Golf Course Environmental Profile

Volume III

Nutrient Use and Management on U.S. Golf Courses

With Forewords by Greg Norman, World Golf Hall of Fame Member, and
Mark D. Kuhns, CGCS, 2009 GCSAA President

GCSAA

Environmental Institute for Golf

The Environmental Institute for Golf is the philanthropic organization of the Golf Course Superintendents Association of America.

Golf Course Superintendents Association of America

Golf Course Environmental Profile

Nutrient Use and Management on U.S. Golf Courses

Volume III

Funded by:
The Environmental Institute for Golf
and
The Toro Giving Program

Table of Contents

Our Mission

GCSAA is dedicated to serving its members, advancing their profession and enhancing the enjoyment, growth and vitality of the game of golf.

Environmental Institute for Golf

The Environmental Institute for Golf is committed to strengthening the compatibility of the game of golf with our natural environment.

Acknowledgments

The Golf Course Superintendents Association of America and The Environmental Institute for Golf wishes to thank:

The Toro Giving Program for providing a grant to help fund this research.

The thousands of golf course superintendents who took the time and effort to complete the survey.

Golf's allied associations for their support in this endeavor.

Foreword

In today's world of golf, the safe and efficient application of nutrients is not an option, it is essential. Essential to the health of the ecosystems in which the game is played; essential to delivering a playing experience using sustainable practices that provide economic value to a community; and essential to ensuring the protection of the quality of our water supply.

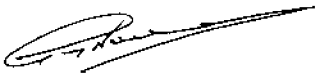
The "Nutrient Use and Management on U.S. Golf Courses" report, the third in the series from the Golf Course Environmental Profile, demonstrates the practical and careful use of nutrients by professional superintendents in every day applications. Perhaps most importantly, the report sets a benchmark for improving performance in the future. The research, education, resources and outreach programs funded by The Environmental Institute for Golf and the Golf Course Superintendents Association of America are all critical components of water quality and compliance with the laws intended to protect water sources from nutrient runoff.

Along with water conservation, water quality is of utmost importance for the golf course industry. As we learned from the last survey, superintendents are responsible users of water. The same can now be said about the use of nutrients. Consider these facts:

- Superintendents apply nutrients within the ranges recommended by university scientists.
- Superintendents calibrate fertilization equipment frequently to ensure nutrients are applied effectively, efficiently and appropriately.
- Superintendents consider many variables when making nutrient use decisions. Integrating multiple factors helps ensure quality turfgrass and environmental protection.

While we know that golf can continue to improve and perform better, the data provided by the Golf Course Environmental Profile provides us a position of strength. Based on the data, we have the power to develop new tools, research and education to ensure the protection of the environment, improve golf's economics and provide a safe place for young and old alike to enjoy the game, and teach its many values and life lessons. You can be assured that the golf course industry is assessing and measuring its practices for the essential health and sustainable growth of the game for today and tomorrow.

Regards,



Greg Norman
Advisory Council Chair
The Environmental Institute for Golf

Foreword

When the concept of measuring and documenting the profile of golf courses first arose, Golf Course Superintendents Association of America (GCSAA) and The Environmental Institute for Golf (EIFG) leadership and staff knew the task would be arduous. There had never been a national, comprehensive survey of golf courses that would establish baseline information for the golf industry. We were entering uncharted waters and did not fully know what to expect.

We quickly learned from the first survey that provided insight on land use and environmental stewardship activities on golf courses that the industry had quite an appetite for the information, and that GCSAA golf course superintendents were responding impressively to our request for data. Furthermore, we found that the information had great value in communicating with a variety of constituents including lawmakers, media, environmental community, citizen groups, etc. The availability of hard data went a long way in focusing discussions and enhancing communications.

This report is the third in a series of five that will establish a baseline for the management of golf courses in the U.S. The aforementioned property profile and environmental stewardship report was followed by a water use and conservation report released in January 2009. This report, "Nutrient Use and Management on U.S. Golf Courses," examines how facilities manage fertilization programs. The next two reports — one on pesticide use and the other on energy use and environmental practices — will be released in 2010. To measure change, the five surveys will be repeated in the future.

These reports build upon each other, and with each set of data the picture becomes clearer. We have found that golf facilities, supported by the efforts of GCSAA members, are incorporating environmental stewardship practices. Leveraging the data, we have been able to go out with that message and clarify some of the environmental criticisms that have plagued the industry for years. We are encouraged that the last two reports will provide additional opportunities to further strengthen golf courses as community assets, delivering tangible social, environmental and economic benefits. Certainly such an undertaking requires significant resources, and we thank The Environmental Institute for Golf and The Toro Giving Program for making this project possible.

While we are encouraged by the information, we acknowledge the fact that improvements or changes in behavior will be necessary. It might sound trite to say "we don't know what we don't know," but with this information decisions can be made with greater confidence. I not only look forward to the final two reports of this first phase, but to the day when we repeat the surveys to measure change and, hopefully, our progress.

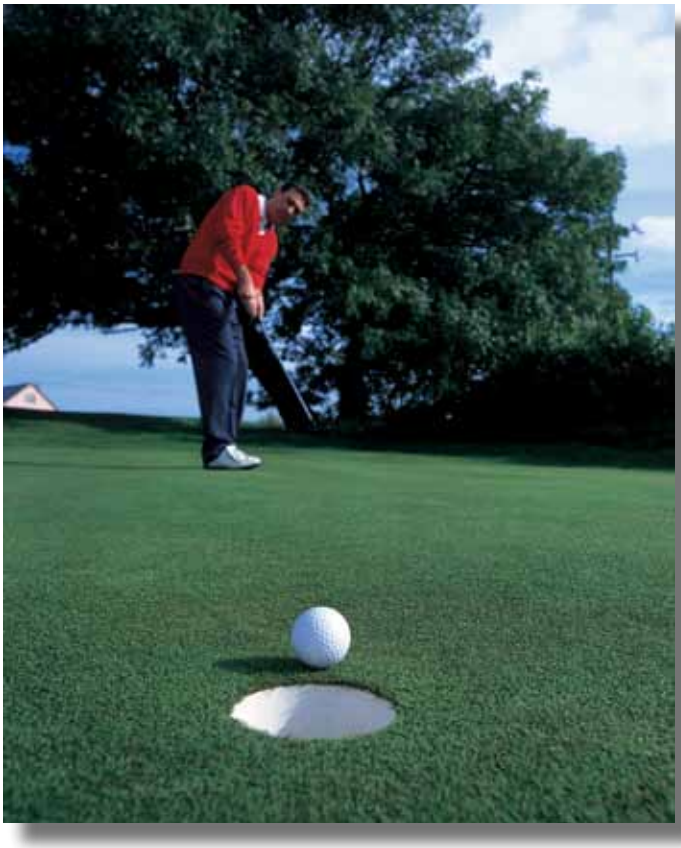
Lastly, I want to thank the more than 2,500 superintendents who completed this survey. These requests are quite detailed and require significant time in compiling the data. The high return rate reflects positively on our members as they seek to communicate and enhance their stewardship efforts. Through their dedication, the golf industry and the environment will benefit.

Sincerely,

Mark D. Kuhns, CGCS
2009 GCSAA President

Executive Summary

For the first time the golf course management industry has accurate data on nutrient use on golf courses in the U.S. The Golf Course Environmental Profile developed by GCSAA and the EIFG provides data that give new insight into property features, management practices and inputs associated with golf courses across the U.S. The first two reports are on golf facility land use and environmental stewardship and water use and conservation and can be found at www.eifg.org. The third volume, "Nutrient Use and Management on U.S. Golf Courses," provides a baseline for comparison with results from future surveys to document changes in nutrient use and management practices over time. This information can help guide the agronomic and environmental initiatives of the golf course management industry.



The objectives of the nutrient use and management survey were to determine:

- the amount of nutrients applied to golf courses
- the sources of the nutrients applied
- how superintendents make decisions about nutrient applications
- whether superintendents use written nutrient management plans or operate under governmental restrictions
- how fertilizers are stored and how often fertilizer application equipment was calibrated

Methodology

Superintendents at all golf facilities in the U.S. (16,386) were invited to participate in this survey. A total of 2,561 completed surveys were returned, yielding a 15.6% return rate. Analysis of the returned surveys indicated a representative sample of golf facilities was received with the exception of facility type. Responses from private facilities accounted for 40% of the returned surveys but made up 29% of golf facilities. Therefore, proportions of the collected sample were weighted to resemble known golf course demographics. The data were analyzed and compared across facility types, maintenance budgets and agronomic regions.

Results and Recommendations

Nutrient Use

Summed over all golf course components and all golf courses, in 2006 a total of 101,096 tons of nitrogen were applied to 1,311,000 acres (154 pounds of nitrogen per acre); 36,810 tons of phosphate were applied to 1,131,000 acres (65 pounds of phosphate per acre); and 99,005 tons of potash were applied to 1,260,000 acres (157 pounds of potash per acre). These application rates are within the guidelines recommended by university scientists.

To offer context, it is helpful to compare the rate of fertilizer applied to turfgrass on golf courses with agricultural crops like corn and tomatoes. Corn is a widely grown agronomic crop and tomatoes are a high-value, intensely maintained vegetable crop. Turfgrass on golf courses is fertilized at a slightly higher rate than corn and at a slightly lower rate than tomatoes.

Nitrogen Fertilizer Sources

For 18-hole golf facilities nationally, slow-release nitrogen sources accounted for 64% of the nitrogen applied, and quick-release nitrogen sources accounted for 36%. Organic nutrient sources were applied to 66% of 18-hole golf facilities in 2006. Organic sources of nutrients comprise 24% of the total annual amount of nutrients applied on 18-hole golf facilities.

Soil Amendments and Turfgrass Supplements

In 2006, 43% of 18-hole facilities did not use soil amendments. The highest use of soil amendments was in the Southwest, where it is common for soil and irrigation water to have a high sodium content. A much larger percentage of respondents, 74%, use a turfgrass supplement such as biostimulants, humates and amino acids/proteins.

Nutrient Management Plans and Fertilizer Restrictions

Of 18-hole golf facilities, 49% had a written nutrient management plan or written fertilizer program in 2006, but only 6% of facilities were required by government or tribal authorities to have such a plan. A higher maintenance budget correlates with the likelihood that a golf facility would use a written nutrient plan or fertilizer program. Nationally, only 9% of 18-hole golf facilities reported restrictions on fertilizer applications. Restrictions were most likely in the North Central (16%) and Pacific (10%) agronomic regions.

Recommendation for Nutrient Management Plans.

GCSAA recommends that all golf facilities use guidelines developed by university scientists to develop written nutrient management plans based on the characteristics and expectations unique to each facility.

Nutrient Application Decisions

Superintendents consider multiple factors when making nutrient application decisions. Integrating many variables into their decisions leads to effective applications for the turfgrass while protecting the environment. The most common factors superintendents used to make decisions about nutrient applications and the percentage of 18-hole golf facilities using that factor were: visual observations of turfgrass (85%), previous product performance (84%), soils/soil analysis (84%) precipitation/temperature/weather (83%), turfgrass species (81%) and disease pressure (79%).

Recommendation for Nutrient Application Decisions.

In order to foster sustainability at the golf facility, superintendents should consider the location, climate and condition of the turfgrass as well as the rate, time of year and products to be used when making nutrient management decisions.

Soil Testing

From 2002 to 2006, 95% of 18-hole golf facilities performed soil testing on greens, 75% on tees, 80% on fairways and 26% on rough.

Recommendation for Soil Testing.
GCSAA recommends that superintendents routinely conduct soil tests on the rough, because it receives the greatest total amount of phosphate and potash. Soil testing has the potential to curtail costs and promote fertilizer programs that meet, but do not exceed, the nutritional needs of the turfgrass.

Fertilizer Storage and Equipment Calibration

On average, superintendents at 18-hole golf facilities calibrated their fertilizer application equipment before 67% of applications, thereby improving the accuracy of their fertilizer applications.

Nationally, 91% of 18-hole golf facilities stored fertilizer on site for three consecutive calendar days or more in 2006. Half of those golf facilities used a dedicated storage facility.

Recommendation for Fertilizer Storage.
GCSAA recommends that golf facilities that store fertilizer should use a dedicated fertilizer storage area designed for that purpose.

