2	77	...
Aerifier - 2 inches	1.0	93	...
Aerifier - 5 inches	2.1	88	...
Disk drill	1.2	105	...
	Fairway Cultivation Study		
Cultivation	55.0	38	320
No Cultivation	52.0	43	287

Differences not significant at the 5% level.

[1] The amount of crabgrass for the first two studies is recorded as an average of the number of plants counted. The ratings for the third test are average estimations of the per cent of area infested with crabgrass.

Cultivated plots of the different tests had from 11 per cent less crabgrass to 36 per cent more crabgrass than the non-cultivated plots. In the Frequency of Cultivation Test, treatments receiving six cultivations and no cultivation had an average of 323 and 326 crabgrass plants, respectively. In no test could any marked contrasts in the amount of crabgrass in cultivated and uncultivated treatments be recognized by visual inspection.

The quantity of crabgrass found in cultivated and non-cultivated plots of creeping bentgrass turf are reported in Table 9. In the Time of Cultivation Study, five of the seven cultivation treatments had 31 to 59 per cent less crabgrass than the check. Spring and summer cultivation did not show a tendency to increase the amount of crabgrass. In the Bentgrass Cultivation-Rate of Nitrogen Test, the cultivated treatments had 12, 17, and 68 per cent more crabgrass than their respective non-cultivated counterparts. The average number of crabgrass plants in the cultivated plots of creeping bentgrass turf did not differ significantly from the number in the non-cultivated plots for either test.

Table 9. The quantity of crabgrass found in cultivated (Aerified) and non-cultivated plots of creeping bent turf. August, 1950.

Cultivation Treatment	Average number of crabgrass plants
Time of Cultivation Study on Bent Turf	
Aerifier	
Spring	130
Summer	104
Fall	62
Spring & Summer	61
Aerifier	
Spring & Fall	65
Summer & Fall	40
Spring, Summer, & Fall	68
Check--no cultivation	98
Bentgrass Cultivation-Rate of Nitrogen Test	
No Cultivation (6.4 lbs. of N)	22
Cultivation (6.4 lbs. of N)	37
No Cultivation (4.8 lbs. of N)	17
Cultivation (4.8 lbs. of N)	19
No Cultivation (3.2 lbs. of N)	52
Cultivation (3.2 lbs. of N)	61

Differences not significant at the 5% level.

<u>Results of Water Penetration Tests</u>--Water penetration rates obtained on cultivated and non-cultivated turf are reported in Table 10. No significant differences were found between the rates of water penetration on cultivated and non-cultivated turf for any of the four studies on which measurements were taken. The maximum increase in percolation rates was 18 per cent, and the maximum decrease in percolation rates was 50 per cent for the cultivated plots, compared with the uncultivated plots. There was a trend for the percolation rates to be lower on the cultivated plots than on the uncultivated plots of both the Fairway Cultivation Study and the Time of Cultivation Study on Bentgrass Turf. This trend is of interest, since these tests would appear to offer the greatest opportunity for cultivation to improve the percolation rate. In the first test, the soil is of the heaviest texture found on any of the tests (clay loam), and it receives heavy fairway traffic. The soil of the second test area has a tendency to be more compact as a result of the higher water usage and the increased mower traffic that is associated with the putting-green type of turf maintenance. Also, this latter area has been treated with arsenate of lead, which has destroyed most of the earthworm population.

The water penetration rates for the Fairway Cultivation Test are assembled according to chemical topdressing

Table 10. Water penetration rates on cultivated and non-cultivated plots of fairway and putting-green type of turf. Fall, 1950.

Cultivation Treatments	Number of Cultivations	Time since Cultivation	Water penetration rate[1]
		days	cc/cm²/min.
Frequency of Cultivation Study September, 1950			
No Cultivation	..	...	3.95
Two Cultivations	3	177	3.86
Six Cultivations	11	32	4.33
Method of Cultivation Study September 30, 1950			
No Cultivation	..	...	3.31
Aerifier - 2 inches	4	184	3.69
Aerifier - 5 inches	4	184	3.89
Disk drill	4	184	3.43
Fairway Cultivation Study October 13, 1950			
No Cultivation	..	...	1.44
Aerifier	7	186	1.09
Time of Cultivation Study on Bentgrass Turf November 14, 1950			
Aerifier			
Spring	2	224	0.65
Summer	2	115	0.71
Fall	3	50	0.56
Spring & Summer	4	115	0.51
Aerifier			
Spring & Fall	5	50	0.82
Summer & Fall	5	50	0.38
Spring, Summer, & Fall	7	50	0.55
Check - no cultivation	..	...	0.75

Differences not significant at the 5% level.

[1] The average penetration rate is based on 80, 160, 240, and 60 cylinder readings for the respective tests.

treatment in Table 11. The plots receiving lime and lime plus gypsum had 23 and 13 per cent higher water penetration rates, respectively, than the plots receiving fertilizer only. While the differences are not significant, the results show a rather consistent trend for more rapid water penetration on the lime treated plots.

Table 11. The effect of lime and gypsum on the penetration rate of water into established turf of the Fairway Cultivation Study. October 13, 1950.

Treatment	Water Penetration Rate		
	Non-cultivated Plots	Cultivated Plots	Average Rate
	cc/cm^2/min.	cc/cm^2/min.	cc/cm^2/min.
Fertilizer	1.22	1.02	1.11
Lime-fertilizer	1.61	1.09	1.37
Gypsum-lime-fertilizer	1.55	1.06	1.26

Differences not significant at the 5% level.

Results of P_2O_5 Tests--The effects of cultivation on the penetration rates of phosphorus are given in Table 12. Available phosphorus is reported for samples taken at 0-2, 2-4, and 4-6 inch soil depths from fertilized turf of the Fairway Cultivation Study. Statistical analysis of the results obtained for the spring of 1949 and the spring and fall of 1950 did not show significant differences in the amount of available phosphorus for samples taken from

Table 12. A summary of the effects of cultivation (Aerifier) on the penetration rates of phosphorus into the sod of the Fairway Cultivation Study. 1949-1950.

Cultivation Treatment	Depth of Sample	Avail. Phos. (P_2O_5) Per Acre[1] Spring 1949	Fall 1949	Spring 1950	Fall 1950	2 yr. av.
	inches	lbs.	lbs.	lbs.	lbs.	lbs.
Cultivation	0-2	21.9	26.9	45.5	56.7	37.8
No Cultivation	0-2	20.9	17.7	43.4	59.5	35.4
Cultivation	2-4	7.3	8.0	9.6	13.0	9.5
No Cultivation	2-4	7.0	7.8	10.5	13.8	9.8
Cultivation	4-6	6.2	5.4	6.2	8.3	6.5
No Cultivation	4-6	5.7	4.0	5.9	9.9	6.4

[1]The values given are the average of the three subplots receiving phosphorus fertilizer. The values for the Fall, 1949, tests are the average of two replications, and those for the other seasonal tests are the average of four replications. Analysis of the Spring, 1949, and the 1950 results did not show any statistical differences at the 5% level.

cultivated and non-cultivated turf. Table 12 and Figure 5 illustrate the results obtained in the two-year period, which show a rather consistent trend for the phosphorus readings to be higher in the 0-2 inch soil horizon of the cultivated plots than of the uncultivated plots. This was reflected in the two-year average as a 6 per cent increase. The two-year averages of P_2O_5 at the 2-4 and 4-6 inch levels were very similar for the cultivated plots and the non-cultivated plots.

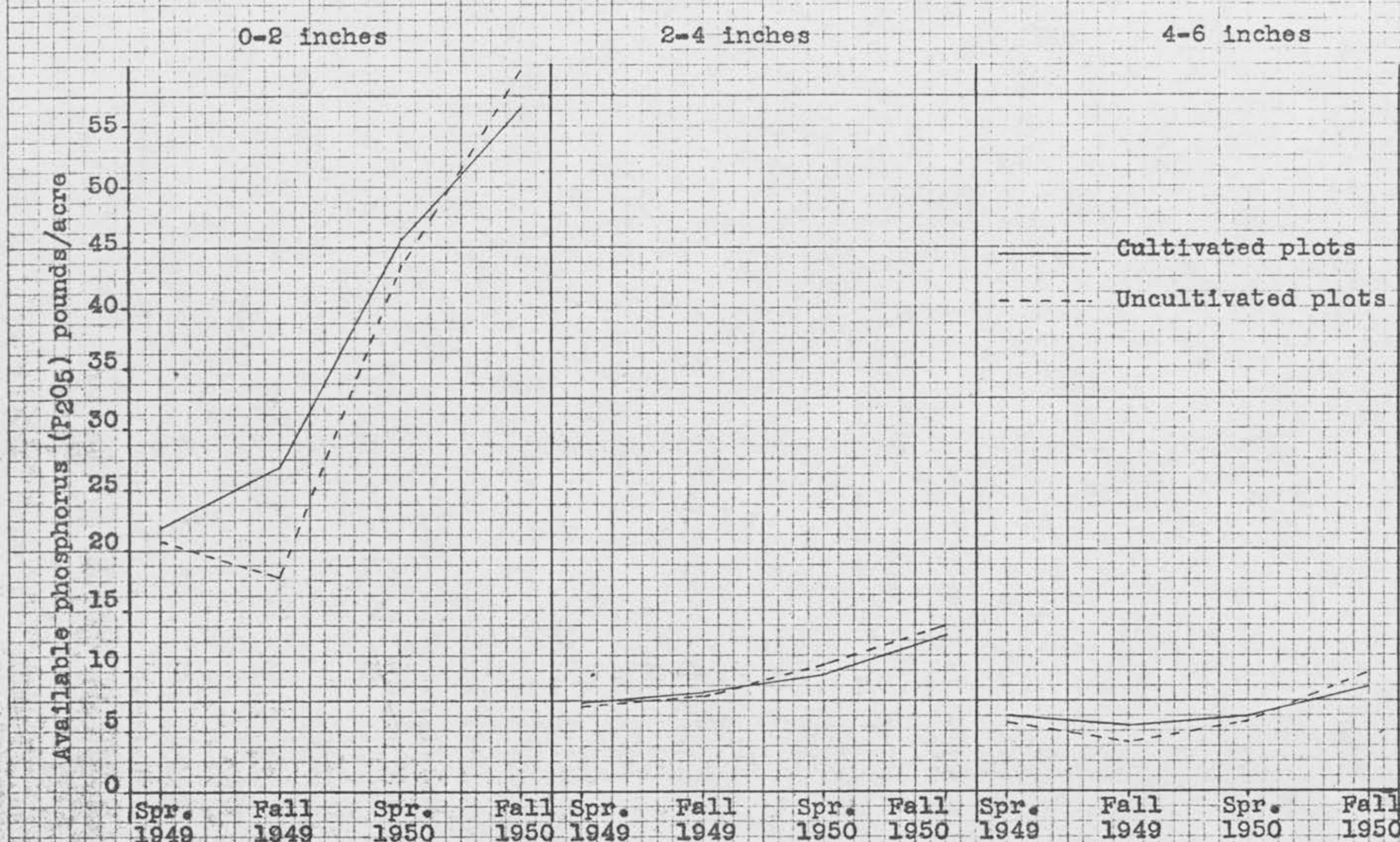

Figure 5. Available phosphorus found in successive seasons at depths of 0-2, 2-4, and 4-6 inches in cultivated and non-cultivated plots which received superphosphate in the Fairway Cultivation Study.

