# PHOSPHORUS AND POTASSIUM NUTRITION IN TURFGRASS CULTURE

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Soil fertility is a management tool which has a great affect on the physiological state of the turf, ecology of the turf community, and conditions within the soil. The main component of any fertility program is the proper use of nitrogen, phosphorus, and potassium. Correct use of these nutrients will not assure a good turf stand but they are essential for a healthy turf.

Phosphorus and potassium often receive less attention than nitrogen, yet they are no less important. Deficiencies, excesses or imbalances of these elements can result in a variety of effects within both the plant and the soil.

Phosphorus:

Phosphorus is an integral component of many physiological functions within plants. The energy transformations in plants require phosphorus in the form of ATP (adenosine triphosphate). It is a coenzyme in many plant pathways. Carbohydrate transformations during metabolism and assimilation of fats involving phospholipids both require phosphorus. It is also a constituent of RNA and DNA which are the genetic materials of cells.

An understanding of the relationship between phosphorus and the growth and development of a turfgrass plant is essential for proper management. Major plant effects are discussed below.

Establishment. The need for phosphorus during establishment has been noted but research is still limited in this area. Turf seedlings require phosphorus for growth and development.

Rooting. Finer, more highly branched roots, and increased rooting have been attributed to phosphorus. However, very high amounts of phosphorus have been reported to decrease rooting of closely cut bentgrass greens and bluegrasses.

Reproduction. Phosphorus deficiency may delay maturity while high phosphorus may hasten it. This is important in the seed industry. As a plant matures phosphorus accumulates in the reproductive tissues. Seeds contain high amounts of phosphorus as phytin. As the seed germinates the phosphorus is used for growth and development. Seed setting is enhanced by high phosphorus.

Tillering. Phosphorus deficiency may reduce tillering in turfgrasses. The moisture content of tillers has been shown to be reduced in ryegrass by up to 20% by phosphorus deficiency.

Shoot Growth. Limiting phosphorus can reduce shoot growth. On ryegrass increasing phosphorus resulted in a greater increase in top growth (dry weight) than root growth.

Ecology. Altering the phosphorus level of the soil can change the ecology of the turfgrass community. Bluegrasses, especially *Poa annua* L, are favored by high phosphorus while bentgrass species are effected little. Ryegrasses and clovers are also enhanced by high phosphorus as are fescues. Bermuda grass shows little response in mixture studies.

Moisture Content of Grass. In ryegrass the moisture content of shoots may be increased by phosphorus deficiency, but the moisture content of tillers reduced.

High Temperature Stress. The resistance of Kentucky bluegrass to high temperature stress can be lowered by high nitrogen combined with high phosphorus. High phosphorus alone generally has no effect.

Nutrient Interactions in Plants. Precipitation of iron phosphate on roots and in seeds has been shown. At low iron and high phosphorus levels iron nutrition can be inhibited. Precipitation of iron phosphate can also interfere with phosphorus movement in the plant.

Under very acidic conditions where aluminum is prevalent, phosphorus may be precipitated in the root cortex. The addition of lime in some cases will precipitate the aluminum and allow for better phosphorus utilization.

Competitive inhibition of several plant processes involving phosphorus by arsenic has been demonstrated. This can result in a decrease in energy storage by plants as well as direct inhibition of some enzymes.

In addition to the variety of effects on plants which phosphorus is involved in, there are several soil-phosphorus relations which can influence plant growth. These are summarized below.

Soil Reaction. Very high rates of monocalcium phosphate can result in a decrease in soil pH. This usually occurs around a phosphorus fertilizer band, but can also happen when phosphorus is broadcast at very high rates. In the latter case the change is normally small and would probably only occur in soils with a pH less than 7.0.

Phosphorus Fixation. Soils, even if comparatively sandy, are capable of fixing appreciable quantities of phosphorus. Phosphorus readily reacts with iron, aluminum and calcium to form compounds which are relatively insoluble. This prevents leaching and results in the accumulation of phosphorus in the top few inches of the soil profile. Only under very unusual circumstances, such as repeated high applications of phorphorus over many years, will the retention capacity of the soil be exceeded and movement of phosphorus down the profile occur. Such high applications are not required for plant growth and can be detrimental as well as uneconomical.

The amount of phosphorus which a soil can retain is related to soil texture, type of clay, and iron, alumunum and calcium content. Finer textured soils are generally higher than coarse soils in iron, aluminum and/or calcium content. They are therefore capable of fixing more phosphorus. Also, kaolinite clay can retain more phosphorus than other types of clay.

At a soil reaction of above 7.0 free calcium carbonate may exist. Phosphorus will precipitate on the surface of free calcium carbonate and become unavailable for plant uptake.