Conclusions

The Golf Course Environmental Profile surveys have established the percentage of facilities that are carrying out particular management practices, making it possible for GCSAA and the EIFG to communicate results and make recommendations for improving golf course management practices throughout the country. Additional recommendations will be made as the results of the remaining surveys are published.

Introduction

"Nutrient Use and Management on U.S. Golf Courses" is the third of five reports that make up the Golf Course Environmental Profile. This report includes data about many facets of nutrient use on golf courses — from the amounts of nutrients applied to fertilizer storage data and equipment calibration. These data complement the two previous reports that provide information on property features, land-use acreage, turfgrass species, water use and water conservation practices. Future reports will provide data on pesticide use, integrated pest management, stewardship practices and energy use.

Since 2004, golf course superintendents, golf industry leaders, golf association leaders, environmental advocates, university turfgrass scientists and environmental regulators have participated in meetings, symposiums and conferences hosted by The Environmental Institute for Golf to discuss environmental issues facing the golf industry and to identify future research, education and outreach opportunities. The group reached several important conclusions about the environmental aspects of golf including:

- The golf industry did not have comprehensive national data on the property features, management practices and inputs associated with golf courses and golf course maintenance.
- Although many individual golf courses are environmentally proactive, no systematic process was in place to document current practices or track changes that the golf industry nationwide has made to protect and enhance the environment.

In 2006, the Golf Course Superintendents Association of America (GCSAA) initiated a project, funded by The Environmental Institute for Golf through a grant from The Toro Giving Program, to collect data nationally on the property features, management practices, and inputs associated with golf courses and golf course maintenance. To collect the data, a series of five surveys was conducted from 2006 through 2009. The surveys will be repeated to measure changes on golf courses and in golf course maintenance practices over time. The first survey was conducted in 2006 and its manuscript, "Golf Course Profile Describes Turfgrass, Landscape and Environmental Stewardship Features," was published in November 2007 in *Applied Turfgrass Science*, a peer-reviewed scientific journal (4). Its companion report, "Property Profile and Environmental Stewardship of Golf Courses," was also produced in November 2007. The second survey of the series was conducted in late 2006 and its manuscript, "Golf Course Environmental Profile Measures Water Use, Source, Cost, Quality and Management and Conservation Strategies," was published in *Applied Turfgrass Science* in 2008 (10). Its companion report, "Water Use and Conservation Practices on U.S. Golf Courses," was also produced in 2008. In 2007, the third survey of the series was completed and its manuscript, "Golf Course Environmental Profile Measures Nutrient Use and Management and Fertilizer Restrictions, Storage and Equipment Calibration," was published in *Applied Turfgrass Science* in 2009 (11). Its companion report, "Nutrient Use and Management on U.S. Golf Courses was also published in 2009. All of the published Golf Course Environmental Profile reports and journal articles are available on The Environmental Institute for Golf's Web site, www.eifg.org. For more information on the Golf Course Environmental Profile, please contact The Environmental Institute for Golf at 800-472-7878.

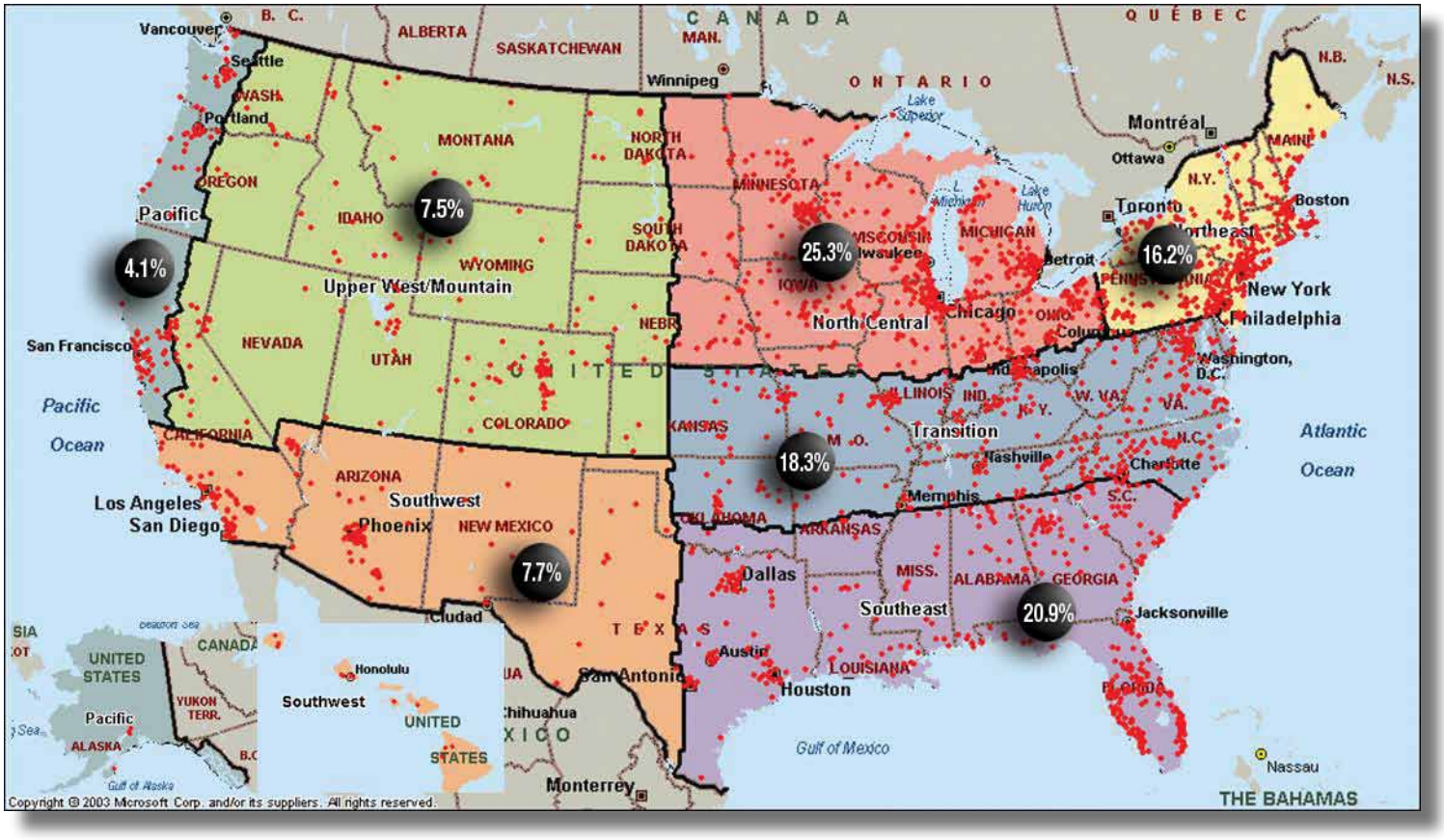
Summary of Methodology

Input on the survey questions was collected from golf, environmental, academic and regulatory sources. GCSAA staff drafted survey questions, which were reviewed and revised by a group of golf course superintendents, golf association leaders and environmental advocates.

The National Golf Foundation (NGF) was contracted to conduct the survey, manage the recruitment of participants and complete the analysis of data in collaboration with GCSAA. The NGF adheres to The Code of Marketing Research Standards developed by the Marketing Research Association (5). The NGF refined and formatted the survey instrument for online and paper versions.

The same survey procedures were used for this survey as were used in the previous two surveys (4,10). An attempt was made to recruit 16,386 superintendents at golf facilities in the U.S. to complete the nutrient use survey. Surveys were sent beginning March 19, 2007 by e-mail or mail and accepted until May 9, 2007. Several reminders to complete and submit the survey were sent by e-mail and mail.

Figure 1. Percentage of the total number of completed surveys by agronomic region. Small red dots indicate locations of golf facilities responding to the survey.



Of the 16,386 superintendents contacted, 2,561 completed and returned surveys, yielding a 15.6 percent return rate. The analysis classified the golf courses by agronomic region, course type (daily fee, municipal or private) and number of holes. Agronomic regions were determined by grouping geographic areas with similar climatic and agronomic characteristics, and boundaries were drawn using county borders (3,9). Analysis of the returned surveys indicated a representative sample of golf facilities was received with the exception of facility type. Responses from private facilities accounted for 40 percent of the returned surveys but made up 29 percent of golf facilities. Therefore, proportions of the collected sample were weighted to resemble the known golf course demographics. Weighted data are presented in this report (Figure 1, Table A1).

Data were analyzed to run descriptive statistics and explore relationships among the variables such as agronomic region, course type and number of holes. The words "significant" and "significantly" are used frequently in the report to describe statistical differences. For example, "Private golf facilities were significantly more likely than public facilities to test the soil on all components of the golf course." In the mathematical sense, "significant" means that differences are important, distinct and too great to be caused by chance.

The nutrient use data have been analyzed and compared across facility types, maintenance budgets and agronomic regions. The facility type was characterized as private or public. Private facilities require a membership, and public facilities allow anyone to play for a fee. Golf facilities were divided into three annual maintenance budget categories: more than $1 million, $500,000 to $1 million and less than $500,000. The final major comparison was by agronomic region. The continental U.S. was divided into seven agronomic regions: Northeast, North Central, Transition, Southeast, Southwest, Upper West/Mountain and Pacific. The regional analysis identifies variation in nutrient use and management across the U.S.

Where 18-hole equivalent data are presented, data within a region were averaged over facility type and budget. The number of 18-hole equivalents in the U.S. is 14,969, and was determined by taking the total number of golf holes and dividing by 18 (7).

Survey Objectives

The objectives of the third survey, "Nutrient Use and Management of U.S. Golf Courses," were to determine the amount of nutrients applied to golf courses, how superintendents make decisions about nutrient applications, and whether they use written nutrient management plans or operate under governmental restrictions. The survey also inquired about the sources of the nutrients applied, how fertilizers are stored and how often fertilizer application equipment was calibrated.

For the purposes of this survey, nutrients are any substances used or required by an organism for food and can be categorized as micronutrients or macronutrients. Plants, including turfgrasses, require at least 18 elements for proper growth. Each element has a unique function and is required in different amounts by the various turfgrass species. A deficiency of any one element can limit plant growth, but most elements are supplied to turfgrasses by natural soil processes (From Rosen and Horgan) (8).

Three elements — nitrogen, phosphorus and potassium — are considered primary macro-nutrients because they are often required in larger quantities than are readily available through natural soil processes. Deficiencies of the other nutrients are relatively rare and are generally associated with unusual soil conditions such as acid, alkaline or extremely sandy soil (From Rosen and Horgan) (8).

The nitrogen content of fertilizer is expressed as nitrogen (N), the phosphorus content is expressed as phosphate (P_2O_5), and the potassium content is expressed as potash (K_2O). Fertilizer recommendations, fertilizer rates and the annual amount of fertilizer applied are usually expressed as nitrogen, phosphate (rather than phosphorus), and potash (rather than potassium). The terms phosphate and potash will be used in this report when referring to fertilizers containing phosphorus and potassium applied by survey respondents. Superintendents were asked to indicate the rate of application of nitrogen, phosphate and potash to greens, tees, fairways, rough, practice areas, turfgrass nurseries, grounds and no-mow/native areas. Superintendents generally express nutrient application rates in pounds per 1,000 square feet, and it is expressed in this manner in the report. Total use of nutrients is expressed in pounds per acre (1 acre = 43,560 square feet).

