CHAPTER 1

THE EFFECT OF SAMPLING DEPTH AND THATCH ON SOIL TEST RESULTS FROM TURFGRASS AREAS

Test Areas and Laboratory Procedures

Several turfgrass areas with known fertility histories were sampled for soil testing to study the effects of sampling depth, thatch, soil modification, and various management practices on soil test results. These areas were located at the Joseph Valentine Turfgrass Research Center at The Pennsylvania State University, University Park, Pennsylvania. The areas sampled included the 1966 Nitrogen Source Test, the Penncross Fertility Test, the Soil Modification Plots, and the 1971 Nitrogen Source Test.

The fertility status of all soil samples was determined by chemical tests as outlined by Hinish (1974); however, slight modifications of these basic procedures were used for specific sets of samples. Soil samples were generally air dried, crushed, and sieved through a 2-mm screen. Mineral and organic matter not passing through the screen was discarded. Scoops were then used to take an assumed weight of 5.0 g soil for pH and buffer pH (pH-B) determinations, 3.57 g soil for phosphorus determinations, and 2.5 g soil for calcium, magnesium, and potassium determinations. Chemical tests consisted of determining pH using a 1:1 soil-water paste; pH-B (from which lime requirement is calculated) using Woodruff's solution in the soil to solution ratio of 1:2; phosphorus using Bray P1 solution in the soil to extracting solution ration of 1:7; and calcium, magnesium, and potassium using

1N NH_4OAc buffered at pH 7.0 in the soil to extracting solution ratio of 1:10.

1966 Nitrogen Source Test

This test represented a study of eight nitrogen sources applied in split and single applications at several rates. The experimental design of the test was a randomized complete-block with three replications. The area was established to 'Merion' Kentucky bluegrass (*Poa pratensis* L.) on Hagerstown silt loam soil. No lime was applied to the area after its establishment. Mowing of the turf occurred once weekly at a height of 3.1 cm with clippings removed. Moberg, Waddington, and Duich (1970) reported on the treatments and the maintenance of this test area.

Methods and Materials. Plots fertilized with IBDU (isobutylidene diurea), Uramite (ureaform), Ures (urea-parafin product), Milorganite (activated sewage sludge), urea, and a complete fertilizer having 2/3 of the nitrogen from ureaform (18-6-12 UF) were sampled in August, 1973, for soil testing, as were the check plots (Table 1). With the exception of the phosphorus in the Milorganite treatment, phosphorus and potassium applications were made in the N-P-K ratio of 6.9-1.0-3.8 for all treatments sampled. Samples were taken at depths of 0 - 5, 5 - 10, and 10 - 15 cm with the soil surface considered to begin at the soil-thatch layer interface. Soil fertility values (pH, pH-B, phosphorus, potassium, calcium, and magnesium levels, cation exchange capacity, and the percent saturation of the individual cations) were determined for each of the samples to study the effects of previous

Table 1. Treatments from the 1966 Nitrogen Source Test sampled for soil testing.

Nitrogen Source	Annual Rate of Application		
	N	P +	K ≠
	kg/100 m^2		
18-6-12 UF	2.44(2)*	0.35	1.36
18-6-12 UF	1.44(2)	0.21	0.80
IBDU	2.44(2)	0.35	1.36
IBDU	1.44(2)	0.21	0.80
IBDU	1.44(1)	0.21	0.80
Uramite	2.44(2)	0.35	1.36
Urex	2.44(2)	0.35	1.36
Milorganite	2.44(3)	0.53	1.36
Urea	1.44(9)	0.21	0.80
Check	---	---	---

* Numbers in parentheses are the number of applications per year made to apply the listed amount of nitrogen.

\+ P applied including that contained in nitrogen source.

≠ K applied including that contained in nitrogen source.

fertilization and sampling depth on soil test results. Analysis of variance was computed for soil fertility values with sources of variation being fertilizer treatment and sampling depth.

Results and Discussion. Soil test results are shown in Table 2. The significance of F-ratios for the analysis of variance is indicated in Table 33.

Soil test results for samples taken from this test showed a general trend of decreasing fertility values with depth. P levels, Mg levels, and Mg saturation steadily decreased with depth. K levels, K saturation, and CEC were higher in the surface 5 cm than in the lower two depths. This accumulation of nutrients nearer the surface could have been the result of the relatively slow downward movement through the soil of the surface applied nutrients, and of higher levels of organic matter near the surface increasing the CEC with a subsequent increase in adsorbed nutrients.

Conflicting results, however, were obtained for Ca levels and Ca saturation. Ca saturation increased rather than decreased with depth, while Ca levels showed an increasing, but nonsignificant, trend with depth. These results may be at least partially explained by the lack of any lime being applied to the area since its establishment. Greater plant uptake in the upper 5 cm due to a more extensive root system near the surface, coupled with a lack of lime applications, could have resulted in a depletion of Ca near the surface and the subsequent trend of increasing Ca and Ca saturation with depth.

The pH also increased with depth, while the pH-B was higher in the 10 - 15 cm range than in the upper 10 cm. Increasing pH with

Table 2. The influence of sampling depth on soil test results from the 1966 Nitrogen Source Test.

	Soil Test Results									
Depth	pH	pH-B	P	K	Mg	Ca	CEC	K	Mg	Ca
cm			kg/ha	meq/100 g				% saturation		
0- 5	6.7 c*	6.8 b	160 a	0.49 a	1.9 a	7.4 a	11.7 a	4.2 a	16.7 a	63.0 c
5 - 10	6.8 b	6.8 b	131 b	0.31 b	1.2 b	7.7 a	10.9 b	2.9 b	11.2 b	71.2 b
10 - 15	6.9 a	6.9 a	102 c	0.29 b	0.9 c	7.8 a	10.4 b	2.8 b	9.4 c	75.2 a

* Means in each column not followed by the same letter are significantly different at the 5 percent level of probability.

depth could be explained by a combination of increasing base saturation with depth (due to increasing Ca saturation) and to decreasing amounts of organic matter. Increasing pH-B with depth could also have resulted from higher levels of organic matter near the surface, with the organic matter contributing more to the buffer capacity of the soil than the other colloidal materials.

Despite these significant trends of soil fertility values with depth, change in fertilizer recommendations due to sampling depth based upon The Pennsylvania State University system was minimal.[1] P recommendations for this area were not affected by sampling depth, despite P levels being 56 kg/ha higher in the surface of 5 cm than in the 10 - 15 cm range. Lime recommendations were 24 kg/100m^2 higher for the surface 5 cm than for the lower depths. K recommendations were 0.4 kg K/100m^2 lower for the surface 5 cm than for the lower depths. However, due to the minimizing of differences in potassium saturation with depth caused by changes in CEC, soil testing programs which base K fertilizer recommendations on K levels rather than on K saturation may have larger differences in recommendations with sampling depth.

