WINDMILL RIDGE GOLF COURSE

Greens Root-Zone Soil Test

Root-Zone tests on greens #2,#3,#6,#7,#11,#12 and#16

Michael D. Vogt, CGCS, CGIA

5/23/2012

This report is a guide to recommendations on the nutrition and sodium remediation of the greens root-zone at Windmill Ridge Golf Course.

Introduction

Soil samples and the results of the tests are to be interpreted only by trained individuals. Simply looking at lab results and not possessing an understanding of unique golf turf nutrition programs and or inherent problems on specific site may lead to erroneous recommendations.

Below are the findings and recommendations based on Windmill Ridges' golf greens root-zone soil tests that were sampled.

Protocol

Soil samples were taken on May 10th, 2012. Samples from greens #2, #3, #6, #7, #11, #12 and #16 were removed to a depth of approximately six inches at multiple random sites on each green. Volumes of root-zone mix in each random sample was approximately one cup of dry material including thatch, root material and turf surface. The samples were bagged, marked and shipped to Logan Labs in Lakeview, Ohio, within 48 hours of collection; the same lab that Windmill Ridge used in the past to insure continuity of testing procedures.

Green Root-Zone Soil Test Results

For the sake of organization I have addressed each area in this report in the order in which they appear on the Logan Labs test results in Appendix #2 on pages 14 and 16.

Total Exchange Capacity

Soils can be thought of as storehouses for plant nutrients. Many nutrients may be supplied to plants solely from reserves held in the soil. Others are added regularly to soils as fertilizer for the purpose of being withdrawn as needed by turf. The relative ability of soils to store one particular group of nutrients, the cations, is referred to as cation exchange capacity or CEC.

The Windmill Ridge green root-zones are composed of a mixture of sand and organic matter. The sand has no real charge and organic matter particles have a net negative charge. Thus, these negatively-charged soil particles will attract and hold positively-charged particles, much like the opposite poles of a magnet attract each other. By the same token, they will repel other negatively-charged particles, as like poles of a magnet repel each other.

Sodium Fraction in CEC

Sodium has a double positive charge (Na ++) and has appeared in several soil tests as an element in sufficient concentration that may cause damage to the root-zone as well as turf on greens. For this reason I recommend the use of gypsum (2CaSO4) to displace sodium in the greens root-zone (this reaction is illustrated in Figure 2 on page 6).

pH of the Root-Zone

Soil pH testing is done to see how acidic or alkaline the soil is. pH means potential hydrogen. It measures the number of free hydrogen (H+) ions in the soil water.

It's a logarithmic scale that goes from 0 to 14 with 0 being most acidic, 7 being neutral and 14 being most alkaline. Because it's a logarithmic scale each jump is a tenfold increase so a soil with a pH of 5 is 10 times more acidic than one with a pH of 6 and a 100 times more acidic than one with a pH of 7.

All of greens root-zone mixture pH ranges from 7.5 to 7.8; all these measurements are well within ideal guidelines.

Organic Matter in the Root-Zone

All of the results of organic matter in the root-zone proved to be within acceptable ranges; 0.79% – 1.50%, any percentage greater than 2% would facilitate an aggressive aerification program with hollow tines to remove thatch and heavy topdressing to fill in the channels from sealing with additional organic matter.

Cations and Anions

These examples will help understand the root-zone soil tests and the role of anions and cations.

- Table salt is an example of a compound held together by an ionic bond between cations and anions. Salt is formed when positive sodium ions come together with negative chlorine ions.

- Cations are atoms that have lost an electron, and as a result, they have a positive charge. Cations and anions are often found in water because of the nature of the water molecule.

Anions *(Negatively Charged)*

Sulfur (S^{--})

Although sulfur in the root-zone tested low, many of the spray applied fertilizers currently used contains enough sulfur for turfgrass nutrition on the greens at Windmill Ridge (CPR® is 1% sulfur and should be continued to be used as planned, or similar).