Survey Results

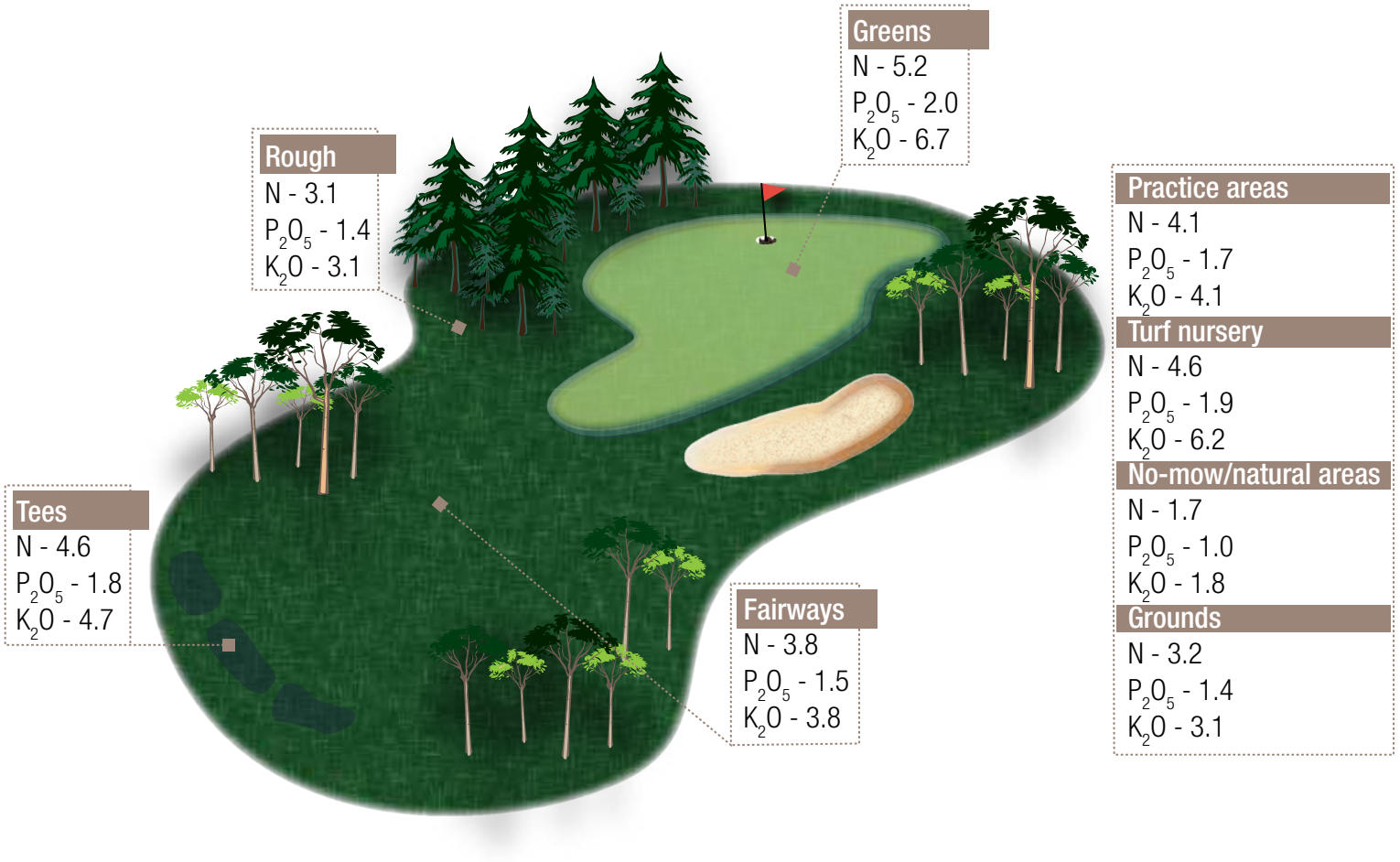
Nutrient Use

Nutrient Use Application Rate by Facility Characteristics

The annual rate of nitrogen, phosphate and potash applied to each golf course component (greens, tees, fairways and roughs) varies depending on the total number of holes, facility type (public or private) and annual maintenance budget (Table A2).

- The nutrient application rate was highest on golf facilities with 27 or more holes. Eighteen-hole golf facilities applied higher rates of nutrients than 9-hole golf facilities.
- Private 18-hole golf facilities applied higher rates of nutrients than public 18-hole golf facilities.
- Eighteen-hole golf facilities with maintenance budgets greater than $1 million and from $500,000 to $999,999 applied higher rates of nutrients than facilities with maintenance budgets below $500,000.

Figure 2. The average annual rate of nitrogen (N), phosphate (P_2O_5) and potash (K_2O), in pounds per 1,000 square feet, applied in 2006 to an average 18-hole golf course in the U.S.



Nutrient Application Rate by Golf Course Component

Greens, tees and fairways require the highest turfgrass quality for the game of golf and are the highest priority for play. Generally, these areas receive the nutrients needed to produce high-quality playing surfaces.

- The annual rate of nitrogen, phosphate and potash applied to greens, tees, fairways, practice areas and turfgrass nurseries is higher than the rate applied to rough, no-mow/natural areas and grounds on 18-hole golf facilities (Figure 2, Table A2).
- The nutrient rate applied to turfgrass nurseries reflects the rate needed to produce high-quality turfgrass to replace damaged turfgrass on a green, tee or fairway.

Nutrient Application Rate by Agronomic Region

The specific rate of each nutrient applied to all golf course components within each agronomic region is described in Table A2. To simplify the comparison of nutrient use across regions, the average rate of nitrogen, phosphate and potash used for the entire golf course was calculated. The rate comparison, total amount applied and total acres fertilized are discussed separately for each nutrient. In general, the nutrient rate applied varies significantly among regions because of the differences in length of growing season, turfgrass species grown, and winter overseeding practices.

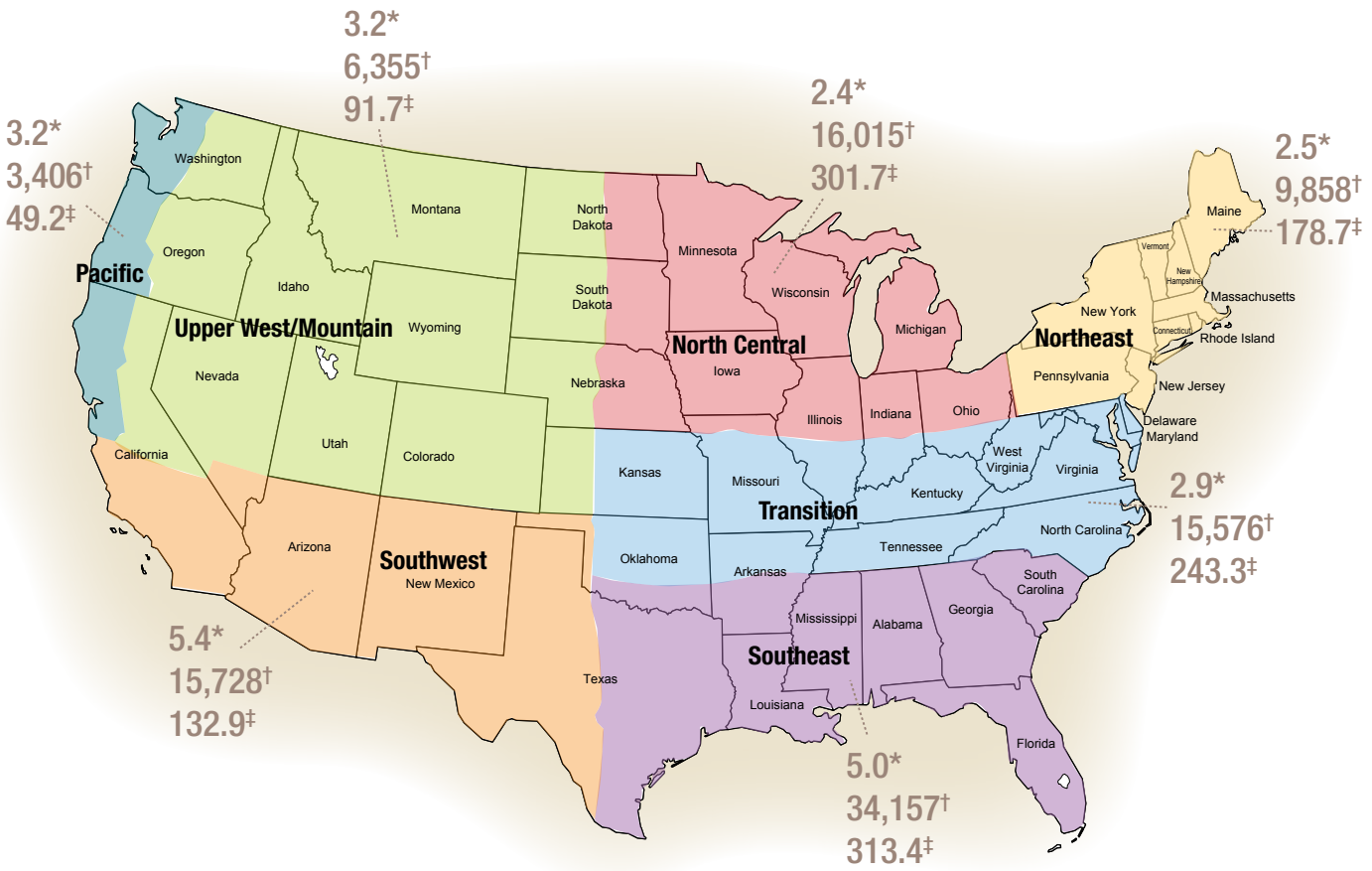


Figure 3. Nitrogen applications to U.S. golf courses by agronomic region.
***Average amount of nitrogen applied per 1,000 square feet.**
†Total nitrogen applied in tons per year.
‡Total area (in thousands of acres) that receives nitrogen.

Nitrogen

Adequate nitrogen produces vigorous growth and green color in turfgrass plants. Too little or too much nitrogen can cause problems. Too little available nitrogen leads to slow growth, increased chance of some diseases, yellowing of plants and a thin turfgrass stand, resulting in increased weed pressure. Too much nitrogen leads to excessive leaf growth, reduced root growth, low carbohydrate reserves, poor tolerance of environmental stresses and increased susceptibility to some diseases (From Rosen and Horgan) (8).

- Nitrogen is the primary nutrient applied by golf course superintendents to manage the growth and performance of turfgrass. In general, fertilizer programs are designed around the application of nitrogen.
- Nationally, the average rate of nitrogen applied is 3.5 pounds per 1,000 square feet.
- The annual rate of nitrogen applied is highest in the Southeast, Southwest, Transition and Pacific regions, in part, because those regions have longer growing seasons (Figure 3).
- Bermudagrass is a widely used species in the Southeast and Southwest regions and requires a higher annual nitrogen rate than other turfgrass species grown on golf courses (2,4,6).
- The practice of winter overseeding contributes to the high annual nitrogen application rates in the Southeast and Southwest agronomic regions (Table A2). The winter overseeded grass requires fertilization throughout the fall, winter and mid-spring.
- The estimated total amount of nitrogen applied to all golf courses in 2006 was 101,096 tons. The total number of acres fertilized with nitrogen was 1,311,000 (Figure 3, Table A3).