Nutrient Interactions in Soils. Phosphorus is involved in many interactions with other elements in soils. High nitrogen rates can enhance phosphorus uptake in turfgrasses, which may subsequentially be removed as clippings. However, while total phosphorus uptake may increase, the percentage of phosphorus in the foliage may decrease. This could be due to physiological stimulation of the plant by nitrogen. The nitrogen-phosphorus balance in soils has been demonstrated to influence magnesium and calcium concentrations in plants. At low phosphorus levels, increasing nitrogen enhanced the magnesium concentration in turfgrass. Conversely, at high phosphorus levels increasing nitrogen rates decreased magnesium and calcium concentrations.

Relations between phosphorus and potassium are often unclear. In bluegrass the percent phosphorus was increased by increasing the potassium levels, however, opposite results have been reported for other plants. Phosphorus-potassium interactions have been reported to reduce rhizome development. A decrease of Ophiobolus patch disease on bentgrass turf has been attributed to phosphorus-potassium interactions.

Phosphorus and arsenic in soils can influence each other. Additions of phosphorus have often been used to reduce arsenic toxicity, but at least one case of enhanced arsenic toxicity on a soil very low in reserve iron has been demonstrated. Plant tissue tests indicate that arsenic uptake is accentuated by increasing the phosphorus rates. The effect of the additional arsenic would normally be offset by a greater uptake of phosphorus.

Zinc deficiency may be favored by high phosphorus levels. This has occurred in several plants. There is some evidence that phosphorus can enhance manganese uptake. More research is needed to determine possible interactions between phosphorus and micronutrients.

Organic matter accumulation can be promoted by high phosphorus. Also, high organic matter content may cause phosphorus fixation.

Potassium:

Potassium is an unusual element in that it does not form a stable structural part of any molecule in plants, yet it is essential for growth and development. Among its many functions are involvement in amino acid synthesis, carbohydrate synthesis and translocation, protein synthesis, reduction of nitrates, nutrient uptake, and regulation of transpiration and respiration. It is a cofactor (enzyme activator) in many plant processes.

Potassium can react in plants and soils to produce many different effects. The major effects it exhibits in plants are summarized below.

Respiration. The degradation of carbohydrates into simpler compounds and energy (respiration) is influenced by potassium levels. A deficiency of potassium causes enhanced respiration and depletion of carbohydrate reserves.

Transpiration. Potassium deficiency will increase the transpiration rate in plants and possibly promote wilting. High potassium levels enhance water retention and increased tugor pressure.

Rooting. An enhancement of root growth and root branching due to increased potassium rates has been observed on bluegrasses and bentgrasses. Potassium resulted in a greater increase in root growth than shoot growth. Increased rooting due to potassium may partially account for the enhanced drought tolerance of potassium sufficient plants.

Rhizomes and Stolons. Rhizome and stolon weights are increased by potassium, but the correct nitrogen-potassium balance is important. Low nitrogen will result in a reduced response to potassium compared to high nitrogen.

Tillering. Potassium increases tillering. The effect is greatest at high nitrogen levels. At low nitrogen and high potassium some reduction in tillering over low nitrogen-intermediate potassium has been demonstrated.

Ecology. Many weeds and clover are favored by high potassium. Bluegrasses are favored over bentgrasses by increasing potassium.

Amino Acid Content. Potassium deficient plants are often low in protein content but high in amino acids which are required for protein synthesis. Plants high in amino acid content are more susceptible to diseases.

Drought, Heat, Cold Tolerance. As discussed above high potassium can increase rooting which can in turn enhance the drought tolerance of a grass. Turgor pressure is accentuated by potassium which helps reduce wilting. High potassium in conjunction with high nitrogen can increase the high temperature tolerance of turf. Potassium may improve cold tolerance of turfgrasses. Its effects on water retention and the soluble protein content are the probable causes of the enhanced low temperature survival.

Disease Tolerance. Potassium levels have an important influence on the disease tolerance of turfgrasses. Low potassium levels can result in increased susceptibility to dollar spot, brown patch, *Ophiobolus* patch, *Fusarium* patch, leafspot, and Corticium red thread. This is due to the influence of potassium nutrition on water retention, amino acid levels, water absorption, carbohydrate levels, plant vigor, and cell wall structure. Nitrogen-potassium interactions are also important to disease tolerance.

Wear Tolerance. High potassium enhances turgor pressure. High turgor pressure results in a turfgrass which is more rigid, erect and more able to withstand wear. Wear tolerance is especially important on high traffic turfs.

Nutrient Interactions in Plants. The interactions between nitrogen and potassium are numerous. Main effects are disease tolerance, winter survival, drought survival, heat stress tolerance, carbohydrate content, tiller development and dry matter yield. The correct balance between these nutrients is very important.

