POTASSIUM CONSIDERATIONS IN BENTGRASS PUTTING GREENS
Maintained under typical golf course management systems

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Understanding the nutrient benefit and interactions of potassium (“K”) on high sand content golf course putting greens is necessary for efficient nutrient management and the development of healthy plants. The golf course putting green represents the most important part of a golf course. The golf course manager’s ability is often judged on the condition of the putting green. Frequent applications of fertilizer are applied at low rates in order to avoid rapid vertical growth and the associated negative impact to maintenance, turfgrass health, and poor playing (golfing) quality. Rapid top-growth resulting from nitrogen (N) applications is easily avoided by controlling the rate and frequency of applied nitrogen. Affects of nitrogen applications are easy to see because of the well known relationship between N application rates and visual response in the form of green color and clippings (yield). Golf course managers adjust N applications based on the desired growth rate of the grass. At certain times, rapid growth is required to recover from environmental damage, excess traffic from golfers or equipment, disease recovery, and recovery from core aeration.

Fertilizer is applied as liquid-foliar in 30 to 50 gallons of water per acre. The objective of liquid foliar applications is to supply supplemental nutrition that typically supplies one week of nutrition before the next application is made. “Soil” applications of fertilizer are applied over the surface of the turfgrass followed by irrigation or rain. Solubility of the fertilizer product is important because the golf manager must avoid granules laying on the surface. The surface granules are subject to removal by mowers, crushing into the leaf blade causing plant injury, and interfering with the roll of the golf ball.

Applications of some fertilizer nutrients, such as nitrogen and iron, cause a predictable response in the form of darker green color or growth. Other nutrients, such as K, rarely result in a visual or tangible turfgrass response. Nevertheless, K is considered an important nutrient, and is often applied to putting greens in amounts equal to, or greater than, N. This paper discusses current theories concerning the use and reported benefits of K in high sand content putting green management programs. The research data is often conflicting with regard to turfgrass response to K applications. This paper will identify areas where managers could better manage K applications toward the development of a healthier bentgrass plant. Areas where additional research is needed will be identified.

PUTTING GREEN MANAGEMENT SYSTEMS

Creeping bentgrass (*agrostis palustris*) is a cool season grass preferred for the majority of golf course greens in cool season climate regions (Beard, 2002). The reason for using creeping bentgrass is due mainly to the ability of the species to withstand low cutting heights of 1/8-inch without dying. Putting surfaces are expected to be firm, dry, and resist "ball marking" from the impact of the golf ball. It should be noted that cutting heights were 50-100% higher in past years but the demand for ultra-short, smooth, "pool table-like" putting surfaces has become the norm and is expected by all golfers. Golf course managers are expected to delivery this type of putting surface and they are judged (and hired) on their ability to achieve this goal.

Modern putting greens are often constructed with 12-inches of root zone mix consisting of about 90-97 percent sand, with less than 2% organic matter and minimal (less than 7%) silt and clay. A gravel and drainage pipe system designed to rapidly remove excess root zone water is placed below the 12-inch root zone. The system is designed to provide specific porosity, moisture holding capacity, drainage, and resistance to compaction. (USGA, 2004) Cation exchange capacity of this system is typically less than 10 meg/100g and therefore has a low capacity to retain positively charge cations. Retention of nutrients is very low and presents a challenging situation with regard to fertilizer programs and grass nutrient status. The common program of applying light frequent applications of nutrients often results in low nutrient status of plants and difficulty in supplying high enough levels of macronutrients to the plant. When higher rates of macronutrients are applied, their retention in the root zone is limited because they are subject to rapid uptake or leaching. The majority of educational information available concerning soil-fertilizer relations is based on soils containing much higher amounts of organic matter and clay and does not apply to a high sand root zone system. Another situation that makes fertilizer management decisions difficult is the fact that putting green root zone physical characteristics change over time as the plants deposit organic matter in the form of decaying roots. In addition, putting greens are topdressed with sand of various particle sizes and small percentages of silt and clay. In general, over time, changes include: (GCM, 2007)

- An increase in organic matter in the top 4 inches of the profile
- Non-decomposed organic layer in the top inch (thatch)
- 70% decrease in infiltration rates
- 53% increase in capillary porosity
- 30%+ decrease in non-capillary porosity (air pores)

These changes to the physical characteristics of greens will affect the release nutrient release characteristics of the root zone. Each of the elements listed above have a direct effect on root health. A limited root system will affect the absorption rate and efficiency of K, or any nutrient, from the root zone. In addition, soil water properties will also limit the uptake of nutrients that are primarily dependent on mass flow. These factors make nutrient management difficult because golf course managers are constantly dealing with declining root systems from intense low-cut management, environmental stress such as shade, and purposely limiting irrigation in order to keep surfaces firm and dry.

