Phosphorus and Potassium Mobility in Putting Greens

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Phosphorus and potassium leaching in putting greens is important for several reasons. Some leaching of P from surface fertilizer applications can be desirable because it moves the nutrient deeper into the turfgrass rootzone where it may stimulate root development. On the other hand, leaching of P out of the rootzone is undesirable because the P can enter surface waters and promote aquatic weed and algae growth in ponds and lakes. Extensive leaching of K does not have undesirable environmental effects, but does represent excessive and inefficient use of fertilizer and indicates a need for more frequent and lighter applications of the nutrient.

Putting greens at the Nakoma Golf Club were used for this study. Soil samples were collected last November from all 18 greens plus the practice green at soil depths of 0 to 4, 4 to 8, and 8 to 12 inches. The samples were analyzed for Bray P-1 extractable P and K, pH in dilute calcium chloride, organic matter content, and percent sand and silt plus clay.

The putting greens sampled range widely in age and composition. This is reflected in the ranges and averages in soil analyses that were observed (Table 1). This is desirable for the present study because it gives a wide range of soil properties over which the effects of different factors on P and K mobility could be examined.

The organic matter content of 80:20 rootzone mixes, when expressed on a weight basis, generally ranges between 1.8 and 2.0%. Many of the greens in the present study have considerably more organic matter than this (Table 1) because of the use of highly organic native mineral soil when the greens were originally constructed. Percent sand in the top 4 inches of the older Nakoma greens averages 81%, as compared to 63 to 66% at greater depths. This reflects more than 10 years of core aeration and sand topdressing. Soil pH values range from 6.6 to 7.6. In general, the older the green, the longer it has been irrigated with hard water and the higher the pH.

In the newest greens, P levels at soil depths greater than 4 inches are typically less than 50 lb/A (Table 1). The older greens have as much as 439 lb P/A at the 8- to 12-inch depth. Thus, the evidence is that over time substantial amounts of P have leached in these greens. The soil K levels at different depths (Table 1) likewise suggest that K has been quite mobile over time.

The approach taken in this study was to mathematically relate P or K levels at the 4- to 8-inch soil depth to the levels of these nutrients, soil pH, organic matter percent, percent sand or percent silt plus clay at the 0-to 4-inch depth. From these relationships, it becomes possible to examine what factors contribute to P and K mobility and to calculate for different situations the approximate soil test P and K levels where leaching becomes pronounced.

Table 1. Ranges and averages of soil properties measured.

Soil property		Soil depth (inches) 0 to 4	4 to 8	8 to 12
Sand, %	Range	74 to 95	51 to 96	36 to 97
	Average	81	66	63
Silt plus clay, %	Range	2 to 13	2 to 45	2 to 63
	Average	13	28	31
Organic matter, %	Range	2.6 to 8.5	1.6 to 21.6	1.2 to 18.2
	Average	5.6	6.0	6.3
pH	Range	6.6 to 7.2	6.8 to 7.6	6.8 to 7.6
	Average	7.0	7.2	7.2
P, lb/A	Range	281 to 602	43 to 533	42 to 439
	Average	448	213	184
K, lb/A	Range	189 to 694	38 to 270	20 to 373
	Average	296	131	128

As illustrated in Figure 1, P levels in the 4- to 8-inch soil zone of the putting greens were determined primarily by the amounts of P and percent sand in the 0- to 4-inch zone. The higher the 0- to 4-inch P level or the higher the sand content of the soil, the more P leached into the 4- to 8-inch soil layer. This makes sense given what is known about P retention in soil. Phosphorus is adsorbed onto soil colloid surfaces. This takes it out of the soil solution and prevents it from leaching. Native soils have such high P adsorption capacities that P normally moves only very short distances in them. When significant movement of P does occur, it signifies that soil P levels have exceeded the soil's P adsorption capacity. Sand has little or no P adsorption capacity. Thus, as the sand content of the greens increased, the P adsorption capacity decreased and more P leached. Similarly, as soil P levels exceed the P adsorption capacities, more and more leaching took place.

The equation that mathematically describes the so-called response surface in Figure 1 was used to estimate the P levels in the 0- to 4-inch soil zone, at which there was significant leaching of P into the underlying soil. The calculations indicated that, in soil containing 65% sand, P leaching became substantial when the soil test P level exceeded 599 lb P/A. When the sand content was 95%, the P level where leaching began was only 2 lb/A. In other words, indicates are that in putting greens containing this amount of sand, the soil's P adsorption capacity is very, very low. It is, however, doubtful that it is as low as what calculations indicate. Regardless, the indication is that P leaches readily in USGA specification putting greens. Use of calcareous sand or a very acid peat high in aluminum or iron would undoubtedly increase the P adsorption capacity by a substantial amount and

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allow for buildup of higher soil test P levels before leaching becomes noticeable.

