BEST MANAGEMENT PRACTICES FOR THE ENHANCEMENT OF ENVIRONMENTAL QUALITY ON FLORIDA GOLF COURSES

GCSAA
Golf Course Superintendents Association of America

Florida Chapter
GCSAA
Golf Course Superintendents Association of America

BEGINNING IN THE LATE 1990'S,

several pioneers in the Florida golf course management industry had the vision and awareness to create the first Golf Course Best Management Practices manual. The Florida Golf Course Superintendents Association collaborated with the University of Florida, the United States Golf Association, the Florida Department of Environmental Protection and the Florida Department of Agriculture and Consumer Services (FDACS) and successfully published this manual in early 2007.

Since its publication, this manual has been referenced in the FDACS fertilizer rule (5E-1.003, F.A.C.), the 2020 Florida Senate Bill 712 (Clean Waterways Act) and many local ordinances around the state. In 2012 the manual was updated, and the Florida GCSA began the Golf Course Best Management Practices Certification Program, a voluntary program to demonstrate our industry's responsibility to the environment. As the first of its kind, the Florida manual was also used by the Golf Course Superintendents Association of America in their national initiative to have state-specific Golf Industry BMP manuals in all 50 states by 2020; a lofty goal that was achieved.

In addition to their social and recreational benefits, golf courses are prolific wildlife habitats in both urban and rural settings. As our urban areas expand, the golf courses are giving back much more than the game of golf, they are providing environmental benefits to the entire community through their green spaces and in protecting water resources. The scientifically documented best management practices contained in this publication help superintendents strengthen their environmental stewardship practices and protect Florida's natural resources. We are active stakeholders in the efforts to improve the environmental health of Florida with particular attention paid to our water ways. We are proud environmental stewards and we know this manual is instrumental in maintaining our commitment to the environment and the commitment of our industry to the most up to date standards.

Andy Neiswender, President
Florida Golf Course Superintendents Association

ACKNOWLEDGMENTS

A Best Management Practices document such as this is a living document that evolves and is modified over time as new knowledge is gained and practices are improved. As such, not only does the list of contributors grow, the likelihood of the unfortunate omission of the names of contributors also increases.

This document is built upon three prior versions dating back to the mid-1990s. The most significant contributor to this early work is Dr. Michael Thomas who devoted much energy and determination to this effort during his tenure at the Florida Department of Environmental Protection. The legacy of his work is contained on each page of this current edition.

Those listed below graciously took the mantle, reviewed and improved the earlier work, to yield this current version.

SECTION 1: ENVIRONMENTAL CONCEPTS

- Ralph Dain, Golf Course Superintendents Association of America
- Kyle Sweet, CGCS, The Sanctuary Golf Club
- Dr. Mark Clark, University of Florida

SECTION 2: ENVIRONMENTAL MONITORING

- Ralph Dain, Golf Course Superintendents Association of America
- Kyle Sweet, CGCS, The Sanctuary Golf Club
- Dr. Mark Clark, University of Florida

SECTION 3: PLANNING, DESIGN AND CONSTRUCTION

- Jan Bel Jan, ASGCA, Jan Bel Jan Golf Course Design
- Ralph Dain, Golf Course Superintendents Association of America

SECTION 4: IRRIGATION

- Don Rainey, University of Florida, IFAS Extension
- Dr. Michael Dukes, University of Florida

SECTION 5: NUTRITION AND FERTILIZATION

- Dr. Travis Shaddox, University of Kentucky (formerly with the University of Florida)
- Dr. Jason Kruse, University of Florida
- Christy Lyle, ProPlus Products, Inc.

SECTION 6: CULTURAL PRACTICES

- Todd Lowe, Bayer Environmental Sciences (formerly with the USGA)
- Andy Jorgensen, CGCS, On Top of the World Communities, LLC
- Dr. Jason Kruse, University of Florida
- Mark Kann, University of Florida

SECTION 7: LAKE AND AQUATIC MANAGEMENT

- Mark Hoyer, University of Florida
- Dr. Chuck Cichra, University of Florida

SECTION 8: TURF PEST MANAGEMENT

- Dr. Adam Dale, University of Florida
- Dr. Phil Harmon, University of Florida
- Dr. Billy Crow, University of Florida
- Dr. J. Bryan Unruh, University of Florida

SECTION 9: PESTICIDE MANAGEMENT

- Dr. Adam Dale, University of Florida
- Dr. Phil Harmon, University of Florida
- Dr. Fred Fishel, University of Florida
- Dr. J. Bryan Unruh, University of Florida

SECTION 10: MAINTENANCE OPERATIONS

- Todd Lowe, Bayer Environmental Sciences (formerly with the USGA)
- Andy Jorgensen, CGCS, On Top of the World Communities, LLC

SECTION 11: POLLINATOR PROTECTION

- Dr. Adam Dale, University of Florida
- Kyle Sweet, CGCS, The Sanctuary Golf Club

SECTION 12: ENERGY CONSERVATION

- Tim Hiers, CGCS, White Oak Conservation
- Andy Neiswender, Belleair Country Club
- Andy Jorgensen, CGCS, On Top of the World Communities, LLC

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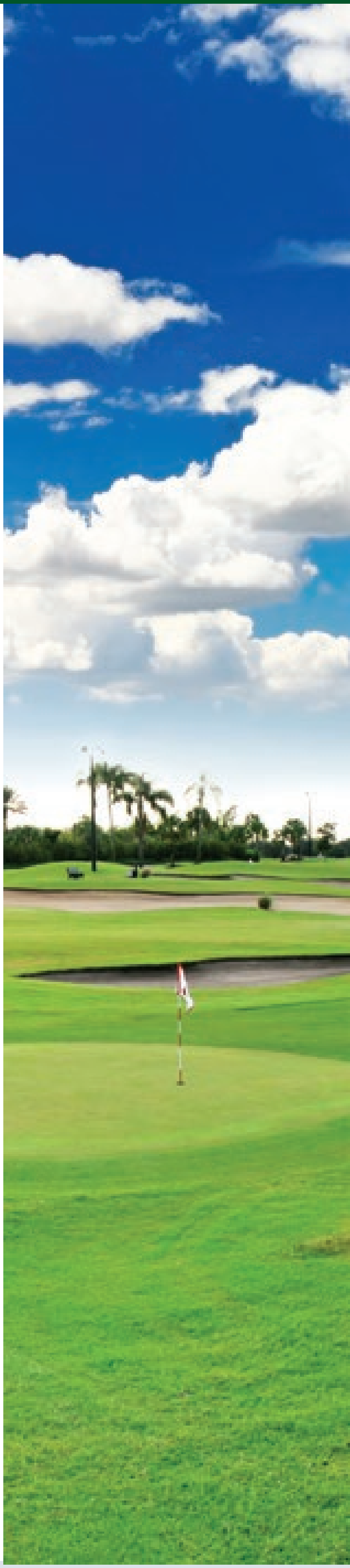

FOREWORD

This publication provides the Golf Course Superintendent with sound management strategies to maintain the golf course in a positive manner with respect to environmental protection, water quality protection, and conservation. It is also intended to provide elected officials, regulators, developers, and others with an overview of golf course management practices and how they relate to environmental issues.

This is a living document. As science and technology progress, golf industry representatives will work in conjunction with the University of Florida, staff from the Florida Department of Environmental Protection (FDEP) and the Florida Department of Agriculture and Consumer Services (FDACS), and other interested parties to determine the extent to which this document will be amended.

A comprehensive program of best management practices (BMPs) should include a combination of components that are properly selected, designed, operated, and maintained. BMP options should be screened for feasibility based on the following factors:

- *Physical and technical limitations*
- *Operational and management limitations*
- *Pollutant reduction/water conservation effects*
- *Profitability/cost considerations*
- *Other benefits or disadvantages*
- *Public acceptance*

If these BMPs are adopted by rule, as provided by Subsection 403.067(7)(c)1, Florida Statutes (F.S.), certain protection from liabilities may be established through the voluntary implementation of BMPs that have been verified by FDEP to be effective in protecting water quality.

http://www.leg.state.fl.us/Statutes/index.cfm?App_mode=Display_Statute&URL=0400-0499/0403/Sections/0403.067.html

Shortened link: http://bit.ly/38WkrZm

You may also scan this QR code with your smartphone.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAPFCO	Association of American Plant Food Control Officials
AB-DTPA	Ammonium bicarbonate-DTPA
A-E method	Adams-Evans method
ASABE	American Society of Agricultural and Biological Engineers
ASLA	American Society of Landscape Architects
ASR	Aquifer storage and recovery
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing Materials
BMP	Best management practice
$CaSO_4$	Calcium sulfate
CCE	Calcium carbonate equivalent
CDTA	Cyclohexanediaminetetraacetic acid
CEC	Cation exchange capacity
Cl	Chloride
CMC	Chemical mixing center
CO_2	Carbon dioxide
Cu	Copper
CUP	Consumptive use permit
DAP	Diammonium phosphate
DCIA	Directly connected impervious area
DO	Dissolved oxygen
DTPA	Diethylenetriaminepentaacetic acid
EDDHA	Ethylenediaminedi (o-hydroxyphenylacetic acid)
EDTA	Ethylenediaminetetraacetic acid
EPA	U.S. Environmental Protection Agency
ESTL	Extension Soil Testing Laboratory
ET	Evapotranspiration
F.A.C.	Florida Administrative Code
FDA	U.S. Food and Drug Administration
FDACS	Florida Department of Agriculture and Consumer Services
FDCA	Florida Department of Community Affairs
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FDOT	Florida Department of Transportation
Fe	Iron
FFDCA	Federal Food, Drug, and Cosmetic Act
FFWCC	Florida Fish and Wildlife Conservation Commission
FGCSA	Florida Golf Course Superintendents Association

FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FIS	Florida Irrigation Society
FNGLA	Florida Nursery, Growers and Landscape Association
F.S.	Florida Statutes
FWEA	Florida Water Environment Association
FWS	U.S. Fish and Wildlife Service
GCSAA	Golf Course Superintendents Association of America
GLPs	Good lab practices
gph	Gallons per hour
gpm	Gallons per minute
GPS	Global positioning system
HOC	Height of cut
IBDU	Isobutylidene diurea
IPM	Integrated pest management
IRAC	Insecticide Resistance Action Committee
K	Potassium
MAP	Monoammonium phosphate
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
NELAC	National Environmental Laboratory Accreditation Conference
NELAP	National Environmental Laboratory Accreditation Program
NH_3	Ammonia (gas)
NH_4+	Ammonium nitrogen
NO_2	Nitrite
NO_3-	Nitrate
NO_3-N	Nitrate nitrogen
$NO_3 + NO_2$	Nitrate + Nitrite
NOAA	National Oceanic and Atmospheric Administration
NWFWMD	Northwest Florida Water Management District
OSHA	Occupational Safety and Health Administration
P	Phosphorus
PAMs	Polyacrylamides
Pb	Lead
PGA	Professional Golfers' Association of America
PM	Preventive maintenance

continued next page

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

PPE	Personal protective equipment
PO_4	Orthophosphate
ppm	Parts per million
PREC	Pesticide Registration and Evaluation Committee
psi	Pounds per square inch
PTO	Power takeoff
QA/QC	Quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RUP	Restricted use pesticide
S	Sulfur
SCU	Sulfur-coated urea
SDS	Safety Data Sheet
SFWMD	South Florida Water Management District
SJRWMD	St. Johns River Water Management District
SMZ	Special management zone
SWFWMD	Southwest Florida Water Management District
TDR	Time and frequency domain reflectometer
TN	Total nitrogen
TKN	Total Kjeldahl nitrogen
TMDL	Total maximum daily load
TP	Total phosphorus
TS	Total solids
TSS	Total suspended solids
TVA	Tennessee Valley Authority
UAN	Urea-ammonium nitrate
UF	Ureaformaldehyde
UF—IFAS	University of Florida—Institute of Food and Agricultural Sciences
USACOE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDA—ARS	U.S. Department of Agriculture—Agricultural Research Service
USDA—NRCS	U.S. Department of Agriculture—Natural Resources Conservation Service
USGA	United States Golf Association
VFD	Variable frequency drive
VOC	Volatile organic compound
WMD	Water management district
WUE	Water use efficiency
WUP	Water use permit
Zn	Zinc

INTRODUCTION

This document on **Best Management Practices (BMPs)** covers many of the aspects of managing a golf course in an environmentally sound manner.

Environmental stewardship begins with an understanding of the environment and how it can be harmed. From there, it is not difficult to look at each management practice, and take steps to prevent contamination, waste, and habitat loss. Once identified, past errors can be corrected, and the effects of existing situations can be lessened resulting in a better balance with the environment.

Florida's environment is unique. It varies from the red clay hills of the Panhandle to the coral shores of the Keys; from the deep sands of the Suwannee Valley and the Central Ridge to pine flatwoods throughout the state; and it includes the vast river of grass called the Everglades. Ninety percent of Florida's drinking water comes from underground aquifers, many of which have only a highly permeable layer of sand above to protect them from contamination by chemicals used in daily life, such as gasoline, dry-cleaning fluids, pesticides, and solvents. Nutrients, such as the nitrogen and phosphorus contained in fertilizers, reclaimed water, and septic discharge, may upset the balance of Florida's waterbodies, leading to noxious weeds, algae blooms, fish kills, and the replacement of game fish with less desirable species.

Golf is one of the most popular sports in America today, for men, women, and children. It provides recreation, exercise, business opportunities, and a chance to get outdoors and enjoy nature for more than 9 million people every year.

The Florida golf course industry is the largest of any state in the United States and its impacts, especially on the state's economy are substantial. According to the 2019 edition of the National Golf Foundation's *Golf Facilities in the U.S.* report, Florida was ranked highest with 1,306 golf courses and 986 golf course facilities in 2018. According to *The Florida Golf Economy — Full Report* commissioned by Golf 20/20; the Florida golf course industry had a direct economic impact on the state's economy estimated at $8.2 billion with a total economic impact of $11 billion in 2013. The industry also provided more than 132,000 jobs and $3.6 billion in wages in Florida in 2013. That same year, the Florida golf industry raised more than $383 million for charitable causes and generated more than $2.1 billion in hospitality and tourism, and $1.1 billion in real estate (SRI International, 2015).

Many supporters of golf, including the Golf Course Superintendents Association of America (GCSAA), United States Golf Association (USGA), and the American Society of Golf Course Architects, are actively promoting environmentally friendly golf course design and management. Audubon International has more than 2,300 courses enrolled in the Cooperative Sanctuary Program, more than 900 of which have become certified sanctuaries. The U.S. Fish and Wildlife Service's (FWS) Safe Harbor Program is available for courses that have crucial habitat for threatened or endangered species. Similarly, *Wildlife Links* is a joint venture of the USGA and the National Fish and Wildlife Foundation.

In the past, relationships within ecosystems were not well understood, and it seemed that the capacity of the oceans, rivers, lakes, and the soil itself was limitless. These relationships are better known now, and many golf courses are leading the way through environmental stewardship of their properties.

In the mid-1990s, the Center for Resource Management brought together a diverse group of golf and environmental organizations and developed a manual titled *Environmental Principles for Golf Courses in the United States*. Sixteen organizations were involved, ranging from the U.S. Environmental Protection Agency (EPA) and the USGA, to the Sierra Club and Audubon International. Permission to use excerpts from these principles has been graciously granted, and they are used throughout this manual. The following are the basic precepts of the manual:

Enhance local communities ecologically and economically

Offer and protect habitats for wildlife and plant species

Recognize that every golf course must be developed and managed with consideration for the unique conditions of the ecosystem of which it is a part

Provide important green space benefits

Use natural resources efficiently

Respect adjacent land use when planning, constructing, maintaining, and operating golf courses

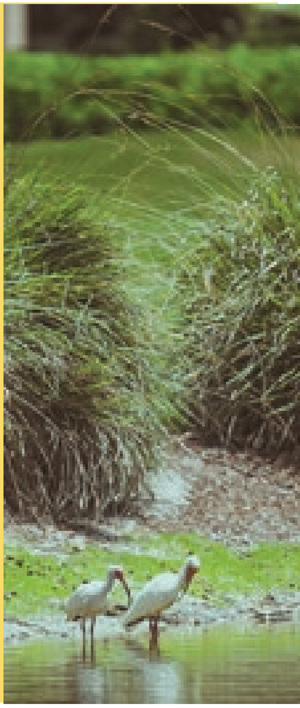
Create desirable playing conditions through practices that preserve environmental quality

Support ongoing research to scientifically establish new and better ways to develop and manage golf courses in harmony with the environment

Document outstanding development and management practices to promote more widespread implementation of environmentally sound golf

Educate golfers and potential developers about the principles of environmental responsibility

Promote the understanding that environmentally sound golf courses are quality golf courses



The process begins with the site selection and initial design by the developer and golf course architect; obviously these factors cannot be easily changed for existing golf courses. However, most environmental impacts are created at least as much, if not more so, by day-to-day decisions and operations. In addition, some golf courses modify golf holes and make renovations over time that can allow many of those initial design decisions to be modified. Irrigation systems do not need to be removed and replaced all at once, but state-of-the-art systems can be installed on one or two holes per year as golf course features are rebuilt and other changes occur. Other practices, such as the use of integrated pest management (IPM) and BMPs for turf management involving cultural practices, nutrition, and irrigation timing and duration cost little or nothing to implement. They require only education, thought, and skill on the part of golf course management personnel. Best of all, these BMPs may save money and can be implemented almost immediately.