The available phosphorus readings for unfertilized plots of cultivated and non-cultivated turf are given in Table 13. The cultivated plots gave 30, 26, and 2 per cent higher phosphorus values in the 0-2 inch, 2-4 inch, and 4-6 inch soil horizons, respectively, than the uncultivated plots. In addition, Table 13 and Figure 6 show a trend for the phosphorus readings to be higher in the 0-2 and 2-4 inch horizons of the cultivated plots than in the corresponding horizons of the uncultivated plots. The available phosphorus readings of the 0-2 inch depth of the 1950 spring test were significantly higher for the cultivated treatment than for the uncultivated treatment.

Table 13. Available phosphorus in samples collected at three soil depths from unfertilized plots of cultivated and non-cultivated turf of the Fairway Cultivation Study. 1949-1950.

Cultivation Treatment	Depth of Sample	Available P_2O_5 per acre[1]				
		Spring 1949	Fall 1949	Spring 1950	Fall 1950	2-year average
	inches	lbs.	lbs.	lbs.	lbs.	lbs.
Cultivation	0-2	20.8	18.0	17.5[2]	16.0	18.1
No Cultivation	0-2	13.8	20.0	10.0	11.8	13.9
Cultivation	2-4	8.0	6.0	7.3	7.0	7.1
No Cultivation	2-4	6.3	5.0	4.0	7.0	5.6
Cultivation	4-6	5.3	5.0	5.5	4.5	5.1
No Cultivation	4-6	4.5	5.0	5.3	5.0	5.0

[1]All values except those for Fall, 1949, are the average of four replications. The values given for Fall, 1949 are the average of two replications.

[2]The treatment differs significantly from the check at the 5% level. Statistical tests were not run on the values for the fall of 1949, and those of the two-year average.

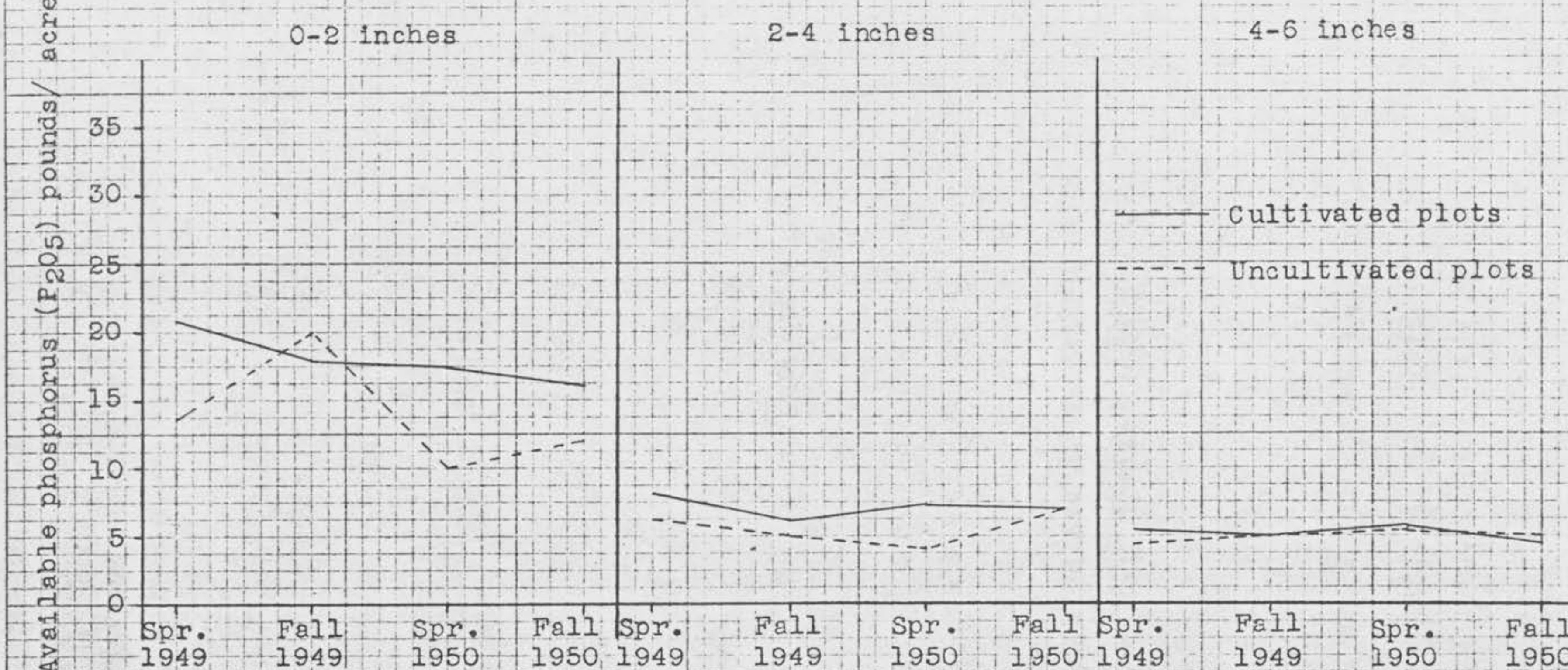

Figure 6. Available phosphorus found in successive seasons at depths of 0-2, 2-4, and 4-6 inches in cultivated and non-cultivated plots which received no superphosphate in the Fairway Cultivation Test.

The results of the soil tests for phosphorus on the Fairway Cultivation Study were assembled according to chemical treatment in Table 14. The available phosphorus readings were significantly higher on fertilized plots than on unfertilized plots at the 0-2 and 2-4 inch depths in the spring of 1950, and at all depths in the fall of 1950. In the fall of 1949, at the 2-4 inch soil depth, the use of gypsum and lime with fertilizer gave a 90 per cent higher available phosphorus reading than the check. This suggests that chemical treatment may have given appreciable increases of available phosphorus at the 2-4 inch depth after 12 months. Table 14 also shows a general trend for the available phosphorus readings to be highest in the samples collected from the fertilized plots that received additional treatment of lime and gypsum. The combination of lime plus gypsum plus fertilizer, which generally gave higher available phosphorus readings than lime plus fertilizer, gave significantly higher readings for the 0-2 and 4-6 inch depths in the fall of 1950.

<u>The pH values for the Fairway Cultivation Study</u>--The effects of lime application on the soil pH of cultivated and non-cultivated turf are given in Table 15 and Figures 7 and 8. In every seasonal comparison, the average pH readings of non-cultivated plots were slightly higher than those of the

Table 14. The effect of fertilizer, lime, and gypsum treatment on the available phosphorus content of soil samples taken at three depths of the Fairway Cultivation Study. 1949-1950.

Treatment	Depth of Sample	Available P_2O_5 per acre[1]				
		Spring 1949	Fall 1949	Spring 1950	Fall 1950	2-year average
	inches	lbs.	lbs.	lbs.	lbs.	lbs.
Check	0-2	17.3	19.0	13.6	13.9	16.0
Fertilizer	0-2	19.9	16.5	33.1	52.0	30.4
Lime Fertilizer	0-2	21.9	21.7	49.3	58.1	37.8
Gypsum lime fertilizer	0-2	22.5	27.5	51.0	64.4	41.4
L.S.D. 5% level		n.s.	....	10.2	12.4	....
L.S.D. 1% level		n.s.	....	14.6	17.8	....
Check	2-4	7.1	5.5	5.6	7.0	6.3
Fertilizer	2-4	6.6	6.3	8.8	12.9	9.0
Lime fertilizer	2-4	7.3	5.5	9.6	15.3	9.4
Gypsum lime fertilizer	2-4	7.5	12.0	11.8	11.9	10.8
L.S.D. 5% level		n.s.	....	3.7	4.0	....
L.S.D. 1% level		n.s.	....	n.s.	5.8	....
Check	4-6	4.9	5.0	5.4	4.8	5.0
Fertilizer	4-6	6.0	4.3	5.6	8.0	6.0
Lime fertilizer	4-6	5.5	4.3	6.9	8.0	6.2
Gypsum lime fertilizer	4-6	6.3	5.0	5.5	11.3	7.0
L.S.D. 5% level		n.s.	....	n.s.	3.2	....
L.S.D. 1% level		n.s.	....	n.s.	4.5	....

[1] The values for Fall, 1949, are the average of two replications, and those of the other seasonal tests are the average of four replications. No statistical analysis was made for the Fall, 1949, or the two-year average.

Table 15. The average pH values of cultivated and non-cultivated plots of limed and unlimed turf of the Fairway Cultivation Study. 1949-1950.

Cultivation Treatment	Depth of Sample	Average pH value[1]			
		Spring 1949	Fall 1949	Spring 1950	Fall 1950
	inches				
		Limed Plots			
Cultivation	0-2	6.13	5.60	6.08	6.25
No Cultivation	0-2	6.15	5.65	6.30	6.30
Cultivation	2-4	5.78	5.40	5.80	5.98
No Cultivation	2-4	6.00	5.70	6.23	6.28
Cultivation	4-6	5.73	5.50	5.78	5.88
No Cultivation	4-6	5.98	5.70	6.20	6.13
		Unlimed Plots			
Cultivation	0-2	5.70	5.35	5.55	5.58
No Cultivation	0-2	5.83	5.85	5.83	5.78
Cultivation	2-4	5.80	5.35	5.65	5.68
No Cultivation	2-4	5.93	5.95	5.98	5.98
Cultivation	4-6	5.70	5.50	5.73	5.70
No Cultivation	4-6	5.88	5.90	5.93	6.03

[1]All values are the average of four replications, except those for Fall, 1949, which are the average of two replications.