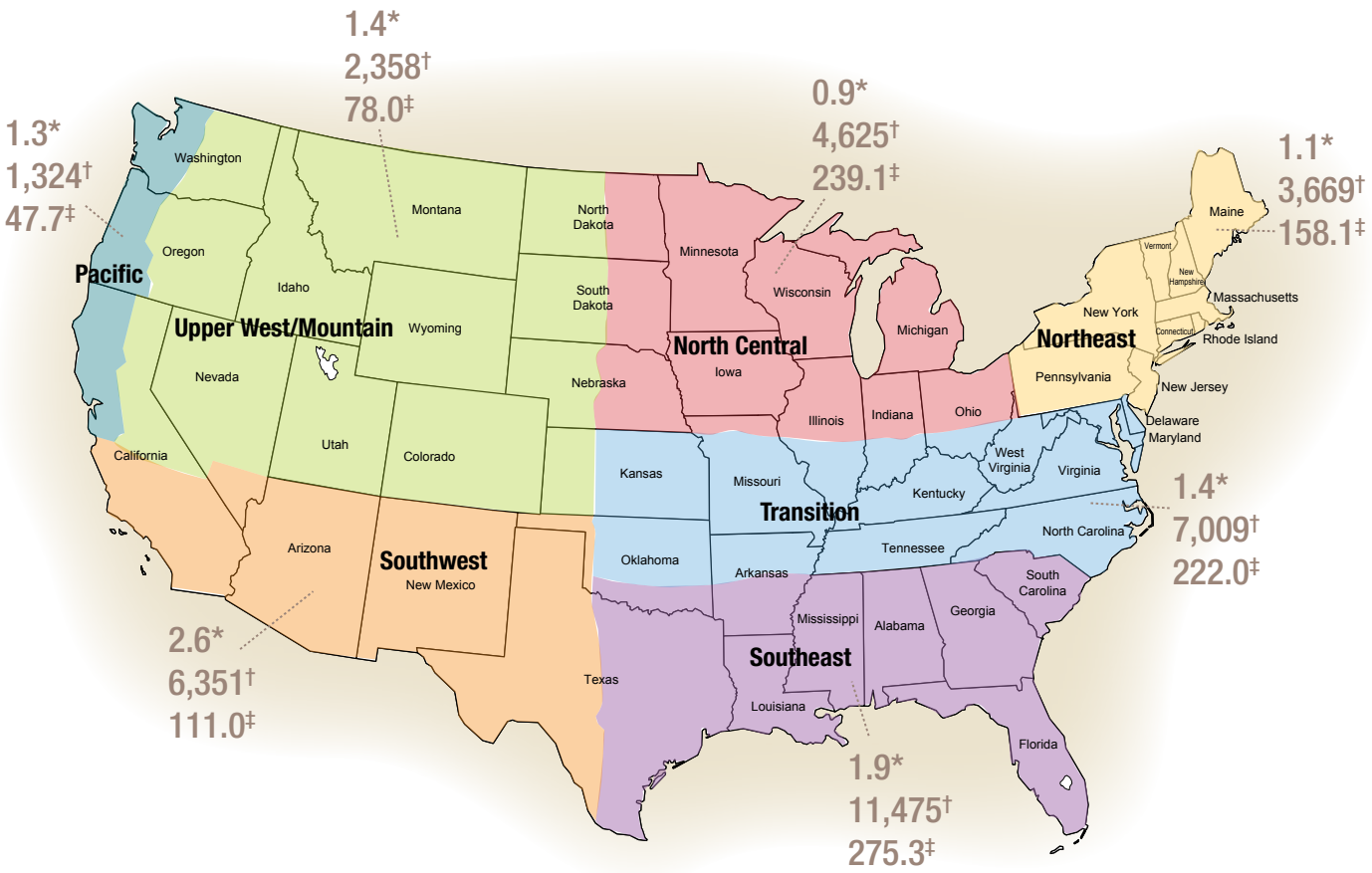


Figure 4. Phosphate applications to U.S. golf courses by agronomic region.
***Average amount of phosphate applied per 1,000 square feet.**
†Total phosphate applied in tons per year.
‡Total area (in thousands of acres) that receives phosphate.

Phosphate

Phosphorus is important in stimulating root growth and promoting plant development during establishment of turfgrass from seed, sod or stolons, but established turfgrass generally shows little response to phosphorus fertilization unless unique soil conditions exist that do not provide adequate phosphorus for the plants. Soils naturally high in phosphorus are apt to provide sufficient phosphorus for vigorous turfgrass growth for many years without adding fertilizers containing phosphorus (From Rosen and Horgan) (8).

A soil testing laboratory can determine the current level of phosphorus in a particular soil. This inexpensive procedure is the best way to accurately determine whether the turfgrass requires additional phosphorus (From Rosen and Horgan) (8).

The phosphorus content of fertilizers is expressed as phosphate (P_2O_5). Annual phosphate application rates follow trends similar to nitrogen application rates across agronomic regions (Figure 4, Table A2).

- The average rate of phosphate applied nationally is 1.5 pounds per 1,000 square feet.
- The estimated total amount of phosphate applied to all golf courses in 2006 was 36,810 tons, which was applied to 1,131,000 acres (Figure 4, Table A3).

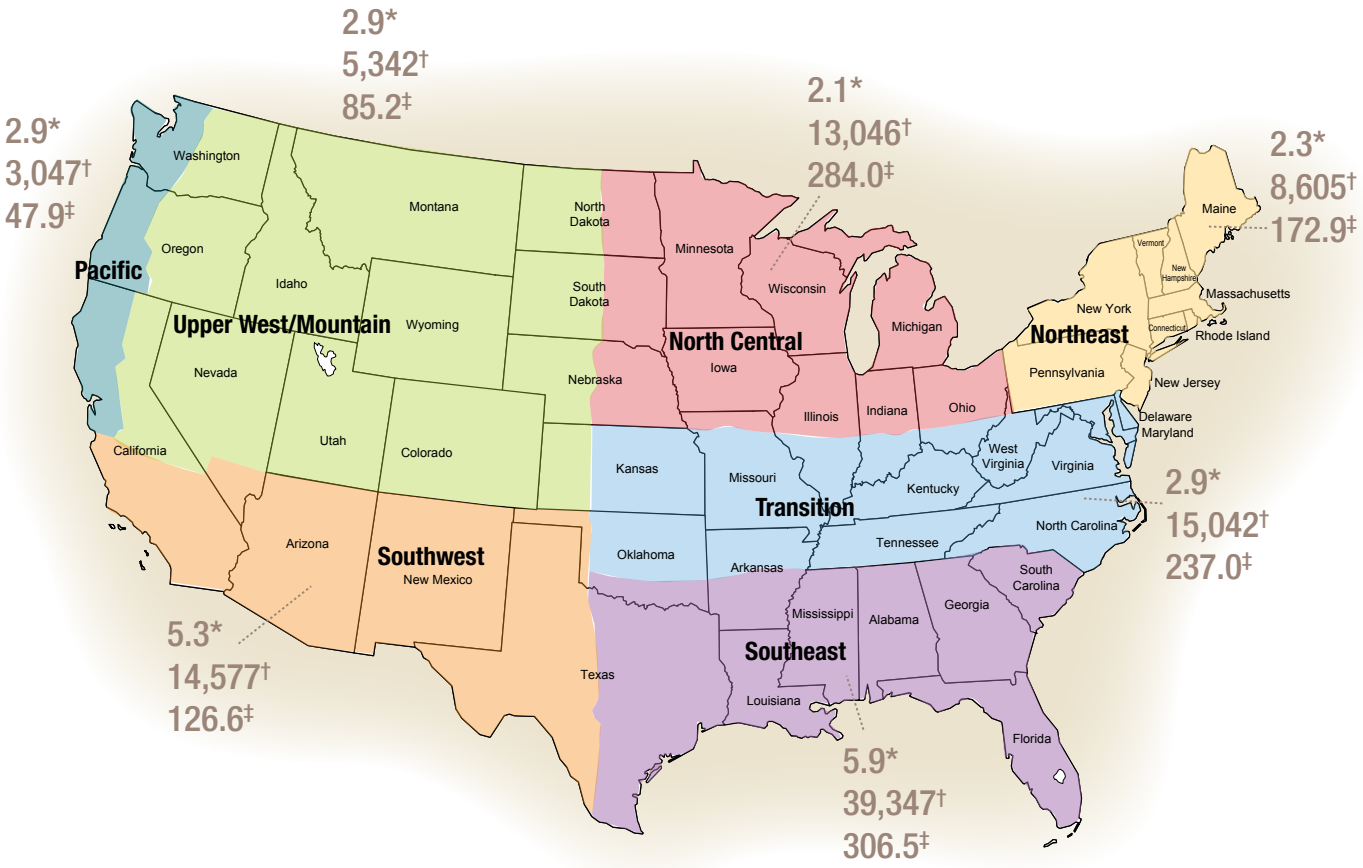


Figure 5. Potash applications to U.S. golf courses by agronomic region.
***Average amount of potash applied per 1,000 square feet.**
†Total potash applied in tons per year.
‡Total area (in thousands of acres) that receives potash.

Potash

Potassium is important in the synthesis or creation of some plant components and the regulation of many physiological processes including more efficient use of nitrogen by the plant. Potassium deficiencies in turfgrass may reduce tolerance to environmental stress (From Rosen and Horgan) (8).

Potassium is held on the surfaces of soil particles and is not likely to move in most soils, though it can gradually move out of the root zone in sandy soils. Where soils are high in native potassium, supplemental potassium fertilization may be unnecessary; however, where soils are low in native potassium, supplemental applications are very important. Soil tests are essential to determine the potassium level of a soil and to develop a potassium fertility program (From Rosen and Horgan) (8).

The potassium content of fertilizers is expressed as potash (K_2O). The annual potash application rates follow trends similar to nitrogen application rates across agronomic regions (Figure 5, Table A2).

- The average rate of potash applied nationally is 3.6 pounds per 1,000 square feet.
- The estimated total amount of potash applied to all golf courses in 2006 was 99,005 tons applied to a total of 1,260,000 acres (Figure 5, Table A3).

Trends in Nutrient Use

Survey participants were asked to state whether their nutrient use had increased, decreased, or stayed the same from 2002 to 2006. The percentage of those reporting increases, decreases or stayed the same varied by component of the golf course, nutrient and region of the country. Nationally, for all components of the golf course except putting greens, 50% to 70% of respondents at 18-hole golf facilities reported that they fertilized with the same amount of nitrogen, phosphate, and potassium in 2006 as in 2002 (Tables 1, A4). A more detailed explanation of specific increase or decrease in nutrient use from 2002 to 2006 for 18-hole golf facilities is described below.

Greens

- Thirty-two percent of golf facilities decreased the amount of phosphate applied, while 17% increased the amount of phosphate applied to greens.
- Forty-eight percent of golf facilities increased the amount of potash applied, while 13% decreased the amount of potash applied to greens.

Tees

- Thirty percent of golf facilities increased the amount of nitrogen applied, while 17% decreased the amount of nitrogen applied to tees.
- Thirty-eight percent of golf facilities increased the amount of potash applied, while 11% decreased the amount of potash applied to tees.

Table 1. Percentage of average 18-hole golf facilities for which the total annual amount of nitrogren, phosphate and potash applied to each component of the golf course in 2002 had increased, stayed the same or decreased in 2006.

Golf course component/nutrient	Amount of nutrients applied annually		
	Increased	Stayed the same	Decreased
	% of average 18-hole facilities		
Greens			
Nitrogen	24	46	29
Phosphate	17	51	32
Potash	48	39	13
Tees			
Nitrogen	30	53	17
Phosphate	18	59	23
Potassium	38	51	11
Fairways			
Nitrogen	24	50	25
Phosphate	15	56	29
Potash	33	50	17
Rough			
Nitrogen	22	52	26
Phosphate	14	57	29
Potash	24	55	21
Practice areas			
Nitrogen	31	54	15
Phosphate	19	60	21
Potash	33	56	12
Turf nursery			
Nitrogen	24	58	18
Phosphate	18	51	21
Potash	33	56	10
No-mow/native areas			
Nitrogen	8	66	26
Phosphate	6	66	29
Potash	9	67	25
Grounds			
Nitrogen	19	70	11
Phosphate	12	70	17
Potash	21	70	10

Fairways

- Twenty-nine percent of golf facilities decreased the amount of phosphate applied, while 15% increased the amount of phosphate applied to fairways.
- Thirty-three percent of golf facilities increased the amount of potash applied, while 17% decreased the amount of potash applied to fairways.

Rough

- Twenty-nine percent of golf facilities decreased the amount of phosphate applied, while 14% increased the amount of phosphate applied to rough.

Practice areas

- Thirty-one percent of golf facilities increased the amount of nitrogen applied, while 15% decreased the amount of nitrogen applied to practice areas.
- Thirty-three percent of golf facilities increased the amount of potash applied, while 12% decreased the amount of potash applied to practice areas.

Turf nursery

- Thirty-three percent of golf facilities increased the amount of potash applied, while 10% decreased the amount of potash applied to turf nurseries.

No-mow/native areas

- More facilities decreased than increased the annual amount of nitrogen, phosphate and potash applied to no-mow/native areas.

Grounds

- Twenty-one percent of golf facilities increased the amount of potash applied, while 10% decreased the amount of potash applied to grounds.

Nitrogen Use by Time of Year

Survey respondents were asked to identify the time of year they apply nitrogen to golf course turfgrass. Nationally, average 18-hole golf facilities apply a high percentage of the nitrogen — 87% of the yearly total amount — from March through October (Table A5).

- More nitrogen is applied from May through June and from September through October.

Turfgrass Species

Cool-Season

Kentucky bluegrass
Annual bluegrass
Rough bluegrass
Creeping bentgrass
Fine fescue
Tall fescue
Perennial ryegrass
Intermediate ryegrass

Warm-Season

Bermudagrass
Zoysiagrass
Seashore paspalum

- These periods of application reflect the active growing seasons of both cool- and warm-season grasses when turfgrass requires nitrogen for optimal performance.
- The seasonal application of nitrogen differed by agronomic region because of the differences in length of the growing season.
- In January and February, significantly more nitrogen was applied in the Southwest and in the Southeast regions than in the other regions because these regions have the largest acreage of winter-overseeded turfgrass (4).