THE IMPORTANCE OF K

Managers of golf course putting greens consider K an important nutrient for turfgrass health, growth, and development because of its reported role in a number of plant physiological responses including cellular metabolism, environmental stress resistance, disease resistance, internal water management, and wear tolerance (Pessarakli, 2008; Beard, 1973). K applications are often based on soil reports or some relations to total nitrogen applications, but do not always improve turfgrass performance (Woods, et al., 2006; Fulton, 2002). K applications do not always improve color response which is a primary indicator of turfgrass quality (Christians, et al., 1979). While not related to color response, K applications have been reported to increase bentgrass yield and root weight (Dest and Guillard, 2001). Other studies show K applications yielded no turfgrass response even when soil test levels showed low K levels. The study concluded that acceptable creeping bentgrass performance can be achieved across a wide gradient of soil K levels and current published literature concerning K management should be reevaluated. (Woods, et al., 2006)

MONITORING K LEVELS

The two methods of monitoring K levels in a high sand content putting green system are soil and tissue tests. Tissue testing for K involves gathering samples from clippings that are mostly new growth. It is not practical to collect specific above-ground plant parts from low-cut turfgrass and most research studies, as well as field samples, are taken from clippings. Care must be taken when preparing and sending samples. K does not form covalent bonds of organic compounds and exists in the plant as active K+ ions. It is readily leached out of dead tissue of plants (Troeh and Thompson, 2005). This may account for extremely low K tissue levels in samples that rot during shipment to the tissue testing lab. Tissue testing is used by very few golf managers. There could be several reasons for this. 1) Lack of understanding about how to interpret test results 2) Access to local laboratories that return results in 24 hours 3) Cost 4) They do not see the value.

K sufficiency levels in creeping bentgrass are not clearly defined. Mills reports between 2.2% and 2.6% as sufficient (Mills and Jones, 1996). Others report 1.5% - 3.0% as sufficient (McCarty, 2005; Carrow et al.,2000; Marschner, 1995). Critical low levels for bentgrass are reported to be lower than 1% (Carrow, et al., 2001). Results from over 200 tissue tests performed by Kuo Testing on golf courses in the Pacific Northwest show the average result of tissue K to be 1.89%, with only 2% of the samples below 1% (Exhibit A). It is generally assumed that tissue K concentration is increased by K applications and this holds true in most research studies (Dest and Guillard, 2001; Woods, et al., 2006). Tissue K levels can be similar in bentgrass leaves even though soil K levels vary significantly (Shearman, et al., 2005).

Many laboratories and universities recommend soil testing as a way to determine if levels of soil K are acceptable. Soil K levels of 150-250ppm are considered adequate (Marx, 1999).

Soil testing is used by turf managers with more regularity than tissue testing. Frequency of testing varies and is often initiated by fertilizer sales companies. In my experience, most golf course managers take tests yearly, or every other year. The tests are usually complete, containing pH, organic matter, CEC, electrical conductivity, and all macro and minor elements.

The low CEC of sand may limit K availability, especially if the sands are calcareous. Regardless of extraction method, all show an increase in soil extractable K following K fertilizer application. However, a weak correlation between tissue K content and soil K levels suggests that soil K concentrations may not be a reliable predictor of tissue K content in a calcareous sand root zone (Woods, et al., 2005). It has been shown that basing a K management program on soil tests from low CEC, calcareous sand, is not practical or accurate. Putting green soil K levels as low as 65ppm has shown no response to K applications. The lack of K response may be attributed to the CEC being so low that even small applications of K are not retained in the sand, and leached below the root zone (Johnson, et al., 2003). In addition to exchangeable K that is identified in soil tests, there is additional K that might be released from weathering into the sand root zone from non-exchangeable sources. This K release is dependent on the mineral characteristics of the sand (Dest and Guillard, 2001). For sand based putting green root zones, it may be true that a critical soil K level cannot be identified using basic soil testing methods. This summary is suggested by Petrovic (Petrovic, et al., 2005).

AFFECTS OF LOW K PLANT CONTENT

Visual deficiency of K in turfgrass is limited. In some cases, early spring chlorosis may be seen (Pessarakli, 2008) but most references to K deficiency are increased disease, lack of wear tolerance, increased drought stress, and damage for temperature extremes(Goss, 1998, Shearman, et al., 2005). While not clearly evident from above ground plants, potassium does influence drought tolerance, and can reduce the incidence of some diseases such as *Helminthosporium* spp, brown patch, take all patch, *Fusarium* patch, red thread and dollar spot (Beard, 1973).