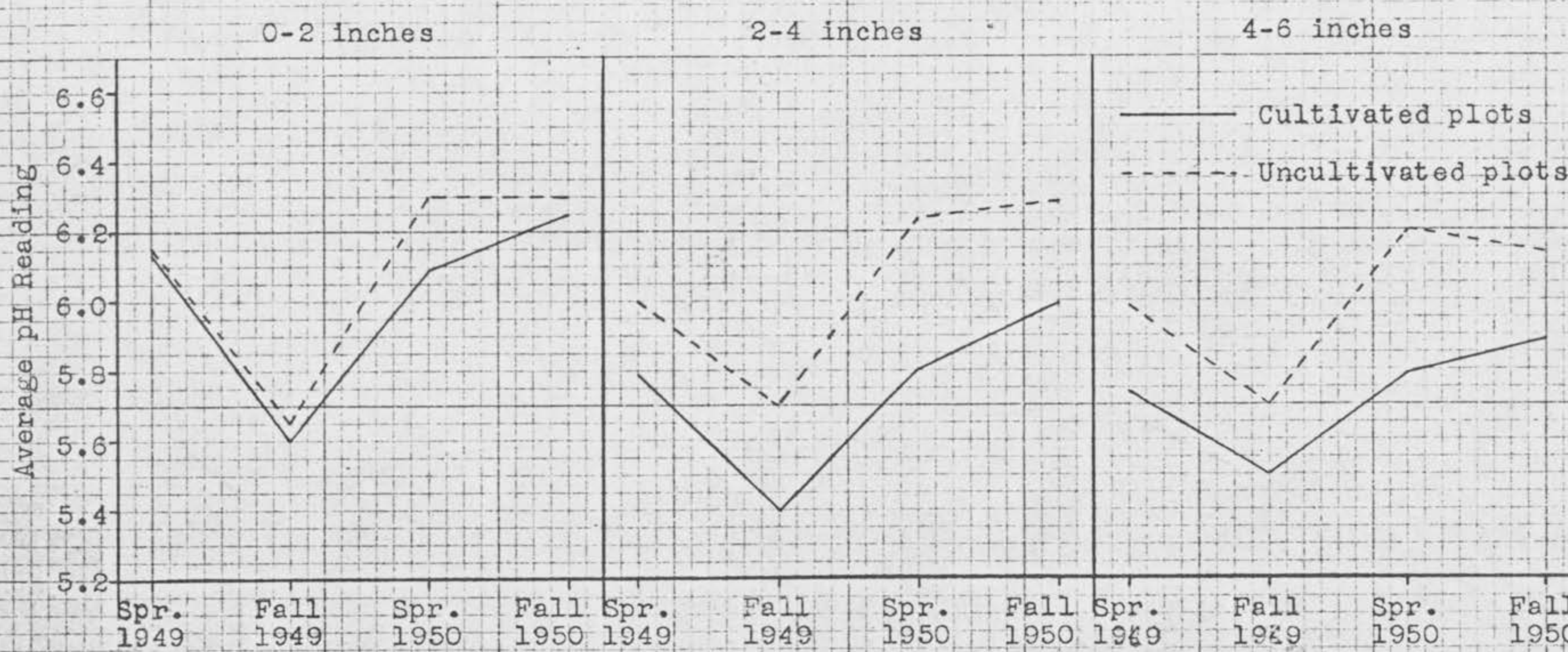

Figure 7. pH values obtained in successive seasons at depths of 0-2, 2-4, and 4-6 inches in cultivated and non-cultivated plots which received ground limestone in the Fairway Cultivation Test.

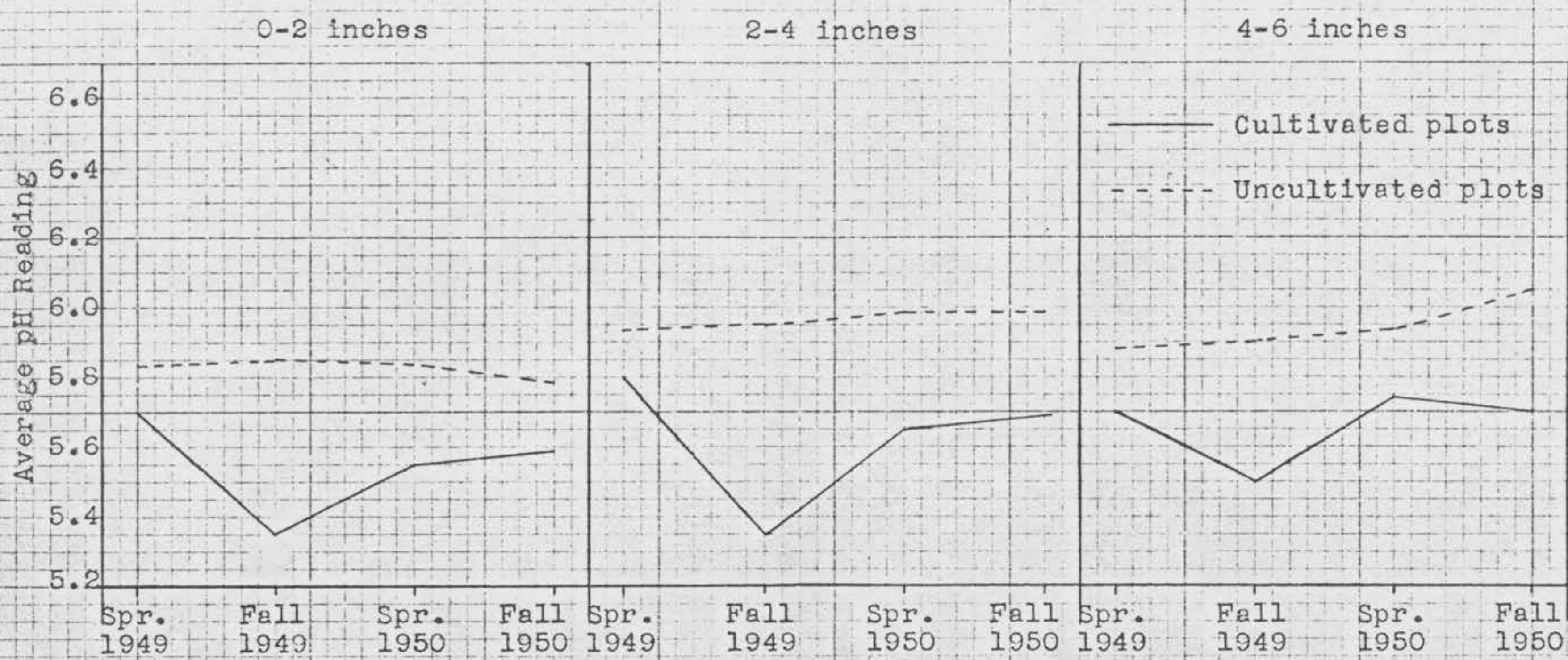

Figure 8. The pH values obtained in successive seasons at depths of 0-2, 2-4, 4-6 inches in cultivated and non-cultivated plots which received no lime in the Fairway Cultivation Study.

cultivated plots. The pH values are assembled to show the effect of lime treatment in Table 16. After 18 months, some of the limed plots showed higher pH values at the 2-4 inch depth than the check plots. After 24 months, no effects of lime application were apparent at the 4-6 inch depth.

Soil Air Space and Soil Volume Weights Determined for the Frequency of Cultivation Study--Table 17 gives the soil air space readings and the volume weights obtained from turf receiving different amounts of cultivation. The samples taken from cultivated turf had consistently lower air space readings and higher volume weights than the samples taken from the uncultivated turf. Analysis of the results did not show any significant differences.

Root Weights Obtained from the Fairway Cultivation Study--Rootgrowth, topgrowth, and thatch determinations made on samples taken from cultivated and non-cultivated plots of the Fairway Cultivation Study are given in Table 18. A total of 40 root samples, from the 1.25-6 inch horizon of the cultivated plots, yielded 8 per cent more dry weight than similar samples taken from uncultivated plots. The plant top yields and the thatch content of the 0-1.25 inch surface layer were 10 and 8 per cent higher, respectively, on the cultivated plots. None of these differences were significant.

Table 16. The effect of lime application on the soil pH of the Fairway Cultivation Study. 1949-1950.

Treatment	Depth of Sample	Average pH value[1]			
		Spring 1949	Fall 1949	Spring 1950	Fall 1950
	inches				
Cultivated Plots					
Check	0-2	5.80	5.70	5.93	5.88
Fertilizer	0-2	5.70	5.35	5.55	5.58
Lime-fertilizer	0-2	6.13	5.60	6.08	6.25
Gypsum-lime-fertilizer	0-2	6.25	6.10	6.30	6.23
Check	2-4	5.83	5.75	5.98	5.98
Fertilizer	2-4	5.80	5.35	5.65	5.68
Lime-fertilizer	2-4	5.78	5.40	5.80	5.98
Gypsum-lime-fertilizer	2-4	6.00	5.90	6.08	6.08
Check	4-6	5.80	5.85	6.00	6.03
Fertilizer	4-6	5.70	5.50	5.73	5.70
Lime-fertilizer	4-6	5.73	5.50	5.78	5.88
Gypsum-lime-fertilizer	4-6	5.83	5.75	5.95	5.93
Non-Cultivated Plots					
Check	0-2	5.88	6.20	5.85	5.85
Fertilizer	0-2	5.83	5.85	5.83	5.78
Lime-fertilizer	0-2	6.15	5.65	6.30	6.30
Gypsum-lime-fertilizer	0-2	6.20	5.80	6.25	6.28
Check	2-4	5.98	6.20	5.98	6.00
Fertilizer	2-4	5.93	5.95	5.98	5.98
Lime-fertilizer	2-4	6.00	5.70	6.23	6.28
Gypsum-lime-fertilizer	2-4	6.05	5.85	6.08	6.13
Check	4-6	5.90	6.25	6.00	6.05
Fertilizer	4-6	5.88	5.90	5.93	6.03
Lime-fertilizer	4-6	5.98	5.70	6.20	6.13
Gypsum-lime-fertilizer	4-6	5.95	5.90	5.98	5.98

[1]All pH values represent an average of four replications, except those for Fall, 1949, which are the average of two replications.

Table 17. Soil air space and soil volume weights determined for turf receiving different amounts of cultivation in the Frequency of Cultivation Study. November, 1950.

Cultivations per season	Depth of Sample	Days since Cultivation	Air Space	Volume Weight
	inches		%	
None	1-4	..	23.2	1.47
Two	1-4	54	21.8	1.48
Six	1-4	54	21.5	1.49

Differences not significant at 5% level.

Table 18. Rootgrowth, topgrowth, and thatch determinations made on cultivated and non-cultivated plots of the Fairway Cultivation Study. October, 1950.

Cultivation Treatment	Topgrowth of samples	Thatch (0-1.25 inch)	Weight of roots (1.25-6 inches)
	gms.	gms.	gms.
Cultivation	8.03	53.68	7.25
No Cultivation	7.31	49.85	6.70

Differences not significant at 5% level.

DISCUSSION OF RESULTS

Colonial bentgrass, grown in solutions with oxygen tension readings as low as 0.25 p.p.m., had less extensive rootgrowth; an increased top to root ratio; and a lower percentage of nitrogen than cultures that were grown with an oxygen tension of approximately 4.6 p.p.m. The low nitrogen content of the plants grown in unaerated solution suggests that they failed to absorb ions as freely because of an inadequate oxygen supply; or possibly their smaller root systems provided less surface for absorption of nutrients. The first premise offers the best explanation since investigations with other plants have shown that an adequate supply of oxygen is necessary for both cation and anion accumulation (21, 42).