Cations (Positive Charged) continued

Phosphorous (P^{-}as P_2O_5)

Although the roots absorb phosphates, the concentration of phosphorous in the soil is usually very low because phosphorous has low water solubility. There are basically three valences of phosphorous in a soil solution and all three are anions. Therefore they are attracted to the cations and form many insoluble salts. Many of the granular fertilizers containing phosphorus are ineffective because the phosphorous in the fertilizer forms these insoluble salts quickly in the soil. Again, a form of phosphorous fertilizer in a spray solution is recommended; such as TrueFoliar® P, 6-12-6 with Micronutrients from Nutra-Rational or similar.

Cations (Positive Charged)

Calcium (Ca^{++})

With the exception of #16 green (which is slight below recommended levels) all calcium levels are well with acceptable ranges. With additional applications of gypsum this low calcium level on #16 green will be corrected. However, continue spray applications of TrueFoliar® 8-0-4 with calcium or similar. Notice on the section base saturation that the amount of calcium is in line with recommendations, this element is in balance within the root-zone.

Magnesium (Mg^{++})

Magnesium is slightly deficient in the soil, although spray applications are used to supplement this important element. Magnesium is key in the production of chlorophyll and proven to be beneficial in certain disease prevention strategies. Continue using the product TrueFoliar®, 6-0-0 with Mg and Mn providing 6% magnesium through spray applications. On the base saturation percentage section this element is on the low side of what the root-zone mix should be able to hold.

Potassium (K^{+})

On a measure of pounds per acre, potassium shows a deficiency of between 55 and 102 pounds per acre. Again, supplemental spray applications should provide sufficient potassium. As a percent of base saturation potassium is in good balance. Additional amounts of potassium should be applied in the fall to bolster amounts held on root-zone sites as an exchangeable cation. Continue spray applications of TrueFoliar® 8-0-4 with calcium or similar, this product also contains 4% soluble potassium.

Sodium (Na^{++})

As mentioned at the bottom of page 2, sodium levels remain high in all samples. In the base saturation section of the root-zone soil test, amounts are as high as three times the recommended thresholds. High levels of sodium in the root-zone may cause severe problems especially during weather induced turf stress periods.

Cations, Sodium (Positive Charged) continued

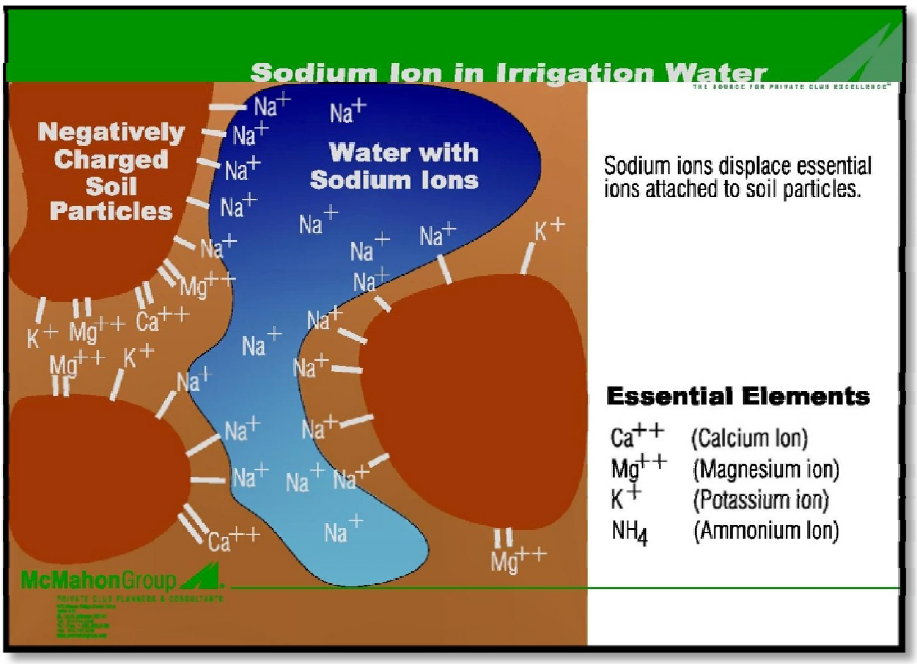


Figure 1 Sodium in water and soil relationship

My recommendation to irrigate greens for longer periods of time and continue to vent and apply gypsum is important to help mitigate this sodium problem. It is essential that these recommendations be followed - without irrigation flushing; venting to aide in water and air movement and gypsum to remediate sodium in the root-zone, turf will continue to struggle during stress periods.