Nitrogen Fertilizer Sources

Slow-Release and Quick-Release Nitrogen Fertilizers

Quick-release or soluble forms of nitrogen are available to turfgrass plants soon after application. Ammonium nitrate, ammonium sulfate and urea are quick-release forms of nitrogen commonly used in turfgrass fertilizers. Fertilizers containing these forms of nitrogen produce a rapid response in turfgrass growth and color, and they are generally less expensive than slow-release forms of nitrogen (From Rosen and Horgan) (8).

Slow-release forms of nitrogen depend on chemical and physical processes that occur in soil to gradually break down the fertilizer particles and release nitrogen for use by plants. When nitrogen is properly applied, losses through leaching are usually minimized. The length of time during which one application of slow-release nitrogen will release nitrogen varies considerably with the type of fertilizer, soil temperature and moisture, and activity of soil microorganisms. When compared with quick-release forms of nitrogen, the slow-release forms last longer, can be applied at higher rates and have a lower potential to burn or dry up the leaves of the grass plant. Slow-release fertilizers are particularly beneficial on sandy soils (From Rosen and Horgan) (8).

Slow-Release and Quick-Release Nitrogen Use

Survey respondents were asked what percentage of the nitrogen used at their facilities came from slow-release or quick-release formulations. For 18-hole golf facilities nationally, slow-release nitrogen sources accounted for 64% of the nitrogen applied, and quick-release nitrogen sources accounted for 36% (Table A6).

- Eighteen-hole golf facilities with maintenance budgets of less than $500,000 applied a significantly higher percentage of nitrogen from slow-release sources than golf facilities with maintenance budgets of $500,000 to $999,999, which applied significantly more nitrogen from slow-release sources than golf facilities with a maintenance budget of more than $1 million.
- The percentage of nitrogen applied from slow-release sources is higher in the North Central (69%) and Northeast (67%) agronomic regions and significantly lower in the Southwest (47%) (Table A6).

Organic Nutrient Use

Golf course superintendents have many fertilizers to choose from to meet the nutritional needs of turfgrass. To gain a better understanding of fertilizers applied on golf courses, respondents were asked about the use of organic and synthetic nutrient sources.

Organic fertilizers generally contain nutrients from either plant or animal products, whereas

Organic sources of nutrients comprise 24% of the total annual amount of nutrients applied on 18-hole golf facilities.

synthetic fertilizers generally contain nutrients that have been synthesized or created by reacting various elements and compounds. For the purposes of this survey, an organic nutrient source was defined as "materials derived from either plant or animal products containing one or more elements (other than carbon, hydrogen, or oxygen) which are essential for plant growth" (1).

Survey respondents were asked whether organic sources of nutrients were used on the golf facility. If organic nutrient sources were used, the respondents were asked to indicate how much of the total annual nutrient applications were derived from organic sources (Table A6). In addition, they were asked to identify the source of the organic product such as animal waste or commercial sewage sludge (Table A7).

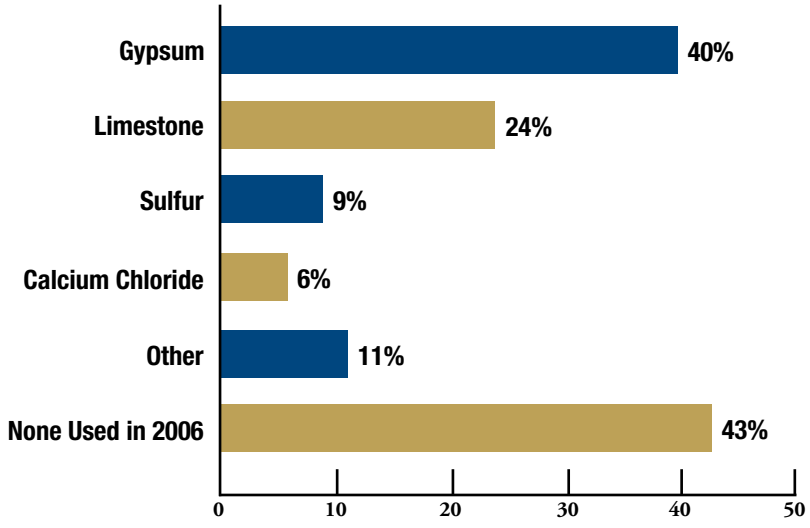
- Organic nutrient sources were applied to 66% of 18-hole golf facilities in 2006.
- Organic sources of nutrients comprise 24% of the total annual amount of nutrients applied on 18-hole golf facilities.
- In 2006, the most-used organic nutrient sources were animal waste (59%) and commercial sewage products (40%) (Table A7).
- Nationally, 18-hole golf facilities showed a net increase of 35% in the amount of nutrients applied from organic nutrient sources from 2002 to 2006.

Soil Amendments

The soil amendments considered in this survey were limestone, sulfur, gypsum and calcium chloride. The optimal soil pH (a measure of acidity and alkalinity) for turfgrass is 6.0 to 7.0. Turfgrass will survive and can perform well outside of the optimal range, but as soil pH moves away from the optimum, turfgrass performance may decline.

Limestone is applied to raise soil pH. Limestone increases soil alkalinity to offset acidic conditions and move the soil toward a more neutral and preferred condition. Sulfur is applied to lower pH. Sulfur increases soil acidity to offset alkaline conditions so the soil reaches a more neutral pH.

Figure 6. The percentage of 18-hole golf facilities that used various soil amendments in 2006.



In soil, sodium in excess of calcium and magnesium breaks down soil structure (the organization of soil particles and spacing between them). Poor soil structure leads to poor water infiltration, low levels of oxygen, and poor performance and death of turfgrass plants. Sulfur, gypsum and calcium chloride can be applied to overcome the negative effects of sodium on soil structure.

Survey respondents were asked to identify the soil amendments applied at their golf facility (Figure 6, Table A8).

- For 18-hole golf facilities, 43% did not apply soil amendments, 40% applied gypsum, 24% limestone, 9% sulfur, 6% calcium chloride, and 11% applied other amendments.
- Soil amendment use was most common on private 18-hole golf facilities with a maintenance budget higher than $1 million.
- Eighteen-hole golf facilities with a maintenance budget of $500,000 to $999,999 were more likely to apply soil amendments than facilities with a maintenance budget below $500,000.

Turfgrass Supplements

Turfgrass supplements include a broad range of products applied to improve turfgrass quality. Turfgrass supplements may contain one or more of the following: biostimulants, humates or humic acid, amino acids or proteins, sugar, microbial organisms, compost, biocontrol agents and compost teas. The benefits of many turfgrass supplements are poorly defined or unknown. For this survey, fertilizers and soil amendments are not considered turfgrass supplements.

- In 2006, 74% of golf course superintendents applied one or more types of turfgrass supplements at 18-hole golf facilities in the U.S. (Table A9).
- The most common types of turfgrass supplements applied were biostimulants (50%), humates (49%) and amino acids/proteins (46%).
- Private 18-hole golf facilities with a maintenance budget greater than $1 million were most likely to use turfgrass supplements.
- The specific turfgrass supplement applied varied by agronomic region, with golf course superintendents in the North Central (40%) region the least likely to apply turfgrass supplements.

Nutrient Management Plans

Survey respondents were asked whether they utilize a written nutrient management plan or a written fertilizer program at the golf facility. Written nutrient management plans or written fertilizer programs were used at 49% of 18-hole golf facilities in the U.S. (Table A10). The use of these written plans or programs was more common at golf facilities with 27+ holes (60%) than at 18-hole (49%) or 9-hole (40%) golf facilities. Use of written plans or programs is nearly equal at public (50%) and private (49%) golf facilities. A higher maintenance budget correlated with the likelihood that a golf facility would use a written nutrient plan or fertilizer program.

- Between 2002 and 2006, only 6% of 18-hole golf facilities were required by a federal, state, local, or tribal authority to have a written nutrient management plan (Table A10).
- Golf facilities that were required to have written nutrient management plans did not differ by number of holes, facility type or maintenance budget.
- Eighteen-hole golf facilities in the Upper West/Mountain (11%), Transition (9%), Northeast (8%) and Pacific (8%) agronomic regions were most likely to be required to have a written nutrient management plan.

Seventeen percent of 18-hole golf facilities had a written nutrient management plan because they voluntarily participated with a non-regulatory organization such as a watershed protection or environmental conservation group (Table A10).

- Participation rates in voluntary programs are higher for public (18%) than private (14%) facilities.
- Participation rates were higher for facilities with higher maintenance budgets.
- The participation rate of 18-hole golf facilities in the Pacific (31%) region was significantly higher than the participation rates in the other agronomic regions.

Fertilizer Restrictions

Superintendents indicated whether their golf facility operated under fertilizer restrictions and whether those restrictions were enacted by a federal, state, local or tribal authority. Nationally, only 9% of 18-hole golf facilities reported restrictions on fertilizer applications (Table A10), and those restrictions were most likely in the North Central (16%) and Pacific (10%) agronomic regions (Table A10).

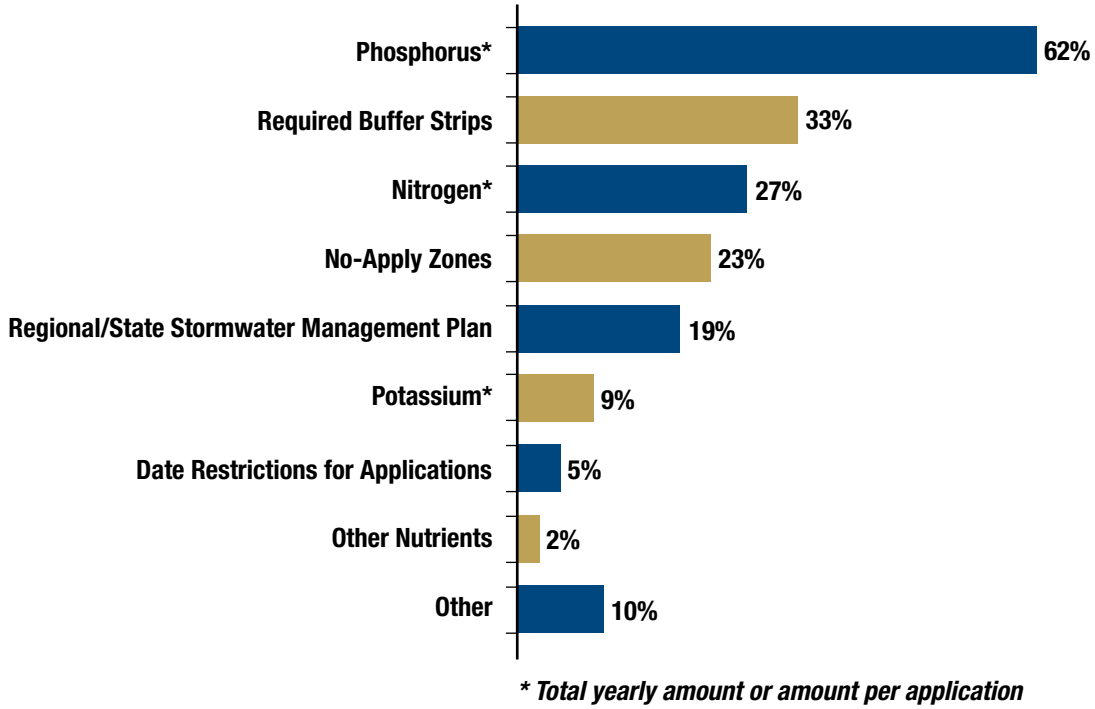
The most common fertilizer restrictions encountered by 18-hole golf facilities are listed below (Figure 7):

- phosphorus (62%) including the yearly total and/or amount per application
- required use of buffer strips (33%)
- nitrogen (27%) including the yearly total and/or amount per application
- no-fertilizer application zones (23%)

Respondents reported the effects of fertilizer restrictions on their nutrient application program as:

- minimal (50%)
- some (26%)
- none (16%)
- significant (8%)

Figure 7. The percentage of 18-hole golf facilities operating under various types of fertilizer application restrictions.