Colonial bentgrass in solution culture did not show increased growth with oxygen tensions greater than 4 p.p.m., but it did show considerable ability to make satisfactory growth with oxygen tensions as low as 1 to 2 p.p.m. In contrast, tomatoes, soybeans, and oats have shown marked growth increases with oxygen levels of 6 p.p.m. and higher (19). Tests with Kentucky bluegrass (*Poa pratensis*) and Chewing's fescue (*Festuca rubra*) have indicated that these grasses tolerate comparatively low oxygen levels (16). Thus, the turf grasses appear to be more tolerant of low oxygen tension in solution culture than some of the other crop plants. In fact, the results obtained with Colonial bentgrass suggest that under certain conditions fresh water, moving through the soil, could supply enough oxygen to prevent injury to the plant.

The reduced rootgrowth of Colonial bentgrass in the compacted soil may have been caused by a low oxygen supply, or by decreased ability of the soil organisms to supply nutrients. Since decreased rootgrowth was the principal response of the grass to soil compaction, this result probably was produced primarily by a low oxygen supply. These results show that unsatisfactory root development may occur on severely compacted soil. An inadequate root system may easily have as serious effects on turf maintenance as do decreased activity of the soil organisms and water runoff that leads to drought or to loss of fertilizer and lime.

It seems logical to expect that turf cultivation might encourage the movement of water into established turf sod. Yet, the results do not show that cultivation produced any significant changes in the penetration rate. Since two of the four tests showed negative results, it is of interest to consider some factors that may have been responsible. A rather consistent tendency was observed for water penetration to be slower on the cultivated plots than on the uncultivated plots of the Fairway Cultivation Study. This area had the heaviest soil and a turf that has been established approximately 15 years. These conditions might lead one to expect the best results from cultivation for this test. Instead, the results were more favorable on the younger turf that had a lighter soil texture. Consideration of the factors concerned with water penetration into the soil may offer some explanation for these results, which seem contradictory to expectations. Continuous pore spaces in the soil are important for rapid movement of water through the soil (34, 44, 45). Nelson and Baver (34) state that virgin soils, or those which have not been cultivated for a number of years, are likely to have a more continuous pore system than disturbed soils. Since the soils of the Fairway Cultivation Study were of a clay loam texture, cultivation may have closed channels that otherwise would remain open for a considerable period of time.

Water penetration readings from the Time of Cultivation Study on creeping bentgrass turf showed that location in the test area was far more critical than cultivation or the lack of cultivation. Individual cylinder readings for a given plot were very uniform compared with those obtained in other tests. Still, several of the plots showed abnormal behavior. The cultivated plots nearest the edge of the test had water penetration rates twice those of other cultivated plots, although no readings were taken closer than four feet from the edge of the maintained area. Since the greatest differences between plots depended upon location rather than cultivation, it is unlikely that the cultivation treatments did much to increase the water penetration rates on this test.

Since all lime and phosphorus applications were made following cultivation, a limited amount of these chemicals should fall in the cultivation perforations. However, the results obtained in this study do not indicate that an appreciable amount entered the soil in this manner, or that lime and phosphorus penetrated the soil more rapidly on the cultivated treatments. While these results do not show any benefit from cultivation, it is still possible that cultivation may increase the rate of movement of lime and phosphorus into soils that are highly compacted or of heavy texture. Also, the results should vary with the cultivation technique.

Since a straight line relationship exists between diffusion rates of air and soil porosity (6), the air space readings may be considered an indication of the rate of air movement into the soil. The failure of plots receiving six cultivations to show lower volume weights or greater amounts of soil air space than the uncultivated plots suggests that cultivation did not provide lasting improvement of soil aeration. Also, the failure of turf cultivation to encourage a significant increase in the penetration rates of water and phosphorus supports this statement. These results are contrary to some expectations. However, Bradfield (8), in referring to other crops, questioned the possibility of developing a tillage treatment for improving the physical condition of the soil, a treatment that would provide lasting benefit and would not be obliterated by the first hard, beating rain. Furthermore, cultivation has been generally considered destructive of soil structure (1). Compaction caused by cultivation implements may also be considered destructive of soil structure. These statements may offer a partial explanation for the failure to observe a significant improvement in the penetration rates of water, lime, and phosphorus as a result of the turf cultivation treatments. Possibly, cultivation may encourage the movement of these materials into the turf sod when special conditions exist, such as severe compaction or heavy surface thatch.

The high available phosphorus readings for the upper layers of soil indicate that cultivation has encouraged greater activity of the soil organisms. The tendency for pH values to be lower on the cultivated plots also suggests that the activity of the microorganisms has been affected by the cultivation treatments. Greater decomposition of the accumulated, non-living stems, roots, and leaves may have supplied the increase in available phosphorus. However, the quantities of surface thatch collected with the root samples did not indicate that decomposition was more rapid on the cultivated plots. In fact, samples from the cultivated plots yielded 8 per cent more organic matter than those from the uncultivated plots. Since there was no way to determine if new growth had been encouraged by the cultivation treatment, the effect on decomposition could not be measured directly. Nevertheless, these results show that the effect of cultivation on the decomposition of organic matter may be an important factor that deserves further study.

Failure of cultivation to produce consistent or significant increases in the crabgrass and dandelion populations indicates that a large majority of the weeds grow from seed resting at the surface. Without doubt, cultivation exposed viable seed, but the quantity was not great enough to result in a marked increase in the number of weeds. Also, it has been suggested that breaking the turf cover by cultivation provides space for establishment of weeds, especially in summer. Evidently, this factor failed to play an important role in these tests.

Cultivation did not produce any readily observed differences in turf quality, or in the amount of clover or annual bluegrass. Since turf management practices can produce effects over a period of years, the results presented should be considered as representative of the effect of only two years' cultivation. It is possible that continued treatment might produce significant changes in the turf quality. Also, unusual conditions, such as extended drought periods, might produce marked differences between cultivated and non-cultivated turf.

While the root samples from cultivated turf did not show a large increase over those from uncultivated turf, it is possible that cultivation may have enhanced root decay and thereby masked an increase of new roots. Cultivation must have an influence on the functional root system, since numerous field observations reveal that roots develop abundantly in the openings produced by cultivation (Figure 9). This root development may be of value to the plant and it should aid in keeping the cultivation channels open.

Theoretically, turf cultivation offers great promise of benefit to turf grasses. Yet, the present study failed to show significant values for the practice on two different soils with different types of maintenance.

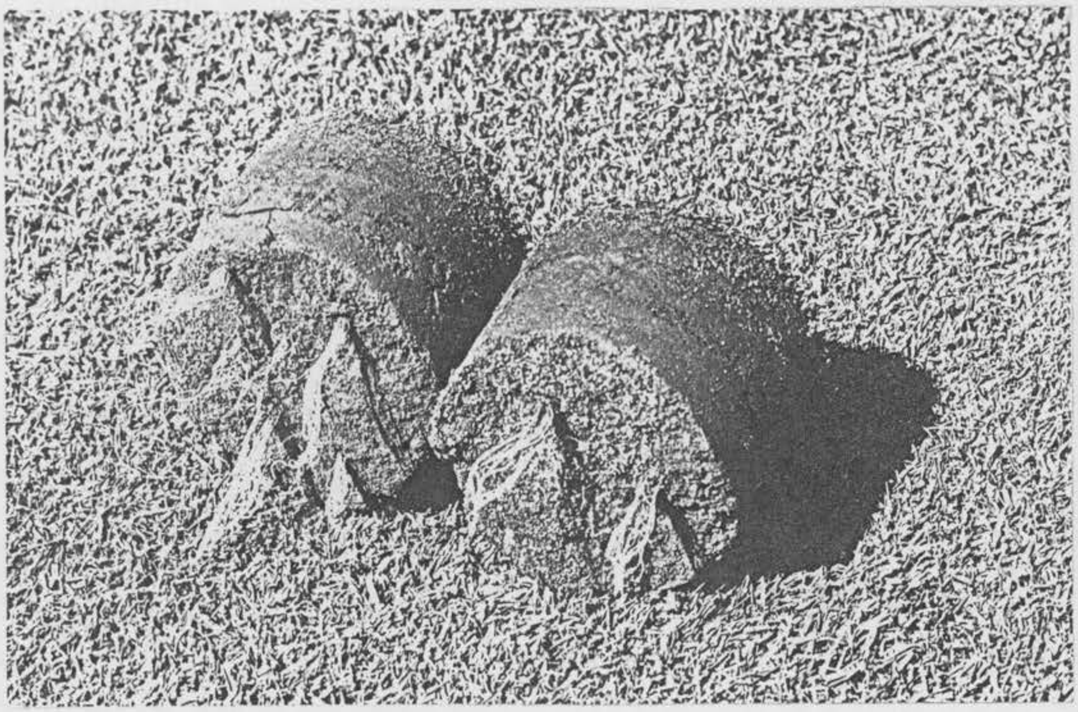

Figure 9. Turf plugs showing tufts of roots which developed in openings created by cultivation.

Since cultivation does not appear to have general application for all turf areas, the most important need of continued research is to determine where the technique may have a significant effect on the turf. Cultivation treatments should be established on turf areas that have varied degrees of soil compaction, ranging from moderate to extreme density. Cultivation may be beneficial on severely compacted soil, whereas on less dense soils it might be found to serve as a compaction treatment, especially if the soil moisture content is high. Also, consideration should be given to cultivation techniques. Extreme degrees of cultivation should be used in comparison with the standard treatments. Possibly, deeper or more thorough cultivation is needed.

Wherever turf cultivation may prove beneficial, such factors as increased rootgrowth; more rapid penetration of water, air, lime, and phosphorus; and greater decomposition of organic matter may be responsible for the results. Additional study of these factors is required. The effect of cultivation on different grass species, different soil types, and water runoff should be determined. Truly, many factors require a large amount of careful study before turf cultivation can be used with knowledge of the results to be obtained. Fundamental research offers the only hope for solving the numerous problems concerned with turf cultivation.

SUMMARY AND CONCLUSIONS

The purpose of this study was to obtain information on a series of cultivation trials on golf course type of turf, and related problems. The effect of solution aeration and soil compaction on Colonial bentgrass, Agrostis tenuis, was observed in greenhouse studies. The results of two seasons of turf cultivation were observed on five different field studies established on loam and clay loam soil. Two of these tests were established on creeping bent turf mowed at putting green height, and the other three tests were established on fairway type of turf. The Aerifier was used for cultivation in all the field studies. In addition, a disk drill was used in one of the tests as a second type of cultivation treatment. In each of these studies the effects of cultivation were observed with regard to one or more of the following criteria: turf quality; amount of annual bluegrass, clover, crabgrass, dandelions, and disease; and the rate of water penetration. Depth of phosphorus penetration and the amount of rootgrowth were measured for one of the tests on fairway type of turf. Volume weights and soil air space were measured on one of the cultivation tests. The data collected are the basis for the following statements.