The reprinted article in Appendix #1 should be helpful in understanding the program of flushing/leaching greens. You will need to estimate time required to flush/leach greens at Windmill Ridge based on outflow of drain tiles; if tiles can be located. If tiles cannot be located a soil probe should be used before and after irrigation to assure that the column sand achieved good dry-down. After irrigation a probe should be used to examine that water is sufficiently distributed and sand is not "waterlogged" in the upper surface.

The sand profile should be uniformly moist after heavy irrigation, not "waterlogged". Properly irrigated sand greens should <u>not</u> be soft after heavy irrigation. Water rapidly flowing through the sand profile will "pull" air behind the drainage, filling the macro pores of the sand with fresh air.

Irrigation techniques are important to managing sand greens with salt issues. Be aware, light irrigation will lead to excessive salts in the top several inches of the soil profile; this area is where the bulk of the turf roots exist.

Cations, Sodium (Positive Charged) continued

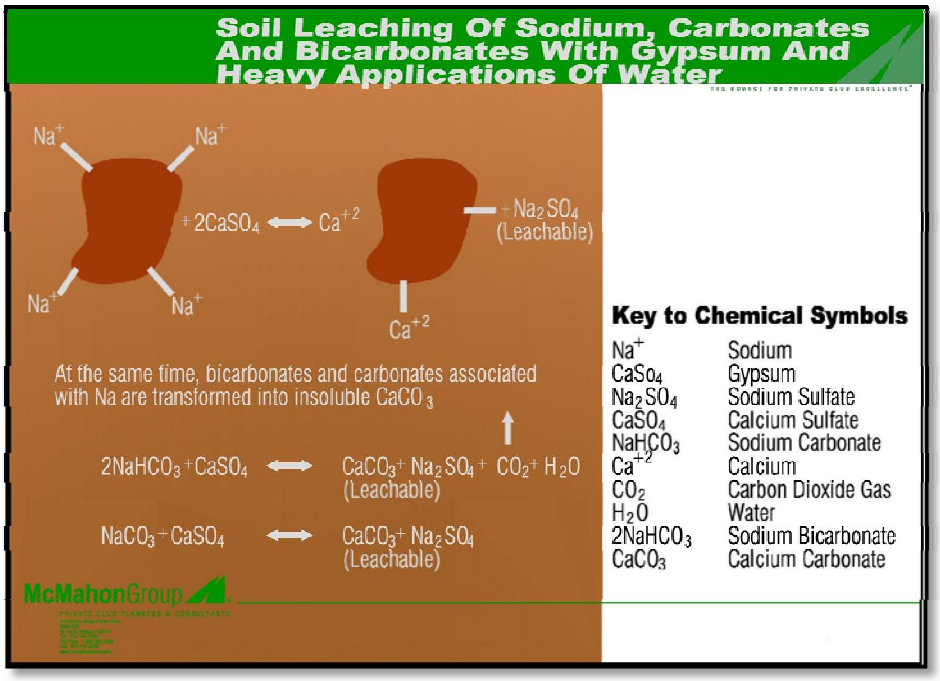


Figure 2 Water and gypsum used to flush sodium ions

Sodium Induced Wilt

Sodium induced wilt occurs within plants when sodium moves into cells at a high concentration, causing desiccation of cell walls and ultimately wilt.