With the exception of a sampling depth x treatment interaction for P levels, interactions did not occur between sampling depth and treatments for soil fertility values. No consistent trend of treatment effect on P levels with sampling depth was noticeable (Table 3). An

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[1]This system based phosphorus recommendations on ranges of phosphorus as measured in lb/A, potassium recommendations on ranges of potassium saturation, and lime recommendations on a combination of pH and pH-B. Phosphorus, potassium, and lime recommendations were made in lb/1000 ft^2 of P_2O_5, K_2O, and $CaCO_3$ equivalent respectively. Values were converted in these discussions to kg/100m^2.

Table 3. The influence of fertilizer treatment on soil phosphorus levels at different sampling depths.

Nitrogen Source	Annual Application		Soil Phosphorus			
			Sampling Depth (cm)			
	N	P	0 - 5	5 - 10	10 - 15	Avg.
	kg/100m^2		kg/ha			
18-6-12 UF	2.44(2)*	0.35	176	150	106	144
18-6-12 UF	1.44(2)	0.21	168	125	96	130
IBDU	2.44(2)	0.35	131	124	91	115
IBDU	1.44(2)	0.21	149	109	88	115
IBDU	1.44(1)	0.21	139	109	88	112
Uramite	2.44(2)	0.35	147	143	116	135
Urex	2.44(2)	0.35	165	133	118	139
Milorganite	2.44(3)	0.53	203	160	104	156
Urea	1.44(9)	0.21	124	128	106	119
Check	--	--	195	131	102	143

* Numbers in parentheses are the number of applications per year made to apply the listed amount of nitrogen.

unexpected trend did develop, however, with the check treatment, which had received no P. P levels were higher in the surface 5 cm for the check treatment than for all other treatments except the Milorganite treatment. This may have been the result of no N being applied to the check plots, which greatly reduced turfgrass growth thus limiting the amounts of P removed from the soil. However, in the 5 - 10 and 10 - 15 cm sampling depths, approximately half of the treatments had higher P levels than the check treatment. This result could be an indication of greater removal of P by the turfgrass plant in the upper 5 cm of soil.

Soil Modification Plots

This area represented a continuing study on the effect of types of soil amendments, level of soil modification, compaction, and aerification on soil physical and chemical properties. Eighty-one soil mixtures with different levels of soil, peat, and various amendments were included in the study. The specific materials used in the soil mixtures were Hagerstown silt loam topsoil, reed-sedge peat, coarse sand, mortar sand, concrete sand, blast furnace slag (US Steel slag and Wunderley slag), Perl-lome (perlite), Turface (calcined clay), and Fertl-soil (a commercial soil mixture). Experimental design of the area was a split-plot randomized complete-block with three replications. Soil mixtures represented main plots, with main plots split into compaction and aerification treatments. This 'Penncross' creeping bentgrass (*Agrostis palustris* Huds.) area received putting green management, with fertilizer applied in the N-P-K ratio of 4.6-1.0-1.9 for the years 1962-1974. Nitrogen applications were approximately 5.8 kg/100m^2 in the early years of the test, while being reduced to approximately 2.9 $kg/100m^2$ in the following years. No lime was applied after the establishment of the area. Waddington et al. (1974) reported in detail on the materials used in this study, and on the establishment and maintenance of the area.

Methods and Materials. In September, 1974, five soil mixtures representing different levels of soil modification with sand were sampled in all compaction and aerification subplots at the following depths:

0-3.8 cm plus thatch
0-3.8 cm
3.8-7.6 cm
7.6-11.4 cm
11.4-15.2 cm.

The five mixtures contained 0, 40, 50, 60, or 80% coarse sand, 20% peat, and the remainder soil. Soil fertility values were determined for all samples to study the effects of the level of soil modification, sampling depth, thatch, compaction, and aerification on soil test results. Analysis of variance was computed for soil test results with sources of variation being soil mixture, compaction treatment, aerification treatment, and sampling depth. Samples including thatch were analyzed as a fifth sampling depth.

Results and Discussion. Soil test results are shown in Table 4. The significance of F-ratios for the analysis of variance is indicated in Table 34.

The general trend of soil fertility values with sampling depth for this area were similar to the 1966 Nitrogen Source Test. P levels, Mg levels, Mg saturation, and CEC steadily decreased with depth.

Table 4. The influence of sampling depth and thatch on soil test results of five soil mixtures from the Soil Modification Plots.

	Soil Test Results									
Depth	pH	pH-B	P	K	Mg	Ca	CEC	K	Mg	Ca
cm			kg/ha	meq/100 g				% saturation		
0- 3.8 plus thatch	6.7 b*	6.8 a	140 a	0.20 a	2.1 a	7.9 a	12.2 a	1.6 a	18.0 a	64.7d
0- 3.8	6.8 a	6.9 a	132 a	0.11 b	2.0 a	7.8 a	11.4 b	0.9 b	18.2 a	67.9 c
3.8- 7.6	6.9 a	6.9 a	81 b	0.10 c	1.8 b	7.7 a	11.1 bc	0.9 b	16.6 b	69.2 bc
7.6-11.4	6.9 a	6.9 a	49 c	0.10 c	1.6 c	7.6 a	10.6 c	0.9 b	15.9 c	71.0 ab
11.4-15.2	6.9 a	6.9 a	36 d	0.10 c	1.5 d	7.6 a	10.5 c	0.9 b	14.8 d	71.5 a

* Means in each column not followed by the same letter are significantly different at the 5 percent level of probability.

Again, possibly higher levels of organic matter near the surface and the relatively slow downward movement of surface applied P could explain these results. Although Ca levels showed a nonsignificant decreasing trend with depth, Ca saturation once again increased with depth due to a decrease in CEC with depth.

K levels were slightly higher in the surface 3.8 cm than the lower depths, while K saturation was not affected by sampling depth. Much larger differences for both values occurred in the 1966 Nitrogen Source Test. K levels decreased by .18 meq/100g soil from the surface 5 cm to the 5 - 10 cm depth in the 1966 Nitrogen Source Test, while only decreasing by .01 meq/100g soil from the surface 3.8 cm to the lower depths in the Soil Modification Plots. Decreases in K saturation from the surface 5 cm to the 5 - 10 cm depth in the 1966 Nitrogen Source Test were highly significant. Two factors could have accounted for these differences. First, less K in relation to the amount of N was applied to the Soil Modification Plots. Fertilizer was applied in the N:K ratio of 1.8:1 on the 1966 Nitrogen Source Test, and of 2.4:1 on the Soil Modification Plots. Also, the Soil Modification Plots and 1966 Nitrogen Source Test were established to bentgrass and Kentucky bluegrass respectively. Bentgrass generally is considered more efficient in soil K extraction. Therefore, more of the applied K on the Soil Modification Plots may have been used by the turf, resulting in less accumulation of applied K near the surface. Second, the Soil Modification Plots were irrigated more frequently than the 1966 Nitrogen Source Test. Also, the five soil mixtures sampled contained from 0 to 80% added sand by volume, while the soil of the 1966 Nitrogen

Source Test hád no added sand. Therefore, greater leaching of K near the surface in the Soil Modification Plots may have occurred, with smaller differences between the surface depth and lower depths resulting.