1. Colonial bentgrass, Agrostis tenuis, grown in solution culture, was found to be tolerant of lower oxygen tension than has been reported for various other cultivated plants. Low oxygen supply was observed to give poor root branching, high top to root ratios, and low percentages of total nitrogen in the tops and roots.

2. Colonial bentgrass, Agrostis tenuis, grown in compacted soil developed a less extensive root system and higher top to root ratios than the check cultures.

3. Turf cultivation did not encourage significant or consistent increases in the number of dandelions or crabgrass plants.

4. Water penetration readings, taken on cultivated and uncultivated turf, did not differ significantly.

5. Plots receiving phosphorus fertilization showed significantly greater quantities of available phosphorus at depths of 0-2, 2-4, and 4-6 inches, after 24 months, than those receiving no phosphorus fertilization. Cultivation did not produce any significant effect on the rate of phosphorus penetration into the soil. However, the phosphorus readings showed a tendency to be higher in the 0-2 inch soil horizon of the cultivated plots than in the same horizon of the uncultivated plots, for both fertilized and unfertilized turf.

6. The pH values of cultivated plots showed a consistent trend to be lower than those of uncultivated plots for all soil depths. This indicates that cultivation did not encourage an important increase in the rate of calcium penetration.

7. Two and six cultivations per season, when compared with no cultivation, did not produce significant changes in the air space or volume weight of the soil.

8. Forty root samples from cultivated plots had an average yield of 8 per cent more dry weight than forty samples from non-cultivated plots. In addition, dry weight values for topgrowth, and thatched plant material in the 0-1.25 inch layer were 10 and 8 per cent greater, respectively, on the cultivated plots than on the uncultivated plots. None of these increases were significant at the 5 per cent level.

9. Turf cultivation treatments conducted for two years have not produced significant improvement in the turf quality of three-year old turf on a loam soil on the New Jersey Experiment Station turf plots, nor of fifteen-year old turf on a clay loam soil located on a fairway at the Rutgers Golf Course.

10. The study suggests that indiscriminate cultivation, as practiced, may be of little or no value; it seems

desirable that cultivation be limited to specific conditions. These conditions must be determined by further research.

11. There is a basic need to determine the potential value of different cultivation techniques on individual grasses, soil types, and different intensities of soil compaction and surface thatch. Also, the effect of cultivation on root development, the grass population, water penetration, lime and phosphorus penetration, and soil air space require further study. Research on these problems can provide the information required to ascertain the exact role of turf cultivation.

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APPENDIX

Table 1. The influence of nutrient solutions differing in oxygen content on the development of Colonial bentgrass, _Agrostis tenuis_.

Aeration Level	Replication 1	2	3	4	Average
Test A, 1948					
Oxygen Content of Solution in p.p.m.					
Low	4.00	3.80	2.50	3.70	3.50
Medium	3.20	2.00	2.40	2.60	2.55
High	5.00	6.90	2.80	3.80	4.63
Dry Weight of Tops in Grams					
Low	8.09	6.28	7.23	9.33	7.73
Medium	8.26	10.97	8.96	9.32	9.38
High	10.92	10.25	12.68	11.07	11.23
Dry Weight of Roots in Grams					
Low	1.52	1.32	1.06	1.37	1.32
Medium	1.55	1.73	1.31	1.32	1.48
High	2.38	2.04	1.83	2.23	2.12
Test B, 1949					
Oxygen Content of Solution in p.p.m.					
Low	1.28	1.38	1.09	1.67	1.36
Medium	3.68	4.77	5.05	3.39	4.22
High	6.60	6.90	5.06	6.80	6.34
Dry Weight of Tops in Grams					
Low	10.66	12.08	11.16	9.60	10.88
Medium	12.18	12.13	11.34	10.79	11.61
High	11.77	10.29	10.20	8.91	10.29

Table 1. (Continued)

Aeration Level	Replication 1	2	3	4	Average
	Test B, 1949 (Continued)				
	Dry Weight of Roots in Grams				
Low	0.74	0.74	0.78	0.72	0.74
Medium	1.09	1.19	0.76	0.87	0.98
High	0.90	0.97	0.94	0.89	0.93
	Test C, 1950				
	Oxygen Content of Solution in p.p.m.				
Low	0.20	0.20	0.30	0.30	0.25
Medium	0.70	1.10	0.50	0.50	0.70
High	4.40	4.40	4.40	5.20	4.60
	Dry Weight of Tops in Grams				
Low	3.62	4.00	5.90	5.33	4.64
Medium	6.18	5.90	5.69	5.22	5.60
High	7.16	4.91	4.44	6.89	5.85
	Dry Weight of Roots in Grams				
Low	0.70	0.71	1.13	1.39	0.98
Medium	1.03	1.08	1.37	1.18	1.17
High	2.00	1.90	1.44	1.85	1.80

Table 2. The influence of different levels of aeration on root length and on total nitrogen content of Colonial bentgrass, *Agrostis tenuis*, grown in solution culture during 1950.

Aeration Level	Replication 1	2	3	4	Average
	Root Length in cms.				
None	24	26	30	24	26.0
Medium	30	31	30	34	31.3
High	30	34	31	31	31.5
	Solution pH				
None	6.0	6.0	6.4	6.4	6.20
Medium	6.4	6.2	6.4	6.4	6.35
High	6.4	6.4	6.4	6.4	6.40
	Per Cent Nitrogen of Tops				
None	3.21	3.08	3.08	3.36	3.18
Medium	4.84	3.73	4.48	4.45	4.38
High	4.89	4.71	4.63	4.35	4.65
	Per Cent Nitrogen of Roots				
None	2.54	2.38	2.07	2.02	2.25
Medium	2.79	2.72	2.15	3.05	2.68
High	3.34	3.31	3.34	4.40	3.60

Table 3. The effect of soil compaction on Colonial bent-grass, *Agrostis tenuis*, grown in 8 x 11 inch jars from January 28, to June 16, 1950.

Soil Treatment	Replication 1	2	3	4	5	Average
			Dry Weight of Clippings in Grams			
Compact-8[1]	11.69	13.65	15.60	14.75	14.74	14.09
Loose-8	8.61	10.95	14.09	11.31	11.61	11.31
Compact-3	16.62	17.97	18.32	19.16	19.81	18.38
Loose-3	15.90	16.48	16.78	17.42	19.57	17.25
			Dry Weight of Tops in Grams			
Compact-8	13.00	13.00	15.00	12.00	20.00	14.60
Loose-8	11.00	15.00	14.00	15.50	15.00	14.10
Compact-3	16.50	15.00	18.00	17.00	17.50	16.80
Loose-3	15.00	16.00	16.50	19.00	20.00	17.30
			Dry Weights of Roots in Grams			
Compact-8	2.31	2.59	2.57	2.66	2.91	2.61
Loose-8	2.47	3.14	4.94	2.76	3.57	3.38
Compact-3	3.76	4.58	3.55	3.96	3.72	3.91
Loose-3	4.98	6.49	5.98	6.68	4.69	5.76

[1]Number of clippings designated by 8 and 3.

Table 4. Turf quality observed on plots receiving two and six cultivations (Aerifier) per season in the Frequency of Cultivation Study. 1950-1951.

Treatment	Replication 1	2	3	4	Average
	Clipping Weights in Grams				
No cultivation	71	68	79	57	68.8
Two cultivations	69	72	69	61	67.8
Six cultivations	58	74	68	57	64.3
	Per Cent Colonial Bentgrass				
No cultivation	40	50	55	45	47.5
Two cultivations	30	60	50	45	46.3
Six cultivations	50	50	55	45	50.0
	Per Cent Annual bluegrass				
No cultivation	35	30	25	35	31.3
Two cultivations	50	20	30	35	33.8
Six cultivations	30	30	25	35	30.0

Table 5. Turf quality and per cent clover on plots receiving different cultivation treatments in the Methods of Cultivation Study. September, 28, 1950.

Cultivation Treatment	Replication				Average
	1	2	3	4	
		Turf Rating			
No cultivation	2.7	3.2	2.8	2.8	2.9
Aerifier-2 in.	4.0	3.3	3.5	3.2	3.5
Aerifier-5 in.	3.5	3.2	3.2	3.2	3.3
Disk drill	3.2	3.2	3.0	3.0	3.1
		Per Cent Clover			
No cultivation	23	23	13	20	20
Aerifier-2 in.	22	12	13	13	15
Aerifier-5 in.	28	10	10	17	16
Disk drill	25	23	18	15	18

Table 6. Turf cover, per cent clover, and per cent annual bluegrass on cultivated (Aerifier) and on non-cultivated plots of the Fairway Cultivation Study. October 8, 1950.

Cultivation Treatment	Replication 1	2	3	4	Average
			Per Cent Turf Cover		
Cultivation					
Subplot 1	70	90	80	90	83
Subplot 2	90	60	90	80	80
Subplot 3	90	90	90	80	88
Subplot 4	90	70	80	80	80
Average	85	78	85	83	83
No cultivation					
Subplot 1	80	90	80	90	85
Subplot 2	50	70	70	70	65
Subplot 3	80	80	80	70	78
Subplot 4	80	90	90	80	85
Average	73	83	80	78	78
			Per Cent Clover		
Cultivation					
Subplot 1	20	10	50	20	25
Subplot 2	10	10	..	20	10
Subplot 3	20	30	10	10	18
Subplot 4	20	30	10	20	20
Average	17.5	20.0	17.5	17.5	18.1
No Cultivation					
Subplot 1	20	40	60	20	35
Subplot 2	10	10	10	30	15
Subplot 3	10	10	10	10	10
Subplot 4	10	10	10	10	10
Average	12.5	17.5	22.5	17.5	17.5

(Continued)

Table 6. (Concluded)

Cultivation Treatment	Replication 1	2	3	4	Average
	Per Cent Annual Bluegrass				
Cultivation					
Subplot 1	20	20	70	40	38
Subplot 2	30	40	40	60	43
Subplot 3	40	40	70	70	55
Subplot 4	30	50	50	70	50
Average	30	38	58	60	46
No Cultivation					
Subplot 1	30	30	50	40	38
Subplot 2	40	30	50	70	48
Subplot 3	40	30	60	50	45
Subplot 4	20	30	40	60	38
Average	33	30	50	55	42

Table 7. The amount of large brownpatch, Rhizoctonia solani, occurring under different nitrogen and cultivation treatments of the Bentgrass Cultivation-Rate of Nitrogen Test. 1950.

