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Effect of P, K, and Lime on Growth, Composition, and ^{32}P Absorption by Merion Kentucky Bluegrass[1]

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ABSTRACT

Information is needed concerning the effects of different soil fertility levels on the activity of turfgrass roots in that part of the soil profile sampled for routine soil tests. In Pennsylvania, a sampling depth of 5 to 7.5 cm is suggested for established turf. A study was conducted on 'Merion' Kentucky bluegrass (*Poa pratensis* L.) to determine relationships among lime, phosphorus, and potassium applications; soil test results; foliar growth and elemental analysis; and root activity as determined by ^{32}P uptake from three soil depths. In the field, soil pH values were 5.8 and 7.0, P ranged from 13 to 137 ppm, and K ranged from 0.14 to 0.43 meq./100g. Liming increased the Ca content in clippings from 0.35 to 0.42%. Phosphorus treatments increased P from 0.32 to 0.44%, and K was increased from 2.00 to 2.45% by K fertilization. Clipping yield was increased by P treatments. Sod plugs from the field were used in the greenhouse to determine root activity. Agar discs containing ^{32}P were placed at a depth of 1.3, 3.8, or 6.4 cm, and clippings were assayed for ^{32}P after 20 and 33 days. Shallow placement of ^{32}P resulted in more absorption. A soil P × depth interaction was found for ^{32}P absorption. A significant positive correlation between soil P and ^{32}P absorption was obtained for the 1.3 cm depth, whereas a nonsignificant correlation was found for the 6.4 cm placement. Results indicated that P enhanced rooting, and the magnitude of absorption from the 1.3-cm depth exemplified the need for P near the soil surface for optimum turf establishment.

Additional index words: Poa pratensis L., Turfgrass, Soil test, Fertilization, Radioisotope.

INFORMATION is needed concerning the effects of phosphorus and potassium on the activity of turfgrass roots in that part of the profile samples for routine soil tests. A depth of 5 to 7.5 cm is suggested for sampling in Pennsylvania for established turf because for most turfgrasses the majority of the root sytem is located near the soil surface. However, there is limited documentation of the root activity within this zone.

Traditionally, experiments in turf use foliar color, growth, and elemental composition to determine response to fertilization. These measurements assess the plant response above ground which may or may not reflect the response of the root system. Evaluations of the fertilizer effects on rooting are difficult. Many different techniques have been utilized to assess rooting, but most of them determined the weight or volume of roots, or observed their pattern of growth (3, 6, 8, 13). Volume, weight, and distribution of roots provide useful information, but none of these measurements necessarily reflect the activity or absorptive capacity of the root system. Tracer techniques with ^{32}P have been used to measure the absorptive capacity of plants (2, 4, 10, 12, 15), and it was concluded that this isotope satisfactorily reflected the absorptive capacity of the species involved and was judged to provide accurate information as to the soil zones from which absorption was most rapid.

The objectives of the work reported here were: 1) to determine the effects of lime, P, and K treatments on soil test results and tissue analyses and 2) to determine the zone of maximum root absorption for 'Merion' Kentucky bluegrass (*Poa pratensis* L.) as affected by P, K, and liming.

MATERIALS AND METHODS

In September 1969, a soil fertility test area was established on Hagerstown clay loam (fine, mixed, mesic Typic Hapludalf) at University Park, Pa. The area was seeded to Merion Kentucky bluegrass.

Limestone and P were applied to three replications in a split block design, and main plots (3.66 × 7.62 m) were split for K treatments. Rates were as follows: 0 and 54 kg limestone/100 m^2 in seedbed designated as L_1 and L_2, respectively); 0, 0.85, 1.7, 3.4, and 6.8 kg P/100 m^2 (P_1, P_2, P_3, P_4, P_5) as normal superphosphate with P_3, P_4, and P_5 in the seedbed and P_2 applied to established turf (May 1970); and 0, 1.45, 2.9, and 5.8 kg K/100 m^2 (K_1, K_2, K_3, K_4) as KCl applied to established turf over the period 1970-1973. Limestone and superphosphate applied prior to seeding were incorporated to a soil depth of approximately 10 cm. Nitrogen fertilization with ureaform averaged 2.5 kg N/100 m^2/season.

In November 1974, the area was sampled to determine soil test values, clipping yields, chemical analyses of clippings, and root activity. The only K treatments included in the sampling were K_1 and K_4.