There are ways regulate the movement of sodium into the cell, but removal of sodium is by far a better solution. I have identified a potential for this problem upon my arrival at Windmill Ridge last September, now it can be positively identified though this last root-zone soil test. A very good indication of this problem in the field is when wilt occurs at times in the day when wilt should not normally occur, such as early morning or late afternoon. Identifying the problem both in the field, and with help of root-zone soil tests, the golf course maintenance staff can help reduce a significant amount of plant stress that can often lead to other problems such as disease attack and or turf death.

By removing sodium from the soil this process will also make a significant difference in the health of soil microbial populations, allowing for better nutrient uptake, improved checks and balances for the control of pathogens, and a better root-zone physical structure.

Again, key management steps that will improve sodium mitigation will also help to prevent sodium induced wilt, these include:

Sodium Induced Wilt (continued)

- Venting as often as possible (at least twice per month-weather dependent);
- Applications of gypsum (5 pounds per 1,000 ft^2);
- Water heavy and infrequently, minimum 45 minutes per set (flushing or leaching);
- Spray application of high quality nutrients as outlined above;
- Increasing potassium levels, especially in fall.

Base Saturation Percentage

Base Saturation percentage refers to a measurement, or estimate of the percent of the soil exchange sites that is occupied by a particular nutrient (nutrient saturation), or the sum of a group of nutrients (total base saturation). This information gives us another tool to use in predicting the soils ability to provide adequate nutrients, and indicate needed changes in turf fertilization programs.

We must keep in mind that when the soil CEC is between 0 and about 3, the percent saturation has less meaning agronomically. This is because the holding power of the soil is so low that even a deficient amount of a cation nutrient could result in a relatively high saturation. In those cases, the soil test is telling us that we should consider making multiple split applications of those cations needed in large amounts, (that's the reason we spray apply nutrients during the season on sand root-zones) because the soil in unable to retain any significant amount from a single or seasonal applications.

Thus, cation exchange capacity (CEC) is the amount of nutrients the root-zone can hold and base saturation percent is the percentage of nutrients in the soil. An example would be CEC is a certain sized bag and base saturation is what items are in that bag expressed as a percentage.

Hydrogen (H^+) in the soil is not considered a nutrient. It is more of a place-holder. Plant roots and soil microorganisms exchange Hydrogen for nutrient cations.

Trace Elements

Boron (B)

Total soil boron content can range from around 10 to 100+ ppm. However, only a small fraction of this amount is available to the turf. Much of the total soil boron is present as a component of Tourmaline, a highly insoluble mineral. Most of the remainder is in secondary, moderately insoluble minerals. The forms of boron that are available to plants include inorganic borate complexes of Ca, Mg, and Na, plus various organic compounds formed from plant and microbe decomposition. Normal ranges for boron is 8-20 PPM in regular soil, Windmill Ridge values are acceptable noting the pH is above 6.

Trace Elements (continued)

Iron (Fe^{++})
Iron is essential for many plant functions, some of them are chlorophyll development and function, energy transfer within, plant respiration, plant metabolism and nitrogen fixation. Iron is an important constituent of certain plant enzymes and proteins.

At Windmill Ridge iron is applied regularly in a chelated form and should supply the turf with sufficient amounts of iron through spray applications. The green root-zone tests report levels of 92-201 ppm within recommended ranges or 100-300 ppm. Continue spray applications of CRP® 4-0-1 with iron or similar at regular intervals.

Manganese (Mn^{++})
Manganese role in vital plant functions are many, some of them are; assimilation of carbon dioxide in photosynthesis, synthesis of chlorophyll and in nitrate assimilation.

Mn is also proven to decreased disease incidence in turf. Because Mn plays many critical roles in the biosynthesis of phenolics and lignin, grasses deficient in Mn are unable to respond to pathogen attack by producing phytoalexins that would inhibit spore germination and block fungal invasion. As a result, disease out-breaks are more frequent and difficult to control in turf with Mn deficiencies.

Many soil fungi that normally would not be pathogenic or only weakly so will cause disease in Mn deficient plants. In short, the grass is unable to do its part in resisting infection and has little chance of growing out of an infection.