Treatment	Replication 1	2	3	Average
Per Cent Infection Estimated in July				
No Cultivation (6.4 lbs. N)	40	40	20	33
Cultivation (6.4 lbs. N)	45	35	15	32
No Cultivation (4.8 lbs. N)	20	10	40	23
Cultivation (4.8 lbs. N)	20	5	30	18
No Cultivation (3.2 lbs. N)	5	..	5	3
Cultivation (3.2 lbs. N)	10	..	10	7
Per Cent Infection Estimated in September				
No Cultivation (6.4 lbs. N)	33	23	30	29
Cultivation (6.4 lbs. N)	25	30	25	27
No Cultivation (4.8 lbs. N)	22	35	7	21
Cultivation (4.8 lbs. N)	23	35	11	23
No Cultivation (3.2 lbs. N)	15	33	23	24
Cultivation (3.2 lbs. N)	8	28	25	20
Square Inches of Infested Area in September				
No Cultivation (6.4 lbs. N)	2,281	2,527	3,160	2,656
Cultivation (6.4 lbs. N)	2,526	3.743	3,057	3,109
No Cultivation (4.8 lbs. N)	2,339	1,448	562	1,450
Cultivation (4.8 lbs. N)	2,774	3,118	1,547	2,480
No Cultivation (3.2 lbs. N)	1,982	2,376	2,003	2,120
Cultivation (3.2 lbs. N)	1,118	2,686	1,230	1,678

Table 8. Quantities of dandelions, crabgrass, and buckhorn observed in cultivated and non-cultivated plots of fairway type of turf. 1950.

Treatment	Replication 1	2	3	4	Average
	Frequency of Cultivation Study				
	Number of Dandelions				
No Cultivation	20	18	20	13	17.8
Two Cultiv./yr.	11	21	20	10	15.5
Six Cultiv./yr.	37	6	12	12	16.8
	Number of Crabgrass Plants				
No Cultivation	215	470	264	353	326
Two Cultiv./yr.	308	342	460	629	435
Six Cultiv./yr.	216	327	252	495	323
	Methods of Cultivation Study				
	Number of Dandelions				
No Cultivation	.8	.8	.8	2.3	1.2
Aerifier-2 in.	1.7	.7	.5	.5	1.0
Aerifier-5 in.	5.0	.3	.8	2.2	2.1
Disk drill	.8	.8	.2	3.0	1.2
	Number of Crabgrass Plants				
No Cultivation	93	113	69	32	77
Aerifier-2 in.	141	89	65	77	93
Aerifier-5 in.	117	82	89	64	88
Disk drill	115	160	65	78	105
	Fairway Cultivation Study				
	Number of Dandelions				
Cultivation	63	100	26	29	55
No Cultivation	65	47	26	70	52

(Continued)

Table 8. (Concluded)

Treatment	Replication 1	2	3	4	Average
	Fairway Cultivation Study				
	Number of Crabgrass Plants				
Cultivation	48	40	35	28	38
No Cultivation	45	50	43	35	43
	Number of Buckhorn Plants				
Cultivation	639	575	62	3	320
No Cultivation	858	200	76	13	287

Table 9. The quantity of crabgrass found in cultivated (Aerified) and non-cultivated plots of creeping bent turf. August, 1950.

Treatment	Number of Crabgrass Plants			
	Replication			
	1	2	3	Average
Time of Cultivation Study on Bent Turf				
Aerifier				
Spring	164	210	15	130
Summer	79	204	24	104
Fall	66	105	17	62
Spring and Summer	29	126	30	61
Aerifier				
Spring and Fall	67	74	53	65
Summer and Fall	19	47	53	40
Spring, Summer, and Fall	91	79	33	68
Check - No Cultivation	28	218	48	98
Bentgrass Cultivation-Rate of Nitrogen Test				
No Cultivation (6.4 lbs. N)	48	12	7	22
Cultivation (6.4 lbs. N)	62	28	20	37
No Cultivation (4.8 lbs. N)	38	10	4	17
Cultivation (4.8 lbs. N)	41	9	6	19
No Cultivation (3.2 lbs. N)	143	13	1	52
Cultivation (3.2 lbs. N)	138	21	25	61

Table 10. Water penetration rates on cultivated and non-cultivated plots of fairway and putting-green type of turf. Fall, 1950.

Cultivation Treatments	Time Required for 20 Readings (in seconds) Replication 1	2	3	4	Average time per 20 readings	Rate of water penetration cc/cm²/min.
		Frequency of Cultivation Study September, 1950				
No Cultivation	2,867	1,855	1,527	2,034	2,071	3.95
Two Cultivations	3,322	1,685	1,222	2,245	2,119	3.86
Six Cultivations	2,622	1,694	1,453	1,796	1,891	4.33
		Method of Cultivation Study September 30, 1950				
No Cultivation	2,409	2,348	2,897	2,251	2,476	3.31
Aerifier - 2 inches	2,079	2,582	2,371	1,835	2,217	3.69
Aerifier - 5 inches	2,327	2,114	1,563	2,410	2,103	3.89
Disk drill	1,878	2,330	3,287	2,035	2,383	3.43
		Fairway Cultivation Study October 13, 1950				
No Cultivation						
Subplot 2	7,430	4,415	7,290	7,595	6,683	1.22
Subplot 3	5,305	5,949	5,635	3,505	5,099	1.61
Subplot 4	5,880	5,600	4,475	5,202	5,289	1.55
Average	6,205	5,321	5,800	5,434	5,690	1.44

(Continued)

Table 10. (Concluded)

Cultivation Treatments	Time Required for 20 Readings (in seconds) Replication 1	2	3	4	Average time per 20 readings	Rate of water penetration cc/cm²/min.
Fairway Cultivation Study (Continued) October 13, 1950						
Aerifier						
Subplot 2	11,910	6,238	6,845	7,140	8,033	1.02
Subplot 3	12,400	6,460	4,515	4,080	6,864	1.19
Subplot 4	9,955	8,976	5,985	5,955	7,718	1.06
Average	11,422	7,225	5,782	5,725	7,539	1.09
Time of Cultivation Study on Bentgrass Turf November 14, 1950						
Aerifier						
Spring	11,340	12,360	14,115		12,605	0.65
Summer	12,825	10,110	11,580		11,505	0.71
Fall	14,230	15,055	14,190		14,492	0.56
Spring and Summer	18,380	14,320	15,420		16,040	0.51
Spring and Fall	13,310	8,750	7,875		9,978	0.82
Summer and Fall	21,985	33,245	9,320		21,517	0.38
Spring, Summer, Fall	11,880	7,160	25,700		14,913	0.55
Check - no cultivation	11,165	7,890	13,510		10,855	0.75

Table 11. The effect of lime and gypsum on the penetration rate of water into established turf of the Fairway Cultivation Study. October 13, 1950.

Treatment	Time Required for 20 Readings (in seconds) Replication 1	2	3	4	Average: time per 20 readings	Rate of water penetration cc/cm²/min.
			Non-cultivated Plots			
Fertilizer	7,430	4,415	7,290	7,595	6,683	1.22
Lime-fertilizer	5,305	5,949	5,635	3,505	5,099	1.61
Lime-fertilizer-gypsum	5,880	5,600	4,475	5,202	5,289	1.55
			Cultivated Plots			
Fertilizer	11,910	6,238	6,845	7,140	8,033	1.02
Lime-fertilizer	12,400	6,460	4,515	4,080	6,864	1.19
Lime-fertilizer-gypsum	9,955	8,976	5,985	5,955	7,718	1.06
			Average of Cultivated and Non-cultivated Plots			
Fertilizer	9,670	5,327	7,068	7,368	7,358	1.11
Lime-fertilizer	8,853	6,205	5,075	3,793	5,982	1.37
Lime-fertilizer-gypsum	7,918	7,288	5,230	5,579	6,504	1.26

Table 12. A summary of the effects of cultivation (Aerifier) on the penetration rates of phosphorus into the sod of the Fairway Cultivation Study. 1949-1950.

Treatment	Pounds of P_2O_5 Per Acre				
	Replication				
	1	2	3	4	Average
		Spring, 1949			
Cultivation 0-2"					
Subplot 2	20	14	23	23	20.0
Subplot 3	18	13	32	22	21.3
Subplot 4	21	26	23	28	24.5
Average	19.7	17.7	26.0	24.3	21.9
No Cultivation 0-2"					
Subplot 2	15	27	22	15	19.8
Subplot 3	25	27	21	17	22.5
Subplot 4	25	20	18	19	20.5
Average	21.7	24.7	20.3	17.0	20.9
Cultivation 2-4"					
Subplot 2	7	6	7	6	6.5
Subplot 3	7	9	9	7	8.0
Subplot 4	5	7	10	7	7.3
Average	6.3	7.3	8.7	6.7	7.3
No Cultivation 2-4"					
Subplot 2	5	10	8	4	6.8
Subplot 3	5	7	8	6	6.5
Subplot 4	6	11	11	3	7.8
Average	5.3	9.3	9.0	4.3	7.0
Cultivation 4-6"					
Subplot 2	11	4	3	6	6.0
Subplot 3	5	4	5	8	5.5
Subplot 4	4	6	9	9	7.0
Average	6.7	4.7	5.7	7.7	6.2
No Cultivation 4-6"					
Subplot 2	7	6	5	6	6.0
Subplot 3	4	6	6	6	5.5
Subplot 4	4	8	6	4	5.5
Average	5.0	6.7	5.7	5.3	5.7

(Continued)

Table 12. (Continued)

Treatment	Pounds of P_2O_5 Per Acre				
	Replication				
	1	2	3	4	Average
		Fall, 1949			
Cultivation 0-2"					
Subplot 2	15	30			22.5
Subplot 3	13	30			21.5
Subplot 4	28	45			36.5
Average	18.7	35.0			26.9
No Cultivation 0-2"					
Subplot 2	15	6			10.5
Subplot 3	13	35			24.0
Subplot 4	4	33			18.5
Average	10.7	24.7			17.7
Cultivation 2-4"					
Subplot 2	6	6			6.0
Subplot 3	6	3			4.5
Subplot 4	22	5			13.5
Average	11	5			8.0
No Cultivation 2-4"					
Subplot 2	6	7			6.5
Subplot 3	5	8			6.5
Subplot 4	5	16			10.5
Average	5.3	10.3			7.8
Cultivation 4-6"					
Subplot 2	6	6			6.0
Subplot 3	5	5			5.0
Subplot 4	4	6			5.0
Average	5.0	5.7			5.4
No Cultivation 4-6"					
Subplot 2	3	4			3.5
Subplot 3	2	5			3.5
Subplot 4	2	8			5.0
Average	2.3	5.7			4.0

(Continued)

Table 12. (Continued)