Although pH was slightly lower in the surface 3.8 cm than at the lower depths, the difference was nonsignificant. The pH-B was not affected by sampling depth. Both pH and pH-B were significantly affected by sampling depth in the 1966 Nitrogen Source Test. However, the differences between the two areas in pH and pH-B with sampling depth are probably of little practical importance.

Lime and K recommendations were not affected by sampling depth. However, P recommendations were 0.2 kg P/100m^2 lower for the surface 3.8-7.6-11.4 cm than for the 3.8-7.6-11.4 cm ranges, and were 0.4 kg P/100m^2 lower for the surface 3.8 cm than for the 11.4-15.2 cm range. In the 1966 Nitrogen Source Test, lime and K recommendations were affected by sampling depth, while P recommendations were not.

Ordinarily, The Pennsylvania State University soil testing program recommends that thatch be removed from the soil sample before it is analyzed. However, thatch is a surface layer composed primarily of organic matter which may also be intermixed with soil. Fertilizer is surface applied to established turfgrass areas; therefore, nutrients that are available for plant growth may accumulate or be trapped in the thatch layer. To establish whether such an accumulation had taken place, the same five soil mixtures in the Soil Modification Plots were sampled at a depth of 0-3.8 cm with thatch included in the samples. Routine soil test procedures were followed. Soil test results for these samples were compared to samples taken from the same depth but with thatch removed before testing.

Although most soil fertility values were not greatly affected, certain values were significantly affected by the inclusion of thatch with the sample (Table 4). P levels, Mg levels, and Mg saturation were not affected by the inclusion of thatch with the sample. The pH was slightly lower when thatch was included, although pH-B was not significantly affected. Ca levels were not affected by the inclusion of thatch, but Ca saturation was lower. Lowering of Ca saturation when thatch was included in the sample could have been due to the same factors that caused saturation to increase with sampling depth.

The greatest effects from the inclusion of thatch were on CEC, K levels, and K saturation. All of these values were significantly higher in samples containing thatch. Increases in CEC could be attributed to increases in organic matter content contributed by the thatch layer. Increases in K and K saturation could be the result of a combination of two factors. First, K had to move through the thatch layer since it had been surface applied, resulting in greater accumulation in this layer than at lower depths. Second, increased CEC contributed by the organic matter in the thatch layer increased the total amount of applied K adsorbed.

P recommendations were not affected by the inclusion of thatch with the soil sample. However, lime recommendations were 24 $kg/100m^2$ higher and K recommendations were 1.2 kg $k/100m^2$ lower for samples including thatch. Similar differences might be expected in systems basing K recommendations upon actual K levels rather than upon K saturation, since both K levels and K saturation increased by nearly the same factor when thatch was included in the sample.

When samples including thatch were analyzed as a fifth sampling depth, interactions between soil mixture and sampling depth occurred for K and P levels. The soil mixture x sampling depth interaction on K levels was highly significant, but appeared to be primarily the result of a soil mixture x thatch interaction (Figure 1). For all mixtures, K levels were greater in samples containing thatch. However, as the amount of soil in the mixture increased (or the amount of sand decreased), the actual and relative increases in K contributed by the thatch became greater. Three factors may have contributed to this effect. First, the mixtures with higher sand contents had greater infiltration rates, resulting in greater movement of water through these mixtures. Greater movement of water through these mixtures could have resulted in greater leaching of K, with lower levels of K resulting. Second, increasing amounts of sand in the soil mixtures resulted in lower CEC. This would result in lower levels of adsorbed K. Since the thatch layer generally consists of a mixture of thatch and soil, differences in K levels for samples containing thatch versus those without thatch would be increasingly greater the lower the sand content of the soil was. Finally, due to the lower levels of K in the sandier mixtures, more K may have been removed by the plant from the thatch layer relative to other depths in the sandier mixtures resulting in smaller differences between samples with and without thatch.

The soil mixture x sampling depth interaction on P levels was also highly significant. Ranking of the five mixtures for P levels