** Total yearly amount or amount per application*

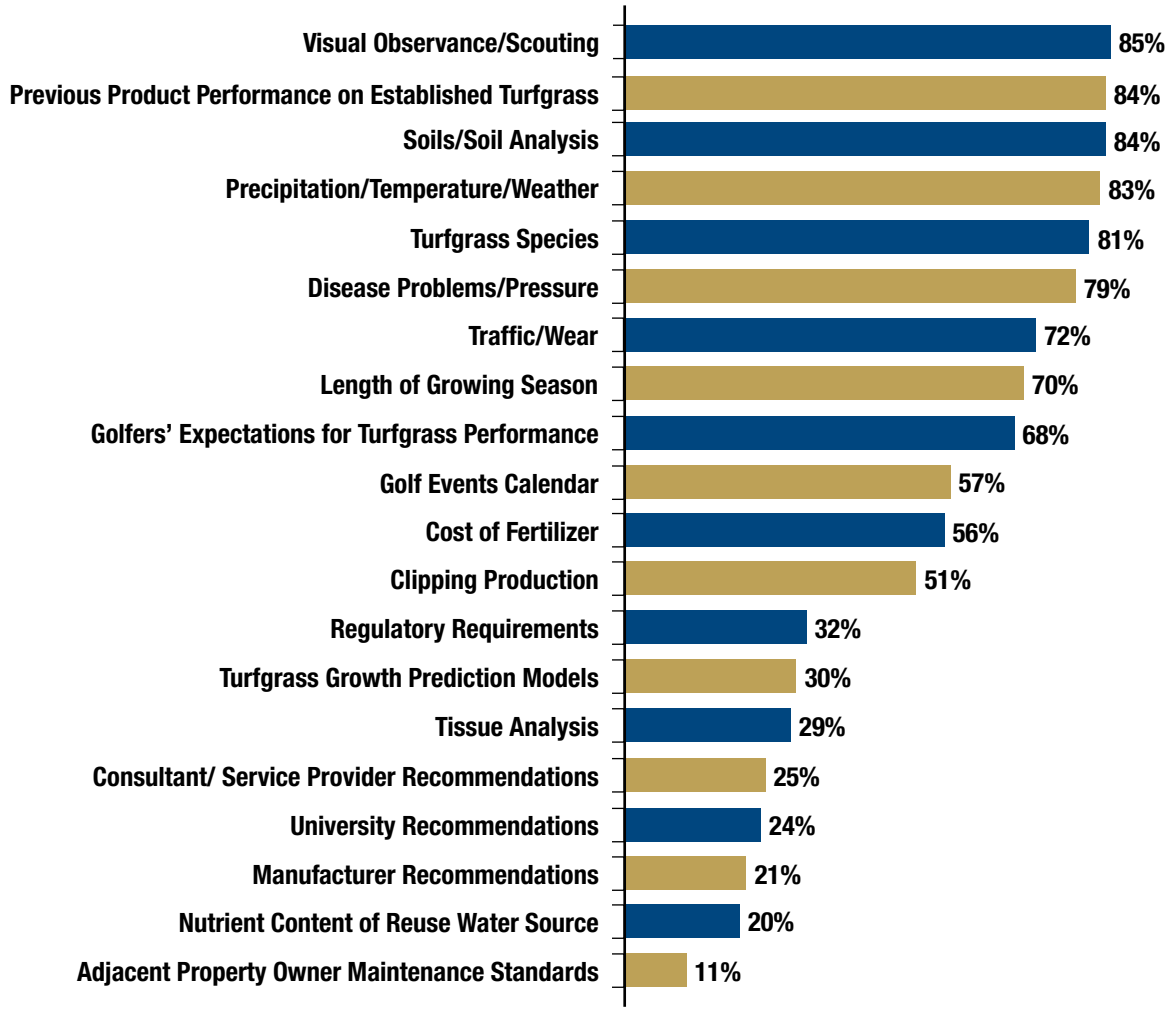
Nutrient Application Decisions

Superintendents consider many factors when making decisions about nutrient applications (Table A11). The relative importance of a specific factor differed by agronomic region reflecting the vast differences in conditions among agronomic regions.

The most common factors used to make decisions about nutrient applications and the percentage of 18-hole golf facilities using that factor (Figure 8):

- visual observations of turfgrass (85%)
- previous product performance (84%)
- soils/soil analysis (84%)
- precipitation/temperature/weather (83%)
- turfgrass species (81%)
- disease pressure (79%)

Figure 8. The percentage of 18-hole golf facilities that use the listed factor in making nutrient application decisions in 2006.



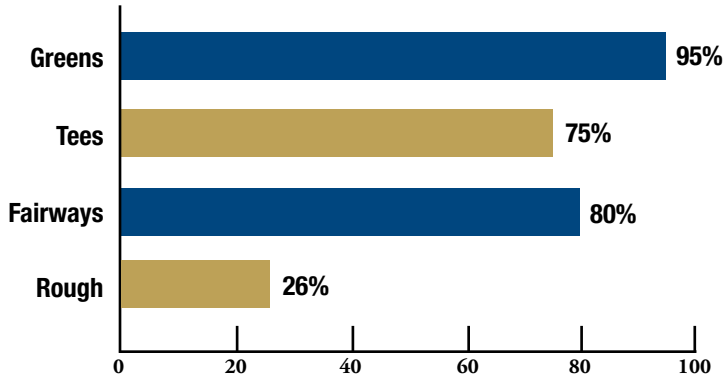
Soil Testing

Superintendents were asked how often they conduct soil testing at the golf facility. Since 2002, 95% of 18-hole golf facilities have performed soil testing on greens, 75% on tees, 80% on fairways and 26% on rough (Figure 9, Table A12).

- With the exception of soil testing on greens, facilities with more than 27 holes were significantly more likely to soil test than 18- and 9-hole golf facilities.
- Private golf facilities were significantly more likely than public facilities to test soil on all components of the golf course.
- Facilities with a maintenance budget of more than $1 million conducted significantly more soil tests than facilities with a budget of $500,000 to $999,999. Both of the higher budget categories soil test all golf course components significantly more than facilities with maintenance budgets below $500,000.
- Soil testing is performed least often in the North Central region (Table A12).

Soil testing by a professional laboratory will help superintendents make appropriate decisions about nutrient applications.
Photo by Pat Gross, USGA

Figure 9. The percentage of 18-hole golf facilities that conducted soil testing on various components of the golf course since 2002.



An example of a fertilizer and pesticide storage facility.

Fertilizer Storage

On a national basis, 91% of 18-hole golf facilities stored fertilizer on site for three consecutive calendar days or more in 2006. Half of the golf facilities that stored fertilizer for more than three consecutive days had a dedicated storage area for fertilizer that included an impervious floor, ventilation, containment features, locks and restricted access.

Of 18-hole golf facilities with a facility designed for fertilizer storage:

- Private facilities (55%) outnumbered public facilities (48%)
- Golf facilities with a maintenance budget above $1 million (63%) outnumbered those with a maintenance budget of $500,000 to $999,999 (54%) and those with budgets below $500,000 (41%)
- Eighteen-hole golf facilities in the Southeast (59%) and Pacific (58%) regions were more likely to have fertilizer storage than 18-hole golf facilities in other agronomic regions (44% to 51%)

On average, superintendents at 18-hole golf facilities calibrated their fertilizer application equipment before 67% of applications.

Fertilizer Equipment Calibration

Respondents were asked how often they calibrated their fertilizer application equipment before making applications to greens, tees, fairways or rough. More frequent calibration of fertilizer application equipment increases the accuracy of nutrient application. On average, superintendents at 18-hole golf facilities calibrated their fertilizer application equipment before 67% of applications.

Recommendations

Environmental Stewardship

The results of the nutrient use survey indicate that golf course superintendents use a variety of nutrient sources. Quick-release and slow-release nitrogen sources and synthetic and organic nutrient sources are applied to most golf courses in the U.S. No matter the nitrogen source (quick- or slow-release, synthetic or organic), superintendents decide the rate applied, the frequency of application, the time of year applications are made and the product used and are therefore responsible for producing the desired affect on the turfgrass without negatively affecting the environment.

GCSAA recommends that superintendents evaluate all sources of nutrients based on their agronomic performance, cost, potential impact on water quality and other environmental concerns and choose products that foster sustainability of the golf facility. By itself, the source of nutrients (quick-release, slow-release, synthetic, organic) is not an indicator of the environmental stewardship of the golf facility. The potential for nutrients to move from the application site is influenced by application rate, frequency of application, time of year, product applied, soil type, soil moisture content, temperature, turfgrass density and the intensity and amount of rainfall/irrigation following application. Understanding and adjusting to the influence of these factors is the responsibility of a golf course superintendent.

Soil Testing

Since 2002, only 26% of 18-hole golf facilities have conducted soil tests on the rough. On an average 18-hole golf facility, the rough comprises 50 acres (4), more than any other component of a golf course. Since the greatest total amount of phosphate and potash are applied to rough, GCSAA recommends that superintendents routinely conduct soil tests on the rough to determine phosphorus and potassium fertilizer needs. This practice has the potential to curtail costs and promote fertilizer programs that meet, not exceed, the nutritional needs of the turfgrass.

Fertilizer Storage

In 2006, 50% of the 18-hole golf facilities that stored fertilizer for more than three consecutive days used a dedicated storage area. GCSAA recommends that all golf facilities that store fertilizer do so in an area that is specifically designed for that purpose.

Nutrient Management Plans

Approximately 50% of golf facilities nationally use a written nutrient management plan or a written fertilizer program. A written nutrient management plan or a written fertilizer program provides the means to achieve goals and should be used by all golf facilities. The GCSAA recommends that all golf facilities use guidelines developed by university scientists to develop written nutrient management plans based on the characteristics and expectations unique to each facility.

Conclusions

The Golf Course Environmental Profile was designed to provide baseline information for the golf course management industry. A series of five surveys was conducted to determine property features, management practices and inputs associated with golf courses and golf course maintenance in the U.S. The baseline information will provide the basis for documenting change over time and help set priorities for education, research and environmental programs for the golf course management industry.

For the first time, the golf course management industry has accurate data on nutrient use on golf courses in the U.S. Summed over all golf course components and all golf courses, in 2006 a total of 101,096 tons of nitrogen were applied to 1,311,000 acres (154 pounds nitrogen per acre); 36,810 tons of phosphate were applied to 1,131,000 acres (65 pounds phosphate per acre); and 99,005 tons of potash were applied to 1,260,000 acres (157 pounds potash per acre). These application rates are within the guidelines recommended by university scientists (2,3,6).

One way to put nutrient use on golf courses in context is to compare it with nutrient use by other agricultural crops in rate per acre applied and total amount applied (rate per acre multiplied by the number of acres fertilized). Nutrient use of corn and tomatoes were chosen for comparison with

Superintendents consider multiple factors in making fertilizer application decisions, including whether to use liquid (left) or granular (right) formulations.
Left, Photo by David Phipps, Stone Creek Golf Course
Right, Photo by Pat Gross, USGA

nutrient use on golf course turfgrass. Corn is a widely grown agronomic crop, and tomatoes are a high-value, intensely maintained vegetable crop.

In 2005, corn was grown on an estimated 76,122,000 acres in the U.S. and was fertilized with 4,690,000 tons nitrogen, 1,696,000 tons phosphate and 1,901,000 tons potash. The application rates were: 138 pounds nitrogen, 58 pounds phosphate and 84 pounds potash per acre. Not all acres of corn were fertilized with nitrogen, phosphate or potash (12). When the rates of fertilizer per acre were compared, golf course turfgrass was fertilized with 112% as much nitrogen and phosphate and 187% as much potash per acre as corn. When comparing the total amount of fertilizer applied to golf course turfgrass and corn, the turfgrass was fertilized with 0.8% of the nitrogen and phosphate and 2.1% of the potash applied to corn (12).