Treatment	Pounds of P_2O_5 Per Acre				
	Replication				
	1	2	3	4	Average
		Spring, 1950			
Cultivation 0-2"					
Subplot 2	35	28	37	35	33.8
Subplot 3	42	32	35	70	44.8
Subplot 4	47	70	55	60	58.0
Average	41.3	43.3	42.3	55.0	45.5
No Cultivation 0-2"					
Subplot 2	21	30	37	42	32.5
Subplot 3	30	50	65	70	53.8
Subplot 4	32	29	55	60	44.0
Average	27.7	36.3	52.3	57.3	43.4
Cultivation 2-4"					
Subplot 2	9	9	10	9	9.3
Subplot 3	8	9	7	10	8.5
Subplot 4	7	7	14	16	11.0
Average	8.0	8.3	10.3	11.7	9.6
No Cultivation 2-4"					
Subplot 2	6	9	13	5	8.3
Subplot 3	7	9	11	16	10.8
Subplot 4	8	15	16	11	12.5
Average	7.0	11.0	13.3	10.7	10.5
Cultivation 4-6"					
Subplot 2	6	4	7	4	5.3
Subplot 3	7	11	6	6	7.5
Subplot 4	6	3	8	6	5.8
Average	6.3	6.0	7.0	5.3	6.2
No Cultivation 4-6"					
Subplot 2	4	6	10	4	6.0
Subplot 3	3	5	9	8	6.3
Subplot 4	4	8	4	5	5.3
Average	3.7	6.3	7.7	5.7	5.9

(Continued)

Table 12. (Concluded)

Treatment	Pounds of P_2O_5 Per Acre				
	Replication				
	1	2	3	4	Average
		Fall, 1950			
Cultivation 0-2"					
Subplot 2	24	60	70	60	53.2
Subplot 3	70	38	55	90	63.3
Subplot 4	40	55	50	70	53.8
Average	44.3	51.0	58.3	73.3	56.7
No Cultivation 0-2"					
Subplot 2	37	55	55	55	50.5
Subplot 3	32	50	70	60	53.0
Subplot 4	70	70	90	70	75.0
Average	46.3	58.3	71.7	61.7	59.5
Cultivation 2-4"					
Subplot 2	6	11	18	16	12.8
Subplot 3	6	14	21	21	15.5
Subplot 4	9	11	11	12	10.8
Average	7.0	12.0	16.7	16.3	13.0
No Cultivation 2-4"					
Subplot 2	11	20	11	10	13.0
Subplot 3	13	13	17	17	15.0
Subplot 4	7	8	17	20	13.0
Average	10.3	13.6	15.0	15.7	13.8
Cultivation 4-6"					
Subplot 2	6	8	10	7	7.6
Subplot 3	4	7	8	4	5.8
Subplot 4	12	9	15	9	11.3
Average	7.3	8.0	11.0	6.7	8.3
No Cultivation 4-6"					
Subplot 2	8	9	10	6	8.3
Subplot 3	5	16	8	12	10.3
Subplot 4	8	9	13	15	11.3
Average	7.0	11.3	10.3	11.0	9.9

Table 14. The effect of fertilizer, lime, and gypsum treatment on the available phosphorus content of soil samples taken at three depths of the Fairway Cultivation Study. 1949-1950.

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
		Spring, 1949			
Subplot 1					
Cultivated 0-2"	10	26	30	17	20.8
Uncultiv. 0-2"	9	21	12	13	13.8
Average	9.5	23.5	21.0	15.0	17.3
Subplot 2					
Cultivated 0-2"	20	14	23	23	20.0
Uncultiv. 0-2"	15	27	22	15	19.8
Average	17.5	20.5	22.5	19.0	19.9
Subplot 3					
Cultivated 0-2"	18	13	32	22	21.3
Uncultiv. 0-2"	25	27	21	17	22.5
Average	21.5	20.0	26.5	19.5	21.9
Subplot 4					
Cultivated 0-2"	21	26	23	28	24.5
Uncultiv. 0-2"	25	20	18	19	20.5
Average	23.0	23.0	20.5	23.5	22.5
Subplot 1					
Cultivated 2-4"	10	8	5	9	8.0
Uncultiv. 2-4"	6	8	5	6	6.3
Average	8.0	8.0	5.0	7.5	7.1
Subplot 2					
Cultivated 2-4"	7	6	7	6	6.5
Uncultiv. 2-4"	5	10	8	4	6.8
Average	6.0	8.0	7.5	5.0	6.6

(Continued)

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (in lbs.) Replication 1	2	3	4	Average
	Spring, 1949 (Continued)				
Subplot 3					
Cultivated 2-4"	7	9	9	7	8.0
Uncultiv. 2-4"	5	7	8	6	6.5
Average	6.0	8.0	8.5	6.5	7.3
Subplot 4					
Cultivated 2-4"	5	7	10	7	7.3
Uncultiv. 2-4"	6	11	11	3	7.8
Average	5.5	9.0	10.5	5.0	7.5
Subplot 1					
Cultivated 4-6"	6	6	4	5	5.3
Uncultiv. 4-6"	4	5	5	4	4.5
Average	5.0	5.5	4.5	4.5	4.9
Subplot 2					
Cultivated 4-6"	11	4	3	6	6.0
Uncultiva. 4-6"	7	6	5	6	6.0
Average	9.0	5.0	4.0	6.0	6.0
Subplot 3					
Cultivated 4-6"	5	4	5	8	5.5
Uncultiv. 4-6"	4	6	6	6	5.5
Average	4.5	5.0	5.5	7.0	5.5
Subplot 4					
Cultivated 4-6"	4	6	9	9	7.0
Uncultiv. 4-6"	4	8	6	4	5.5
Average	4.0	7.0	7.5	6.5	6.3

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
		Fall, 1949			
Subplot 1					
Cultivated 0-2"	13	23			18.0
Uncultiv. 0-2"	25	15			20.0
Average	19.0	19.0			19.0
Subplot 2					
Cultivated 0-2"	15	30			22.5
Uncultiva. 0-2"	15	6			10.5
Average	15.0	18.0			16.5
Subplot 3					
Cultivated 0-2"	13	30			21.5
Uncultiv. 0-2"	13	35			24.0
Average	13.0	32.5			21.7
Subplot 4					
Cultivated 0-2"	28	45			36.5
Uncultiv. 0-2"	4	33			18.5
Average	16.0	39.0			27.5
Subplot 1					
Cultivated 2-4"	6	6			6.0
Uncultiv. 2-4"	6	4			5.0
Average	6.0	5.0			5.5
Subplot 2					
Cultivated 2-4"	6	6			6.0
Uncultiv. 2-4"	6	7			6.5
Average	6.0	6.5			6.3

(Continued)

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
	Fall, 1949 (Continued)				
Subplot 3					
Cultivated 2-4"	6	3			4.5
Uncultiv. 2-4"	5	8			6.5
Average	5.5	5.5			5.5
Subplot 4					
Cultivated 2-4"	22	5			13.5
Uncultiv. 2-4"	5	16			10.5
Average	13.5	10.5			12.0
Subplot 1					
Cultivated 4-6"	6	4			5.0
Uncultiv. 4-6"	4	6			5.0
Average	5.0	5.0			5.0
Subplot 2					
Cultivated 4-6"	6	6			6.0
Uncultiv. 4-6"	3	4			3.5
Average	4.5	5.0			4.3
Subplot 3					
Cultivated 4-6"	5	5			5.0
Uncultiv. 4-6"	2	5			3.5
Average	3.5	5.0			4.3
Subplot 4					
Cultivated 4-6"	4	6			5.0
Uncultiv. 4-6"	2	8			5.0
Average	3.0	7.0			5.0

(Continued)

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
	Spring, 1950				
Subplot 1					
Cultivated 0-2"	13	20	23	14	17.5
Unculti v. 0-2"	2	13	12	12	9.8
Average	7.5	16.5	17.5	13.0	13.6
Subplot 2					
Cultivated 0-2"	35	28	37	35	33.8
Unculti v. 0-2"	21	30	37	42	32.5
Average	28.0	29.0	37.0	38.5	33.1
Subplot 3					
Cultivated 0-2"	42	32	35	70	44.8
Unculti v. 0-2"	30	50	65	70	53.8
Average	36.0	41.0	50.0	70.0	49.3
Subplot 4					
Cultivated 0-2"	47	70	55	60	58.0
Unculti v. 0-2"	32	29	55	60	44.0
Average	39.5	49.5	55.0	60.0	51.0
Subplot 1					
Cultivated 2-4"	10	5	8	6	7.3
Unculti v. 2-4"	3	8	4	1	4.0
Average	6.5	6.5	6.0	3.5	5.6
Subplot 2					
Cultivated 2-4"	9	9	10	9	9.3
Unculti v. 2-4"	6	9	13	5	8.3
Average	7.5	9.0	11.5	7.0	8.8

(Continued)

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
Spring, 1950 (Continued)					
Subplot 3					
Cultivated 2-4"	8	9	7	10	8.5
Uncultiv. 2-4"	7	9	11	16	10.8
Average	7.5	9.0	9.0	13.0	9.6
Subplot 4					
Cultivated 2-4"	7	7	14	16	11.0
Uncultiv. 2-4"	8	15	16	11	12.5
Average	7.5	11.0	15.0	13.5	11.8
Subplot 1					
Cultivated 4-6"	7	6	3	6	5.5
Uncultiv. 4-6"	3	9	5	4	5.3
Average	5.0	7.5	4.0	5.0	5.4
Subplot 2					
Cultivated 4-6"	6	4	7	4	5.3
Uncultiv. 4-6"	4	6	10	4	6.0
Average	5.0	5.0	8.5	4.0	5.6
Subplot 3					
Cultivated 4-6"	7	11	6	6	7.5
Uncultiv. 4-6"	3	5	9	8	6.3
Average	5.0	8.0	7.5	7.0	6.9
Subplot 4					
Cultivated 4-6"	6	3	8	6	5.8
Uncultiv. 4-6"	4	8	4	5	5.3
Average	5.0	5.5	6.0	5.5	5.5

(Continued)

Table 14. (Continued)

Treatment	Available P_2O_5 Per Acre (In lbs.)				
	Replication				
	1	2	3	4	Average
Fall, 1950					
Subplot 1					
Cultivated 0-2"	10	16	22	16	16.0
Uncultiv. 0-2"	6	16	9	16	11.8
Average	8.0	16.0	15.5	16.0	13.9
Subplot 2					
Cultivated 0-2"	24	60	70	60	53.5
Uncultiv. 0-2"	37	55	55	55	50.5
Average	30.5	57.5	62.5	57.5	52.0
Subplot 3					
Cultivated 0-2"	70	38	55	90	63.3
Uncultiv. 0-2"	32	50	70	60	53.0
Average	51.0	44.0	62.5	75.0	58.1
Subplot 4					
Cultivated 0-2"	40	55	50	70	53.8
Uncultiv. 0-2"	70	70	90	70	75.0
Average	55.0	62.5	70.0	70.0	64.4
Subplot 1					
Cultivated 2-4"	4	8	6	10	7.0
Uncultiv. 2-4"	6	9	4	9	7.0
Average	5.0	8.5	5.0	9.5	7.0
Subplot 2					
Cultivated 2-4"	6	11	18	16	12.8
Uncultiv. 2-4"	11	20	11	10	13.0
Average	8.5	15.5	14.5	13.0	12.9

(Continued)

Table 14. (Concluded)

Treatment	Available P_2O_5 Per Acre (in lbs.)				
	Replication				
	1	2	3	4	Average
	Fall, 1950 (Concluded)				
Subplot 3					
Cultivated 2-4"	6	14	21	21	15.5
Uncultiv. 2-4"	13	13	17	17	15.0
Average	9.5	13.5	19.0	19.0	15.3
Subplot 4					
Cultivated 2-4"	9	11	11	12	10.8
Uncultiv. 2-4"	7	8	17	20	13.0
Average	8.0	9.5	14.0	16.0	11.9
Subplot 1					
Cultivated 4-6"	4	6	5	3	4.5
Uncultiv. 4-6"	4	6	2	8	5.0
Average	4.0	6.0	3.5	5.5	4.8
Subplot 2					
Cultivated 4-6"	6	8	10	7	7.8
Uncultiv. 4-6"	8	9	10	6	8.3
Average	7.0	8.5	10.0	6.5	8.0
Subplot 3					
Cultivated 4-6"	4	7	8	4	5.8
Uncultiv. 4-6"	5	16	8	12	10.3
Average	4.5	11.5	8.0	8.0	8.0
Subplot 4					
Cultivated 4-6"	12	9	15	9	11.3
Uncultiv. 4-6"	8	9	13	15	11.3
Average	10.0	9.0	14.0	12.0	11.3

Table 16. The effect of lime application on the soil pH of the Fairway Cultivation Study. 1949-1950.