Soil was sampled at three depth increments: 0 to 2.5, 2.5 to 5, and 5 to 7.5 cm, which are designated as D_1, and D_2 and D_3. The pH was determined using a 1:1 soil-water paste. Phosphorus was extracted with Bray P_1 solution, and K, Mg, and Ca were extracted with neutral, 1 *N* NH_4OAc.

Clipping yields from 3.6 m^2 were obtained by mowing one swath across each plot. Clippings were retained and dried for chemical analysis by emission spectrometry (1).

Three sod plugs (7.5 cm in diam and with 7.5 cm soil depth) were taken to a greenhouse for root absorption studies. Plugs were sliced at a depth of 1.3, 3.8, or 6.4 cm (the midpoints of D_1, D_2 and D_3); an agar disc containing ^{32}P was inserted at the sliced depth; and the plugs were placed in plastic-coated cartons. The agar discs were prepared by mixing $H_3{}^{32}PO_4$ with agar (15 g agar to 1 liter of water), pouring 30 ml into a styrofoam cup, and allowing the agar to solidify. The discs were 7.5 cm in diam and 0.6 cm thick, and contained 23.5 μCi of ^{32}P. Twenty days after placement of the agar discs, the grass was cut at 1.3 cm and weighed. After the clippings were dried at 70 C for 24 hours, 50 mg of dry tissue was ashed at 400 C, fixed to a planchet with five drops of glycerin, and counted using standard techniques. Thirteen days after the initial harvest, a second harvest was treated in the same manner. Plugs were watered as needed throughout the greenhouse experiment.

Data were analyzed using analysis of variance, and means were compared using Duncan's L.S.D. test with K = 100 (14).

RESULTS AND DISCUSSION

Field Results

Lime and fertilizer applications caused significant differences in soil test levels (Table 1). Soil pH increased from 5.8 to 7.0. Phosphorus fertilization in-

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Table 1. Effect of P, K, and lime treatments and sampling depth on soil test results.

Soil test value	Lime		P					K		Soil depth		
	L_1	L_2	P_1	P_2	P_3	P_4	P_5	K_1	K_4	D_1	D_2	D_3
pH	5.8 b†	7.0 a	6.4 a	6.4 a	6.4 a	6.4 a	6.4 a	6.4 a	6.3 b	6.3 c	6.4 b	6.5 a
P (ppm)	59 a	51 a	13 d	22 d	38 c	65 b	137 a	56 a	54 a	55 b	61 a	50 c
K (% satn)	2.8 a	2.8 a	2.8 a	2.6 a	3.0 a	2.8 a	2.8 a	1.4 b	4.2 a	3.3 a	2.6 b	2.5 b
Mg (% satn)	5.0 a	4.7 b	5.3 a	4.9 ab	5.0 ab	4.8 b	4.2 c	4.9 a	4.8 b	5.7 a	4.7 b	4.2 c
Ca (% satn)	48.7 b	84.5 a	65.8 a	67.0 a	63.9 a	68.5 a	67.6 a	69.0 a	64.2 b	63.0 c	66.4 b	70.3 a
CEC (meq/100 g)	10.1 a	10.1 a	9.8 a	10.0 a	10.2 a	10.0 a	10.4 a	9.9 b	10.3 a	10.5 a	10.2 b	9.6 c

† Means for lime, P, K, and soil depth treatments followed by the same letter are not significantly different.

Table 2. Effect of treatments on soil test results at three depths.

Soil depth	Lime		P					K	
	L_1	L_2	P_1	P_2	P_3	P_4	P_5	K_1	K_4
cm	meq Ca/100 g		ppm P					meq K/100 g	
0 -2.5	5.0	8.2	14	24	36	58	144	0.18	0.52
2.5-5.0	4.7	8.8	14	22	42	79	148	0.13	0.39
5.0-7.5	5.1	8.2	12	21	36	58	120	0.11	0.37
Avg.	4.9 b	8.4 a	13 d	22 d	38 c	65 b	137 a	0.14 b	0.43 a

creased the Bray P_1 extractable P from 13 to 137 ppm, and K increased the exchangeable K from 0.14 to 0.43 meq/100 g soil. Significant differences also occurred with sampling depth.