While no one would claim that a golf course has no environmental impact, golf courses do provide environmental benefits. In an otherwise paved urban area, they provide valuable green space. Turfgrass and other plants provide cooling evapotranspiration (ET) to an urban heat island, oxygen from photosynthesis, the absorption of stormwater and its pollutants, habitat for birds and other wildlife, and myriad more subtle advantages over other types of urban development.

At present, these BMPs are not regulatory or enforcement based. In some situations, however, the law may provide substantial incentives should they be formally adopted, and there are situations in which BMP use could reduce legal or regulatory exposure. Golf course superintendents should maintain records and provide documentation regarding the implementation of all BMPs used and applied on their facilities, and to document should certain BMPs not be applicable to their specific situations. Adequate records are very important for the documentation of BMP implementation and are an integral part of any BMP program. The priorities for BMP implementation are as follows:

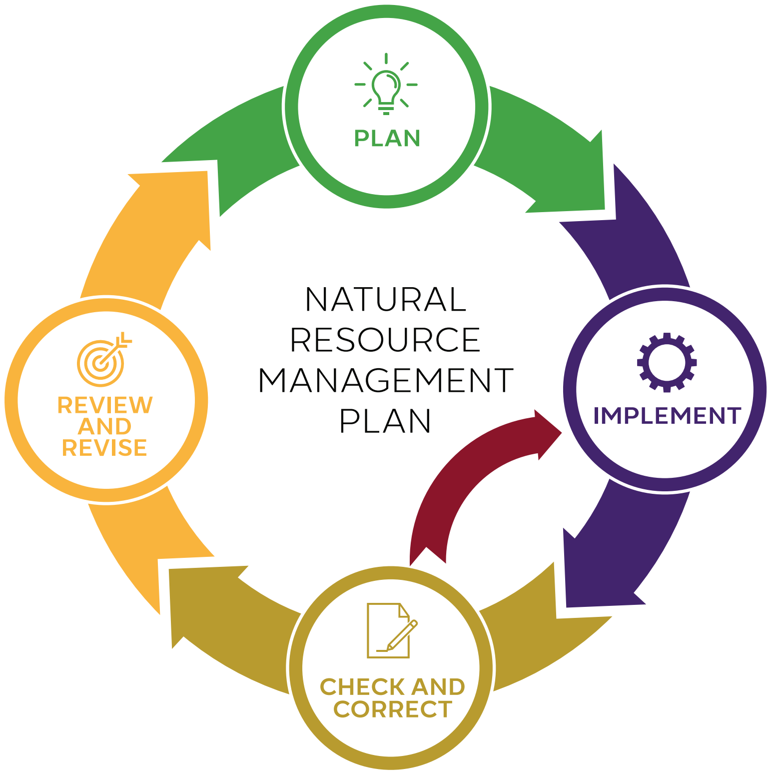
1. **To correct any identified existing water quality/ quantity problems**
2. **To minimize water quality/ quantity problems resulting from land use and operations**
3. **To improve the effectiveness of existing BMPs implemented**
4. **To seek additional improvement of BMPs based on new, quantifiable information.**

All golf course superintendents are encouraged to routinely perform an environmental assessment of their operations. This resource allocation assessment process is a tool to aid in identifying which BMPs should be considered to achieve the greatest economic and environmental benefit based on site-specific circumstances. The incentives for adopting BMPs include the following:

- **Improved turf quality**
- **Improved golf outing experiences**
- **Reduced environmental impacts**
- **Improved worker safety**
- **Efficient allocation of resources**
- **Reduced maintenance expenditures**
- **Reduced regulatory requirements**
- **Opportunity for industry self-regulation.**

Research is never-ending process and as new challenges arise additional research is needed to answer evolving questions. As new knowledge is gained, these BMPs will be revised over time to reflect changes in the level of knowledge. As such, this BMP manual is a living document. As new technologies are introduced to the Golf Course Industry, such as drone-based remote sensing of water and disease stresses, autonomous mowers, and site-specific computerized irrigation that is corrected for overnight rainfall, show promise of further reductions in adverse environmental effects and better, more cost-effective opportunities for golf course management.

This manual will not have all the answers to every question that comes up. Other references are available with far more detail on almost every subject. Many are listed throughout the text and in the References section of this document. It is hoped that the principles described in these chapters will give direction and understanding to the search for those answers. Using BMPs is a continuous process, as shown in the figure below.



1 National Golf Foundation. 2019. Golf Facilities in the U.S.

2 SRI International. 2015. The Florida golf economy-full report, 1-3.

3 https://audubonninternational.org/wp-content/uploads/2019/03/ACSP-Golf-Fact-Sheet-2018.pdf

4 https://www.fws.gov/endangered/landowners/safe-harbor-agreements.html

5 https://www.usga.org/content/dam/usga/pdf/Water%20Resource%20Center/usga-wildlifelinks.pdf

6 Center for Resource Management, 1996.

SECTION 1
ENVIRONMENTAL CONCEPTS

Steps should be taken to preserve wildlife and native plant habitats within the course environment. It is also important to consider how course management practices impact the surrounding natural ecosystems.

These natural systems support, maintain and service renewable functions such as filtering runoff, immobilizing air particulate, carbon sequestration, and temperature moderation. All of which contribute to sustaining good air and water quality conditions for both humans and animals.

ACCORDING TO A USGA STUDY, THE GOLF COURSE ECOSYSTEM:

- Provides wildlife habitat
- Protects topsoil from water and wind erosion
- Improves community aesthetics
- Absorbs and filters rain
- Improves health and reduces stress for more than 24.5 million golfers
- Improves air quality
- Captures and cleanses runoff in urban areas
- Discourages pests (e.g., ticks and mosquitoes)
- Restores damaged land areas (e.g., former landfill or mining sites)
- Makes substantial contributions to the community's economy

AIR QUALITY

Golf courses can have a positive impact on air quality, compared to other urban greenspaces. The air-purifying actions of healthy turf and plant life are offset only by impacts such as the limited air pollution of the maintenance machinery, increased traffic, and the energy used to heat and cool the buildings and run the irrigation system. Similarly, N_2O emission resulting from fertilizer applications to turf have been shown to contribute to greenhouse gases but can be reduced by irrigating after fertilization and using controlled-release fertilizers.

Good design and proper maintenance practices can do much to minimize these effects; energy-efficient facilities can be designed, and petroleum engine-driven equipment can be kept properly tuned and running at peak efficiency. Minimizing pesticide spray drift and solvent use can also reduce air pollution.

SOIL AND WATER QUALITY

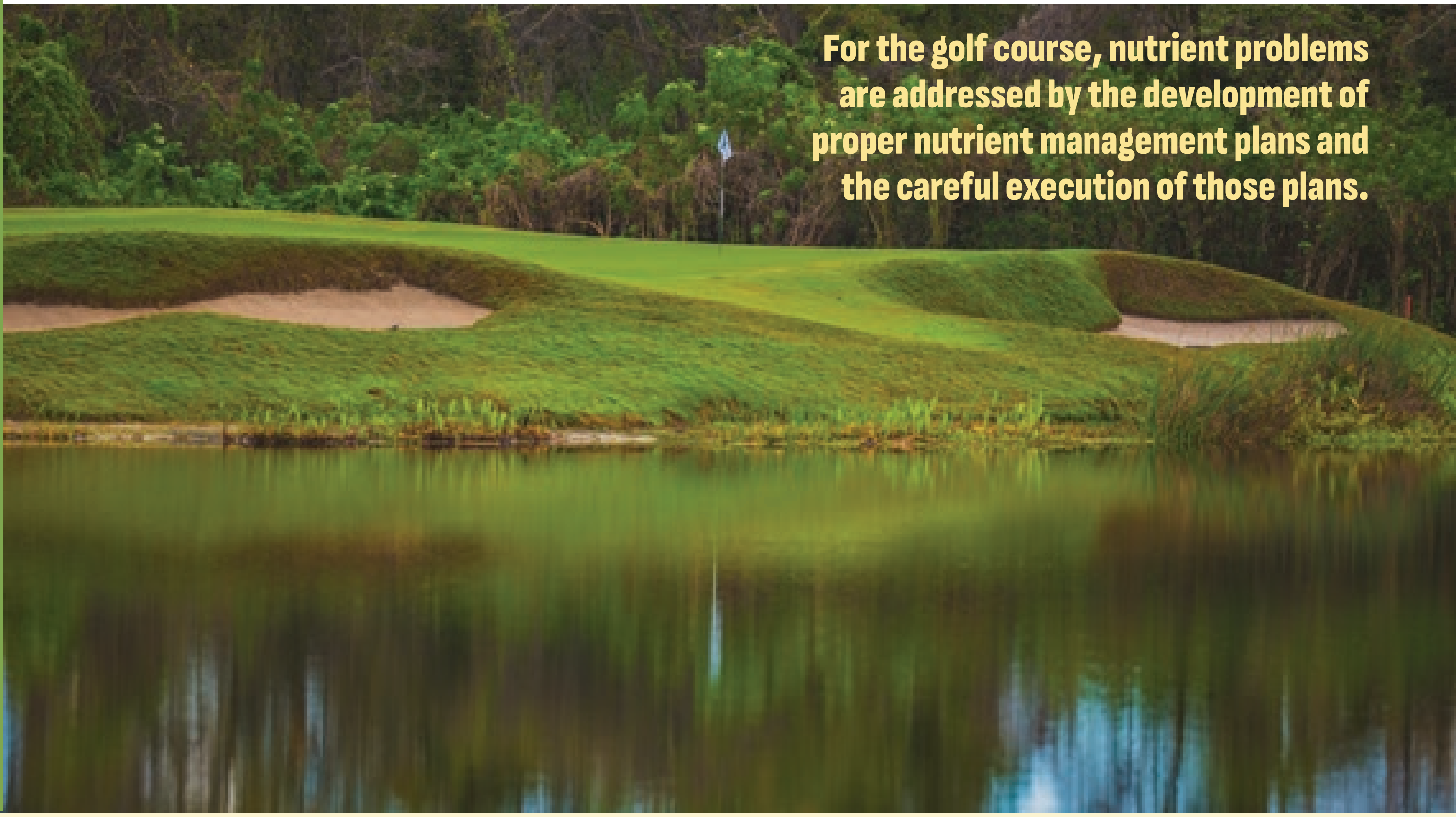
There are several significant environmental concerns for golf courses related to protecting soil and water quality. These concerns primarily relate to plant nutrients, pesticides, erosion, and sediment (turbidity), as well as the handling and disposal of waste materials.

Nutrients

There are three major nutrient requirements for plants that are supplied by the addition of fertilizer: nitrogen (N), phosphorus (P), and potassium (K). While all are essential for plant growth and are normally present in limited amounts in groundwater and surface water, potassium — unlike nitrogen and phosphorus — is not an element of impairment causing environmental concerns.

In many parts of Florida, where phosphate is naturally abundant in the rock and soil, algae and plant life in waterbodies are limited by the amount of nitrogen available. Liebig's Law of the Minimum states that growth is limited by whatever is in shortest supply. The environmental effect of contributing excess nutrients depends on the ecosystem. Most freshwater systems are phosphorus limiting, and marine systems are nitrogen limiting. Too much nitrogen can lead to algal blooms, which can result in fish kills from a lack of oxygen in the water. Conversely, in the Everglades and much of south Florida, natural levels of phosphorus are very low, and it is the limiting nutrient in wetlands and surface waters. Excess phosphorus often leads to the growth of noxious aquatic plants and other damaging organisms. In the same way that nutrients are applied to golf courses to enhance growth, a limiting nutrient unintentionally added to surface waters will increase plant growth.

Nitrates are a form of nitrogen of special concern with regard to groundwater quality. The federal standard for nitrate-nitrogen (NO_3-N) in drinking water is 10 parts per million (ppm). In Florida, the law considers most groundwater to be potential drinking water and applies the standard to almost all groundwater. Nitrates can leach into groundwater from animal wastes, septic tanks, sewage treatment plants, or the overapplication of fertilizers.



Pesticides

Pesticide use on golf courses is a very controversial topic. Pesticides differ in their mode of action, chemical properties, and the effects they exert on nontarget organisms such as pets, fish, and humans. Some pesticides are toxic to the bees, a beneficial pollinator, or affect birds, wildlife, fish, or other aquatic life in rivers, streams, and lakes. Some golfers or people living nearby may also be sensitive to certain chemicals.

Pest control on a golf course should not begin with pesticides. The fundamental basis of an environmentally sound pest control program is a process called Integrated Pest Management (IPM). IPM focuses on the basics of identifying the pests, monitoring pest-thresholds, choosing pest-resistant varieties of grasses and other plants, enhancing the habitat for natural pest predators, scouting to determine pest populations and determining acceptable thresholds, and applying biorationals and other less toxic alternatives to chemical pesticides whenever possible. Chemical pesticide applications are carefully chosen for effective and site-specific pest control that has a minimal effect on beneficial organisms and the environment, and to minimize the development of pesticide resistance by varying the type of pesticide used so that resistant strains do not thrive.

Pesticides unintentionally enter the environment in three ways. Wind may move pesticides away from their targets while being applied. This is called spray drift. They may also leach through the soil into groundwater or be carried in stormwater runoff to surface water. As with nutrients, proper management is the key to minimizing the adverse effects of pesticides on the environment. Many of the older, environmentally unacceptable pesticides were taken off the market decades ago. However, traces may still remain in the soil and groundwater.

Professional pesticide applicators on golf courses are licensed by the state only after receiving specialized training and passing state-administered examinations. In addition, they must obtain additional continuing education credits to renew their license every four years. This continuing education ensures that those responsible for pesticide applications on golf courses are aware of the least toxic and most environmentally sound methods of pest control.

Wastes

The disposal of waste products on golf courses presents the same sort of problems as it does throughout society. The improper disposal of wastes can pollute soil and water, fill up landfills, and create nuisance odors and unsightly areas.

Grass clippings and other plant material should be composted and used in gardens and other landscaped areas around the course or provided to homeowners. Proper composting procedures should be followed allowing sufficient time for pesticide residues to degrade. As at any office or home, paper, cans, glass, and many other materials should be recycled.

Mixing pesticides and cleaning equipment of residual material must be handled properly in accordance with the pesticide label and applicable regulations. Usually, the best way is to place the diluted wash water back into the sprayer and apply it as a weak pesticide to an appropriate site or reuse in subsequent pesticide applications.

Equipment wash areas can also generate waste such as grass clippings and traces of fuel, oil, and metals that are washed off the engines and moving parts.

Solvents, oils, and other regulated or hazardous wastes must be properly disposed of by recycling or by transport by a licensed transporter to an appropriate facility. In most cases, the amount of hazardous waste can be greatly reduced using alternative solvents or other practices.

A superintendent can save substantial money with an aggressive pollution prevention program. Again, the key factor in determining a facility's impact on the environment is the management of a golf course by its superintendent.

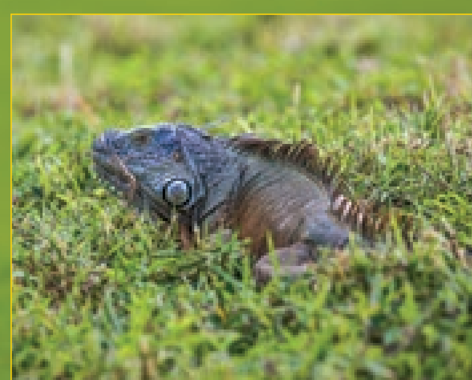
WILDLIFE HABITAT

The fragmentation, destruction, or elimination of wildlife habitat and wildlife corridors through the urbanization of both natural and agricultural areas has increased the need to preserve future urban green space for wildlife habitat. In many of Florida's fast-growing cities, golf courses are some of the few sources of open green space. It has been shown that most golf courses can provide significant, high-quality habitat to a large and diverse population of birds, mammals, and other wildlife. Golf courses are increasingly being recognized for their potential to provide valuable wildlife habitat. Unfortunately, the public perception of this benefit is limited.

The modern golf course can truly become an urban wildlife sanctuary by implementing features that encourage use of the course by local fauna:

- Maintaining most of the nonplay areas in varied types of native vegetation
- Leaving dead trees (snags) where they do not pose a hazard
- Winding natural areas through the course to provide movement corridors with shelter, concealment, and food
- Providing native shoreline and aquatic plants where play is not affected
- Using sound IPM, fertilization, and cultural maintenance practices
- Providing nesting boxes
- Selecting food and cover plants for butterflies and hummingbirds

Even endangered and threatened species can usually coexist if proper care is taken to avoid disturbing nesting places and dens and if adequate food and protection from predators are provided. More recently, golf course superintendents are developing pollinator habitats in out-of-play areas.