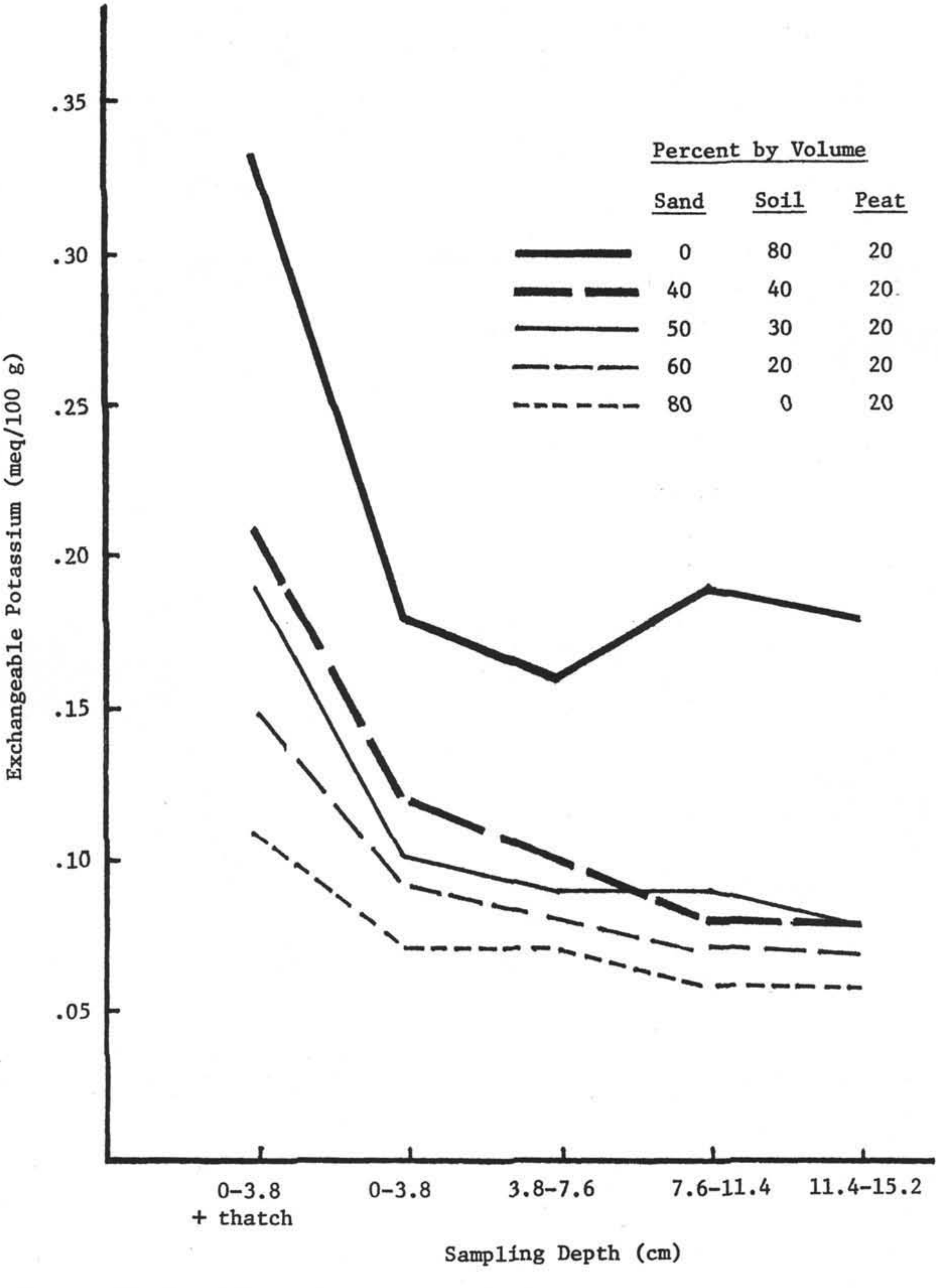

Figure 1. The effect of soil mixture and sampling depth on exchangeable potassium.

changed depending on the sampling depth (Figure 2). The only apparent trend was a nearly complete reversal of the rankings of the five mixtures for P levels for the 0-3.8 cm plus thatch sample versus the 11.4-15.2 cm sample. Evidently, as the level of accumulation near the surface of the surface applied P decreased, the level of P accumulating in the lower depths increased. Only the mixture with 80 percent sand and no soil failed to follow this trend, being lowest in P in the 0-3.8 cm plus thatch sample, while being ranked in the middle rather than the highest in the 11.4-15.2 cm sample.

Significant interactions occurred between sampling depth and compaction treatment for pH and P levels. However, no trends were apparent, with differences in values being so small as to be of no practical importance. Significant interactions also occurred between sampling depth and aerification treatments for pH, pH-B, and Ca saturation. Once again, differences in values were of no practical importance.

Penncross Fertility Test

This test represented a continuing study on nitrogen, phosphorus, and potassium fertilization. Five nitrogen sources, four phosphorus rates, and three potassium rates were included in the study. Experimental design of the test was a split-plot randomized complete-block with three replications. The study was divided into two major tests:

(1) The nitrogen-potassium test (started in 1966) - Nitrogen sources represented main plots, which were split into three subplots representing potassium

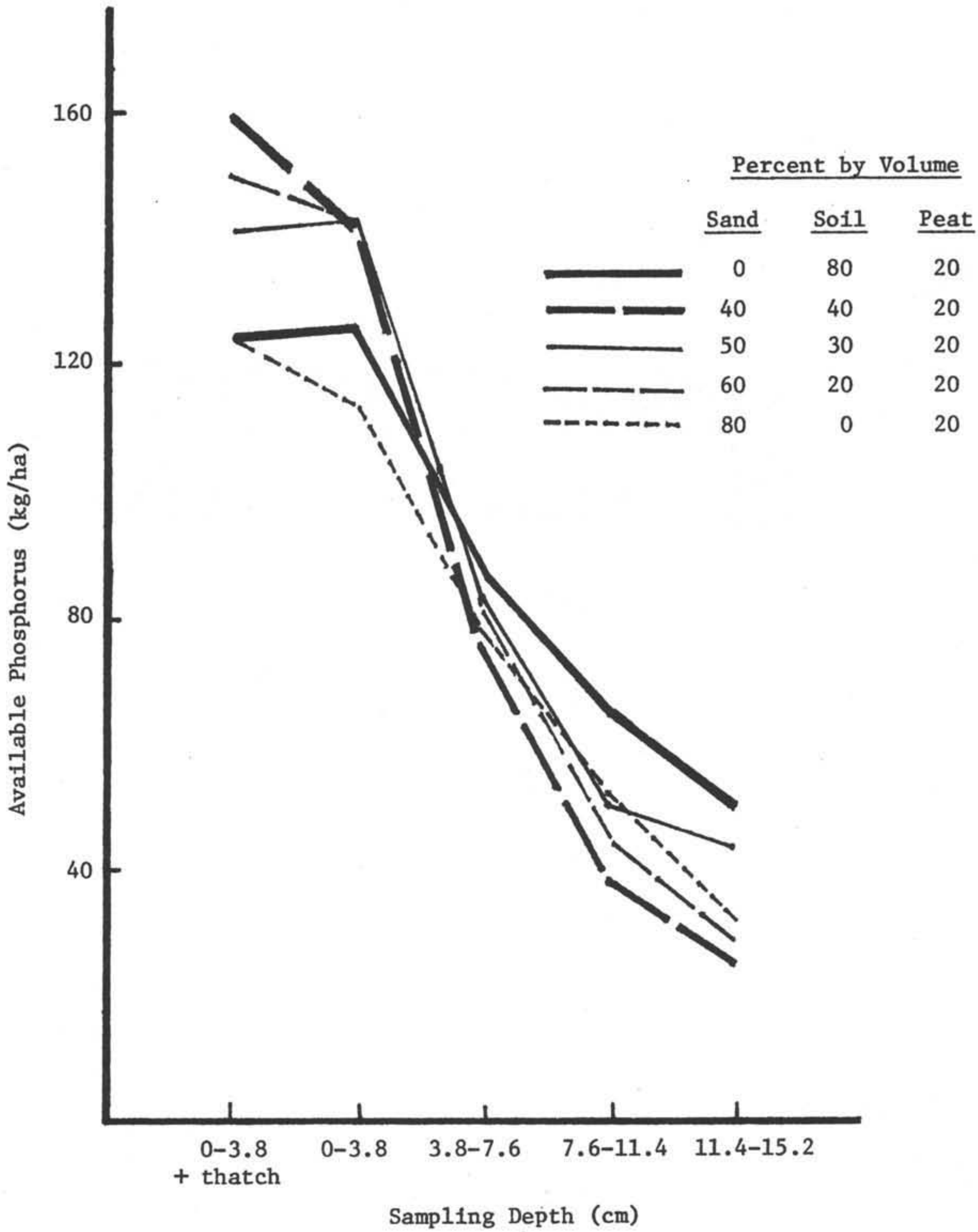

Figure 2. The effect of soil mixture and sampling depth on available phosphorus.

levels. Nitrogen sources used were urea, Milorganite (activated sewage sludge), Agrinite (processed tankage), and Nitroform and Uramite (ureaforms). Nitrogen rates averaged 3.6 kg/100m^2 per season from 1966 to the spring of 1969, and 2.4 kg/100m^2 per season from the fall of 1969 through the fall of 1974. Potassium rates were 0, 1.2, and 2.4 kg K/100m^2 per season from 1966 to the spring of 1969, and 0, 0.75, and 1.50 kg K/100m^2 per season from the fall of 1969 through the fall of 1974. No phosphorus was applied to the nitrogen-potassium test except that contained in Milorganite, which had a N-P-K analysis of 5.5-1.3-0.