Windmill Ridge has values of Mn of 21-48 ppm, slightly below optimum but of no real concern. Continue applications of CRP® 4-0-1 or similar, it contains manganese citrate and manganese EDTA at .25%.

Copper ($Cu^{++)}$
Some fungicides contain high concentrations of copper (copper hydroxide). Toxicities have not been established in turf, however, levels greater than 10 ppm would be a concern especially under low pH values. Windmill Ridge has levels of Cu between 3.48-6.22 ppm which is within acceptable thresholds for sand based root-zones.

Zinc ($Zn^{++)}$
Some fungicides contain high concentrations of zinc (zinc sulfate). Windmill Ridge greens tested low in zinc, 4.58-10.36 ppm. Again the product being used; CRP® 4-0-1 has a chelated zinc nitrate at .20% that should provide an adequate supply of zinc to the turf plant.

Aluminum (Al^{+++})
Aluminum is not an essential element for either plants or animals.

Trace Elements, Aluminum (continued)

The reason for testing for Al is the ability of Al to become toxic in certain concentrations and at certain acid pH levels. The soil pH is probably the single most important management factor controlling the amount of Al in the soil solution. Soluble aluminum (Al) is present in the soil when the pH begins to drop below pH 6.0.

However, it is inconsequential in the vast majority of soils until the pH drops below pH 5.5. Even then, it is rarely a problem until the soil pH drops below pH 5.0. However, the amount of soluble Al increases dramatically in nearly all soils as the soil pH drops below pH 5.0. In these extremely acid soils Al toxicity would present a problem. Windmill Ridge root-zone soil test are 54-151 for Al, no problem exists at these levels with the current range of pH readings.

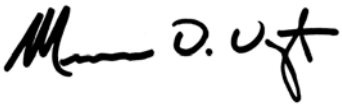
Conclusion

With the exception of high sodium the root-zone these tests proved to be generally good. Spray applications should continue with regards to rates and frequencies; whether using the current product from Lebanon Seaboard Company or similar products.

The new program of venting, irrigation in large volumes-less frequently and gypsum applications will cause the sodium levels in the top six inches of the root-zone to be less of a problem. This sodium remediation is not a “quick-fix”; it may take several months to correct the sodium problem. This program must be followed as long as irrigation water is high in soluble salts. It is very critical to the success of good greens turf that this program be followed carefully.

Regularly scheduled water tests should be taken and recorded to track soluble salts in irrigation water.

Respectfully submitted:



Michael D. Vogt, CGCS, CGIA

Appendix #1

Charging and Flushing High-Sand Greens

Irrigation sufficient to charge the root zone with water and leach excess salts varies according to the structure of the green.

Guy Prettyman and Ed McCoy, Ph.D.

Root zones composed primarily of sand-sized particles are the preferred growing media for putting greens. Sandy root zones provide superior playing conditions by generally meeting the agronomic demands of turf. The overarching factor dictating the use of high-sand root zones is that compaction does not reduce their permeability (1).

Profile design can improve the performance of sand-based root zones. A putting green soil profile consists of the putting surface, the sandy root zone, a subsurface drainage system and perhaps the underlying native subsoil. There are two popular types of putting green profiles: those that employ an underlying gravel layer, and those that do not.

Profiles with a gravel layer are often generically referred to as USGA profiles because they generally reflect the recommendations of the USGA (6). Profiles that do not employ such a layer are often referred to as "California profiles" because they generally reflect the recommendations of the University of California's "pure sand putting green" (2).

In experimental greens having otherwise identical root zones, the presence of the gravel layer, as in a USGA profile, yields greater maximum drainage rates and laterally more uniform soil moistures than does a profile without the gravel layer (5). The paths of water flow exiting the root zone are relatively short and principally vertical in green designs containing the gravel layer. Without this gravel layer, water must move laterally through the root zone for a substantial distance before reaching a drain line and exiting the system. Referring to this gravel layer as a gravel drainage blanket is clearly appropriate considering its major role in root-zone drainage.