WATER CONSERVATION

Potable water supplies in Florida are limited and demand continues to grow. The challenge is to find solutions to balance health and playability while using less water. BMPs and educational programs are necessary to change the public's mindset toward the inevitable changes in water-related issues.

There are many ways to conserve water on a golf course. Ideally, only the play and practice areas should be irrigated under normal conditions. Selecting drought-tolerant varieties of turfgrasses can help maintain an attractive and high-quality playing surfaces while minimizing water use. Out-of-play areas may be planted with drought-resistant native or other well-adapted, noninvasive plants that provide an attractive and low-maintenance landscape. Native plant species are important in providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation. New courses are being designed using a "target golf" concept that minimizes the acreage of irrigated turf. Existing golf courses can make an effort to convert out-of-play areas from irrigated, mowed turf to native plants and grasses to reduce water use and augment the site's aesthetic appeal.

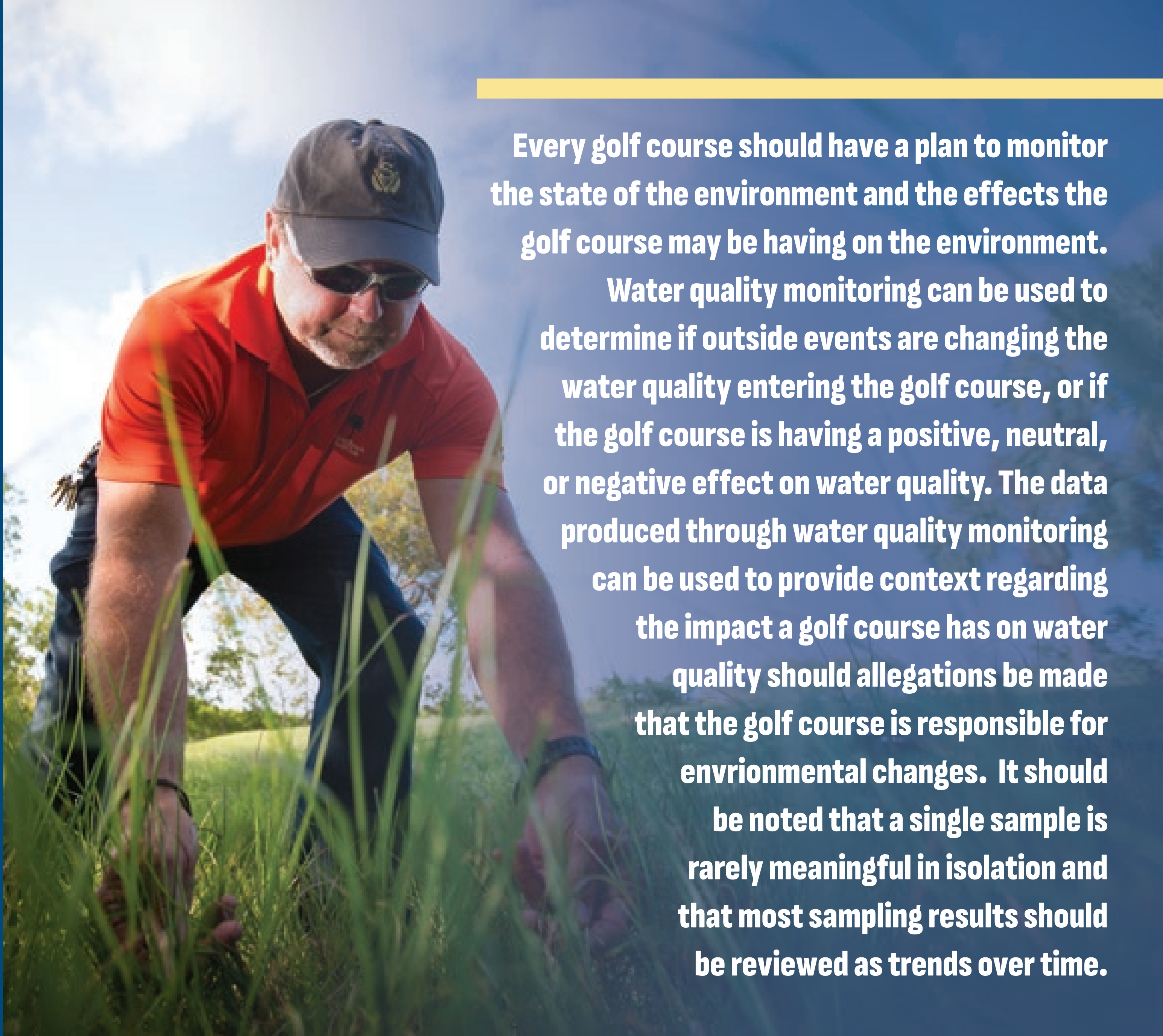
A well-designed irrigation system that is maintained at peak efficiency helps to ensure that the water used is not wasted. The system should be operated to provide only the water that is actually needed by the plants or to meet occasional special needs such as flushing salts from the rootzone. Modern irrigation systems that are computer-controlled with weather stations, automatic rain- and soil moisture—sensing controls, and multiple zones can water different areas accordingly. This allows specific areas on a course that were missed by a passing storm to be irrigated while suspending irrigation in areas that do not need additional water.

The source of irrigation water can also significantly reduce water use. If properly designed, rain and runoff captured in water hazards and stormwater ponds may

provide most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during drought periods. In some cases, golf courses may be located where reclaimed reuse water from a wastewater treatment plant is available. Such water is highly treated for pathogens and is safe for human contact. Reclaimed water is also a potential source of nutrients and should be monitored and evaluated as a source of nutrient load to the golf course. In some coastal areas, nonpotable, brackish water is being successfully used for golf course irrigation. This requires the selection of salt-tolerant grasses such as seashore paspalum (*Paspalum vaginatum*) and the use of drought- and salt-tolerant plants in non-play areas. Horizontal wells are another potential alternative water source. They are very site specific but can tap into surficial groundwater sources, avoiding the use of traditional aquifers and deep wells.

SECTION 2

ENVIRONMENTAL MONITORING



Every golf course should have a plan to monitor the state of the environment and the effects the golf course may be having on the environment. Water quality monitoring can be used to determine if outside events are changing the water quality entering the golf course, or if the golf course is having a positive, neutral, or negative effect on water quality. The data produced through water quality monitoring can be used to provide context regarding the impact a golf course has on water quality should allegations be made that the golf course is responsible for envrionmental changes. It should be noted that a single sample is rarely meaningful in isolation and that most sampling results should be reviewed as trends over time.

Quality Assurance/Quality Control

The purpose of quality assurance/quality control (QA/QC) is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable, and are collected and analyzed using scientifically sound procedures. To this end, Subsection 62-160.110, Florida Administrative Code (F.A.C.), defines FDEP's minimum field and laboratory quality assurance, methodological, and reporting requirements. This rule applies to all programs, projects, studies, or other activities that are required by FDEP, and that involve the measurement, use, or submission of environmental data or reports to FDEP.

However, even if the data are only for proprietary use and are not reported to any regulatory agency, it is strongly recommended that a certified laboratory is used, and all QA/QC procedures followed. Golf course management must have good data to make good decisions, and if a golf course should ever want to produce data for an agency or in court to defend the facility from unwarranted charges, those data must meet QA/QC standards to be defensible as evidence.

The National Environmental Laboratory Accreditation Conference (NELAC) is a voluntary association of state and federal agencies with input from the private sector. NELAC's purpose is to establish and promote mutually acceptable performance standards for the operation of environmental laboratories. The EPA's National Environmental Laboratory Accreditation Program (NELAP) office provides support to NELAC and evaluates the accrediting authority programs. In Florida, the Florida Department of Health (FDOH) provides NELAP environmental laboratory certification. More information and a list of certified laboratories are available at https://fldeploc.dep.state.fl.us/aams/index.asp. Sample specific standard operating procedures (SOPs) are available at https://floridadep.gov/dear/quality-assurance/content/dep-sops.

Predevelopment Monitoring

The development process and preconstruction monitoring should begin as soon as possible, in order to establish a baseline to compare against future monitoring results. Water quality samples for the predevelopment background (baseline) study should be taken at the following locations:

- **Upstream and downstream of the golf course development on adjacent major rivers, streams, or lakes, if present**
- **Flowing tributaries, wetlands, and draining golf course development, if present**
- **Any additional sites selected prior to development**
- **At upgradient and downgradient wells, as suggested by the hydrogeologist or regulatory agency**

Water Quality is typically assessed based on concentration of compounds measured in the water, but the volume of water is also a factor that can affect the concentration as well as assist in interpretation of results. Therefore, an assessment of the relative quantity of water at the time of sampling is also useful. This can be done by measuring the "stage" or water level at the time of sampling or the presence or absence of flow/discharge. This also helps to define whether a measured concentration is moving onto or off of the golf course area.

Four rounds of samples should be taken about three months apart to cover the seasonal weather patterns for an entire year. At a minimum, at least one wet season and one dry season set of samples should be taken. Surface waterbodies are typically more dynamic than groundwater systems and therefore should be monitored more frequently.

Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by FDEP's Total Maximum Daily Load [TMDL] Program). Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments and suspended solids, dissolved oxygen (DO), heavy metals, and any pesticides expected to be used on the golf course. A stream or lake biodiversity analysis should also be conducted to characterize the predevelopment condition and every five years thereafter.

WHAT DO I SAMPLE FOR?

Physical Parameters:

Alkalinity, Conductivity, Dissolved Oxygen (DO), pH, Turbidity or Secchi depth, and Temperature

Chemical Parameters:

Chlorides (Cl)

Nitrogen: Total Nitrogen (TN), Nitrate + Nitrite (NO_3 + NO_2), Ammonia (NH_3), and Total Kjeldahl Nitrogen (TKN)

Phosphorus: Total Phosphorus (TP) and Orthophosphate (PO_4)

Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

Heavy Metals: Copper (Cu), Lead (Pb), and other heavy metals of concern

Pesticides used or known to be used upstream

Biological Parameters:

Biodiversity Index

Monitoring During Construction

Construction site monitoring should focus on sedimentation and erosion discharges. Turbidity and suspended solids are the primary parameters at this stage. Most important are carrying out frequent visual inspections of erosion and sedimentation control BMPs on the construction site and ensuring that the contractor makes prompt and correct repairs should control measures be damaged (i.e., silt fence becomes damaged). The Florida Stormwater Erosion and Sedimentation Control Inspector's Manual is an excellent resource (http://publicfiles.dep.state.fl.us/DEAR/Stormwater_Training_Docs/erosion-inspectors-manual.pdf).

Postconstruction Operational Monitoring

A water quality monitoring plan should be prepared to ensure the ongoing protection of ground water and surface water quality after construction is completed. The same sites should be monitored as during the preconstruction phase, although the monitoring plan can be modified based on site-specific conditions. The plan should include the following:

1. **Postconstruction surface water quality sampling should begin with the installation and maintenance of golf course turf and landscaping. Samples should be collected a minimum of three times per year, with one sampling event scheduled at the beginning of the historical wet season, a second sampling event scheduled towards the end of the wet season, and a third sampling event scheduled during the typical dry season. Should there be no discharge on the scheduled sample date, samples should be taken during the next discharge event.**

2. **Postconstruction surface water quality sampling should continue through the first three years of operation and during the wet and dry seasons every third year thereafter, provided that all required water quality monitoring has been completed and the development continues to implement all current management plans. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality.**

3. **Sampling parameters should be determined based on golf course operation and any basin-specific parameters of concern (identified by the TMDL Program or local regulators).**

SECTION 3

PLANNING, DESIGN AND CONSTRUCTION

The construction phase of a golf course and its ancillary support facilities pose the greatest risk of ecosystem alteration. With proper planning and design, golf facilities can be constructed and maintained with limited impact to existing wildlife and their habitat.

Regulatory Considerations

Local, state, and federal regulations are in place impacting planning, design, and construction of golf courses in Florida. Early engagement among developers, designers, local community groups, and permitting agencies is essential to designing and constructing a golf facility that minimizes environmental impact and meets the needs for the approval process. Proper planning will minimize expenses due to unforeseen construction requirements.

Environmental Considerations

For almost any site, local environmental issues and conditions will need to be addressed. Therefore, the careful evaluation of design criteria and proper routing/siting of golf amenities are essential during the planning process. Developers, designers, and others involved in golf course development are encouraged to work closely with local community groups and regulatory/permitting agencies during planning and siting, and throughout the development process. Early input from these groups and agencies is very important to the development and approval process.

There are four key steps to designing, building, and operating an environmentally responsible golf course. While the following steps are very general, each is subsequently broken down into more detail as a project proceeds:

1. **Consider the property and its surroundings in relationship to the local watershed and ecological community.**
2. **Identify biologic, agronomic, hydrogeologic, and topographic resources and features including invasive species. Determine areas that merit special protection or restoration.**
3. **Create a natural resources management plan and identify those management practices that will protect environmental resources during the construction phase and later during golf course operation.**
4. **Implement an environmental monitoring program (*see Chapter 2 — Environmental Monitoring*). This establishes a baseline for conditions when the project started and provides an early warning of potential problems that may arise, before they become serious or expensive to address. It also may defuse potential controversy later on, if problems should occur, by demonstrating the intended environmental stewardship provided by the golf course.**

The design of a course should be based on the information gathered in the first three steps listed in the sidebar. A good design flows in harmony with the natural landscape. The course should be designed and routed to preserve and enhance wildlife habitat, and the design should be environmentally proactive, with creative design used to enhance ecological sensitivity and biodiversity.

Experienced professionals should conduct a site analysis and feasibility study. They should carefully review Florida's spring watershed areas, which require additional design and BMP measures in addition to those described below. The identification of environmentally sensitive areas and other natural resources is important so that a design can be achieved that carefully balances environmental factors, playability, and aesthetics. From a water resource standpoint, this involves protecting both ground water and surface water, and limiting the use of potable water supplies for irrigation.

All involved in the management, design, and construction of golf courses need to fully understand the role of Basin Management Action Plans. A Basin Management Action Plan (BMAP) is a framework for water quality restoration that contains local and state commitments to reduce pollutant loading through current and future projects and strategies. BMAPs contain a comprehensive set of solutions, such as permit limits on wastewater facilities, urban and agricultural best management practices, and conservation programs designed to achieve pollutant reductions established by a total maximum daily load (TMDL). These broad-based plans are developed with local stakeholders and rely on local input and commitment for development and successful implementation. BMAPs are adopted by Florida Department of Environmental Protection (DEP) Secretarial Order and are legally enforceable. For more information: https://bit.ly/3x5zNn3

Accordingly, in 2016, the Florida Legislature identified 30 Outstanding Florida Springs that require additional protections to ensure their conservation and restoration for future generations. These plans are focused on reducing nitrogen pollution that is impacting the water quality of these springs. Pre-construction and existing golf courses located in the protection zones of springs and special Priority Focus Areas (PFA) must take extra care to avoid leaching and should create special management zones adjacent to sinkholes or surface waters. For more information: https://bit.ly/3i1STqg

The springs BMAPs are developed with specific provisions for the protection and restoration of the state's Outstanding Florida Springs. As per the Florida Springs and Aquifer Protection Act (part VIII of chapter 373, Florida Statutes), the department delineates priority focus areas for each Outstanding Florida Spring that is impaired by excessive nutrient pollution. Using the best data available, the department delineates the priority focus areas considering groundwater travel time to the spring, hydrogeology, nutrient loads in the springshed, and other factors. The priority focus areas are adjusted to rely upon understood and easily identifiable boundaries such as roads or political jurisdictions. The priority focus areas become effective upon incorporation into a BMAP.
For more information: https://bit.ly/3i2dbQp

Although many operational and maintenance BMPs do not come into play until a golf course is fully operational, considering these BMPs up front, including the IPM program, allows the designer to get it right the first time and reduces later costs, while maximizing both environmental and financial returns. Developing comprehensive BMP and IPM plans ensures that maintenance facilities—especially chemical storage and handling areas, equipment cleaning and maintenance areas, and fueling areas—are designed with their specialized needs in mind.

Finally, the design of a golf course is only as good as the construction that makes it a reality.

Design and Construction Best Management Practices:

Retain a qualified golf course superintendent/ project manager at the beginning of the design and construction process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.

Design the course to minimize the need to alter or remove existing native landscapes. The routing should identify the areas that provide opportunities for restoration.

Design the course to retain as much natural vegetation as possible. Where appropriate, consider enhancing existing vegetation through the supplemental planting of native vegetation/ materials next to long fairways, out-of-play areas, and along water sources supporting fish and other water-dependent species.

Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance, invasive, and exotic plants should be removed and replaced with native species that are adapted to that particular site.

Locate the course so that critical wildlife habitat is conserved and the development does not adversely affect viable, occupied native wildlife habitat on the site.

Identify regional wildlife corridors and configure the course to maintain and/or enhance native habitat to facilitate the use of these corridors. Any existing or proposed crossings of wildlife corridors associated with golf course operations and maintenance should be minimized, and unavoidable crossings should be designed to accommodate wildlife movement.