(2) The phosphorus-potassium test (started in 1970) - Phosphorus levels represented main plots, which were split into three subplots representing the same potassium applications as in the nitrogen-potassium test from the fall of 1969 through the fall of 1974. Phosphorus rates were 0, 0.48, 0.96, and 1.92 kg P/100m^2 per season. Nitrogen was applied in the form of Nitroform at the rate of 2.4 kg/100m^2 per season.

The entire area, established in 1960 on unmodified Hagerstown silt loam soil, consisted of 'Penncross' creeping bentgrass maintained as putting green turf. No lime was applied to the area after its establishment. Waddington et al., (1972) reported on the establishment and maintenance of the area.

Methods and Materials. Soil samples were taken to study the effects of previous fertilization, sampling depth, and thatch on soil test results. In September, 1973, all plots in the nitrogen-potassium test were sampled at depths of 0 - 5 and 5 - 10 cm, while all plots in the phosphorus-potassium test were sampled at depths of 0 - 5 cm plus thatch, 0 - 5 cm, and 5 - 10 cm. Soil fertility values were determined for all samples. Analysis of variance was computed for soil test results with sources of variation being nitrogen source, potassium rate, and sampling depth for the nitrogen-potassium test, and phosphorus rate, potassium rate, and sampling depth for the phosphorus-potassium test. Samples including thatch were analyzed as a third sampling depth.

Results and Discussion. Soil test results for the N-K and P-K tests are shown in Tables 5 and 6 respectively. The significance of F-ratios for the analysis of variance are indicated in Tables 35 and 36 respectively.

Compared to the 1966 Nitrogen Source Test and Soil Modification Plots, conflicting results were found for several soil test values from the Penncross Fertility Test. CEC, K values, and K saturation increased rather than decreased with sampling depth in both the N-K and P-K tests. These conflicting results could best be explained by the addition of a sandy topdressing mixture to the originally unmodified soil for a period of fifteen years. This practice resulted in soil of a sandy loam texture with 53.5% sand in the surface 5 cm, while the 5 - 10 cm range of soil was a silty clay loam with only 16.6% sand (Table 7). The higher sand and lower clay content near the surface

Table 5. The effect of sampling depth on soil test results from the nitrogen-potassium (N-K) test.

	Soil Test Results									
Depth	pH	pH-B	P	K	Mg	Ca	CEC	K	Mg	Ca
cm			kg/ha	meq/100 g				% saturation		
0 - 5	7.0 a*	6.9 a	32 b	0.12 b	1.9 a	7.5 a	10.2 b	1.2 b	19.7 a	74.1 a
5 - 10	6.9 b	6.9 a	46 a	0.18 a	1.8 b	7.6 a	10.8 a	1.6 a	16.7 b	70.4 a

* Means in each column not followed by the same letter are significantly different at the 5 percent level of probability.

Table 6. The effect of sampling depth and thatch on soil test results from the phosphorus-potassium (P-K) test.

	Soil Test Results									
Depth	pH	pH-B	P	K	Mg	Ca	CEC	K	Mg	Ca
cm			kg/ha	meq/100 g				% saturation		
0 - 5 plus thatch	7.0 b*	6.9 b	109 a	0.16 b	1.8 a	8.1 ab	10.8 a	1.4 a	17.3 a	75.4 b
0 - 5	7.1 a	7.0 a	104 a	0.12 c	1.7 b	7.8 b	10.0 b	1.3 b	17.7 a	78.9 a
5 - 10	6.9 b	6.9 b	80 b	0.17 a	1.7 b	8.3 a	11.5 a	1.5 a	14.8 b	72.8 b

* Means in each column not followed by the same letter are significantly different at the 5 percent level of probability.

Table 7. Particle-size distribution and textural class at two depths in the Penncross Fertility Test.

	Percent by Weight *							
Depth cm	Very Coarse Sand 2.0-1.0 mm	Coarse Sand 1.0-.50 mm	Medium Sand .50-.25 mm	Fine Sand .25-.10 mm	Very Fine Sand .10-.05 mm	Silt .05-.002 mm	Clay <.002 mm	Textural Class
0 - 5	13.0	22.6	5.9	7.6	4.4	28.7	17.8	sandy loam
5 - 10	4.1	6.6	1.3	1.7	2.9	55.6	27.8	silty clay loam

* Determined using method of Bouyoucos (1962).

caused a lower CEC in the upper 5 cm. However, a higher organic matter level near the surface was probably the reason that differences in CEC with depth were smaller than might have been expected. Lower K levels and K saturation in the surface 5 cm probably was the result of the combined effect of lower CEC and possible greater nutrient removal near the surface.

The effect of sampling depth on P levels was dependent on previous phosphorus fertilization. P values increased with depth on the N-K test, which had not received P applications, and decreased with depth on the P-K test, which had received P applications. Apparently, P uptake by the turfgrass plant was greatest in the surface 5 cm, resulting in a depletion near the surface when no P was applied. When plant requirements were met by P fertilization, excess P accumulated near the surface.

Ca, Mg, and Mg saturation were the only soil test values showing similar trends as in the 1966 Nitrogen Source Test and the Soil Modification Plots. Mg levels decreased slightly with depth in the N-K test, while not changing with depth in the P-K test. Mg saturation decreased with depth in both tests. Ca levels and Ca saturation were not affected by sampling depth in the N-K test. However, in the P-K test Ca levels were lower and Ca saturation was higher in the upper 5 cm.

Lime and fertilizer recommendations were not greatly affected by sampling depth in the Penncross Fertility Test. In both the N-K and P-K tests, lime and P recommendations were the same for both sampling depths. K recommendations were the same for both sampling depths in the P-K test; however, in the N-K test, K recommendations were 0.2 kg K/100m^2 higher for the upper 5 cm.

The effect of the inclusion of thatch with the soil sample on soil test results from the P-K test were similar results to the results for the Soil Modification Plots. P levels , Ca levels, and Mg saturation were not affected. Inclusion of thatch caused a slight increase in Mg values and a slight decrease in pH and pH-B. The Ca saturation was lower in samples which included thatch. The inclusion of thatch resulted in an increase in CEC similar to that in the Soil Modification Plots; however, increases in K values and K saturation were smaller. Although K fertilizer recommendations were 1.2 kg K/100m^2 lower for samples including thatch in the Soil Modification Plots, recommendations for K were not affected in the P-K test. Lime and P recommendations also were not affected by the inclusion of thatch with the soil sample.