K AVAILABILITY

Plants absorb K in the form of K^+ ion. K exists in soil as K ions in mineral structures and as hydrated ions either in solution or adsorbed on cation exchange sites. In sand, there is low cation exchange capacity and solution K is susceptible to leaching. It is likely that nearly all the K absorbed by the root system of plants comes from the exchangeable and non-exchangeable forms (Hausenbuiller, 1972). Golf managers often are forced to irrigate greens frequently at very low rates of water to temporarily alleviate wilt. The irrigation water seldom, if ever moves more than several inches into the soil profile.

The mineral content of sand used for golf course construction, as well as frequent top-dressing applications, is an important consideration in estimating the slow release of K from minerals into the root zone. The three forms of K exist in equilibrium according to the equation:

Non-exchangeable K ↔ Exchangeable K ⟷ Soluble K

Soluble portions of K would readily be leached in a sand root zone. Determining the use of non-exchangeable forms of K can be measured by using a *K-Supplying Power* determination. The release of K from primary minerals from various sands may be sufficient to satisfy bentgrass requirements for K. Dest reports that using a 1 *M* HNO3 extraction method may provide a more accurate method of determining K contributed by non-exchangeable forms in high sand content root zones. (Dest and Guillard, 2001)

RELATIONSHIP TO OTHER NUTRIENTS

Nitrogen (N) applications have been reported to significantly increase K content in turfgrass (Petrovic, et al., 2003). However, this may not result in visual changes to plant growth. Research on Kentucky bluegrass (*Poa pratensis*) shows increased shoot growth with increasing K applications when N was low but decreased with K applications when N was high. This research also states that N-use efficiency increases proportional with increasing K applications. It is possible that increasing K in solution can reduce the amount of nitrogen needed to achieve maximum quality of creeping bentgrass (*agrostis palustris*) (Christians, et al., 1978).

The form of nitrogen in the soil can influence the uptake of K. Excess ammonium NH_4^+ can suppress the uptake of K and where nitrate NO_3^- is limited, K uptake by roots can be suppressed (Duble, R.L.) K applications, in either liquid foliar or granular form, have been shown to decrease tissue content of calcium and magnesium in both root and tissue (Sarvis, 2008).

CULTURAL PRACTICES AFFECTING K UPTAKE EFFICIENCY

Golf course managers have the luxury of manipulating soil moisture in high sand content greens through the use of automated irrigation systems that are computer controlled and designed for high efficiency water applications. It is evident that increasing soil water content would be beneficial since plants absorb K only from solution. Root growth on low cut, highly trafficked, constantly stressed, creeping bentgrass can be seriously compromised during most of the growing season. Root interception, where the root grows into an area of K soil concentration, constitutes less than 1-2% of total K uptake and quickly depletes any K near the root surface. (NRCS, 1973) Diffusion delivers up to 96% of the total K transport to roots and is dependent on the flow of K in solution to the root. Therefore, irrigation plays a major role in delivering K to the plant. Increasing irrigation results in increased tissue content of K and increased leaf turgor pressure (stiffer leaves). The increased uptake of K is related to turfgrass ability to resist quality reduction during times of water stress (Shearman, et al., 2005). A major drawback in improving potassium, and other nutrient uptake, could be the fact that many golf course managers resist applying irrigation water - Even when soils are very dry. Golfers demand firm and dry surfaces on which to play golf.

Healthy plants require optimum soil conditions for maximum root development. Soil porosity is an important element of good root development. Most soils contain about 50% solid and 50% air space. The air space is divided between large pores (non-capillary) and small pores (capillary). In a perfect sand system, the percent of capillary and non-capillary pores should be about equal. However, many sand based greens have a low percentage of non-capillary pores due to plugging with organic matter (thatch) and/or silt and clay from low quality topdressing sand. The result is reduced root growth and root branching that must occur in the non-capillary pore spaces. The root system of putting green turf is further compromised due to the very low cutting height (1/8-inch) and other stresses associated with frequent mowing and excessive traffic.

The factors discussed in this section show a major challenge in managing potassium efficiency in putting green systems. 1) Lack of water in the root zone to move potassium to the root by mass flow and diffusion. 2) Compromised, shallow, and weak root systems.

ENVIRONMENTAL CONDITIONS AFFECTING K UPTAKE EFFICIENCY

Plants normally obtain a substantial amount of mineral nutrients early in the growing season. As they grow larger, soil nutrients become scarcer as the larger plant requires more nutrients and the area around the root is depleted of nutrients (Epstein and Bloom, 2005). In the case of putting green turf, the plant is always the same height, and regardless of nutrient demand, it is possible that it quickly depletes the K ions in the rhizosphere. Soil water that is needed to replenish K supply near the root is limited due to either lack of precipitation or reduced irrigation by the turfgrass manager. As soils warm in the summer microbes are acquiring a larger portion of nutrients released by the minimal amount of organic matter in the sand further increasing competition for the limited supply of soil nutrients.