Use only qualified contractors who are experienced in the special requirements of golf course construction.

Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.

Schedule construction and turfgrass establishment to allow for the most efficient progress of the work, while optimizing environmental conservation and resource management.

Site Selection

The site selection for a golf course and subsequent routing plan largely determine the course's environmental compatibility within the community. The involvement of a golf course architect, land use specialists, water resource managers, and geotechnical professionals is critical in selecting a site and a routing that provide environmental benefits.

Identifying the resources at a site is necessary to understand how to design the course and surrounding development, to understand the long-term maintenance procedures and associated operational costs to be incurred, and to know how best to protect the site's environmental resources.

Watershed

A watershed is a land area that channels rainfall to creeks, streams, and rivers, and eventually to outflow points such as reservoirs, bays, and the ocean. Florida has 29 major watersheds, also known as drainage basins, that funnel surface and ground water and drains each into a single stream, lake, ocean, or other reservoir. Golf courses are situated within and are connected to these watersheds. Consequently, this connectivity can present both opportunities and challenges for managing golf courses. Care must be taken to ensure that pollutants that originate on the golf course remain on the golf course and are not conveyed beyond the area of desired effect/application to areas of unintended impact.

Wetlands

Florida law protects wetlands as waters of the state. Wetlands act both as filters for pollutant removal and as nurseries for many species in Florida. Many people do not realize the vital role wetlands play in purifying surface waters. Very few are aware that wetlands are the spawning grounds and nurseries for hundreds of species of birds and insects, as well as many fish, shrimp, and other species important to the seafood industry. The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of Florida's ecosystem.

Important Steps in Site Selection

Topographical land maps are essential before beginning any type of design activity for a golf course. A qualified designer attempts to work with the existing landscape as much as possible, if only to reduce the costs of earthmoving and fill material. In addition, special geology such as karst topography may require extra effort to avoid sinkholes, springs, and ground water contamination. Wetlands and other low-lying areas may also require special attention.

It is essential to know the soil types that are present to accurately estimate costs and protect the environment. Deep sands may require more fertilization and watering, and may pose a high risk for leaching. Heavy soils may not drain well, may be subject to increased erosion, and may create runoff into nearby waters. The types of soils present significantly affect the expense of golf course construction, especially if large quantities of topsoil must be trucked in to provide proper agronomic properties for turfgrass. As mentioned earlier, long-term maintenance costs also depend on the quality of the soils present on the site.

Studies of water supplies are needed for irrigation systems, and studies of waterbodies or flows on, near, and under the property are needed to properly design a course's stormwater systems and water features, and to protect water resources.

A preliminary site assessment should be conducted to identify critical habitat, natural features, wildlife corridors, environmentally sensitive areas, federal and state endangered and threatened species, and state species of special concern including invasive plants. Wildlife habitat conservation and restoration should play a crucial role in site analysis and selection. The site design should include the preservation of these areas.

While wetlands do pose a special concern, their mere presence is not incompatible with the game of golf. With care, many fine courses have been threaded through sensitive areas, and with proper design and management can coincide. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turfgrass with native vegetation or structural buffers. Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

That said, it is usually better to avoid wetlands construction if practical. Permitting requirements can be daunting, with multiple overlapping jurisdictions of federal, state, and local agencies. At the federal level alone, the U.S. Army Corps of Engineers (USACOE), EPA, FWS, National Oceanic and Atmospheric Administration (NOAA), and maritime agencies may all be involved. Add to this state and local agencies, and nongovernmental environmental or other citizen groups, and you can see why wetlands are usually approached with caution.

If construction along wetlands is being considered, contact the local government and/or local FDEP or water management district office before developing engineering plans. Staff in these agencies can give an early indication as to what may, or may not, be permitted and may be able to point out alternatives that save money and speed up the review process. Remember, most obstacles are easily avoided with enough notice.

Wetland Best Management Practices:

Ensure that proper permitting has been obtained before working on any wetlands.

Ensure that wetlands have been properly delineated before working in and around any wetlands.

Drainage

Adequate drainage is necessary for growing healthy turfgrass. In Florida, where high rainfall events are common in the summer and fall, installation of an internal drainage system may be necessary. A qualified golf course architect, working in conjunction with a stormwater engineer, reviews soils and site conditions to develop an effective stormwater management system that complies with the requirements of the water management district or other permitting agencies.

A quality BMP plan for drainage addresses the containment of runoff, adequate buffer zones, and filtration techniques in the design and construction process to achieve acceptable water quality. Swales and other parts of the system must be properly maintained. Debris and unwanted plant growth can build up and clog the system, so that the required volume of water cannot be moved as designed. This may result in saturated soils, leading to oxygen deprivation in the root zone and upstream flooding.

Drainage Best Management Practices:

When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, slopes, the placement of gravel, and backfilling.

Internal golf course drains should not drain directly into an open waterbody, but should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.

Drainage should discharge through proper drainage and stormwater management devices, for example, vegetative buffers, swales, etc.

The drainage system should be routinely inspected to ensure proper function.

Stormwater, Stormwater Ponds, Lakes, Springs and Water Hazards

Stormwater is the conveying force behind what is called nonpoint source pollution. Nonpoint pollution, which is both natural and human-created, comes not from a pipe out of a factory or sewage treatment plant, but from daily activity. Pollutants commonly found in stormwater include the microscopic wear products of brake linings and tires; oil; shingle particles washed off roofs; soap, dirt and worn paint particles from car washing; leaves and grass clippings; pet and wildlife wastes; lawn, commercial, and agricultural fertilizers; and pesticides.

Stormwater pollutants may be dissolved in the water or carried as fine particles, called suspended solids. These solids may be fine soil particles, organic material, or other kinds of particles, but all may have other chemical pollutants attached to them. One kind of stormwater treatment involves separating out these particles. Other types of treatment include biological or chemical processes, which are often used to remove dissolved materials such as pesticides or nutrients.

The control of stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance, and play areas. In addition to controlling the amount and rate of water leaving the course, it also involves storing irrigation water, controlling erosion and sediment, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns. Keep in mind that not all stormwater on a golf course originates there; some may be from adjoining lands, including residential or commercial developments.

Most golf course developers in Florida plan their lakes and water hazards to be a part of the stormwater control and treatment system. This usually works out well for all concerned. However, natural waters of the state cannot be considered treatment systems and must be protected.

Lakes and ponds may also be used as a source of irrigation water. It is important to consider these functions when designing and constructing the ponds. Peninsular projections and long, narrow fingers may prevent mixing. Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation. Swales and slight berms around the water's edge, along with buffer strips, can greatly reduce the nutrients and contamination that can affect water quality. Careful design may significantly reduce future operating expenses for lake and aquatic plant management.

Stormwater Treatment Train

Stormwater treatment is best accomplished by a "treatment train" approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. For example, stormwater can be directed across a vegetated filter strip (such as turfgrass), through a swale, into a wet detention pond, and then out through another swale to a constructed wetland system.

Photo by Top100 Golfer on Flickr

Swale

Source Controls

Source controls are the first car on the BMP treatment train. They help to prevent the generation of stormwater or introduction of pollutants into stormwater. The most effective methods of stormwater treatment are not to generate stormwater in the first place, or to remove it as it is generated. There are several options for accomplishing these objectives. The most important is eliminating as much directly connected impervious area (DCIA) as possible. DCIA is any area of impervious surface that drains directly to a waterbody without treatment—for example, a roof that drains to a parking lot, down a road, then into a ditch leading to a stream.

Stormwater Source Control Best Management Practices:

Stormwater treatment is best accomplished by a "treatment train" approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment.

Ensure that no discharges from pipes go directly to water.

Eliminate or minimize directly connected impervious areas (DCIAs).

Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.

Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.

Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.

Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.

Erosion and Sediment Control

During construction, temporary barriers and traps must be used to prevent sediments from being washed off-site into waterbodies. Wherever possible, keep a vegetative cover on the site until it is ready for construction, and then plant sod, or otherwise cover it as soon as possible to prevent erosion.

Golf course designers and developers should be familiar with the State of Florida Erosion and Sediment Control Designer and Reviewer Manual, available from FDEP or FDOT. All superintendents overseeing construction, and all construction contractors, should take the FDEP Stormwater, Erosion, and Sedimentation Control Inspector Training course. This two-day class follows the curriculum provided in the Florida Stormwater, Erosion, and Sedimentation Control Inspector's Manual. See the FDEP Web site (available: http://www.dep.state.fl.us/water/nonpoint/erosion.htm) for more information or to find a class near you.

Once construction is completed, permanent barriers and traps can be used to control sediments. For example, depressed landscape islands in parking lots catch, filter, and infiltrate water instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the "first flush" and settle out sediments, while allowing the overflow to drain away.

Erosion and Sediment Control Best Management Practices:

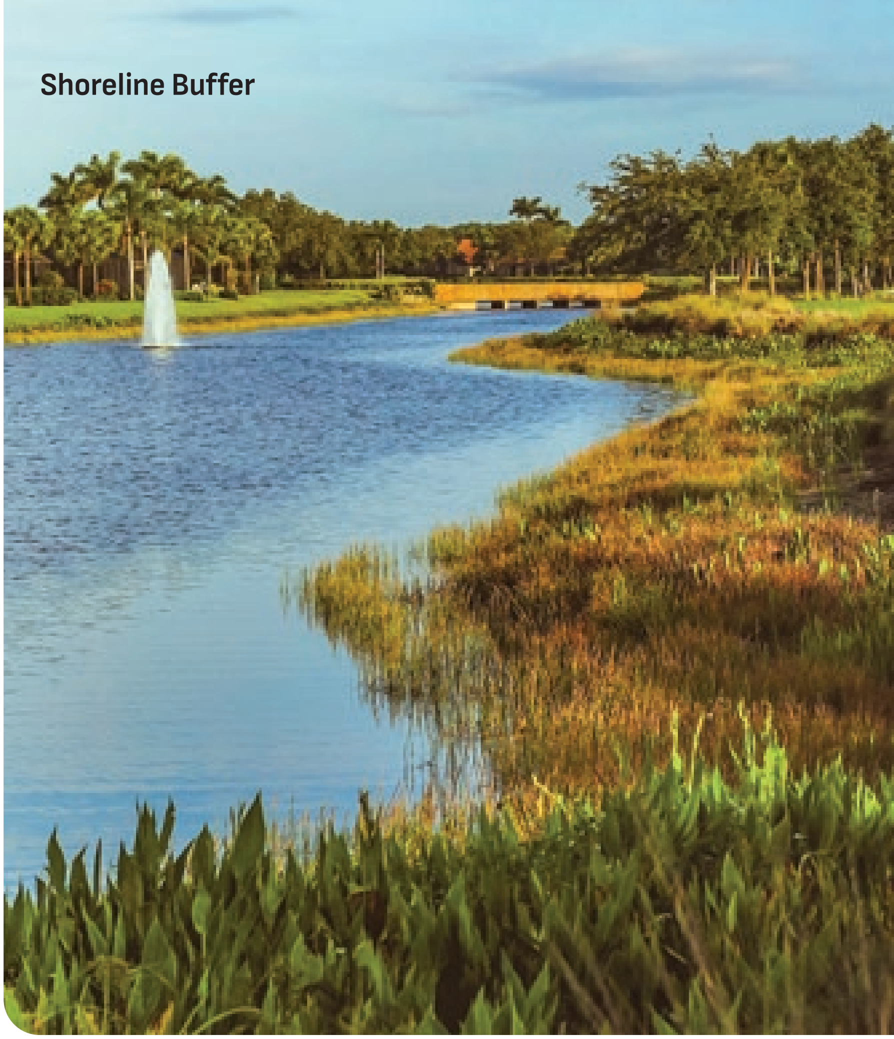
Develop a working knowledge of erosion and sediment control management. Each state has its own specifications including types of acceptable structures, materials, and design features.

Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.

Hydro-seeding or hydro-mulching offers soil stabilization.

Water Quality Buffers

Buffers around the shore of a waterbody or other sensitive areas filter and purify runoff as it passes across the buffer. Ideally, plant buffers with native species provide a triple-play of water quality benefits, pleasing aesthetics, and habitat and food sources for wildlife. As discussed above, it is important to continue these plantings into the water to provide emergent vegetation for aquatic life, even if the pond is not used for stormwater treatment. Effective BMPs in these areas include site-specific fertilization and limits on pesticide use, primarily focusing on the control of invasive species.

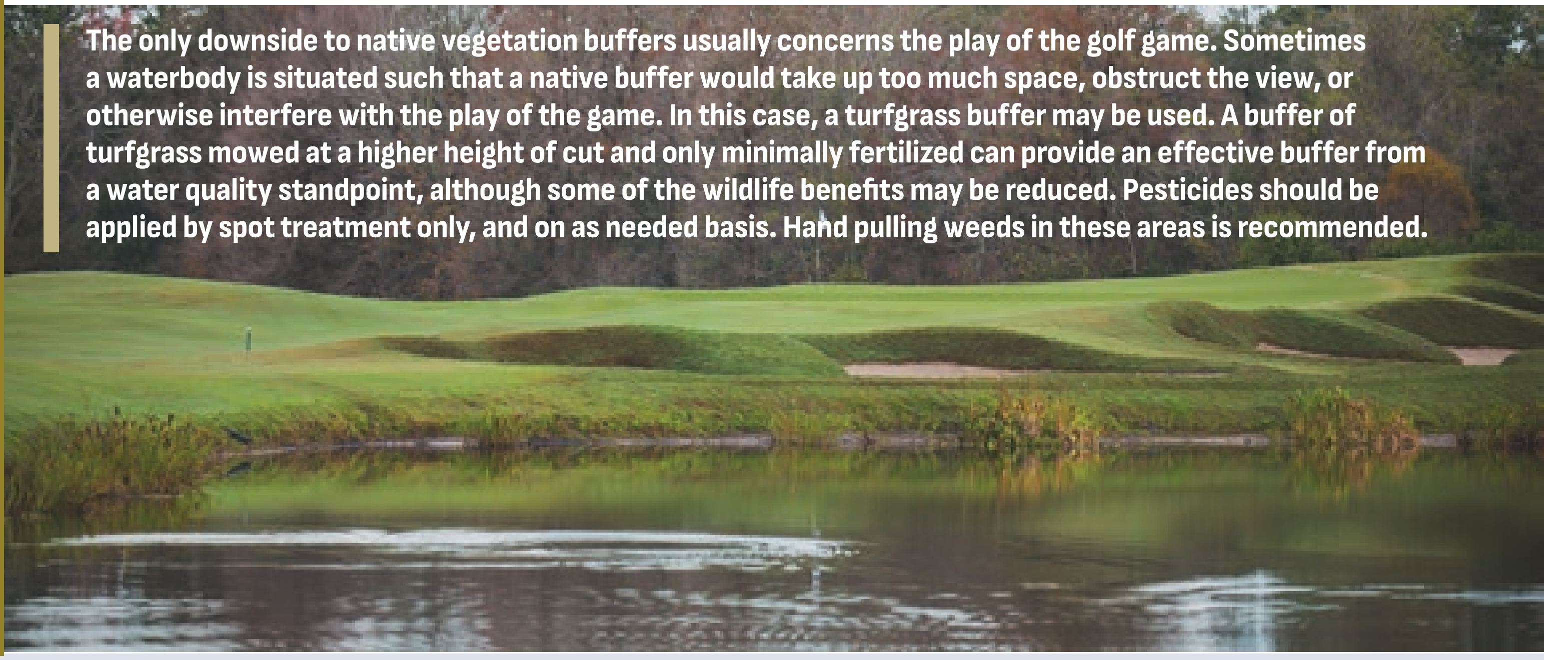


Shoreline Buffer

A measure of protection can be achieved by instituting Special Management Zones around waterbodies. In managed areas around a golf course, the first 25 feet landward is a No Spray Zone (no pesticides used), and from 25 to 50 feet landward is a Limited Spray Zone (selected pesticide use, based on a risk assessment protective of aquatic life).

The No Spray Zones and buffers occupy the same space. It is important to note, however, that Limited Spray Zones and a policy of "no direct discharge" provide advantages to all wildlife by maintaining water quality. All other efforts are completely wasted if water quality is not sufficient for wildlife use. Some species, especially aquatic animals that cannot move large distances, are extremely sensitive to even trace amounts of standard fertilizers and pesticides. It is critical to have a design that incorporates protective measures to maintain water quality.