A K treatment × soil depth interaction ($P = 0.01$) occurred because the decrease in soil K with depth was greater when K fertilizer was applied (Table 2). The higher K near the surface on the unfertilized plots (K_1) could possibly be attributed to contributions from plant tissue and the slightly higher cation exchange capacity near the surface. Lime × depth ($P = 0.05$) and P × depth ($P = 0.01$) were other significant interactions near the surface. Except for the no P and the surface applied P_2 treatments, soil test P was greatest at the 2.5 to 5.0 cm depth. The effect of the surface applied P_2 treatment was apparent throughout the entire sampling depth. Calcium on the limed plots was also highest at 2.5 to 5.0 cm. The reason for higher Ca and P at 2.5 to 5.0 cm was not apparent. The lime and P had been applied 5 years prior to this sampling, and available levels of both Ca and P in the soil decreased over this period. Previous soil tests were not taken at different depths, ~~because~~ and it could not be ascertained whether the differences were present after lime and P incorporation or whether differential uptake and P fixation could have been involved.

Average elemental concentrations in the clippings were as follows: P, 0.37%; K, 2.22%; Ca, 0.38%; Mg, 0.17%; Mn, 49 ppm; Fe, 84 ppm; Cu, 13 ppm; B, 8 ppm; Al, 24 ppm; Zn, 36 ppm; and Na, 33 ppm. Treatments P_1, through P_5 gave P concentrations of 0.32, 0.35, 0.36, 0.38, and 0.44% respectively, with all differences being significant except 0.35 and 0.36. Potassium fertilization increased K from 2.00 to 2.45% and decreased Ca (0.42 to 0.34%), Mg (0.18 to 0.15%), Mn (53 to 46 ppm), Zn (38 to 34 ppm), and Na (42 to 25 ppm). Liming increased Ca (0.35 to 0.42%), but decreased Mn (54 to 44 ppm) and Zn (39 to 33 ppm). Other differences were small in magnitude or nonsignificant.

[a] *, ** Significant at the 0.05 and 0.01 levels, respectively; NS = not significant.

In the field, turf fertilized at the three highest P rates outyielded the 0 and 0.85 kg P/100 m² rates (Table 3); however, yields for P rates ranging from 1.7 to 6.8 kg P/100 m² were not significantly different. It has been previously shown that increased P levels caused increased top growth of Merion Kentucky bluegrass (5, 7). King and Skogley (8) found that the turf quality and growth differences from P treatments imposed during turf establishment were inconsistent, generally lasting only a few months; however, a growth response was still apparent after 5 years on our test area. Soil test values for P were highly correlated with added P ($r = 0.99$) and foliar P ($r = 0.98$); however, yields did not reflect the incremental increases in soil P ($r = 0.69$; not significant at 0.05).

There were no significant differences in clipping yields in the field due to liming or K fertilization.

Greenhouse Results

Yield. As in the field, P significantly influenced clipping yields (Table 3). On the first clipping date, only turf fertilized at P_5 outyielded that at P_1. By the second clipping date (33 days after placement in the greenhouse) both P_4 and P_5 outyielded P_1. When yields for the two harvest dates were combined and represented a longer growing period, all turf fertilized with P outyielded unfertilized turf. Correlation between soil P and yield was improved over field results ($r = 0.97^{**}$ for first harvest; $r = 0.78$ (N.S. at 0.05) for second harvest; and $r = 0.92^{*}$ for combined harvests).[3] These correlations were slightly lower than those found for tissue P and yield, which were 0.97, 0.87, and 0.98 for the first, second and combined harvests respectively. Hall and Miller (5) also found that tissue P and yield were better correlated than soil test P and yield.

No significant differences in growth occurred from lime or K treatments. However, for both treatments more growth occurred during the 13 days after the first clipping than during the 20 days preceding.

On the first clipping date, turf from plugs that had the greatest soil depth had significantly more growth than plugs that were shorter. This may be attributed to less disturbance to the root system. However, by the second clipping, yields from all three plug depths were significantly different. With time, yields from 3.8 and 6.4 cm plugs increased more than these from 1.3 cm plugs.

^{32}P Uptake. Regardless of the other treatments (lime, P, or K), deeper placement of ^{32}P resulted in less absorption (Table 4). Apparently, fewer roots and/or a lower activity of those present contributed to this phenomenon. Less absorption at lower depths

Table 3. Effect of P, K, and lime treatments and plug depth on the clipping yield of Merion Kentucky bluegrass.