Rate of K fertilization and depth of sampling had an interacting effect on K values and K saturation in both the N-K and P-K tests. In the N-K test (Figure 3), increased rates of K fertilization resulted in increased levels of K at both depths. At the two lower rates of K fertilization, there was little difference between the 0 - 5 and 5 - 10 cm depths for K; however, at the highest rate of K fertilization, there was a relatively large increase in K from the 0 - 5 to the 5 - 10 cm depth. Evidently, plant requirements were exceeded only at the highest rate of K fertilization, which caused the accumulation in the soil. Due to the higher sand content, lower CEC, and possibly greater root activity in the surface 5 cm, the accumulation of K occurred to a greater degree in the 5 - 10 cm range.

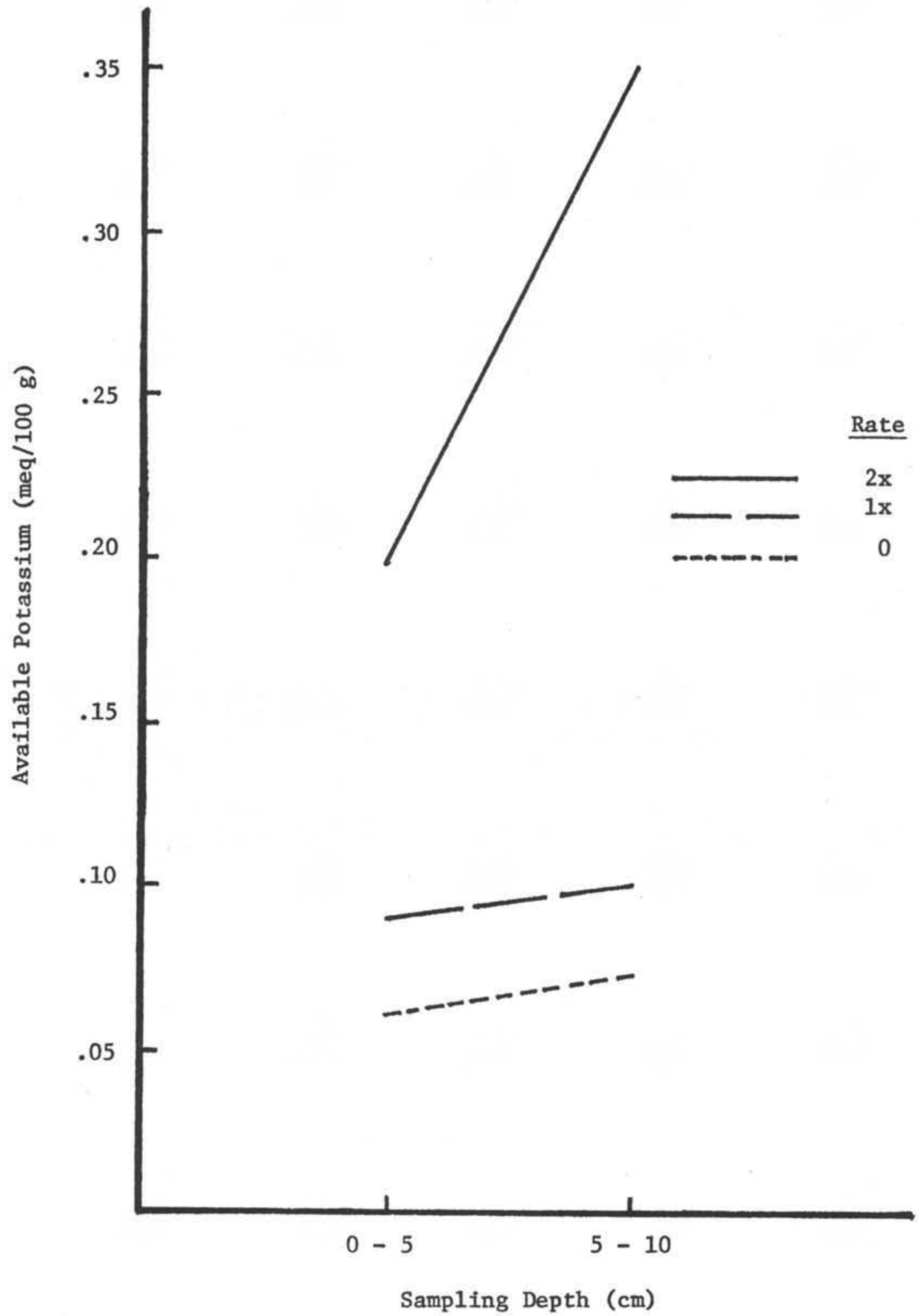

Figure 3. The effect of potassium rate and sampling depth on available potassium (N-K test).

In the P-K test (Figure 4), samples including thatch were analyzed as a third sampling depth. For all sampling depths, as rate of K fertilization increased, the level of K in the soil increased. In plots receiving no K there was little difference between sampling depths for K levels. At the lower rate of fertilization, K was higher in samples containing thatch than in the other two sampling depths. However, at the highest rate of fergilization, K was much higher in the 5 - 10 cm range than in the other two sampling depths. Once again, plant requirements were probably being exceeded only at the highest rate of K fertilization, with the resultant soil accumulation occurring in the 5 - 10 cm depth.

Penncross Fertility and 1971 Nitrogen Source Tests

Inclusion of thatch with soil samples taken from the Soil Modification Plots and Penncross Fertility Test affected several soil test values, particularly K levels, K saturation, and CEC. However, these samples were crushed and sieved through a 2-mm screen, the normal laboratory procedure. As a result, much of the thatch material was sieved from the samples before they were chemically analyzed. To determine the contribution thatch could make on soil fertility values when it was not sieved from the soil sample, duplicate samples were taken from specific treatments of the Penncross Fertility Test and the 1971 Nitrogen Source Test. Since one of the primary effects of thatch in the previous tests was on K, chemical tests were restricted to measuring potassium.