> **The only downside to native vegetation buffers usually concerns the play of the golf game. Sometimes a waterbody is situated such that a native buffer would take up too much space, obstruct the view, or otherwise interfere with the play of the game. In this case, a turfgrass buffer may be used. A buffer of turfgrass mowed at a higher height of cut and only minimally fertilized can provide an effective buffer from a water quality standpoint, although some of the wildlife benefits may be reduced. Pesticides should be applied by spot treatment only, and on as needed basis. Hand pulling weeds in these areas is recommended.**

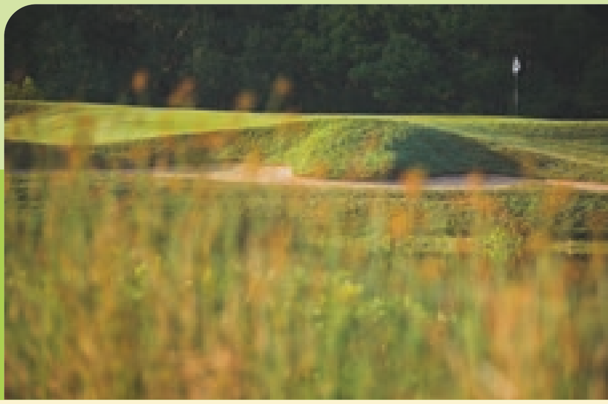


Springs, Spring Runs, and Springshed

The Florida Geological Survey defines springs as a point where underground water emerges to the earth's surface. They flow naturally from underlying aquifers and are classified based on their magnitude or amount of flow coming from the spring vent. Springs and spring runs attract wildlife, provide over-wintering habitat for endangered manatees, contain unique biological communities, and are important archeological sites.

A spring run is defined as "a body of flowing water that originates from a karst spring." The area within groundwater and surface water basins that contributes to the flow of the spring is a spring's recharge basin, also called "springshed." This area may extend for miles from the spring, and the size of the site may fluctuate because of underground water levels.

Florida Spring Classification System and Spring Glossary:
https://ufdcimages.uflib.ufl.edu/UF/00/09/40/33/00001/SP52.pdf



Best Management Practices:

Establish and maintain a 100-foot riparian buffer around springs, spring runs, and springshed.

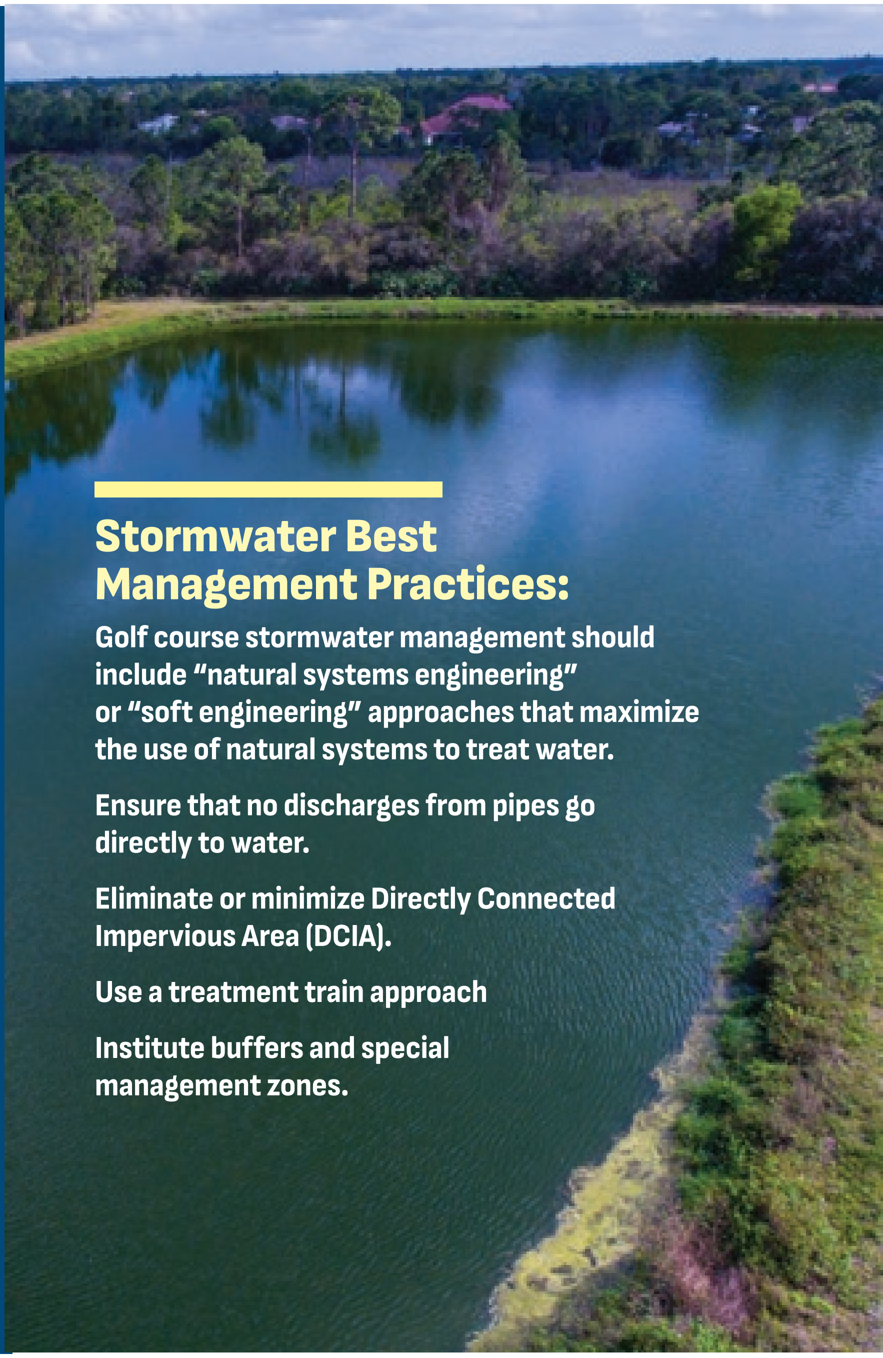
Retention versus Detention Ponds

Retention facilities are designed to hold all or most of the runoff from a storm event until it evaporates or soaks into the ground. Detention facilities absorb the inrush of water during a storm but release it slowly downstream. The characteristics of retention and detention facilities are as follows:

Retention facilities allow water to percolate through the soil into ground water. This traps most of the pollutants in the soil where they can be biologically degraded over time. They are usually designed to trap the first flush of 0.5 to 1 inch of rain and allow additional flow to bypass to another system. In many drainage watersheds, this first flush washes most of the pollutants off the surface and may carry 90% or more of the pollutants from even a large storm. These "offline" retention systems can approach 100% pollutant removal efficiency but take up a lot of space and are dry most of the year.

Wet detention facilities are similar, in that they slow the rate of water discharge to provide flood control, but are designed to have water in them at all times. These areas are biologically active ponds that allow solids to settle. A wet detention pond should have at least 30% of its area as a shallow littoral zone; this is where much of the biological activity takes place. A properly designed and maintained wet detention pond can attain efficiencies of up to 90% solids removal, 40% nitrogen removal, and 65% phosphorus removal.

Dry detention systems, which may be dry when they are not being used, are used primarily for flood control. Dry detention provides little water quality treatment, other than the settling of 20 to 60% of suspended solids. Nutrient removal is generally 20% or less.



Stormwater Best Management Practices:

Golf course stormwater management should include "natural systems engineering" or "soft engineering" approaches that maximize the use of natural systems to treat water.

Ensure that no discharges from pipes go directly to water.

Eliminate or minimize Directly Connected Impervious Area (DCIA).

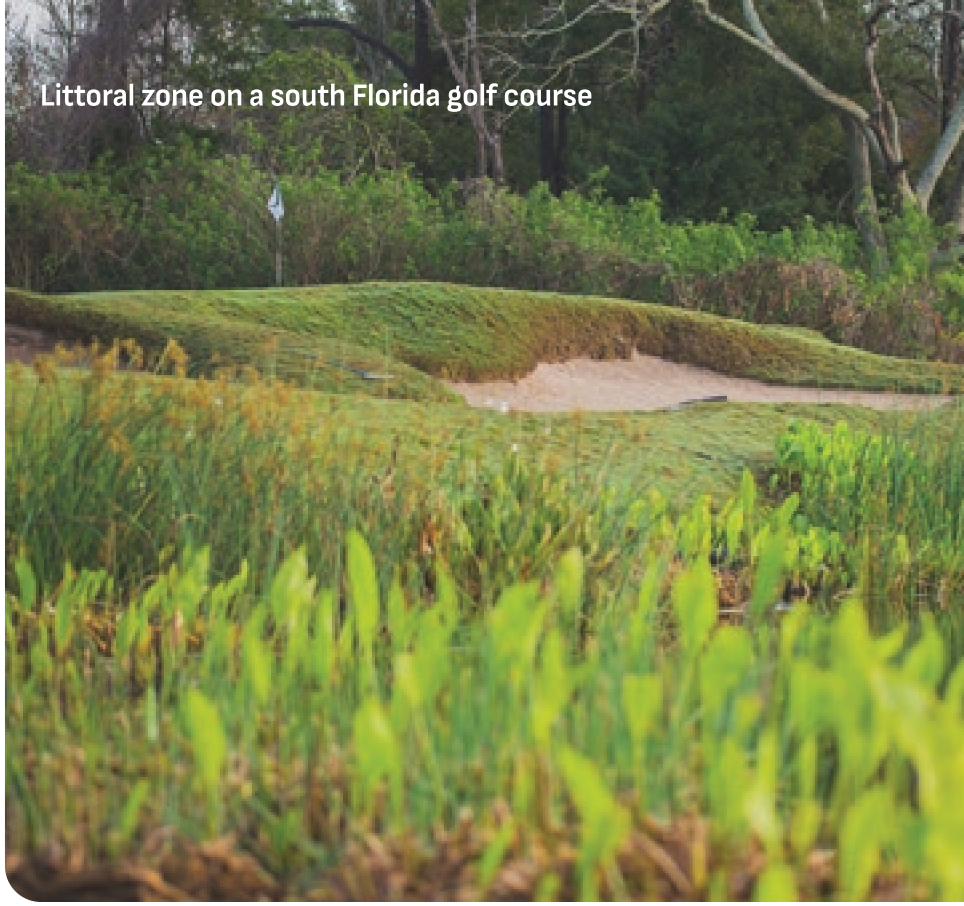
Use a treatment train approach

Institute buffers and special management zones.

Littoral Shelf Planting

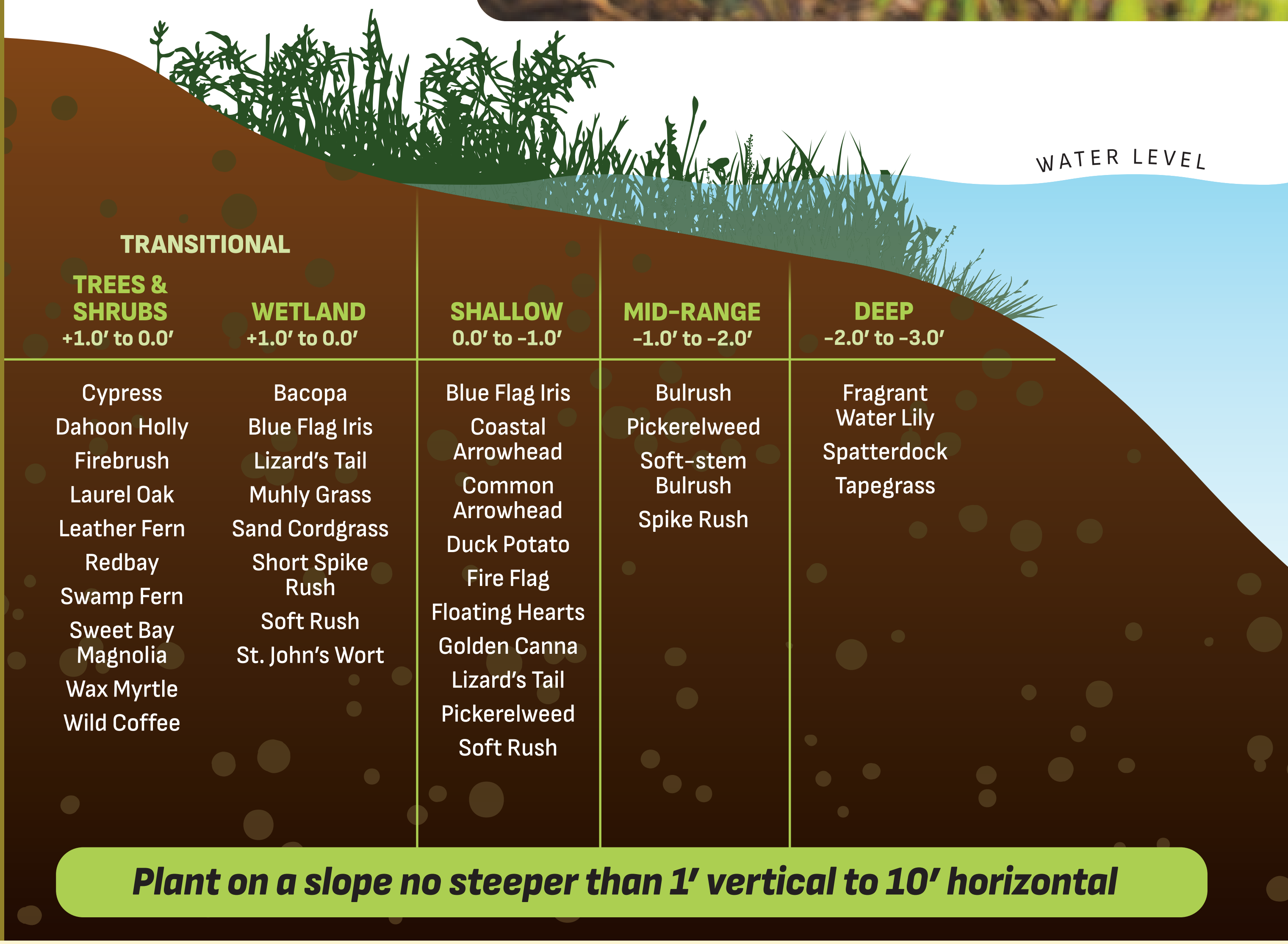
The planting of littoral shelves is critical to the performance of a wet detention system. The mix of species selected must be suited to the design of the shelves and pond, depth and quality of the water, and local climate. An experienced professional should be retained to work with the engineer in designing these areas. The locations of littoral zones must be carefully planned to prevent problems with the playability and maintainability of a water hazard. In general, littoral shelves should be concentrated at a pond's inlets and outlets.

In addition to initial construction, it may be appropriate to incorporate functional littoral zones when a golf course or lake system is redesigned. Littoral zone areas should gradually slope. A minimum slope of 10-foot horizontal to 1-foot vertical is recommended. Planting on slopes less than 6-foot horizontal to 1-foot vertical may not be as successful over the long term. On the other hand, these slopes should not be perfectly graded. Random small dips and ridges of a few inches to a foot or so promote diversity within the plant community and provide a healthier and more productive littoral zone.



Littoral zone on a south Florida golf course

Cross-section of a littoral shelf



Habitat for Aquatic Life

All or most of the out-of-play waterbodies should have shoreline buffers planted with native or well-adapted, noninvasive vegetation to provide food and shelter for wildlife. These buffer areas not only protect water quality but provide very important habitat for many wildlife species. Birds, mammals, frogs, fish, and turtles spend some or all of their life cycles in or around the water. Many species depend on this habitat for breeding, foraging, hunting, fishing, and other essential activities. In addition to serving as habitat, shoreline buffers can also serve as wildlife corridors that connect different ecosystems and allow the movement of species with larger territories. Shoreline buffers should be coordinated with littoral shelf planting to provide as natural a habitat as possible for wildlife, with plenty of emergent vegetation in shallow areas.

Play Areas

Up to 400 rounds of golf per day may be played at many courses at certain times of the year, and some public courses record up to 100,000 rounds of golf played in a year. Therefore, the size and placement of major playing areas should be carefully evaluated to ensure adequate wear patterns. Turfgrass grown in the proper agronomic environment requires less intense maintenance and fewer pesticide applications.

Greens

Greens typically occupy only about 2% of the total course area but account for about 40% of the strokes scored. Golf greens in Florida typically receive heavy use throughout the year. Careful design and very intensive turf management are required to maintain a good putting surface under these conditions. The nature of the game calls for very short mowing, usually daily, which also limits the extent of the root system. As a result, irrigation and fertilization programs should be adjusted to minimize leaching and increase nutrient uptake. This high-stress environment also makes the turf more susceptible to pests.

No procedure or method of greens construction provides an absolute guarantee of success. Success depends on the quality of the materials used, the quality of the installation, and the quality of subsequent management.

Location

Locating a putting surface is almost as much an art as a science. Many elements are important in providing the aesthetic background or challenging hole play that make any round of golf a success. The natural surroundings—such as a body of water, hillside, or depression—the overview of a scenic area, and the strategic use of natural hazards such as trees, in addition to adjacent golf holes, are all incorporated into the location, shape, and size of a green. Environmental and agronomic factors such as surrounding soils or severe slopes, trees, and waterbodies must also be considered, as well as housing developments, highways, and high-population areas.

Greens require full sunlight to maximize photosynthesis and to dry out after heavy precipitation. In addition, frost on shade-covered greens melts more slowly in shade and may increase the potential for cold damage in central and north Florida.

When planning a course, remember that the sun is lower on the horizon during the early spring, late fall and winter months. Trees south, southeast, and southwest of the greens cast longer shadows during these months and may cause problems.