In 2006, fresh tomatoes were grown on 105,600 acres in states reporting data. Tomatoes were fertilized with 11,396 tons nitrogen, 6,529 tons phosphate and 14,933 tons potash, but not all acres of tomatoes were fertilized with nitrogen, phosphate or potash (12). The application rate for each nutrient was 216 pounds nitrogen per acre, 132 pounds phosphate per acre and 286 pounds potash per acre. When the rates of fertilizer per acre are compared, turfgrass on golf courses received 71% as much nitrogen, 49% as much phosphate and 55% as much potash as tomatoes. The examples of fertilizer use cited demonstrate that turfgrass on golf courses is fertilized similarly to other crops.

When concerns are raised about nitrogen and phosphorus entering surface and/or ground water and creating environmental problems, such as the large hypoxic zone in the Gulf of Mexico, golf courses are often pointed to as one of the causes of the problem. In these situations, it is helpful to identify the potential contribution of nitrogen and phosphate from all land uses to understand the scale of the environmental problem. Turfgrass on golf courses is grown on slightly less than 1.5 million acres, and those acres are fertilized with 101,096 tons nitrogen and 36,810 tons phosphate. Corn, which is one of many agronomic crops grown nationwide, is grown on over 76 million acres and is fertilized with 4,690,000 tons of nitrogen and 1,696,000 tons of phosphate. While the total amount of nutrients used at golf facilities are considerably less than corn, golf facilities should incorporate environmental stewardship practices to protect water resources.

Superintendents consider multiple factors when making nutrient application decisions. Integrating many variables into their decisions leads to effective applications for the turfgrass while protecting the environment. This survey also indicates that golf course superintendents frequently calibrate their fertilizer application equipment, which helps to ensure fertilizer is applied at the desired rate.

Literature Cited

1. Association of American Plant Food Control Officials. 2002. AAPFCO Official Publication No. 55. www.aapfco.org/ (verified Oct. 20, 2009).

2. Carrow, R.N., D.V. Waddington and P.E. Rieke. 2001. Turfgrass soil fertility and chemical problems assessment and management. Ann Arbor Press, Chelsea, Mich.

3. Christians, N.E. 1998. Fundamentals of turfgrass management. Ann Arbor Press, Chelsea, Mich.

4. Lyman, G.T., C.S. Throssell, M.E. Johnson, G.A. Stacey and C.D. Brown. 2007. Golf course profile describes turfgrass, landscape and environmental stewardship features. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2007-1107-01-RS.

5. Marketing Research Association. 2008. The code of marketing research standards. Online. Marketing Research Association, Glastonbury, Conn. www.mra-net.org/resources/documents/expanded_code.pdf (verified Oct. 20, 2009).

6. McCarty, L.B. 2001. Best golf course management practices. Prentice-Hall, Upper Saddle River, N.J.

7. National Golf Foundation. 2007. Golf facilities in the U.S., 2007 ed. National Golf Foundation, Jupiter, Fla.

8. Rosen, C.J., B.P. Horgan and R.J. Mugas. 2006. Fertilizing lawns. University of Minnesota Extension Service. Pub. FO-03338. www.extension.umn.edu/distribution/horticulture/DG3338.html (verified Oct. 6, 2009).

9. Shurtleff, M.C., T.W. Fermanian and R. Randell, 1987. Controlling turfgrass pests. Prentice-Hall, Englewood Cliffs, N.J.

10. Throssell, C.S., G.T. Lyman, M.E. Johnson, G.A. Stacey and C.D. Brown. 2009a. Golf course environmental profile measures water use, source, cost, quality, and management and conservation strategies. Online. *Applied Turfgrass Science* doi:10.1094/ATS-2009-0129-01-RS.

11. Throssell, C.S., G.T. Lyman, M.E. Johnson, G.A. Stacey and C.D. Brown. 2009b. Golf course environmental profile measures nutrient use and management and fertilizer restrictions, storage, and equipment calibration. Online. *Applied Turfgrass Science* doi: 10.1094/ATS-2009-1203-01-RS.

12. United States Department of Agriculture, National Agricultural Statistics Service. 2006. Agricultural Chemical Usage 2006 field Crops Summary. Online. http://hotgovdocs.wordpress.com/2007/05/23/agricultural-chemical-usage-2006-field-crops-summary/ (verified Oct. 6, 2009).

Appendix

Table A1. Number of golf facility superintendents, percent of total number of golf facility superintendents, completed surveys received, percent of the total completed surveys received, response rate within the category, and margin of error by agronomic region, course type and number of holes.

	Golf facility superintendents		Completed surveys*			Margin of error (%)§
	No.†	% of total no.	No. rec'd	% of total	Response rate (%)‡	
Region						
Northeast	2,805	17.1	414	16.2	14.8	3.7
North Central	4,140	25.3	649	25.3	15.7	3.0
Transition	3,018	18.4	469	18.3	15.5	3.5
Southeast	3,379	20.6	534	20.9	15.8	3.3
Southwest	1,278	7.8	196	7.7	15.3	5.4
Upper West/Mountain	1,086	6.6	193	7.5	17.8	5.4
Pacific	680	4.1	106	4.1	15.6	7.3
Type						
Daily fee	9,109	55.6	1,127	44.0	12.4	2.3
Municipal	2,487	15.2	409	16.0	16.4	3.7
Private	4,790	29.2	1,025	40.0	21.4	2.3
No. of holes						
9	4,664	28.5	234	9.1	5.0	5.2
18	10,200	62.2	2,124	82.9	20.8	1.6
27+	1,522	9.3	203	7.9	13.3	5.4

* The total number of completed surveys was 2,561.
† The total number of golf facility superintendents was 16,386.
‡ Response rate is the percentage of the total number of completed surveys received for each region, course type and course classification (9, 18, or 27+ holes).
§ At 90% confidence interval.

Table A2. Average nitrogen, phosphate, and potash rate applied in 2006 and average area of each golf course component in thousands of square feet on an average 18-hole golf facility in the U.S. and its agronomic regions.

Golf course component	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
Greens								
Avg. nitrogen rate†,‡	5.2	3.8d	3.6d	4.5c	8.6a	6.3b	4.0d	4.6c
Avg. phosphate rate†,‡	2.0	1.5d	1.3e	2.0b	3.0a	3.0a	1.8bc	1.7c
Avg. potash rate†,‡	6.7	4.1e	4.1e	5.3c	13.0a	9.3b	4.9cd	4.5cd
Avg. area†,§	127	129ab	134a	127b	124b	127b	114c	121c
Tees								
Avg. nitrogen rate†,‡	4.6	4.0c	3.7c	3.7c	6.6a	6.5a	3.9c	4.4b
Avg. phosphate rate†,‡	1.8	1.8b	1.4c	1.7b	2.3a	2.6a	1.6c	1.7b
Avg. potash rate†,‡	4.7	3.7d	3.5d	3.6d	7.6a	6.2b	3.6d	3.9c
Avg. Area†,§	124	102d	120c	125bc	141a	134ab	128bc	115c
Fairways								
Avg. nitrogen rate†,‡	3.8	3.0c	2.9c	3.4b	5.3a	6.0a	3.5b	3.4b
Avg. phosphate rate†,‡	1.5	1.1d	1.0d	1.6c	2.0b	2.7a	1.5cd	1.3cd
Avg. potash rate†,‡	3.8	2.7de	2.5e	3.2c	6.1a	5.5b	3.0de	3.1cd
Avg. area†,§	1,356	1,140	1,229	1,260	1,462	1,752	1,658	1,511
Rough								
Avg. nitrogen rate†,‡	3.1	2.0c	1.9c	2.6b	4.6a	5.0a	3.0b	2.8b
Avg. phosphate rate†,‡	1.4	0.9d	0.7e	1.3c	1.8b	2.6a	1.3cd	1.2cd
Avg. potash rate†,‡	3.1	1.8d	1.5e	2.6c	5.3a	5.0b	2.7c	2.7c
Avg. area†,§	2,318	2,030d	2,549a	2,378b	2,241c	2,462ab	2,178c	2,188bc
Practice areas								
Avg. nitrogen rate†,‡	4.1	3.0d	3.0d	3.4c	5.8a	5.7b	3.3c	3.4c
Avg. phosphate rate†,‡	1.7	1.4c	1.2c	1.7b	2.2ab	2.8a	1.3c	1.2c
Avg. potash rate†,‡	4.1	2.7d	2.8d	3.4c	6.7a	5.3b	2.9cd	2.8cd
Avg. area†,§	307	241b	264b	328a	352a	310a	360a	253b
Turf nursery								
Avg. nitrogen rate†,‡	4.6	3.4e	3.2e	4.3c	7.3a	5.7b	3.8d	4.8bc
Avg. phosphate rate†,‡	1.9	1.4c	1.3c	2.0b	2.7a	2.7a	1.7b	1.9b
Avg. potash rate†,‡	6.2	3.4d	3.7d	5.0c	11.8a	8.9b	4.5c	4.4c
Avg. area†,§	17	9.4c	22a	24a	13ab	16ab	16ab	9.3c
No-mow/natural areas								
Avg. nitrogen rate†,‡	1.7	1.2d	1.3d	1.4cd	2.2bc	3.3a	1.2d	1.8c
Avg. phosphate rate†,‡	1.0	0.8	0.7	1.1	1.2	1.6	0.6	1.2
Avg. potash rate†,‡	1.8	1.1	1.1	1.7	2.6	4.0	1.1	1.8
Avg. area†,§	1,211	1,004a	1,035b	1,040b	1,140b	2,072a	1,726a	1,227ab
Grounds								
Avg. nitrogen rate†,‡	3.2	2.5d	2.5d	2.7d	4.3a	4.8a	3.1d	3.4b
Avg. phosphate rate†,‡	1.4	1.1de	0.9c	1.4c	1.7b	2.3a	1.4cd	1.5bc
Avg. potash rate†,‡	3.1	2.2c	2.2c	2.6b	4.7a	4.5a	3.0b	2.9b
Avg. area†,§	196	135cd	133cd	203b	267a	260a	120d	170bc

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.
‡The average nitrogen, phosphate, and potash rate for each golf course component is expressed in pounds/1,000 square feet/year.
§The average area of each golf course component is expressed in thousands of square feet.

Table A3. Estimated total tons of nitrogen, phosphate and potash applied in 2006, and estimated area of each golf course component receiving nitrogen, phosphate, and potash for all golf facilities in the United States and its agronomic regions.