During the course of our water drainage and redistribution study (5), we collected data on drainage outflow and soil moisture accumulation immediately after irrigation commenced. This research allows us to examine the influence of putting green profile design, root-zone composition, green slope and rainfall rate on irrigation requirements for charging the root zone with water and leaching excess salts.

Material and methods

This study employed four greens profile designs, including:

- A profile with no gravel drainage layer containing nine parts of sand and one part sphagnum
- A profile with no gravel drainage layer containing six parts sand, two parts compost and two parts

topsoil

- A USGA-style profile (i.e., employing a gravel layer) containing nine parts sand and one part sphagnum
- A USGA-style profile containing six parts sand, two parts compost and two parts topsoil

The sand-sphagnum blend had a lab permeability of 20.8 inches per hour and was designated the "high-permeability" mix, whereas the sand-compost-topsoil blend had a lab permeability of 12.6 inches and was called the "low-permeability" mix. When tested by an accredited laboratory, both mixes met the particle size and performance criteria for a USGA root zone.

The high-permeability mix, although not a pure sand, met recently proposed performance criteria for a California root zone (4). The four greens construction treatments were each replicated three times for a total of 12 experimental greens. The turf was a 15-month-old Penncross creeping bentgrass (*Agrostis palustris*) stand maintained at $^{3}/_{16}$ inch.

The rectangular experimental greens were 4 feet by 24 feet, with drain lines 15 feet apart at 2 and 17 feet from one end. The drain lines 2 feet from the end fed tipping-bucket rain gauges to monitor drainage outflow. Additionally, each root zone had soil moisture probes at three depths (3, 6 and 9 inches) and five locations (2, 7, 12, 17 and 22 feet), for a total of 15 probes per green, allowing continuous monitoring of soil moistures.

The set-up allowed monitoring of water drainage and soil moisture accumulation within the root zone as influenced by profile style, root-zone composition, green slope and rainfall rate. The overall study was conducted as a series of 18 individual experimental runs. During an experimental run, one green from each replication was sloped by zero, 2 or 4 percent.

Each green received simulated rainfall of at least 1.9 inches per hour for three hours to ensure a constant drainage rate. Rainfall measurements were collected during this period. Drainage outflow was measured every five minutes, and soil moisture was measured every 20 minutes for the duration of the rain event.

The tipping-bucket data were converted to graphs of cumulative outflow vs. time after rainfall commenced for each treatment combination in the study. From these graphs, we determined the times when drainage outflow started and when a constant drainage rate occurred. These times were converted to rainfall depths by multiplying by the measured rainfall rate. These rainfall depths and corresponding soil moistures were examined for treatment effects.

Results and discussion

For greens without any slope, outflow occurred after about 1.2 inches of simulated rain had fallen, regardless of profile design or root-zone composition. Greens with no gravel drainage layer sloped at 4 percent, however, required slightly less rain to initiate outflows, and sloped USGA-style greens required slightly more.

This general similarity between greens disappeared when we estimated the rain depth needed to achieve constant drainage: The USGA-style greens required more than 2 inches less than greens with no gravel drainage layer. And as slope increased from 0 to 4 percent, rain depths needed for constant drainage rate increased as well.

These results may be interpreted by examining mean soil moistures in the various systems at selected times during the rainfall period. With the exception of the greens with no gravel drainage layer

containing the low-permeability root zone, all greens had similar moistures of about 21 percent by volume before the rainfall simulation began.

As the steady rainfall continued, soil moisture increased in the root zones until it was sufficient to initiate drainage from the greens. This moisture content was about 30 percent by volume in all greens except in the no-slope, low-permeability profile with no gravel drainage layer (which required slightly more soil moisture to produce steady outflows) and the no-slope, high-permeability USGA profile (which required slightly less moisture).