Drainage

Being able to control soil moisture is a key factor in the success or failure of a green. Drainage and runoff from surrounding areas into the desired location of a green can be key to regulating internal water content. The placement of a green downward from a hillside location can create a problem. Surface water runoff from the higher surrounding ground should not flow over the green and instead should be intercepted and directed away from the green.

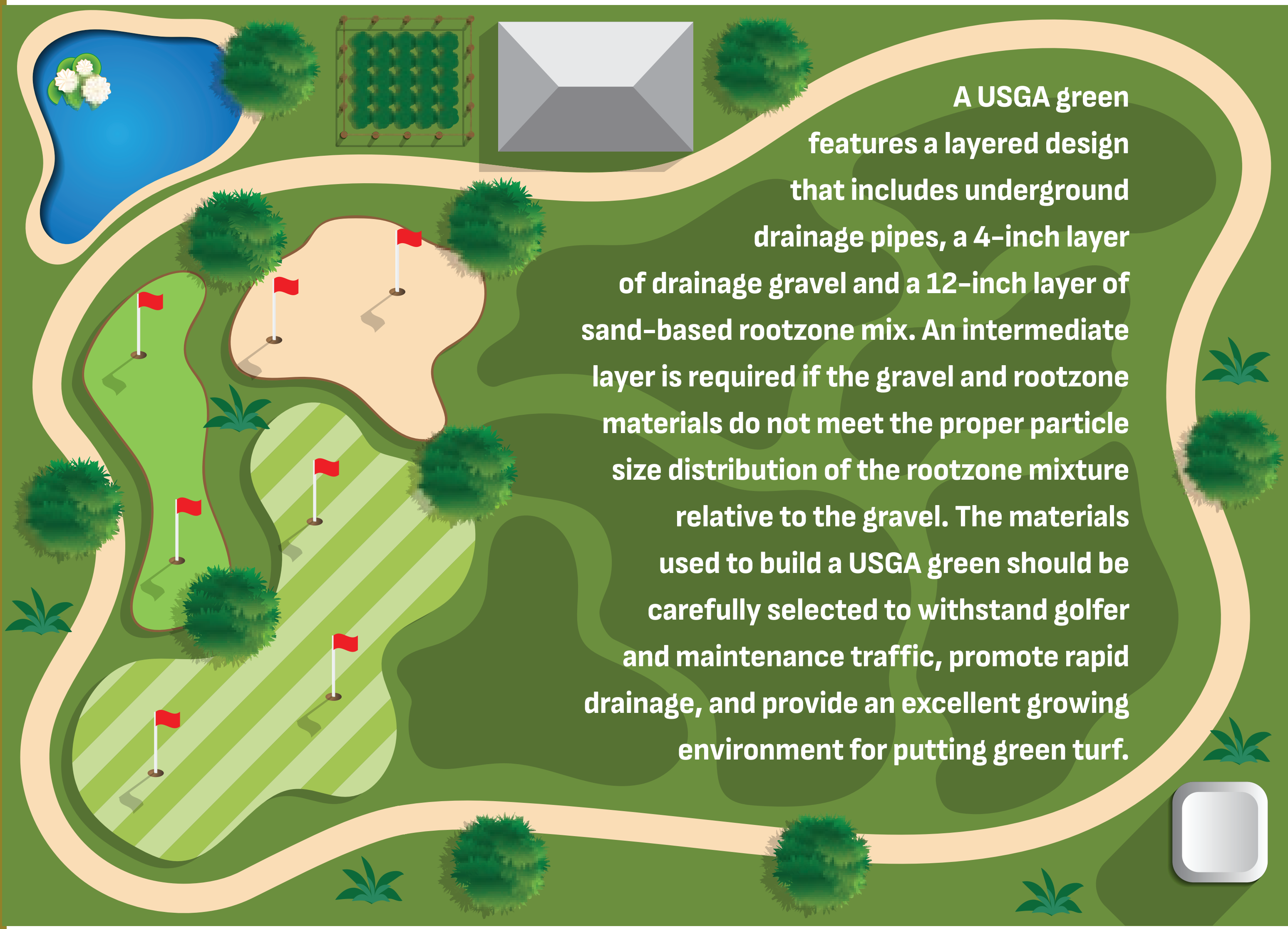
The surface runoff and water from these drainage lines must be directed so that it does not cause environmental harm. This may be achieved by creating swales and buffer strips using nearby fairways, rough, and out-of-play areas before allowing the water to enter a water hazard or other part of the stormwater system. **This water should never be allowed to discharge directly into a wetland, stream, or other waterbody not meant to treat stormwater.**

Size

A golf green should be large enough to allow for the adequate selection of a hole location but not so large as to become a financial and/or agronomic maintenance burden. Smaller-sized greens readily show the effects of concentrated traffic, while larger ones may have increased maintenance costs. In general, golf greens range from 3,000 to more than 7,500 square feet in size.

Profile of the Green

There are many construction techniques for greens. Again, a qualified golf course architect working with experienced agronomic professionals should determine the appropriate technique and methods for greens construction. No matter what method is used, developing a consistent profile throughout all the greens is important for a golf course's maintenance practices.



The USGA construction recommendations create a "perched" water table that does not move (or percolate) readily from the finer to coarser layer until the soil water content of the finer layer is at or near saturation. Other construction methods used throughout Florida provide acceptable conditions when built properly.

A BMP plan must address both surficial and internal greens drainage. This water should not be directly discharged into wetlands, streams, or other waterbodies not meant to treat stormwater. As discussed earlier, water should be allowed to filter through swales or buffer strips before entering waterbodies.

Irrigation Installation

The putting surfaces of the greens are the most intensely managed areas on a golf course. Because the most frequent mowing, cultivation, fertilization, and pest management practices are performed on greens, the irrigation system should be designed and installed so that the putting surfaces, and their slopes and surrounds, can be watered independently. With standard single-head coverage around the greens, either the putting surface or its surrounding area is often watered unnecessarily, wasting water and promoting poor root structure and fungal growth. The use of part-circle heads are a way to conserve water.

Soil Fumigation (Optional)

Fumigation controls most undesirable weeds, insects, and nematodes present in the root-zone mix. Those unfamiliar with soil fumigants should contract with a custom applicator in circumstances that may warrant the use of fumigants.

Planting

To ensure the quality of the grass on greens, use only certified grasses from a licensed grower. To ensure the survival of newly planted sprigs, it is vitally important to provide irrigation throughout the entire planting operation. Greens are typically planted using sprigs but can be sodded. When sodding, ensure that the sod is grown on a similar root-zone profile to avoid the layering of soil types.

Best Management Practices for Designing and Managing Greens:

The shaping of contours with and surrounding a green and the placement of bunkers should allow proper drainage and provide for the treatment and absorption of runoff from the green.

Play should be spread around the green to prevent concentrated traffic in any one area. This helps to prevent turf stress and the additional use of fertilizers or pesticides.

Adequate space should be provided around the greens, so that maintenance practices can be efficiently carried out.

Collars

Collars have similar traffic and receive similar maintenance procedures as greens. Experience shows that constructing collars with root-zone characteristics similar to those of the greens minimizes problems encountered in maintaining these areas.

Tees

Like greens, teeing grounds receive heavy wear and tear from traffic and mowing patterns. Similarly, elements such as shade, soil, and surface drainage require careful design and placement to ensure quality turf and ease of maintenance.

Florida BMPs for teeing grounds ensure, at a minimum, well-drained soils graded to provide 1% fall to the rear or side of the tee as conditions warrant. Irrigation in these areas can be more site specific, and many courses have slopes and surrounds planted with native and/or ornamental grasses to reduce maintenance and long-term water requirements. Zoysiagrass has improved shade tolerance compared with bermudagrass and can perform better in shaded environments.

Part-circle irrigation heads conserve water

Plant Selection: Sunlight, Shade, and Air Circulation

The fundamental principle for the environmentally sound management of landscapes is Right Plant, Right Place. The ideal plant from an environmental standpoint is the one that nature and evolution placed there.

These plants have adapted specifically to the soil, microclimate, rainfall and light patterns, insects and other pests, and endemic nutrient levels over time. As humans, we often have a need to change the natural landscape for living, working, and recreation. When we do so, our challenge becomes to use the most suitable plant materials for the new conditions that meet our design needs. The goal of the BMP is to maintain as close to a natural ecosystem as practical, while meeting the needs of a golf course.

Bermudagrass and seashore paspalum are both grasses that require full or nearly full sunlight. This is especially true on greens, where the grass is cut very short and the leaf area available for photosynthesis is reduced.

Under shaded conditions, turfgrasses have elongated leaf blades and stems as they attempt to obtain sunlight by outgrowing their neighbors. This reduces their overall health and vigor. Coverage is also reduced, and the bare ground that results is conducive to weed growth. It is generally not advisable to grow turfgrass in heavy shade. This is not usually a problem on the playing surfaces of a golf course but may be encountered in nonplay areas. Other ground covers or mulch may be used in these sites. For areas receiving moderate amounts of shade, however, certain species and cultivars are able to maintain suitable growth. Specific management practices discussed in the chapter on Cultural Practices can also encourage better turfgrass health under shaded conditions. Zoysiagrasses and, in some places, St. Augustinegrass, are good choices for partially shaded areas, although they also perform well in full sunlight.

Adequate air circulation is also important. A design in which "dead spots" are created, especially if also partially shaded, can lead to moisture problems and increased fungal or disease pressure. In these conditions, BMPs for tree pruning, understory removal, and irrigation management must be constantly reviewed.

Bunkers

A good BMP-designed golf course must focus significant attention on bunker design and construction. Many questions must be addressed to build bunkers and bunker complexes that are successful over the long term.

Like greens, bunkers may or may not require subsurface drainage. When required, 4-inch perforated drain lines are typically installed in 8-inch-by-6-inch trenches and filled with appropriate gradation stone. A qualified golf architect determines patterns and placement to ensure that the drainage system is effective.

Bunker sand gradation and color are important considerations in the design process and should be carefully reviewed. Geotextile products have been used on steep slope areas to minimize sand erosion, and as separation blankets between subsurface conditions and bunker sand to avoid contamination.

A solid BMP plan addresses maintenance raking practices, entry/exit points for golfers and maintenance equipment, and any site-specific irrigation requirements that may be needed to prevent wind erosion under severe conditions. New bunker materials are being researched, such as recycled materials and other durable products.

Soil Amendments

Traditionally, USGA putting greens have been built using mixtures of sand and peat. Sand is used in relatively high percentages to enhance percolation rates, but high percolation rates can lead to the leaching of applied nutrients and contamination of subsurface water supplies. In addition, sands typically retain relatively small amounts of available water; thus they have low water use efficiency (WUE).

WUE is defined as the quantity of dry matter produced per unit of water applied. The addition of clays, silt, or organic matter increases cation exchange capacity (CEC) and helps to retain nutrients, but their addition may reduce the percolation rate and lead to long-term drainage problems.

Numerous other amendments have been proposed for use in putting green construction. These include clinoptilolite zeolites, polyacrylamides (PAMs), diatomaceous earths, calcined clays, porous ceramics, and iron humates. Field tests suggest that that the rankings for some of these amendments are as follows relative to their influence on soil-available water:
iron humate > diatomaceous earths > calcined clays > peat > zeolites.

Research suggests that amendments with moderate levels of CEC and moderate levels of moisture retention (calcined clays and porous ceramics) produced the highest WUE. Amendments with a very high CEC but low moisture retention (zeolites) and those with a very low CEC but high moisture retention (diatomaceous earths) produced lower WUE. All amendments, however, produced higher WUE levels than sand or sand-peat mixtures.

Iron humate has been shown to induce very high levels of WUE and significantly longer days to wilting when water is withheld compared to other soil amendments listed above. An additional benefit to incorporating iron humate (2.5% V:V basis) in the root-zone mix for a USGA sand putting green is that phosphorus leaching is almost completely eliminated. No detectable levels of P were obtained in the leachate collected from a simulated USGA root-zone profile when iron humate was added as an amendment.

Non-play Areas

As discussed earlier, one of the first steps in planning a golf course is to assess the site's general environment and ecology. Map any environmentally sensitive areas such as sinkholes, wetlands, or flood-prone areas, and identify federal and state endangered or threatened species, and state species of special concern. Whenever possible, habitats consisting of wetlands or other sensitive areas for wildlife should be preserved. Many difficulties associated with any development can be avoided by recognizing these issues in the beginning and managing them appropriately.

During the preconstruction process and after a course has been established, the amount of irrigated and maintained turfgrass should be looked at carefully to determine if it is functional. Many older golf courses and some new ones have more irrigated and maintained acres than are necessary. With the help of a golf course architect, golf professional, golf course superintendent, and other key personnel, the amount of functional turfgrass can be evaluated. Areas that are not in play or are not critical to the design of the course may have turfgrass removed and replanted with native plant material that requires little to no maintenance after establishment. In fact, trees and shrubs may require more water than turfgrass during establishment, but once they are established, they may need very little maintenance if properly chosen, installed, and located.

It is considered a BMP for 50 to 70% of the nonplay areas to remain in natural cover. As much natural vegetation as possible should be retained and enhanced through the supplemental planting of native trees, shrubs, and herbaceous vegetation to provide wildlife habitat in nonplay areas, and along watercourses to support fish and other water-dependent species. By leaving dead trees (snags) where they do not pose a hazard, a well-developed understory (brush and young trees), and native grasses, the amount of work needed to prepare a course is reduced, while habitat for wildlife survival is maintained or improved.

What the Florida Legislature has defined as "Florida-Friendly Landscaping" comprises nine principles. All are consistent with a well-designed and operated golf course, although the nonplay areas obviously offer the most opportunities for mulching and attracting wildlife.

NINE PRINCIPLES OF FLORIDA-FRIENDLY LANDSCAPING

1. Right Plant, Right Place
2. Water Efficiently
3. Fertilize Appropriately
4. Mulch
5. Attract Wildlife
6. Manage Pests Responsibly
7. Recycle
8. Reduce Stormwater Runoff
9. Protect the Waterfront

Maintenance of Non-Play Areas

"Non-play" areas are not within the general area of play, such as the teeing area, penalty areas, bunkers, and putting green. Yet, non-play areas may be identified as part of the golf course property and maintenance responsibility. Non-play areas serve a more aesthetic purpose such as color beds, ornamental foundation plantings, grouped palm and tree plantings, clubhouse entry, and driveway accents. Non-play areas typically contain turfgrass, annual/perennial color beds, ornamental shrubs, palms, trees, and containerized plants that may require supplemental watering. Irrigation, fertilization, and pest control management activities are either routinely performed by in-house golf course staff or outside contracted services.

It is also the Superintendent's responsibility to understand and adhere to the state and local compliance requirements regarding non-play areas. FDEP strongly recommends the certification of at least one in-house team leader or supervisor to be trained and certified in the Green Industry Best Management Practices (GI-BMP). This training provides important information regarding the recommended or mandated BMPs as part of a local landscape fertilizer code, BMAP, or TMDL implementation plan.

As such, non-play turfgrass and ornamental landscape plant care must use recommended GI-BMPs associated with fertilizing, IPM, irrigation, mowing, mulching, and pruning. These BMPs include cultural practices, for example, the proper handling of turfgrass clippings and yard debris.

In summary, who needs to be certified to avoid penalties? This is a commonly asked question by golf course superintendents. Commercially contracted services for the application of fertilizer within non-play and associated common areas (parking lots) are required to obtain both the GI-BMP completion of training certificate and the FDACS Urban Commercial Fertilizer Certificate before operating. Per FDEP, selected course staff are recommended to receive the GI-BMP training and certificate of completion from UF/IFAS Extension. See Appendix for a step-by-step regulatory compliance decision infographic.

Wildlife Habitat

It is important to preserve natural surroundings when developing a course. It is easier to manage wildlife if existing natural conditions and wildlife habitats are preserved. When areas that have been disturbed are replanted, native trees, shrubs, and grasses should be used when possible. Avoid exotic species, particularly invasive plants, or plants that are not well adapted to the local environment. The primary wildlife will probably be small mammals and birds.

Natural cover around a course also serves as a buffer to reduce urban traffic noise and visual distractions, and filters possible pesticides and nutrients from runoff entering streams or ponds. A golf course design that incorporates areas of natural cover may be less expensive to construct and maintain.

Cover provides and promotes important areas in a golf course that are significant for all species. It is a natural part of wildlife habitat and encompasses almost all the factors that wildlife need for their welfare, including shelter from weather; places to nest, loaf, and feed; and concealment from predators or prey. Providing cover for wildlife is easy to accomplish by keeping natural 50 to 70% of the non-play course area. Brush piles, a stand of trees, snags, riparian areas, and roughs are considered cover for some species.

Birds

Providing adequate food all year is important for establishing a healthy bird population. Appropriate trees, plants, and grass species can be planted, or preserved if they already exist. Foods can include various types of wild fruits, forbs, herbs, and seeds, and a large variety of insects.

Many bird species thrive on insects, and it is important to maintain insect populations. Fortunately, insects flourish in most areas. One of the greatest threats to insects is the application of broad-spectrum chemicals applied to a course to control specific pests. With the proper use of IPM on a wildlife-friendly course, insect populations should be adequate.