Treatment	Soil pH Replication 1	2	3	4	Average
Spring, 1949					
Cultivated Plots					
Subplot 1 (0-2")	5.2	6.2	5.8	6.0	5.80
Subplot 2 (0-2")	5.2	5.8	5.8	6.0	5.70
Subplot 3 (0-2")	5.6	6.0	6.3	6.6	6.13
Subplot 4 (0-2")	5.9	6.4	6.2	6.5	6.25
Subplot 1 (2-4")	5.3	6.3	5.9	5.8	5.83
Subplot 2 (2-4")	5.3	5.9	6.0	6.0	5.80
Subplot 3 (2-4")	5.3	5.8	6.0	6.0	5.78
Subplot 4 (2-4")	5.7	6.0	6.0	6.3	6.00
Subplot 1 (4-6")	5.5	6.2	5.8	5.7	5.80
Subplot 2 (4-6")	5.5	5.6	5.8	5.9	5.70
Subplot 3 (4-6")	5.4	5.8	5.9	5.8	5.73
Subplot 4 (4-6")	5.6	5.9	5.9	5.9	5.83
Non-Cultivated Plots					
Subplot 1 (0-2")	5.4	6.2	5.9	6.0	5.88
Subplot 2 (0-2")	5.5	6.0	5.8	6.0	5.83
Subplot 3 (0-2")	6.0	6.2	6.2	6.2	6.15
Subplot 4 (0-2")	6.1	6.1	6.1	6.5	6.20
Subplot 1 (2-4")	5.5	6.3	5.9	6.2	5.98
Subplot 2 (2-4")	5.5	6.2	5.9	6.1	5.93
Subplot 3 (2-4")	5.8	6.1	6.1	6.0	6.00
Subplot 4 (2-4")	5.9	6.2	5.9	6.2	6.05
Subplot 1 (4-6")	5.6	6.2	5.9	5.9	5.90
Subplot 2 (4-6")	5.5	6.2	5.9	5.9	5.88
Subplot 3 (4-6")	5.9	6.0	6.0	6.0	5.98
Subplot 4 (4-6")	5.9	6.0	5.9	6.0	5.95

(Continued)

Table 16. (Continued)

Treatment	Soil pH				
	Replication				
	1	2	3	4	Average
Fall, 1949					
Cultivated Plots					
Subplot 1 (0-2")	5.3	6.1			5.70
Subplot 2 (0-2")	5.2	5.5			5.35
Subplot 3 (0-2")	5.3	5.9			5.60
Subplot 4 (0-2")	6.0	6.2			6.10
Subplot 1 (2-4")	5.3	6.2			5.75
Subplot 2 (2-4")	5.3	5.4			5.35
Subplot 3 (2-4")	5.3	5.5			5.40
Subplot 4 (2-4")	5.9	5.9			5.90
Subplot 1 (4-6")	5.5	6.2			5.85
Subplot 2 (4-6")	5.5	5.5			5.50
Subplot 3 (4-6")	5.4	5.6			5.50
Subplot 4 (4-6")	5.8	5.7			5.75
Non-Cultivated Plots					
Subplot 1 (0-2")	6.1	6.3			6.20
Subplot 2 (0-2")	5.9	5.8			5.85
Subplot 3 (0-2")	5.1	6.2			5.65
Subplot 4 (0-2")	5.0	6.6			5.80
Subplot 1 (2-4")	6.0	6.4			6.20
Subplot 2 (2-4")	5.9	6.0			5.95
Subplot 3 (2-4")	5.2	6.2			5.70
Subplot 4 (2-4")	5.2	6.5			5.85
Subplot 1 (4-6")	6.0	6.5			6.25
Subplot 2 (4-6")	5.8	6.0			5.90
Subplot 3 (4-6")	5.4	6.0			5.70
Subplot 4 (4-6")	5.4	6.4			5.90

(Continued)

Table 16. (Continued)

Treatment	Soil pH				
	Replication				
	1	2	3	4	Average
			Spring, 1950		
			Cultivated Plots		
Subplot 1 (0-2")	5.4	6.2	5.9	6.2	5.93
Subplot 2 (0-2")	5.2	5.5	5.7	5.8	5.55
Subplot 3 (0-2")	5.8	5.9	6.1	6.5	6.08
Subplot 4 (0-2")	6.1	6.1	6.4	6.4	6.30
Subplot 1 (2-4")	5.4	6.3	5.9	6.3	5.98
Subplot 2 (2-4")	5.3	5.5	5.9	5.9	5.65
Subplot 3 (2-4")	5.4	5.8	5.8	6.2	5.80
Subplot 4 (2-4")	5.7	5.9	6.4	6.3	6.08
Subplot 1 (4-6")	5.6	6.3	5.9	6.2	6.00
Subplot 2 (4-6")	5.5	5.6	6.0	5.8	5.73
Subplot 3 (4-6")	5.6	5.8	5.8	5.9	5.78
Subplot 4 (4-6")	5.8	5.8	6.2	6.0	5.95
			Non-Cultivated Plots		
Subplot 1 (0-2")	5.2	6.2	6.0	6.0	5.85
Subplot 2 (0-2")	5.4	6.1	5.7	6.1	5.83
Subplot 3 (0-2")	6.1	6.3	6.3	6.5	6.30
Subplot 4 (0-2")	6.1	6.4	6.1	6.4	6.25
Subplot 1 (2-4")	5.5	6.2	6.2	6.0	5.98
Subplot 2 (2-4")	5.5	6.2	5.9	6.3	5.98
Subplot 3 (2-4")	6.1	6.2	6.2	6.4	6.23
Subplot 4 (2-4")	6.0	6.4	5.9	6.0	6.08
Subplot 1 (4-6")	5.6	6.2	6.3	5.9	6.00
Subplot 2 (4-6")	5.5	6.1	5.9	6.2	5.93
Subplot 3 (4-6")	6.1	6.1	6.3	6.3	6.20
Subplot 4 (4-6")	5.9	6.2	5.9	5.9	5.98

(Continued)

Table 16. (Concluded)

Treatment	Soil pH Replication 1	2	3	4	Average
	Fall, 1950				
	Cultivated Plots				
Subplot 1 (0-2")	5.3	6.2	5.8	6.2	5.88
Subplot 2 (0-2")	5.1	5.6	5.9	5.7	5.58
Subplot 3 (0-2")	6.1	6.0	6.2	6.7	6.25
Subplot 4 (0-2")	6.2	6.1	6.2	6.4	6.23
Subplot 1 (2-4")	5.4	6.4	5.8	6.3	5.98
Subplot 2 (2-4")	5.2	5.6	5.9	6.0	5.68
Subplot 3 (2-4")	5.5	5.9	6.1	6.4	5.98
Subplot 4 (2-4")	5.9	6.0	6.1	6.3	6.08
Subplot 1 (4-6")	5.6	6.5	5.8	6.2	6.03
Subplot 2 (4-6")	5.4	5.7	5.8	5.9	5.70
Subplot 3 (4-6")	5.7	5.8	6.0	6.0	5.88
Subplot 4 (4-6")	6.0	5.9	5.8	6.0	5.93
	Non-Cultivated Plots				
Subplot 1 (0-2")	5.3	6.3	5.9	5.9	5.85
Subplot 2 (0-2")	5.3	6.4	5.5	5.9	5.78
Subplot 3 (0-2")	6.1	6.4	6.2	6.5	6.30
Subplot 4 (0-2")	6.2	6.4	6.2	6.3	6.28
Subplot 1 (2-4")	5.5	6.4	6.1	6.0	6.00
Subplot 2 (2-4")	5.4	6.5	5.9	6.1	5.98
Subplot 3 (2-4")	6.2	6.4	6.2	6.3	6.28
Subplot 4 (2-4")	6.0	6.4	5.9	6.2	6.13
Subplot 1 (4-6")	5.7	6.4	6.1	6.0	6.05
Subplot 2 (4-6")	5.6	6.4	6.0	6.1	6.03
Subplot 3 (4-6")	6.0	6.3	6.0	6.2	6.13
Subplot 4 (4-6")	5.9	6.2	5.9	5.9	5.98

Table 17. Soil air space and soil volume weights determined for turf receiving different amounts of cultivation in the Frequency of Cultivation Study. November, 1950.

Cultivation Treatment	Replication 1	2	3	4	Average
	Per Cent Air Space				
None	20.2	25.3	23.8	23.6	23.2
Two per year	19.0	21.1	23.7	23.4	21.8
Six per year	21.0	21.9	23.5	19.5	21.5
	Volume Weight				
None	1.518	1.439	1.441	1.482	1.47
Two per year	1.501	1.500	1.434	1.498	1.48
Six per year	1.490	1.489	1.455	1.520	1.49

Table 18. Rootgrowth, topgrowth, and thatch determinations made on cultivated and non-cultivated plots of the Fairway Cultivation Study. October, 1950.

Cultivation Treatment	Replication				Average
	1	2	3	4	
	Grams of Topgrowth per 40 Samples				
Cultivation	7.86	8.11	6.60	9.53	8.03
No Cultivation	7.73	6.97	7.24	7.30	7.31
	Grams of Thatch per 40 Samples				
Cultivation	68.28	47.83	62.96	35.64	53.68
No Cultivation	64.69	53.76	37.63	43.31	49.85
	Grams of Roots per 40 Samples				
Cultivation	7.24	8.57	5.84	7.36	7.25
No Cultivation	6.90	6.86	6.46	6.59	6.70