The greens were not at their maximum wetness at this point, however, but continued to build water content as the simulated rainfall continued. When the greens achieved a constant drainage rate, the rainfall inputs were balanced by drainage, and the greens were at their maximum moisture content. For the greens with no gravel drainage layer, this state occurred when mean water contents were about 37 percent, regardless of root-zone composition or slope. For the USGA-style greens, maximum moisture content was about 31 percent, with slightly higher values in low-permeability root zones and with greater slope.

The greater water contents for the greens with no gravel drainage layer were principally the result of greater soil moisture accumulation between drain lines, which delayed constant drainage as more water accumulated. Finally, the effect of slope is simply explained by the greater distance water must travel to reach a drain line in the 4-percent vs. the zero-percent slope configuration.

The rainfall required to fully "charge" a putting green root zone would seemingly equal the amount required to achieve maximum water content and constant drainage. In our study, this ranged from about 6 inches for a green with no gravel drainage layer with a high-permeability root zone at 4-percent slope to 2 inches for the unsloped USGA-style greens. Of course, if pre-rainfall moistures had been drier, greater rain depth would be required to charge the root zone, and greater beginning moisture would have meant less rainfall was needed.

We can't assume, however, that a green with no gravel drainage layer is "charged" only when steady outflows occur. Such greens continued to drain over a 48-hour period, with a steady reduction of soil moisture occurring midway between the drain lines. This root-zone moisture was thus "lost" to the turf and is in excess of what's required to replace moisture that is evapotranspired. Consequently, the rain depths needed to charge a root zone with no gravel drainage layer might be similar to the requirements of a USGA-style green.

Many superintendents judge the irrigation depths needed to charge a root zone by fitting an inspection port on the main drain exiting the green and observing outflow during irrigation. When outflow just reaches maximum, the root zone is judged fully charged. This study suggests that this would be a useful tool for a USGA green. On the other hand, this approach may overestimate the needs of a green with no gravel layer, leading to excess application of water that ultimately drains from the green and therefore becomes unavailable to the turf.

The rain depth required to achieve constant drainage also represents the amount of rain necessary to initiate leaching of the root zone. It is only when this depth of water is applied that the entire root zone, regardless of location relative to a drain, is contributing flow to an outlet. The depth of rainfall required to completely replace root-zone moisture when the root zone is at its maximum water content (see table) was determined by calculating the total water held in the root zone between the drain lines and dividing by the corresponding area of the experimental green.

Compared to the USGA-style greens, the greens with no gravel layer required about 0.85 inches more rain to completely leach their root zones -- or to equal a leaching fraction of 100 percent (3). Further, root-zone composition and slope had little influence on this leaching depth in the greens with no gravel

layer, whereas increasing slope and use of the low-permeability root zone served to increase leaching depths for the USGA-style greens. The difference between profiles is again because of higher water contents of the greens with no gravel layer when the root zones have achieved a constant drainage rate.

Putting the information together implies that, to achieve 100 percent leaching fraction for a green with some existing moisture, one needs to add the rain depth required for constant drainage to the depth required to replace root-zone moisture. Thus, in this study's conditions, a USGA-style green with a high-permeability root zone and 4-percent slope needed 3.4 + 3.8 = 7.2 inches of rain to leach the root zone completely. Of course, leaching requirements are often a smaller percentage of the leaching fraction than what was estimated here and can best be determined by soil testing. Consequently, the values we estimated to "replace root-zone water" would typically be multiplied by this smaller percentage (10 to 25 percent) to determine the actual leaching requirements.

Clearly, the results of this study depend on existing moisture, root-zone permeability and slope and cannot be adopted at face value when deciding water depths to charge or flush a root zone. They do, however, provide some general guidelines for understanding greens behaviors that might aid the superintendent in water management.

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Guy Prettyman recently received his master's degree in soil science from Ohio State University. Ed McCoy, Ph.D., is an associate professor of soil science at Ohio State University.

The authors wish to acknowledge the GCSAA and USGA for their support of this research project.