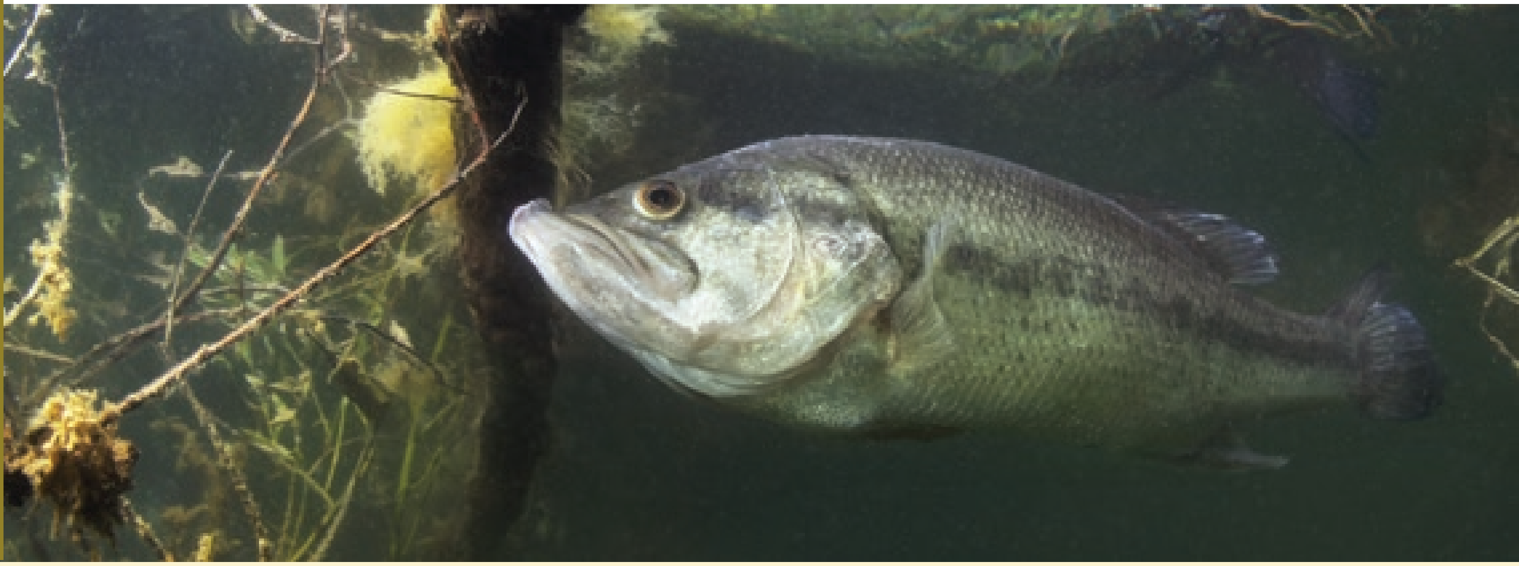
Nesting areas are important for maintaining healthy bird populations. Whenever possible, leave dead tree snags as long as they do not pose a hazard. Snags provide nesting cavities for many birds and are food sources for woodpeckers and other species that eat insects in the bark. Birdhouses and nesting boxes can be placed around a course near areas of appropriate cover and food supply. It is often possible to get members and their families interested in building and maintaining these nesting boxes at little or no cost to the golf course.

Animals

Most four-footed wildlife consists of small mammals, such as squirrels, rabbits, and opossums. These animals need concealment from predators and adequate food supplies. Small brush piles can provide cover. Food sources include nuts, berries, and grubs. Corridors should be provided when possible to allow animals to move from place to place without being exposed to predators. Therefore, perimeter fences or walls should not be installed so that wide-ranging small and large animals can traverse the site. If walls are built, they should provide a minimum clearance of 1 foot between the ground and the lowest portion of a fence or wall, except where it is necessary to exclude feral animals. The animals also need burrows and nesting/bedding places. Whenever possible, these areas should not be disturbed, especially while young are present.

Aquatic Life

A good source of uncontaminated water is important to terrestrial species and is imperative for aquatic species. Proper pesticide management and the use of water quality buffers and riparian zones are important factors in keeping the water clean. Riparian areas (streamside vegetation), which play a vital role in the terrestrial/aquatic communities, should be protected. These areas are transition zones between water and land. They provide cover and food, and help maintain a healthy water source. Vegetation along the water's edge can stabilize surrounding soils, help in flood control, and filter sediments and chemicals that are being transferred into the system.



Assess the condition of water hazards and ponds by measuring temperature, dissolved oxygen, pH, conductivity, water hardness, and phosphorus and nitrogen concentrations. In addition, samples of plankton, algae, rooted aquatic plants, and terrestrial plants should be taken and identified. Observations of fish, wildlife, and general pond condition should be recorded regularly to track overall health of the system over time.

The overgrowth of aquatic plants or algae is aesthetically unappealing and may lower dissolved oxygen levels in the water. As with all plants, aquatic vegetation thrives on nitrogen and phosphorus. Use natural riparian buffers or unfertilized turfgrass buffers to minimize the entry of excessive nutrients.

As with any ecosystem, ponds and lakes require a complete food chain from bacteria to fish. These organisms cycle nutrients, control pests, and enhance the aesthetic value of water. Fish can be added to control vegetation and mosquito populations, help to balance the food chain, or fulfill other purposes.

Forested Buffers

Protecting wildlife habitat on golf courses is especially important in urban environments where highly fragmented, forested areas often provide the best, and sometimes the only, habitat for many wildlife species.

Forested buffers along golf course streams and wetland areas can provide large areas of key habitat and sanctuaries for birds and other wildlife, while protecting water quality. When riparian buffers connect isolated blocks of habitat, they also serve as important travel corridors for species that may not cross large, open areas.

Forest vegetation protects aquatic habitat in several important ways. Trees and shrubs along streams provide temperature moderation through shade, which lowers water temperature in summer and increases it in winter. Shade can also reduce the growth of filamentous green algae and promote the production of diatoms, which are an important food source for aquatic macroinvertebrates. Fallen and submerged logs and the root systems of woody streamside vegetation provide cover for fish and invertebrates, while leaves, branches, limbs, fruits, and other types of forest detritus form the base of the aquatic food chain in headwater or low-order streams.

While many Florida golf courses may not be able to devote such space throughout the golf course, maintaining a 50- to 100-foot forested buffer along watercourses can provide suitable habitat for many wildlife species, including wood ducks, herons, kingfishers, songbirds, foxes, deer, raccoons, turtles, snakes, and salamanders. Smaller buffers may still protect water quality but provide fewer wildlife benefits.

Well-designed forested buffers should contain a mixture of fast- and slow-growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife. Proper design and the selection of appropriate vegetation ensures that these buffer areas do the following:

- Trap and remove upland sources of sediments, nutrients, and chemicals
- Protect fish and wildlife by supplying food, cover, and shade
- Maintain a healthy riparian ecosystem and stable stream channel

Wildlife Management Best Management Practices:

Identify the different types of habitat specific to the site.

Identify federal and state threatened and endangered species, and state species of special concern inhabiting the site.

Preserve critical habitat.

Identify and preserve regional wildlife corridors.

Design and locate cart paths to minimize environmental impacts. Construct the paths of permeable materials, if possible.

Avoid or minimize crossings of wildlife corridors. Design unavoidable crossings to accommodate wildlife movement.

Remove nuisance and exotic/invasive plants and replace them with native species that are adapted to a particular site.

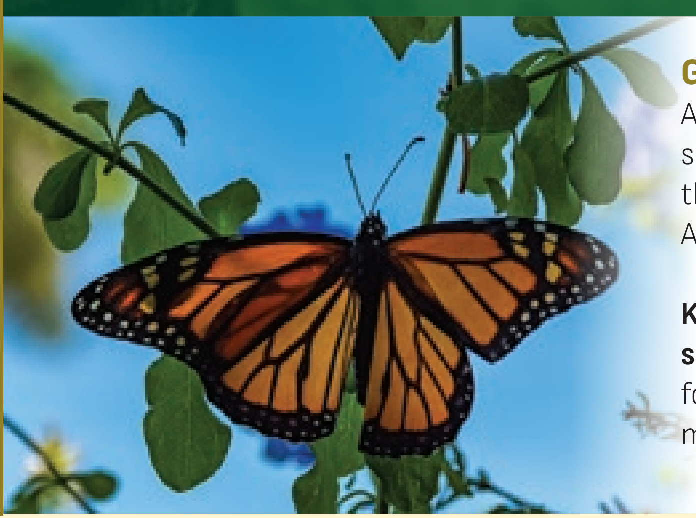
Perimeter fences or walls, if required, should provide a minimum clearance of 1 foot between the ground and the lowest portion of a fence or wall, except in areas where feral animals need to be excluded.

Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.

Construct and place birdhouses, bat houses, and nesting sites in out-of-play areas.

Plant butterfly gardens around the clubhouse and out-of-play areas.

Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.



Gardens

Aesthetic gardens, window boxes, and container gardens should contain a variety of plants of different heights that provide nectar for hummingbirds and butterflies. Again, ***Right Plant, Right Place*** is the key to success.

Know the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for pruning and debris removal and can minimize maintenance costs. Adding proper soil amendments in garden areas can improve the soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost. Amendments are not usually recommended for trees.

The use of organic mulches in gardens and aesthetic areas increases the moisture-holding capacity of plantings and prevents weed growth when applied in sufficient depth. Organic amendments are decomposed by soil microorganisms and add to soil tilth. **Keep mulch 2 to 3 inches away from plants, to prevent fungal growth from excess dampness**.

Excess mulch or compacted mulch may be detrimental, causing water to shed away from the root zone and encouraging overwatering. **Compaction or excessive mulch buildup should be avoided**, especially when annual re-mulching is performed.

Aesthetic Turf

Turfgrass may be used for purely aesthetic reasons to provide a pleasing view around clubhouses, entries, and other areas. However, while it is perfectly acceptable to use turf in this fashion, remember that turfgrasses reduce wildlife benefits and can require more maintenance when compared to natural area plantings. Use turf as a landscape element where needed, but do not think of it as a default filler material. Garden plants, shrubbery, ground covers, or native plants may provide just as pleasing a view and also provide useful food, cover, or other environmental benefits to wildlife; they may also require less maintenance. Around clubhouses and food outlets, be wary of installing plants that promote vermin.

The addition of proper soil amendments can improve soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost.

Aesthetic turf should be maintained in accordance with the practices described in the Florida Green Industries' manual, *Best Management Practices for Protection of Water Resources in Florida* (available: http://fyn.ifas.ufl.edu/professionals/GI-BMP_publications.htm).

Plant Selection

As discussed earlier, the fundamental guide for the environmentally sound management of landscapes is ***Right Plant, Right Place***. The ideal plant from an environmental standpoint is the one that nature placed there. It has adapted specifically to the soil, microclimate, rainfall and light patterns, insects and other pests, and endemic nutrient levels over many years. Where these factors have changed, the challenge is find other suitable plants. A BMP goal is to maintain as close to a natural ecosystem as practical, while meeting the needs of the golf course.

Maintenance Facilities

Maintenance facilities include areas for equipment fueling, washing, storage and repair; the superintendent's office; and areas for storing, mixing, and loading fertilizers and pesticides. Building codes may be more stringent for some of these facilities, so check with local building authorities.

Pesticide Facility

The pesticide facility is one of the most important buildings on a golf course. Few other functional spaces offer the potential for such expensive liability, either for chemical contamination of the environment or for exposure to golf course workers. Proper thought and care in the design, construction, and operation of this facility can greatly reduce liability exposure, while failure to do so can greatly increase the likelihood of costly governmental or civil liability.

Pesticide Storage

Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment. Store pesticides in a roofed concrete or metal structure with a lockable door. Locate this building at least 50 feet from other structures (to allow fire department access and space for a water curtain to protect adjacent structures). Keep pesticides in a separate facility, or at least in a locked area separate from areas used to store other materials, especially fertilizers, feed, and seed. Do not store pesticides near burning materials, near hot work (welding, grinding), or in shop areas. Do not allow smoking in pesticide storage areas.

An eyewash station and emergency shower should be provided and routinely maintained. Provide a space for a written pesticide inventory and the SDS (Safety Data Sheet) files for the chemicals used in the operation on site. Do not store this information in the pesticide storage room itself, although copies may be kept there for convenience.

Be sure that an adequate supply of personal protective equipment (PPE) and other appropriate emergency response equipment is stored where it is easily accessible in an emergency. Do not store emergency supplies only inside the pesticide storage area, since that may be inaccessible during an emergency. **PPE is designed for mixing and application activities, and may not provide adequate protection in an emergency.** Check labels and the SDS sheets for the safety equipment requirements.

Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides to prevent cross-contamination and minimize the potential for misapplication. Always place dry materials above liquids, never liquids above dry materials.

Use shelving made of plastic or reinforced metal. Keep metal shelving painted (unless stainless steel) to avoid corrosion. Never use wood shelving, because it may absorb spilled pesticide materials.

Construct floors of seamless metal or concrete sealed with a chemical-resistant paint. For concrete, use a water to cement ratio no higher than 0.45:1 by weight, and leave a rough finish to provide adhesion for the sealant. Equip the floor with a continuous curb to retain spilled materials. While a properly sealed sump may be included to help recover spilled materials, do not include a drain. Provide sloped ramps at the entrance to allow handcarts to safely move material in and out of the storage area.

When designing the facility, keep in mind that temperature extremes during storage may reduce safety and affect pesticide efficacy. Provide appropriate exhaust ventilation and an emergency wash area. The emergency wash area should be located outside the storage building. Local fire and electrical codes may require explosion-proof lighting and fans. The light/fan switch should be located outside the building so that both are on before people enter and until they have left the building.

BMPs for pesticide storage often address the ideal situation of newly constructed, permanent facilities. However, the user is encouraged to apply these principles and ideas to existing facilities, and to portable or temporary facilities that may be used on leased land where permanent structures are not practical. Plans and specifications for pesticide storage buildings are available from several sources, including the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA–NRCS), the Midwest Plan Service, and the University of Florida's Institute of Food and Agricultural Sciences (UF–IFAS) Pesticide Information Office. These publications also contain recommended management practices for pesticide storage facilities. The References section of this manual contains information on how to obtain these materials.

Pesticide Storage Best Management Practices:

Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment.

Store pesticides in a roofed concrete or metal structure with a lockable door.

Construct floors of seamless metal or concrete sealed with a chemical-resistant paint.

Equip the floor with a continuous curb to retain spilled materials.

Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.

Provide storage for PPE where it is easily accessible in the event of an emergency, but not in the pesticide storage area.

Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides.

Use shelving made of plastic or reinforced metal. Keep metal shelving painted.

Provide appropriate exhaust ventilation and an emergency wash area.

Always place dry materials above liquids, never liquids above dry materials.

Never place liquids above eye level.

Locating Mixing and Loading Activities

Use extreme caution when handling concentrated chemicals. Spills could result in an expensive hazardous waste cleanup. It is important to understand how mixing and loading operations can pollute vulnerable ground water and surface water supplies if conducted improperly and at the wrong site. Locate operations well away from ground water wells and areas where runoff may carry spilled pesticides into surface waterbodies. If these areas cannot be avoided, protect wells by properly casing and capping them, and use berms to keep spills out of surface waters. Areas around public water supply wells should receive special consideration and may be designated as wellhead protection areas. Before mixing or loading pesticides in such areas, consult with state and local government officials to determine if special restrictions apply.

IMPORTANT: For your own safety, always use all PPEs required by the label.

Mixing and Loading Best Management Practices:

Locate operations away from ground water wells and areas where runoff may carry spilled pesticides into surface waterbodies.

Do not build new facilities on potentially contaminated sites.

An open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides.

In constructing a concrete mixing and loading pad, it is critical that the concrete have a water to cement ratio no higher than 0.45:1 by weight.

The sump should be small and easily accessible for cleaning.

Ensure that workers always use all PPEs required by the pesticide label.

- Assess the level of training and supervision required by staff.
- Any material that collects on the pad must be applied as a pesticide or disposed of as a (potentially hazardous) waste.
- Clean up spills immediately!
- Appropriately dispose of materials used to clean up spills (hazmat).

Chemical Mixing Center Design

To minimize the risk of pesticides accumulating in the environment from repetitive spills, most golf course developers construct a permanent mixing and loading facility with an impermeable surface (such as sealed concrete) so that spills can be collected and managed.

A permanent mixing and loading facility, or chemical mixing center (CMC), is designed to provide a place where spill-prone activities can be performed over an impermeable surface that can be easily cleaned and allows the recovery of spilled materials. Where feasible, the facility should be close to the pesticide storage building to reduce the potential for accidents and spills when transferring pesticides to the mixing site. Do not build new facilities on potentially contaminated sites, since subsequent efforts to clean up previous contamination may mean relocating the CMC.