	Lime		P					K		Soil depth (cm)		
Harvest	L_1	L_2	P_1	P_2	P_3	P_4	P_5	K_1	K_4	1.3	3.8	6.4
	mg clippings/plug											
First	181 a†	149 a	150 b	154 b	166 ab	165 ab	189 a	160 a	170 a	154 b	158 b	183 a
Second	281 a	245 a	233 b	264 ab	258 ab	279 a	283 a	260 a	266 a	242 c	262 b	284 a
Combined	231 a	197 a	192 d	209 c	212 bc	222 b	236 a	210 a	218 a	198 b	211 b	234 a
	g clippings/plot											
Field harvest	66 a	59 a	53 b	50 b	70 a	68 a	70 a	62 a	62 a	--	--	--

† For each harvest and treatment, means followed by the same letter are not significantly different.

Table 4. Effect of P, K, and lime treatments on uptake of ^{32}P at three soil depths by Merion Kentucky bluegrass.

	Lime		P					K		
Soil depth	L_1	L_2	P_1	P_2	P_3	P_4	P_5	K_1	K_4	Avg.
cm	Counts/min./mg leaf tissue									
					First harvest					
1.3	466	325	308	391	345	452	480	408	382	395 a
3.8	290	144	120	162	242	310	251	215	220	217 b
6.4	178	133	157	182	147	178	116	160	151	156 c
Avg.	311 a†	201 b	195 c	245 bc	245 bc	313 a	282 ab	261 a	251 a	
					Second harvest					
1.3	519	422	378	493	453	478	551	473	468	471 a
3.8	384	201	210	285	318	384	265	293	292	292 b
6.4	263	247	390	273	196	212	204	280	231	255 b
Avg.	389 a	290 a	326 a	350 a	322 a	358 a	340 a	348 a	330 a	

† For each harvest, means followed by the same letter are not significantly different.

has been reported by O'Donnell and Love (10). They found this relationship of uptake and depth to be consistent to 76.2 cm.

On the first clipping date, absorption of ^{32}P from D_1 was nearly twice that from D_2 and more than twice that from D_3. Since most new roots are initiated from crown buds it should be expected that more absorption would occur near the soil surface. Because more ^{32}P was taken up from D_1 than D_2 and D_3 combined, the nutrient status of this zone is most important.

The greater root activity near the surface, combined with clipping removal, may account for soil P levels being slightly lower at 0 to 2.5 cm than at 2.5 to 5.0 cm for P_3, P_4, and P_5 (Table 2). This effect did not occur with the no P or the surface applied P_2 treatment.

On both clipping dates, more absorption occurred for L_1 than L_2. The pH values for L_1 and L_2 were 5.8 and 7.0 respectively. Liming has been shown by Riley and Barker (11) to decrease the P level in solution. They also reported that root length decreased as the pH increased from 4.7 to 7.5. Research by Miller et al. (9) using ^{33}P has shown that in more acid conditions the higher ratio of $H_2PO_4^-/HPO_4^{2-}$ prevented precipitation of Ca and P at the soil-root interface and increased absorption.

For the first harvest, differences in ^{32}P absorption occurred among the P treatments. Turf fertilized at the two higher P rates absorbed more ^{32}P than turf that was not fertilized with P. By the second harvest, these differences across the P treatments did not exist. However, a significant depth $\times$ P interaction occurred for both harvests. Uptake of ^{32}P increased from P_1 to P_5 for D_1. The correlation of absorption with soil P level for this depth was $r = 0.83$ and 0.80 (both significant at 0.05) for harvests 1 and 2 respectively. However, at D_2 these correlations dropped to 0.66 and 0.21 (NS) and at D_3 these correlations were negative and not significant (—0.72 and —0.62). Reasons for this interaction were not apparent; however, differences in root elongation due to P treatment, the number and absorbing capacity of the roots, and/or the competitive uptake of labeled vs. nonlabeled P, may have caused this depth $\times$ P interaction.

Results from this study indicated that P enhanced the magnitude of absorption at D_1, compared to that at D_2 and D_3 which exemplifies the need for P near the soil surface. Such placement would be of prime importance during turf establishment.

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