Golf course component	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
Greens								
Total nitrogen†	4,807	612	867	775	1,694	485	210	166
Area receiving nitrogen‡	42.9	7.3	11.1	7.9	9.1	3.5	2.4	1.6
Total phosphate†	1,788	222	292	329	581	222	86	58
Area receiving phosphate‡	40.7	6.8	10.1	7.7	8.9	3.4	2.2	1.6
Total potash†	6,140	638	963	902	2,533	702	246	156
Area receiving potash‡	42.1	7.1	10.9	7.8	8.9	3.5	2.3	1.6
Tees								
Total nitrogen†	4,273	502	792	614	1,470	524	224	148
Area receiving nitrogen‡	41.4	5.7	9.9	7.6	10.2	3.7	2.6	1.5
Total phosphate†	1,535	203	259	259	482	198	81	54
Area receiving phosphate‡	38.0	5.3	8.7	7.0	9.6	3.4	2.4	1.5
Total potash†	4,244	441	742	580	1,667	490	200	125
Area receiving potash‡	40.4	5.5	9.7	7.4	10.1	3.6	2.5	1.5
Fairways								
Total nitrogen†	38,655	4,143	6,444	5,564	12,119	6,286	2,590	1,509
Area receiving nitrogen‡	448.1	63.4	101.3	75.8	105.4	47.8	34.2	20.3
Total phosphate†	13,633	1,366	1,812	2,354	4,081	2,494	971	556
Area receiving phosphate‡	393.9	55.0	83.2	69.3	94.6	42.6	29.9	19.3
Total potash†	36,993	3,615	5,391	5,233	13,789	5,527	2,140	1,300
Area receiving potash‡	435.8	61.2	98.6	74.2	103.6	46.4	32.3	19.5
Rough								
Total nitrogen†	42,106	3,661	6,459	6,889	14,526	6,687	2,652	1,234
Area receiving nitrogen‡	626.1	83.2	152.9	122.1	145.9	60.9	40.4	20.6
Total phosphate†	15,593	1,480	1,790	3,211	4,873	2,753	969	519
Area receiving phosphate‡	529.2	74.7	115.7	110.8	126.4	48.1	33.2	20.4
Total potash†	40,444	3,091	4,686	6,594	16,516	6,206	2,179	1,175
Area receiving potash‡	595.3	80.6	139.7	118.3	142.5	57.2	36.6	20.4
Practice areas								
Total nitrogen†	6,554	508	866	954	2,701	879	453	195
Area receiving nitrogen‡	71.3	7.9	13.1	13.0	21.5	7.0	6.3	2.6
Total phosphate†	2,394	210	291	431	878	357	162	67
Area receiving phosphate‡	62.7	7.0	11.2	11.8	18.7	5.9	5.5	2.5
Total potash†	6,505	450	773	918	3,043	785	378	159
Area receiving potash‡	69.1	7.7	12.7	12.6	20.9	6.8	5.9	2.6
Turf nursery								
Total nitrogen†	221	14	48	55	58	27	13	8
Area receiving nitrogen‡	2.3	0.2	0.7	0.6	0.4	0.2	0.2	0.1
Total phosphate†	86	5	18	24	20	12	5	3
Area receiving phosphate‡	2.1	0.2	0.6	0.6	0.3	0.2	0.1	0.07
Total potash†	283	13	55	62	93	40	15	7
Area receiving potash‡	2.2	0.2	0.7	0.6	0.4	0.2	0.2	0.07
No-mow/natural areas								
Total nitrogen†	1,521	174	158	273	384	385	108	40
Area receiving nitrogen‡	39.4	6.5	5.7	8.7	8.1	5.3	4.0	1.0
Total phosphate†	675	93	57	191	140	128	44	23
Area receiving phosphate‡	30.1	5.3	3.9	7.7	5.4	3.7	3.2	0.9
Total potash†	1,703	157	118	323	398	408	88	34
Area receiving potash‡	36.7	6.4	5.1	8.7	7.2	4.6	3.8	0.9
Grounds								
Total nitrogen†	2,960	246	382	454	1,206	457	108	110
Area receiving nitrogen‡	39.6	4.5	7.0	7.7	12.9	4.4	1.6	1.5
Total phosphate†	1,107	91	109	213	420	188	42	45
Area receiving phosphate‡	34.3	3.9	5.5	7.1	11.2	3.8	1.4	1.4
Total potash†	2,873	202	320	432	1,309	421	99	93
Area receiving potash‡	38.4	4.2	6.7	7.5	12.8	4.3	1.5	1.4
Total								
Nitrogen applied†	101,096	9,858	16,015	15,576	34,157	15,728	6,355	3,406
Area receiving nitrogen‡	1,311.0	178.7	301.7	243.3	313.4	132.9	91.7	49.2
Phosphate†	36,810	3,669	4,625	7,009	11,475	6,351	2,358	1,324
Area receiving phosphate‡	1,131	158.1	239.1	222.0	275.3	111.0	78.0	47.7
Potash†	99,005	8,605	13,046	15,042	39,347	14,577	5,342	3,047
Area receiving potash‡	1,260	172.9	284.0	237.0	306.5	126.6	85.2	47.9

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†The estimated total nitrogen, phosphate, and potash applied to each golf course component is expressed in tons/year.
‡The estimated area of each golf course component is expressed in thousands of acres.

Table A4. Percentage of average 18-hole golf facilities for which the total annual amount of nitrogen, phosphate and potash applied to each component of the golf course in 2002 had increased, stayed the same or decreased in 2006.

Golf course component/nutrient	Amount of nutrients applied annually		
	Increased	Stayed the same	Decreased
	% of average 18-hole facilities		
Greens			
Nitrogen	24	46	29
Phosphate	17	51	32
Potash	48	39	13
Tees			
Nitrogen	30	53	17
Phosphate	18	59	23
Potassium	38	51	11
Fairways			
Nitrogen	24	50	25
Phosphate	15	56	29
Potash	33	50	17
Rough			
Nitrogen	22	52	26
Phosphate	14	57	29
Potash	24	55	21
Practice areas			
Nitrogen	31	54	15
Phosphate	19	60	21
Potash	33	56	12
Turf nursery			
Nitrogen	24	58	18
Phosphate	18	51	21
Potash	33	56	10
No-mow/native areas			
Nitrogen	8	66	26
Phosphate	6	66	29
Potash	9	67	25
Grounds			
Nitrogen	19	70	11
Phosphate	12	70	17
Potash	21	70	10

Table A5. **Nitrogen applied by two-month periods for an average 18-hole golf facility in the U.S. and its agronomic regions.**

Months	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% of nitrogen applied†							
Jan–Feb	4	<1e	<1e	3c	9a	11a	1d	6b
Mar–Apr	17	11d	12d	24a	21b	21bc	18c	20bc
May–June	26	30a	29a	22b	23b	19c	29a	23b
July–Aug	19	21a	23a	16c	19b	16c	22a	20ab
Sep–Oct	25	27b	29a	26b	18d	20c	25b	22c
Nov–Dec	9	11b	7c	9b	10b	13a	5d	9b

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.

Table A6. **Quick- and slow-release nitrogen applied as a percentage of the total nitrogen applied, percent of 18-hole golf facilities that applied nutrients from an organic source, percent of yearly total amount of nutrients from organic sources, and net increase in the total amount of nutrients applied from organic sources on an average 18-hole golf facility in the U.S. and its agronomic regions.**

US	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/Mtn	Pac
% quick-release nitrogen applied†							
36	33c	31c	38b	36b	53a	37b	39b
% slow-release nitrogen applied†							
64	67a	69a	62b	64b	47c	63b	61b
% 18-hole facilities that applied nutrients from organic sources							
66	75a	60c	63c	71ab	61c	67bc	61c
% yearly total nutrients from organic sources							
24	30a	25b	25b	17c	22b	23b	22b
% net increase in total amount of nutrients from organic sources							
35	34	29	37	32	58	43	47

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.

Table A7. Percentage of 18-hole golf facilities that use various sources of organic nutrients in the U.S. and its agronomic regions.

Organic nutrient sources	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†‡							
Animal waste§	59	69a	56b	70a	45c	67a	56b	61b
Packaged commercial sewage sludge	40	27d	43b	36cd	62a	21d	35cd	31d
Composted products	20	28a	13c	21b	12c	35a	35a	27ab
Processed animal remains	18	28a	21b	25ab	8d	16c	13cd	10cd
Crop products//	15	14	14	16	17	17	13	17
Local sewage sludge	10	10	8	7	17a	6	9	3
Food waste (any form)	3	3ab	3ab	5a	3ab	1b	3ab	4ab
Kelp/seaweed	3	4a	2b	2ab	1b	2ab	3ab	4a
Other	3	2b	3ab	3ab	3ab	4ab	6a	4ab

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within columns, values for organic nutrient sources do not add up to 100% because respondents used more than one organic nutrient source.
‡Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.
§Animal waste includes manure, bloodmeal, etc.
//Crop products are cornmeal or soybean meal.

Table A8. Percentage of 18-hole golf facilities that used various soil amendments in the U.S. and its agronomic regions in 2006.

Soil amendments	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†‡							
Gypsum	40	34d	24e	41cd	51b	67a	40cd	50bc
Limestone	24	33a	7d	29b	38a	9cd	15c	41a
Sulfur	9	7cd	5d	8c	12b	17a	16a	10bc
Calcium chloride	6	6ab	3c	4bc	8a	7ab	5abc	10a
Other	11	11bcd	7d	9cd	16a	14ab	12abc	5d
None used in 2006	43	43b	67a	41b	26c	26c	42b	24c

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within columns, values for soil amendments do not add up to 100% because respondents used more than one soil amendment.
‡Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.

Table A9. Percentage of 18-hole golf facilities that used various turfgrass supplements in the U.S. and its agronomic regions in 2006.

Turfgrass supplements	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†‡							
Biostimulants	50	51b	37c	59a	58ab	54ab	39c	55ab
Humates	49	46c	30d	48c	66a	62ab	54bc	55bc
Amino acids/proteins	46	46b	38c	52ab	55a	48ab	21c	47ab
Sugar (sucrose, molasses)	17	16bc	10d	20ab	22a	21ab	14bcd	13bcd
Microbial inoculants	15	9b	10b	12b	24a	25a	12b	25a
Compost	14	18b	9de	11cd	7e	30a	31a	15bc
Biocontrol agents	6	7ab	6ab	4b	8a	7ab	6ab	6ab
Compost tea	4	4b	1c	2bc	3b	13a	4b	4b
Other	2	2ab	3ab	2ab	1b	4a	2ab	3ab
None used in 2006	26	24b	40a	26b	19cd	15d	23bc	23bc

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within columns, values for turfgrass supplements do not add up to 100% because respondents used more than one turfgrass supplement.
‡Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.

Table A10. Percentage of 18-hole golf facilities in the United States and within each agronomic region that have written nutrient management plans, have written fertilizer programs, or are subject to restrictions on fertilizer applications.

Nutrient management plans & restrictions	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†							
Nutrient management plan/written fertilizer program	49	45	56	45	50	48	48	51
Written plan required by government/ tribal authority	6	8ab	4bc	9a	3c	2c	11a	8ab
Voluntary participation in written plan‡	17	13b	15b	17b	19b	11b	21ab	31a
Fertilizer applications restricted by government/tribal authority	9	6bc	16a	8b	3c	5bc	7b	10ab

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.
‡Golf courses have a written nutrient management or fertilizer plan because they are voluntarily participating in a watershed protection or environmental conservation organization.

Table A11. Percent of 18-hole golf facilities that use the listed factors to make nutrient application decisions.

Factors in nutrient application decisions	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†							
Visual observations	85	79b	85a	86a	85a	88a	85a	89a
Previous product performance	84	86	86	82	83	82	83	86
Soils/soil analysis	84	84b	77c	85ab	90a	83b	87ab	85ab
Precipitation/temperature/weather	83	88a	83a	83a	85a	75b	77b	83a
Turfgrass species	81	77b	76b	87a	84a	86a	71b	81ab
Disease pressure	79	86a	84a	84a	73bc	68cd	61d	80ab
Traffic/wear	72	70bc	73ab	66c	74ab	78a	75ab	69bc
Length of growing season	70	64b	67b	74a	71a	76a	78a	71ab
Golfers' expectations for turf performance	68	69b	67b	68b	69b	77a	67b	55c
Golf events calendar	57	52cd	56bc	50d	64a	59abc	60ab	66ab
Fertilizer cost	56	53bc	61a	58ab	51c	56abc	52bc	56abc
Clipping production	51	44c	53a	51b	54a	55a	51b	48b
Regulatory requirements	32	32ab	32ab	32ab	37a	26bc	19c	32ab
Turf growth prediction models	30	33a	32a	27bc	30ab	29b	26bc	31a
Tissue analysis	29	27b	22b	27b	40a	38a	27b	24b
Consultant/service provider recommendation	25	27a	29a	19b	22b	24ab	28a	26ab
University recommendations	24	28a	27a	25a	24a	24a	10b	13b
Manufacturer's recommendations	21	22a	24a	20ab	21a	14b	19ab	25a
Nutrient content of reuse water	20	18c	15c	16c	26b	35a	24b	20bc
Adjacent property owner maintenance standards	11	10ab	11ab	10b	12ab	15a	6c	10ab

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.
‡ Within columns, values for application decisions do not add up to 100% because respondents were influenced by multiple factors in making decisions.

Table A12. Percentage of 18-hole golf facilities that use soil testing by golf course component in the U.S. and its agronomic regions.

Golf course component	US	Agronomic region*						
		NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% 18-hole golf facilities†							
Greens	95	94b	90c	96b	99a	99a	97ab	98ab
Tees	75	76bc	68c	77b	84a	69c	75bc	76bc
Fairways	80	79c	72d	79c	87a	86ab	86ab	79bc
Rough	26	20c	12d	33ab	34ab	40a	28b	17cd
Practice areas	35	28c	21d	39ab	48a	41ab	41ab	23cd
Turf nursery	24	21c	14d	29ab	33a	25b	21c	28abc
No-mow/ natural areas	3	3ab	2c	5a	5a	5a	3ab	0c
Grounds	14	13b	7c	19a	21a	11bc	8bc	8bc

*Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.
†Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.

1421 Research Park Drive
Lawrence, KS 66049-3859
Toll Free 800.472.7878

www.gcsaa.org

www.eifg.org