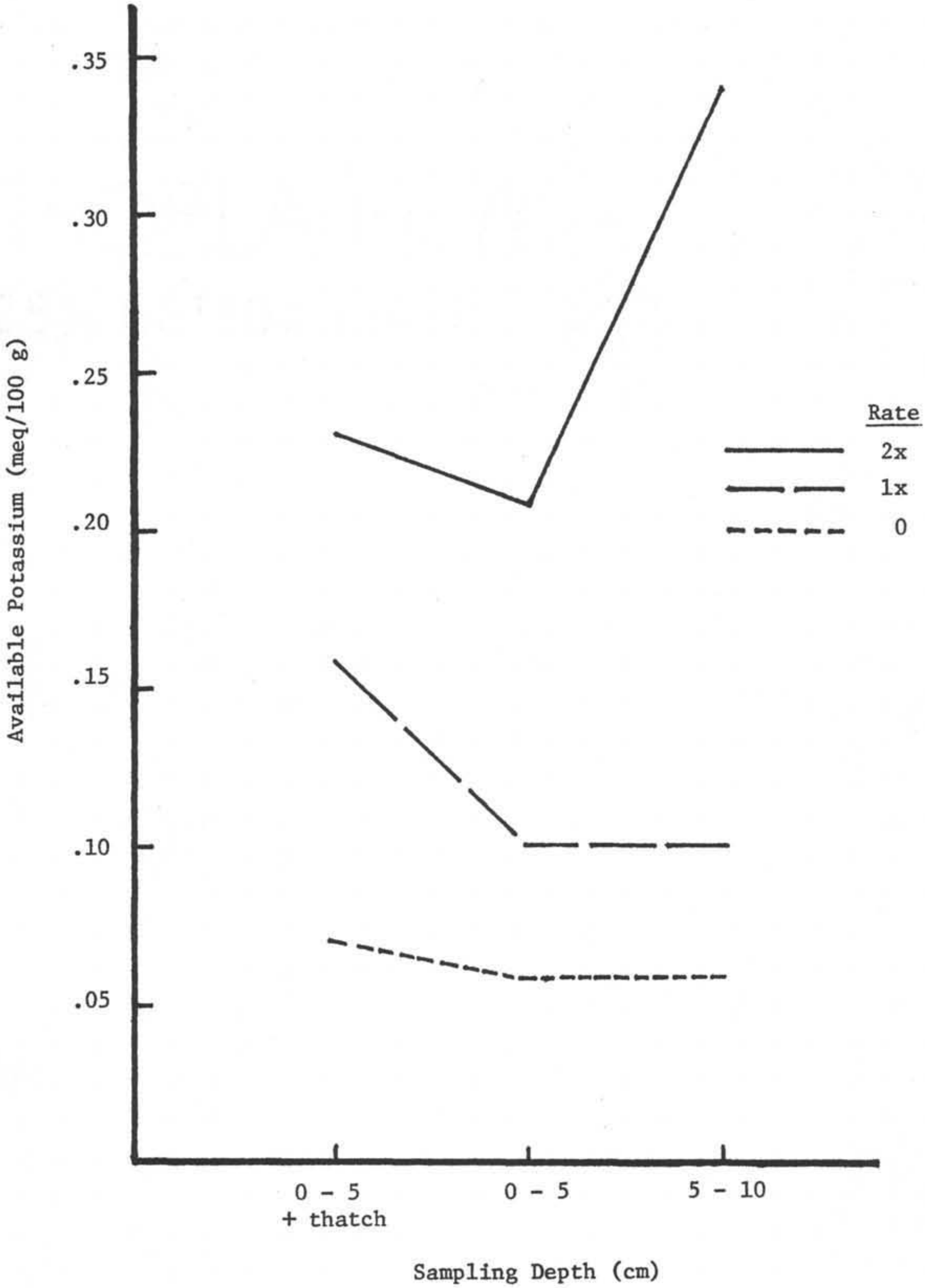

Figure 4. The effect of potassium rate and sampling depth on available potassium (P-K test).

The Penncross Fertility Test was described in the preceding section. Duplicate soil samples were taken in April, 1975, from the Nitroform plots in the nitrogen-potassium test for all levels of potassium. Samples were taken at a depth of 0 - 5 cm plus thatch and were air dried. Half of the duplicate samples had soil and thatch crushed together and were sieved through a 2-mm screen. Mineral and organic matter not passing through the screen was discarded. Weighed rather than scooped 2.5 g samples of the sieved material were then tested for potassium. Soil and thatch were separated in the other half of the duplicate samples, with both the soil and thatch fractions being weighed. Each fraction was crushed but only the soil fraction was sieved. After sieving through a 2-mm screen, a weighed 2.5 g sample of the soil was tested for potassium. The entire unsieved thatch fraction was also tested for potassium, with a soil to extracting solution ratio of 1:10 being maintained. Using the separately determined potassium values for soil and thatch, values for soil plus thatch samples were calculated based upon the previously measured weight ratio of soil to thatch. These calculated values represented levels that might have been expected if the thatch material had not been partially sieved out of the soil plus thatch sample. Analysis of variance was computed for potassium levels with type of sample and potassium rate being sources of variation.

The 1971 Nitrogen Source Test, started in 1971 on a blend of four Kentucky bluegrass varieties ('Merion', 'Pennstar', 'Fylking', and 'Prato'), represented a study of twelve nitrogen sources. Experimental design was a randomized complete-block with three replications.

Three applications of 0.72 kg $N/100m^2$ were made each year for the years 1971 through 1974. The amount of phosphorus and potassium each plot received was dependent on the fertilizer ratio of the individual nitrogen sources. No lime was applied after establishment of the test. Mowing of the turf occurred twice weekly at a height of 3.2 cm, with clippings removed. Soil was Hagerstown silt loam.

To study the influence of thatch on potassium levels when the thatch was not sieved from the soil sample, duplicate samples were taken in April, 1975, from plots fertilized with materials having N-P-K analyses of 23-3.1-5.8, 16-3.5-6.6, and 30-0-0 (Table 8). Samples were taken at a depth of 0 - 5 cm plus thatch. The same procedure for preparing and testing these duplicate samples was used as for the duplicate samples taken from the Penncross Fertility Test in April, 1975. Analysis of variance was computed for potassium levels with type of sample and nitrogen source being the sources of variation.

Results and Discussion. Results for samples from the 1971 Nitrogen Source Test and the Penncross Fertility Test are shown in Table 9. As was the case in the previous tests, the inclusion of thatch with the soil sample increased K levels. However, the increases were significantly larger when thatch was not sieved from the sample. In the 1971 Nitrogen Source Test, when thatch was included in the sample but was sieved, K levels increased by a factor of 1.4. When thatch was included in the sample but was not sieved, K levels increased by a factor of 2.0. Similar results occurred in the Penncross Fertility Test. Although sieved soil plus thatch samples only increased K values by a factor of 1.1 over soil samples without thatch, soil plus thatch samples

Table 8. Treatments from the 1971 Nitrogen Source Test sampled for soil testing.

Fertilizer Analysis	Annual Rate of Application		
	N	P	K
— N-P-K —		$kg/100m^2$	
30-0-0	2.16(3)*	0.00	0.00
23-3.1-5.8	2.16(3)	0.29	0.55
16-3.5-6.6	2.16(3)	0.47	0.90

* Numbers in parenthesis are the number of applications per year made to apply the listed amounts of nitrogen.

Table 9. The effect of type of sample on exchangeable potassium in the Penncross Fertility Test and 1971 Nitrogen Source Test.

Type of Sample	Exchangeable Potassium: Penncross Fertility Test	Exchangeable Potassium: 1971 Nitrogen Source Test
	meq/100 g	
Soil	.14 b*	.26 c
Soil plus thatch +	.15 b	.37 b
Soil plus unsieved thatch ≠	.29 a	.52 a

* Means in each column not followed by the same letter are significantly different at the 5 percent level of probability.