Potassium-phosphorus interactions are not well understood and may vary with plant species, age of plant and other factors. Possible interactions were discussed previously under the phosphorus section.

Sodium content in plants can influence the critical level of potassium. Sodium tends to reduce the potassium requirement. Plants with high sodium levels require less potassium.

In addition to the plant effects contributed to potassium, it also is involved in many soil relationships. These are discussed below.

Fixation and Leaching. Potassium is a cation (positively charged) and subject to cation exchange. Normally when added to soil it will be attracted to the clay particles and retained. The amount of potassium a soil can retain is generally less than for phosphorus. If the retention limit of a soil for potassium is exceeded, potassium will be subject to leaching. Factors which influence the potassium absorption capacity of a soil are soil texture, type of clay and wetting and drying. Finer textured soils are usually able to retain more potassium than coarse soils. If vermiculite clay is present, large amounts of potassium can be fixed. This potassium would be largely in a form unavailable to plants. Wetting and drying tends to increase potassium into unavailable forms. In most soils the large majority of the potassium is in a form not available for plant uptake, but such nonexchangeable potassium can become available over time.

Nutrient Interactions in Soils. The balance of available nitrogen to available potassium in soils is important. These nutrients interact to influence many plant functions as previously discussed. High nitrogen rates can promote potassium uptake and increase potassium depletion if clippings are removed as on greens. Often the extra potassium taken up by the plant is not physiologically required and is termed luxury consumption.

Nitrogen in the ammonia form ($NH_4^+$) can cause an increase in leaching of potassium ($K^+$). These nutrients are of similar size and charge. Thus, when ammonia is applied it can replace potassium from the clay colloid.

Soil interactions between potassium and phosphorus have been discussed in the phosphorus section previously.

Soils with a high degree of calcium saturation have a greater potassium absorption potential than low calcium soils. Thus, soils which are limed are less likely to lose potassium by leaching.

The balance between potassium, calcium and magnesium in soils is important. Plants grown on soils low in magnesium can have magnesium deficiency induced by applications of high potassium rates. Liming with dolomitic limestone or applying magnesium containing fertilizers will alleviate the problem. Conversely, plants grown on soils low in potassium may exhibit potassium deficiency if high magnesium or calcium rates are applied.

Phosphorus and potassium are involved in many plant and soil relationships and are an integral part of any fertilization program. Consideration of these elements should be based on the knowledge of their effects on plants and soils. The turf manager should always keep in mind the importance of nutrient balance and not attempt to regulate growth and development of a turf by utilizing only one or two nutrients.

Selected References


1. Beard, J.B. Principles of Turfgrass Culture. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. To be published in 1972. 672 pages.

2. Bell, R. S. and J. A. DeFrance. Influence of Fertilizers on the Accumulation of Roots from Closely Clipped Bent Grasses and on the Turf. Agronomy Journal 58:17-24. 1944.

3. Gilbert, W. B. and D. L. Davis. Relationship of Potassium Nutrition and Temperature Stresses on Turfgrasses. Agronomy Abstracts. p. 52. 1967.

4. Hanson, A. A. and F. V. Juska, editors. 1969. Turfgrass Science. American Society of Agronomy, Inc. Madison, Wisconsin.

5. Hylton, L. O., Jr., A. Ulrich, D. R. Cornelius, and K. Okhi. Phosphorus Nutrition of Italian Ryegrass Relative to Growth, Moisture Content, and Mineral Constituents. Agronomy Journal 57:505-508. 1965.

6. Madison, J.H. 1971. Principles of Turfgrass Culture . VanNostrand Reinhold Company. New York.

7. Monroe, C. A., G. D. Coorts, and C. R. Skogley. Effects of Nitrogen-Potassium Levels on the Growth and Chemical Composition of Kentucky Bluegrass. Agronomy Journal 61:294-296. 1969.

8. Pellet, H. M and E. C. Roberts. Effects of Mineral Nutrition on High Temperature Induced Growth Retardation of Kentucky Bluegrass. Agronomy Journal 55:473-476. 1963.

9. Satari, A. M. 1967. Effects of Various Rates and Combinations of Nitrogen, Phosphorus, Potassium, and Cutting Heights on the Development of Rhizome, Roat, Total Available Carbohydrate, and Foliar Composition of *Poa pratensis* L. Merion Grown on Houghton Muck. Ph.D. thesis. Michigan State University. pp. 1-127.

10. Woolson, E. A. The Chemistry and Toxicity of Arsenic in Soil. Ph.D. thesis. University of Maryland, College Park. pp. 1-98.