The putting green soil K levels were analyzed in the same manner as for P. The amounts of K in the 4- to 8-inch soil zones were found to be dependent on the amount of K, the organic matter content and soil pH in the 0- to 4-inch soil layer, but not on the amount of silt plus clay present. In comparing the influences of organic matter and pH, the effect of pH was found to be far more important. Hence, a simplified response surface was developed based only on the influences K and pH in the 0- to 4-inch depth on the amount of K found in the 4- to 8-inch soil depth.

As shown in Figure 2, as soil pH increased at a given level of K in the 0- to 4-inch soil depth, the amount of K in the 4- to 8-inch soil layer decreased. In other words, less leaching took place. This influence of soil pH on K leaching can be explained on the basis that K leaching rates in these putting greens are dependent on soil cation exchange capacity and this cation exchange capacity arises primarily from the organic fraction. It is a well-established fact that the cation exchange capacity of organic matter is entirely pH dependent. It increases rapidly as soil pH increases. This increased cation exchange capacity provides more bonding sites for K and, therefore, reduces leaching.

A common perception seems to be that as the pH of a putting green increases, calcium ions become so abundant that they block the bonding of K to cation exchange sites, K leaching increases and more frequent or heavier K fertilization is required. Under the conditions of the present study, where soil pH ranged from 6.6 to 7.2 in the top 4 inches of the rootzone, this clearly was not true.

Calculations similar to those performed for P were done for K as well. Simulating first, a high sand green with 8% silt plus clay (the maximum allowed) and 2% organic matter by weight, indications were that K leaching occurs at any K level from the 0- to 4-inch soil zone unless the soil pH is 6.85 or greater. Increasing the soil pH to 7.4 has the apparent effect of creating a K retention capacity in the soil of 242 lb K/A. Interestingly, this is very close to the 250 lb K/A figure that is often cited as the K level above which K leaching becomes excessive in high sand putting greens.

It must be clearly understood that the relationships and figures presented here really only apply to putting greens similar to those at the Nakoma Golf Club. They could be quite different for greens constructed from different materials. Nevertheless, indications are that the mobility of P and K in putting greens may be much greater than one would suspect from looking at data for native soils.

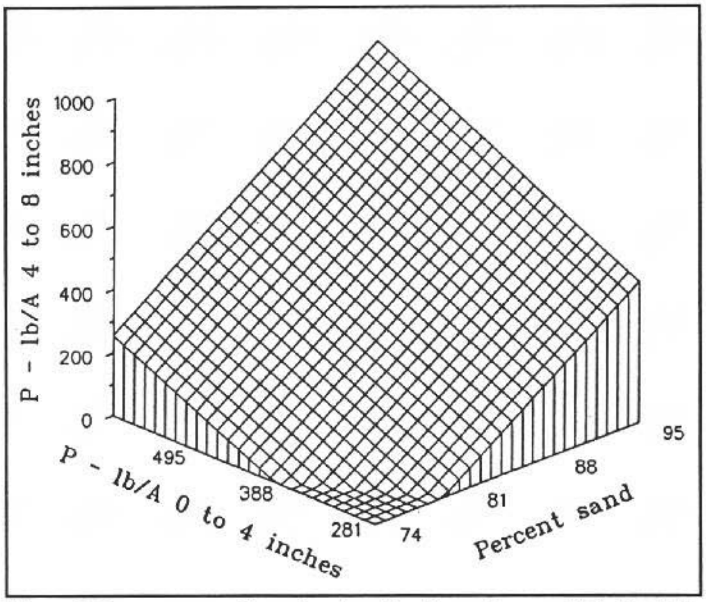

Figure 1. Response surface showing the dependency of P in the 4- to 8-inch soil depth on P and percent sand in the 0- to 4-inch depth.

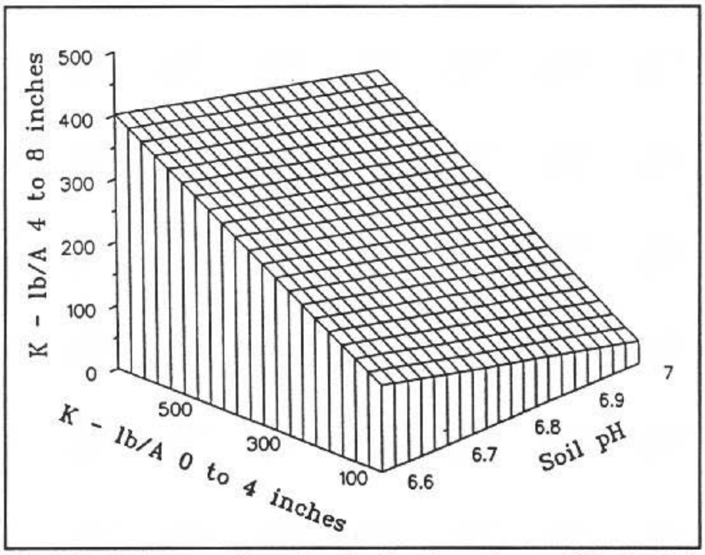

Figure 2. Response surface showing the dependency of K in the 4- to 8-inch soil depth on K and pH in the 0- to 4-inch depth.