\+ Entire soil plus thatch sample sieved through 2-mm screen.

≠ Soil sieved through 2-mm screen, thatch unsieved.

from which the thatch was not sieved increased K values by a factor of 2.1.

This probably occurred because the total amount of organic matter was highest in samples which included thatch which had not been sieved, and lowest in samples from which thatch was totally excluded. Intermediate amounts of organic matter were probably contained in samples which included thatch but which had been sieved. As the amount of thatch, and therefore organic matter, in the samples increased, a corresponding increase in CEC would be expected. An increase in CEC could have caused increases in K values.

In the 1971 Nitrogen Source Test, as the amount of K applied increased (indicated by an increase in K in relation to N in the fertilizer ratio), the levels of K in all samples increased (Table 10). Increasing K levels also occurred with increasing rates of K fertilization for all samples in the Penncross Fertility Test (Table 11). However, a significant interaction also occurred between type of sample and rate of K fertilization. As the rate of K fertilization increased, increases in K levels occurred to a greater extent in the soil plus unsieved thatch samples, indicating a greater accumulation of applied K in the thatch layer than at lower depths.

Summary and Conclusions.

The effects of sampling depth and thatch on soil test results were determined on several turfgrass areas with known fertility and management histories at the Joseph Valentine Turfgrass Research Center at The Pennsylvania State University. Soil fertility values determined included pH, buffer pH (pH-B), phosphorus,

Table 10. The influence of type of sample and fertilizer analysis on available potassium.

Type of Sample	Available Potassium — Fertilizer Analysis (N-P-K) 30-0-0	23-3.1-5.8	16-3.5-6.6
	meq/100 g		
Soil	0.17	0.25	0.37
Soil plus thatch *	0.31	0.36	0.44
Soil plus unsieved thatch +	0.40	0.53	0.64

* Entire soil plus thatch sample sieved through 2-mm screen.

\+ Soil sieved through 2-mm screen, thatch unsieved.

Table 11. The influence of type of sample and rate of potassium fertilization on available potassium.

	Available Potassium		
	Potassium Rate*		
Type of Sample	0	X	2X
	meq/100 g		
Soil	0.10	0.12	0.19
Soil plus thatch +	0.13	0.14	0.27
Soil plus unsieved thatch ≠	0.19	0.20	0.40

* For actual amounts of potassium applied, refer to Methods and Materials Section.

\+ Entire soil plus thatch sample sieved through 2-mm screen.

≠ Soil sieved through 2-mm screen, thatch unsieved.

potassium, calcium, magnesium, cation exchange capacity, and percents potassium, magnesium, and calcium saturation.

Sampling Depth. Soil samples were taken in 5 cm increments to a depth of 15 cm on the 1966 Nitrogen Source Test, in 3.8 cm increments to a depth of 15.2 cm on the Soil Modification Plots, and in 5 cm increments to a depth of 10 cm on the Penncross Fertility Test. All soil fertility values were significantly affected by sampling depth in at least one of the areas sampled. However, the magnitude and direction of change of these values appeared to be dependent on the past management of the area. Factors such as fertilization, topdressing, level of soil modification, and irrigation may have influenced the effect of sampling depth on soil test results.

On the 1966 Nitrogen Source Test, CEC, P, K, Mg, and percents K and Mg saturation decreased with sampling depth. The pH and pH-B increased with sampling depth. These results were probably due to higher levels of organic matter near the soil surface and to the relatively slow downward movement of surface applied P and K. On the Soil Modification Plots, CEC, P, Mg, and percent Mg saturation also decreased with sampling depth. However, pH, pH-B, and percent K saturation were not significantly affected by sampling depth, and K only decreased slightly with depth. Differences in grass species, soil texture, irrigation, and fertilizer ratio on these two areas may have contributed to smaller changes of K with sampling depth on the Soil Modification Plots.

The general trends exhibited for several soil fertility values on the 1966 Nitrogen Source Test and the Soil Modification Plots were not followed on the Penncross Fertility Test. CEC, K, and percent K saturation increased rather than decreased with depth, while pH and pH-B decreased with depth. These trends could be explained by the addition of a sandy topdressing mixture to the previously nonmodified soil of this area, resulting in a sandy loam texture in the surface 5 cm of soil and a silty clay loam texture in the 5 to 10 cm range. P values increased with depth on plots receiving no P, while values decreased with depth on plots receiving P applications.

Although all soil fertility values were significantly affected in at least one of the areas, current Pennsylvania State University fertilizer and lime recommendations for individual increments of soil (e.g. 0 - 5 and 5 - 10 cm) were generally not greatly affected. Therefore, small variations from recommended sampling depths would not be expected to have a great effect on fertilizer and lime recommendations.

Thatch. On the Soil Modification Plots, the inclusion of thatch with the soil sample decreased pH and increased CEC, K, and percent K saturation. K values were greater by a factor of 1.8 in samples containing thatch. The high organic matter content of thatch and the surface application of K may explain these results. Recommendations for the application of K and lime were 1.2 $kg/100m^2$ lower and 24 $kg/100m^2$ higher respectively for samples containing thatch. The effect of including thatch with the soil sample appeared to be dependent on the soil mixture. As the sand content of the soil mixtures decreased, the actual and relative increases in K contributed by the thatch became greater.

On the Penncross Fertility Test, the inclusion of thatch with the soil sample had similar effects. Lower pH and pH-B and higher CEC, Mg, K, and percent K saturation existed in samples containing thatch. However, in contrast to the Soil Modification Plots, K and lime recommendations were not affected by the inclusion of thatch with the soil sample.

During the standard laboratory preparation of the samples, much of the thatch material had been sieved from the samples. To study the actual contribution of thatch to K levels if thatch was not partially removed by the sieving procedure, soil samples including thatch were taken from the Penncross Fertility Test and the 1971 Nitrogen Source Test. K was determined for soil and thatch separately, with soil plus thatch values being calculated based on the measured weight ratios of soil to thatch. Soil plus unsieved thatch samples had K values greater than soil plus sieved thatch samples by factors of 1.4 to 1.9 and values greater than soil samples without thatch by factors of 2.0 to 2.1. Also, as the rate of K application increased on the Penncross Fertility Test, increases in measured K values occurred to a greater extent in the soil plus unsieved thatch samples than in the soil plus sieved thatch samples. Increases in K values were greater for both of these types of samples than for samples without thatch. Apparently, applied K was accumulating to a greater degree in the thatch layer than at lower depths.

Since CEC was higher and K apparently accumulates in the thatch layer, future research should determine whether significant nutrient removal is occurring from the thatch layer, and whether a soil sample which includes thatch would be more representative of the area's nutrient supplying ability than a sample without thatch.