Appendix #2

Soil Report

Job Name **Windmill Ridge Golf Course** Date 5/21/2012

Company Michael D. Vogt Submitted By M. Vogt

Sample Location		Green	Green	Green	Green	Green
Sample ID		#2	#3	#6	#7	#11
Lab Number		17	18	19	20	21
Sample Depth in inches		6	6	6	6	6
Total Exchange Capacity (M. E.)		3.64	3.37	2.77	2.69	2.89
pH of Soil Sample		7.50	7.70	7.70	7.60	7.80
Organic Matter, Percent		1.20	1.28	0.79	0.82	1.04
ANIONS	**SULFUR:** p.p.m.	14	17	17	13	13
	Mehlich III Phosphorous: as (P_2O_5) lbs / acre	402	426	215	209	234
EXCHANGEABLE CATIONS	**Calcium:** Desired Value Value Found Deficit lbs / acre	 919 1047	 917 954	 753 757	 732 748	 785 799
	MAGNESIUM: Desired Value Value Found Deficit lbs / acre	 200 92 -108	 200 87 -113	 200 72 -128	 200 72 -128	 200 83 -117
	POTASSIUM: Desired Value Value Found Deficit lbs / acre	 200 142 -58	 200 109 -91	 200 105 -95	 200 98 -102	 200 107 -93
	SODIUM: lbs / acre	147	166	156	137	139
BASE SATURATION %	Calcium (60 to 70%)	71.83	70.71	68.32	69.40	69.21
	Magnesium (10 to 20%)	10.52	10.75	10.83	11.13	11.98
	Potassium (2 to 5%)	5.00	4.14	4.86	4.66	4.75
	Sodium (.5 to 3%)	8.76	10.70	12.27	11.02	10.48
	Other Bases (Variable)	3.90	3.70	3.70	3.80	3.60
	Exchangeable Hydrogen (10 to 15%)	0.00	0.00	0.00	0.00	0.00
TRACE ELEMENTS	Boron (p.p.m.)	0.43	0.43	0.29	0.37	0.37
	Iron (p.p.m.)	136	167	92	93	104
	Manganese (p.p.m.)	40	33	23	25	26
	Copper (p.p.m.)	3.98	6.22	3.59	3.85	3.59
	Zinc (p.p.m.)	7.65	10.36	4.58	5.11	4.86
	Aluminum (p.p.m.)	81	77	54	59	64

Logan Labs, LLC

Soil Report

Job Name **Windmill Ridge Golf Course** Date 5/21/2012

Company Michael D. Vogt Submitted By M. Vogt

Sample Location		Green	Green			
Sample ID		#12	#16			
Lab Number		22	23			
Sample Depth in inches		6	6			
Total Exchange Capacity (M. E.)		2.67	5.60			
pH of Soil Sample		7.70	7.80			
Organic Matter, Percent		0.92	1.50			
ANIONS	**SULFUR:** p.p.m.	13	13			
	Mehlich III Phosphorous: as (P_2O_5) lbs / acre	199	518			
EXCHANGEABLE CATIONS	**Calcium:** Desired Value Value Found Deficit lbs / acre	725 725	1522 1508 -14			
	MAGNESIUM: Desired Value Value Found Deficit lbs / acre	200 84 -116	200 238			
	POTASSIUM: Desired Value Value Found Deficit lbs / acre	200 98 -102	200 145 -55			
	SODIUM: lbs / acre	129	208			
BASE SATURATION %	Calcium (60 to 70%)	67.99	67.34			
	Magnesium (10 to 20%)	13.13	17.71			
	Potassium (2 to 5%)	4.71	3.32			
	Sodium (.5 to 3%)	10.52	8.06			
	Other Bases (Variable)	3.70	3.60			
	Exchangeable Hydrogen (10 to 15%)	0.00	0.00			
TRACE ELEMENTS	Boron (p.p.m.)	0.37	0.42			
	Iron (p.p.m.)	94	201			
	Manganese (p.p.m.)	21	48			
	Copper (p.p.m.)	3.48	5.64			
	Zinc (p.p.m.)	4.6	9.71			
	Aluminum (p.p.m.)	56	151			

Logan Labs, LLC