SUMMARY

The US Golf Associations (USGA) has proposed a method of selecting sand and amendments to construct a putting green root zone. One purpose is to provide a universal construction method that could be used in all areas of the world. While the focus is mostly on the physical stability of sand, there are known drawbacks with regard to maintaining adequate soil fertility. Green root zones cannot be adequately cultivated to return organic matter deep into the profile. Golf course managers must approach nutrient management of high sand root zones by understanding and researching the unique characteristics of their greens. Although different sands may have similar physical properties, they do not have equal chemical properties. Important considerations for K management of greens are:

1. Identify the parent material of the sand used for construction and determine the K supplying power of the sands
2. Determine exchangeable K based on a qualified local soils laboratory that uses the appropriate extract solution.

3. Understand that irrigation and soil water plays an important role in the delivery of K to the root system.
4. Perform regular tissue testing to maintain K levels above 1% and utilize frequent light applications of K when root growth is compromised. Or, apply foliar applications of K when deficiencies are identified.
5. Be aware of seasonal fluctuations in K uptake and take steps to ensure adequate K is available.
6. Monitor ammonium, calcium, and magnesium levels in the soil and avoid nutrient competition by maintaining appropriate ratios of elements.

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EXHIBT A

Tissue Test Results from Golf Course Putting Greens.

Name	Date	K
TriCity Court	3/14/2010	1.82
Buffalo Hills GC	4/20/2010	1.63
Buffalo Hills GC	4/26/2010	1.6
Meadow Springs	5/3/2010	2.4
Meadow Springs	5/3/2010	2.37
Buffalo Hills GC	5/6/2010	1.77
Canyon Lakes GC	5/6/2010	1.52
Canyon Lakes GC	5/6/2010	1.21
Skeena Valley	5/11/2010	1.97
Skeena Valley	5/11/2010	2.32
Skeena Valley	5/11/2010	2.02
Skeena Valley	5/11/2010	3.14
Buffalo Hills GC	5/12/2010	2.15
Prairie Falls GC	5/17/2010	1.55
Prairie Falls GC	5/17/2010	1.75
Yakima CC	5/17/2010	1.69
Buffalo Hills GC	5/18/2010	1.09
Prairie Falls GC	5/19/2010	1.74
Prairie Falls GC	5/19/2010	1.74
Buffalo Hills GC	5/27/2010	1.65
Moses Lake GC	5/27/2010	2.12
Yakima CC	5/31/2010	2.47
Buffalo Hills GC	6/2/2010	2.29
Buffalo Hills GC	6/7/2010	1.04
Moses Pointe	6/10/2010	2.4
Yakima CC	6/10/2010	2.73
Buffalo Hills GC	6/14/2010	1.01
Desert Blue GC	6/17/2010	1.28
Desert Blue GC	6/17/2010	1.29
Buffalo Hills GC	6/21/2010	1.18
Buffalo Hills GC	6/28/2010	1.54
Burnaby City GC	7/4/2010	1.71
Burnaby City GC	7/4/2010	1.74
Yakima CC	7/4/2010	2.16
Buffalo Hills GC	7/8/2010	2.18
TriCity CC	7/13/2010	2.2
Buffalo Hills GC	7/15/2010	2.2

Buffalo Hills GC	7/19/2010	2.07
Canyon Lakes GC	7/21/2010	1.28
Canyon Lakes GC	7/21/2010	1.29
Yakima CC	7/22/2010	2.27
Moses Lake GC	7/25/2010	2.08
Moses Lake GC	7/25/2010	2.13
Buffalo Hills GC	7/26/2010	0.56
Moses Pointe	7/27/2010	1.4
TriCity CC	8/3/2010	2.19
Buffalo Hills GC	8/4/2010	2.56
Buffalo Hills GC	8/11/2010	2.31
Buffalo Hills GC	8/18/2010	2.2
Buffalo Hills GC	8/25/2010	2.06
Buffalo Hills GC	9/1/2010	1.92
Lewiston CC	9/2/2010	2.69
Lewiston CC	9/2/2010	2.59
Buffalo Hills GC	9/9/2010	2.65
Huntsman Springs	9/20/2010	1.71
Buffalo Hills GC	9/29/2010	0.17
Huntsman Springs	10/4/2010	2.26
Buffalo Hills GC	10/5/2010	2.14
Average		**1.89**