In its most basic form, a CMC consists of a concrete pad treated with a pesticide-resistant sealant and sloped to a liquid-tight sump where all of the spilled liquids can be recovered. When considering a CMC, it is important to assess the level of training and supervision required by the staff using the center, so

that it is operated safely and responsibly. Even the best-designed facility cannot prevent environmental contamination if it is not properly managed.

It is crucial that a CMC facility be properly designed and constructed. Mistakes can be costly and can result in unintended environmental contamination. Several publications, listed in the References section, are available to explain design, construction, and operational guidelines for permanent mixing and loading facilities. These publications should be consulted before any facility is designed.

It is very important that wherever feasible, a CMC should be located away from wells or surface waterbodies and above floodplains. The first principle of CMC management is that any material that collects on the pad must be applied as a pesticide or disposed of as a (potentially hazardous) waste. Because any water, including rain, that collects on the pad must be used as a pesticide or disposed of as a (potentially hazardous) waste, an open building must have a roof with a substantial overhang (minimum 30º from vertical, 45º recommended) on all sides to protect against windblown rainfall.

In constructing a concrete mixing and loading pad, it is critical that the concrete have a water—cement ratio no higher than 0.45:1 by weight. This is needed to minimize cracking and to ensure that the concrete does not fail in tension near the sealant—concrete interface. Superplasticizers and/or fly ash may be added to increase the workability of the mix, but additional water must not be added. The concrete should receive a light broom finish to provide adhesion for the sealant. The 1995 Midwest Plan Service publication, *Designing Facilities for Pesticide and Fertilizer Containment*, listed in the References section, contains full concrete specifications.

Materials other than concrete, such as steel or durable synthetics, may also be used in some cases. These materials are also used for portable CMCs where a permanent facility is not practicable.

The CMC sump should be small and easily accessible for cleaning. There must be a way to pump liquid in the sump to a sprayer or to storage tanks. Immediate application in accordance with the label instructions is usually the preferred method of handling both spills and rinsate. If rinsate storage tanks are used, there should be at least one tank for each group of compatible pesticide types. This allows rinsate to be saved and used as makeup water the next time that type of material is applied.

Fertilizer Storage and Handling

The proper storage of fertilizer is an important BMP at a golf course. Take care when storing fertilizer to prevent the contamination of nearby ground water and surface water. Fertilizer bags are often damaged in handling, sometimes even before they reach the golf course. Any spillage exposed to rain threatens nearby ground water or surface water. In addition, fertilizers are often oxidizers and may pose a serious fire threat to a maintenance area, especially where fuels and other hydrocarbons are present.

Fertilizer Storage and Handling Best Management Practices:

Always store nitrogen-based fertilizers separately from solvents, fuels, and pesticides, since many fertilizers are oxidants and can accelerate a fire. Ideally, fertilizer should be stored in a concrete building with a metal or other type of flame-resistant roof.

Always store fertilizer in an area that is protected from rainfall. The storage of dry bulk materials on a concrete or asphalt pad may be acceptable if the pad is adequately protected from rainfall and from water flowing across the pad. Rule 62-762, F.A.C., addresses the secondary containment of stationary liquid fertilizer tanks larger than 550 gallons. Even where not required, secondary containment is a sound practice.

Sweep up any spilled fertilizer immediately.

Equipment Wash Areas

The first rule of equipment washing is not to wash any equipment unnecessarily. Clean equipment over an impervious area and keep it swept clean to prevent rain from carrying pollutants off the pad. **Grass-covered equipment should be brushed or blown with compressed air before being washed**. Dry material is much easier to handle and store or dispose of than wet clippings. It is best to wash equipment with a bucket of water and a rag, using only a minimal amount of water to

rinse the machine. Spring-operated shutoff nozzles should be used. Freely running hoses waste vast amounts of water, and water can harm the hydraulic seals on many machines.


Recycling washdown system

While there are no state requirements for a closed recycling system for washwater, the use of a well-designed system may be considered a BMP. Some local governments require such a system. The FDEP publication, *Guide to Best Management Practices* for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment Wash Facilities, provides more information on the design and operation of these facilities and the BMPs that may help you avoid the need for a permit (https://bit.ly/3eRXw3Y). A checklist for these practices is also available from FDEP (https://bit.ly/3zyPgxP).

Equipment Wash Area Best Management Practices:

Do not wash equipment unnecessarily.

Clean equipment over an impervious area, and keep it swept clean.

Brush or blow equipment with compressed air before, or instead of, washing.

Use spring-operated shutoff nozzles.

Use a closed-loop recycling system for washwater and follow the FDEP BMPs.

Recycle system filters and sludge should be treated and disposed of as hazardous waste.

Be cautious in operating closed loop equipment where maintenance activities are involved, because the filters can concentrate traces of oils and metals that are washed off the engines and worn moving parts. In some cases, the concentrations of these substances can become high enough that the filters must be treated and disposed of as hazardous waste. Ask the recycling system manufacturer or sales representative, or your FDEP district office, for information about filter disposal. The contractor who handles oil filters, waste oil, and solvents can probably handle these filters, too.

Wash areas may be regulated as industrial waste facilities. Washwater systems with an overflow pipe must connect the overflow either to a sanitary sewer or to a specially designed and permitted treatment system such as a separate drainfield, or contain the discharge and have it hauled and disposed of by a licensed contractor. The overflow cannot discharge to the ground, a storm drain, or a surface waterbody. Normally, no Industrial Wastewater Permit is required if it can be shown that the facility is not discharging to the environment. If no permit is needed, the FDEP district sends a letter saying so. Such a letter can save a lot of expense and grief in the future if FDEP or another agency receives a complaint because someone thinks you are operating illegally. Before designing and constructing the wash system, check with the local FDEP district office for specific rules in your area.

Fueling Areas

Design and manage fuel-dispensing areas to prevent soil and water contamination. Place fuel pumps on concrete or asphalt surfaces. Fuel pumps with automatic shutoff mechanisms reduce the potential for overflows and spills during fueling. Do not locate the pumps where a spill or leak would cause fuel to flow onto the ground, or into a storm drain or surface waterbody.

Stationary fuel storage tanks must be in compliance with FDEP storage tank regulations (Rule 62-761, F.A.C.). Call the nearest FDEP district office for information on these requirements. In general, underground tanks with volumes over 110 gallons and above-ground tanks with volumes over 550 gallons must be registered and located within secondary containment systems unless of double-wall construction. Local regulations may be more stringent.

While secondary containment is not usually required for smaller tanks, it is still a good practice. Also, a roof and containment for equipment with diesel engines are a good idea.

Where permitted by local fire codes, secondary containment structures should be roofed to keep out rainfall. Building a containment structure so that it is tall rather than wide helps to minimize rainfall accumulation by reducing the exposed surface area. If the structure is not roofed, water that accumulates must be managed properly. The best option is to remove the water with a portable sump pump, which ensures that the removal of water is actively managed.

If the containment structure has a discharge port (not recommended), make certain that it is closed and locked except when uncontaminated rainwater is to be drained. If a discharge port is used, a spring-loaded valve is the best way to prevent the port from being inadvertently left open. Only clean water may be discharged to a grassy swale or other approved site. **No discharge is permitted to a waterbody.**

The first line of management is to minimize the possibility of a discharge and the need for disposal. For rainfall, if the containment volume is adequate, the evaporation of accumulated rainfall is often sufficient. Critical levels at which discharge is considered should be established for each facility and the levels marked on the containment wall. This prevents the frequent and unnecessary discharge of small volumes.

Equipment Repair Facilities

Many coolants, oils, and solvents are used in the equipment repair shop. These may harm water supplies and wildlife if improperly disposed of. For more information, see the FDEP website on Hazardous Waste Publications: https://floridadep.gov/waste/permitting-compliance-assistance/content/hazardous-waste-publications

Repair Facility Best Management Practices:

Each piece of equipment should have an assigned parking area. This allows oil or other fluid leaks to be easily spotted and attributed to a specific machine so that it can be repaired.

Use solvent-recycling machines or water-based cleaning machines to cut down on the use of flammable and/or toxic solvents.

Use a commercial hazardous waste management service to remove the old solvents and dispose of them properly.

Hazardous Materials Areas

These areas should be clearly marked, have spill containment, and be secure from vandalism. Ensure that all containers are properly labeled and stored. See the FDEP Web site for current information. (available: http://www.dep.state.fl.us/waste/categories/hazardous/pages/publications.htm).

Parking Lots and Traffic Paths

Roadways associated with a golf course should be constructed with no curb and gutter, and vegetated swales should be used to direct water flow away from the roads. Also, no curb and gutter should be used around the clubhouse or other buildings. The pervious paving of parking lots can substantially decrease stormwater runoff from a site. This not only reduces nonpoint source pollution but also may save money by reducing the size and complexity of stormwater treatment facilities.

While some development codes require curb-and-gutter systems, it is strongly suggested that a variance or waiver be sought on the grounds of improved stormwater management and pollutant load reduction.

SECTION 4

IRRIGATION

Various regions in Florida average between 40 and 60 inches of rainfall a year. However, there are significant seasonal variations in rainfall. Therefore, at certain times of the year rainfall is not adequate to sustain turf health and withstand the rigors of golf in Florida's temperate weather and sandy soils.

Although golf courses use natural rainfall as the greater part of their annual water budget, irrigation with the lowest acceptable quality water is an important part of maintenance. To ensure efficient watering, courses require well-designed irrigation systems with precision scheduling based on soil infiltration rates, soil water-holding capacity, plant water use requirements, the depth of the root zone, and the desired level of turfgrass appearance and performance.

Soils contain a reservoir of water for plants. Water enters the plant through its roots, and then moves through the stem up to the leaves and then into the atmosphere through the leaf by a process termed transpiration. Transpiration serves several important functions. Water and nutrients are transported through the transpiration stream. The evaporation of water from the leaf surface results in evaporative cooling, thus moderating canopy temperature. This is important for maintaining plant cell metabolism. Humans have a similar process when perspiration evaporates and cools our bodies.

Evaporation is the flow, or loss, of water from the soil directly to the atmosphere. Collectively, evapotranspiration (ET) is the total water recycled back into the atmosphere by transpiration and evaporation. ET is largely controlled by solar radiation, humidity, wind velocity and temperature, and soil moisture content. Root system depth and cultural practices significantly affect the rate of ET.

Water Sources

Florida's water management districts issue consumptive use permits (CUPs) or water use permits (WUPs) allowing golf courses to pump enough water to meet their annual needs from reclaimed sources, surface water, or aquifers. Permitted quantities vary by geographic location and soil type.

For more specific information on water-related permits, contact your local water management district. A permitting information portal for all five districts is available at http://flwaterpermits.com.

Developers of new golf courses should understand the reliability of water sources before construction to ensure that sufficient supplies are available for turf grow-in and survival. Course owners and developers should consider all alternative sources that are available. These include, and are not limited to, wells, existing surface water, stormwater runoff detention ponds, reclaimed water, brackish water, reverse osmosis, aquifer storage and recovery (ASR), and horizontal wells. The water management districts require that the lowest quality water appropriate to be considered first for water use permits.

Courses located along the state's coastal margins are likely to use reverse osmosis to remove chlorides (salts) from saline water sources, or to use brackish aquifers in conjunction with seashore paspalum turfgrass, which can be irrigated with saline water.

Brackish Water

Brackish water [total dissolved solids (TDS) = 500 to 2000 mg/L (PPM)] is too salty for human consumption but not as salty as seawater. It may come from near-coastal surface waters, often tidally influenced; from shallow ground water affected by saltwater intrusion; or from very deep aquifers overlain by other freshwater aquifers. In using brackish water, special care must be taken with non-play areas, where landscape ornamentals may be damaged by the saline content. The use of brackish water may also require the periodic flushing of salts that built up at or near the surface of the soil.

Best Management Practices for Brackish Water Supplies

Owners of courses using brackish, highly saline irrigation water should consider using varieties of seashore paspalum, which are more salt tolerant than bermudagrasses.

With courses using high-saline or reclaimed water, the soil needs to be flushed regularly with fresh water to move salts out of the root zone and/or pump a higher volume of brackish water to keep salts moving out of the root zone. Ensure this is done before fertilization to prevent the leaching of recently applied nutrients.

In some areas, it may not be desirable to use brackish water for irrigation. This is most likely to be true in an area with a shallow ground water table of fresh water, and brackish water in a deep well. In this case, the brackish water from the deep well may raise the salinity of the shallow aquifer. This issue should be discussed with the water management district.

Reclaimed Water

The use of reclaimed, or recycled, water from large wastewater treatment plants for golf course irrigation is common in many areas of Florida. Water reuse is governed under Rule 62-610, Part III, F.A.C., and administered by FDEP's Domestic Wastewater Program. Some water management districts exempt reclaimed water from limits on watering, but this may vary with supply and demand in different areas.

Golf courses are efficient and effective users of reclaimed water, and the use of reclaimed water for golf course irrigation is encouraged. A guide to using recycled water is available to aid golf course superintendents in planning for and using reclaimed water on their golf courses is available: http://gsrpdf.lib.msu.edu/ticpdf.py?file=/2000s/2008/080301.pdf

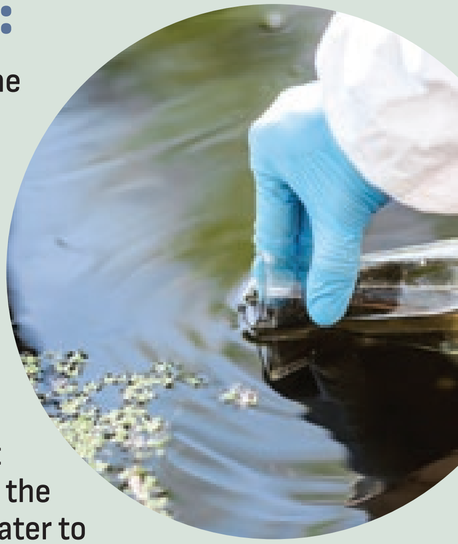
Wastewater treatment plant

FDEP, the water management districts, and several other agencies have signed a Statement of Support for Water Reuse. Key factors in using reclaimed water are as follows:

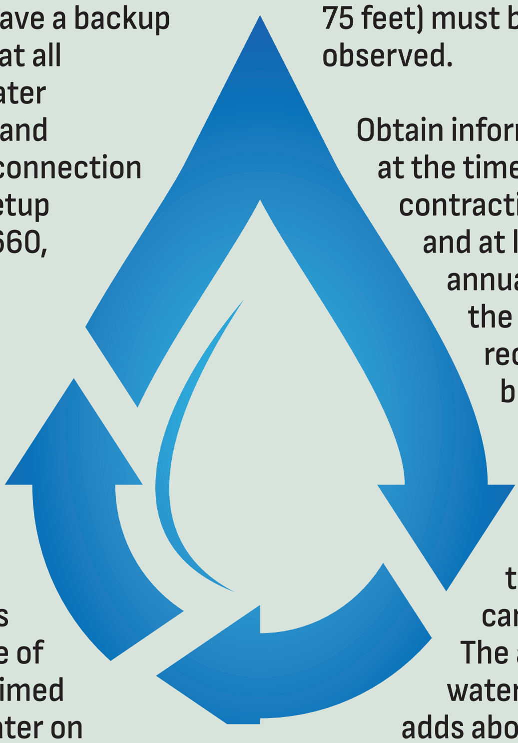
- FDEP and the Florida Water Environment Association (FWEA) have developed a Code of Good Practices for Water Reuse. While this is directed primarily at reclaimed water utilities, golf course managers should discuss the contents with the utility during contract negotiations.
- Obtain information about the quality of the reclaimed water to be delivered at the time of contracting and annually, or more often if available.
- When a golf course enters into a partnership with a reclaimed water utility, the two parties need to work closely together. The utility is in both the water supply and the wastewater disposal business, and the golf course represents an important user. Both parties have needs, constraints, and desires. In the most successful reuse systems, both parties work together to seek mutual satisfaction. Golf courses should be recognized as excellent reclaimed water customers that provide an amenity to the community.

- When negotiating a contract with a utility for reclaimed water, pay attention to provisions related to the amounts of reclaimed water to be delivered, and to the timing of that delivery. Avoid contract provisions that force you to overirrigate, especially during wet-weather periods. Many wastewater treatment plants have to get rid of their water, even if a course does not need it. This often occurs during rainy periods, when courses need it least and treatment plants need to get rid of excess water the most. This can lead to very soggy conditions that can damage a course and result in runoff that increases nonpoint source pollution. If a course must accept a certain quantity of water but may not have an immediate use for it, it may be possible to create storage ponds or to irrigate no-play zones to dispose of the excess water. However, one must be aware of the potentially harmful effects of irrigation on dry upland natural areas.
- A golf course using reclaimed water must identify any nearby potable wells that could be affected by reclaimed water moving into the water table. Setbacks from such wells are mandated by law and must be observed.

Reclaimed Water Best Management Practices:



Ensure that all cross-connection controls are in place and operating correctly. If you are converting from freshwater use to reclaimed water, or if you have a backup water source, be certain that all connections to the freshwater system have been severed and capped. A thorough cross-connection and backflow prevention setup is crucial (Section 62-610.660, F.A.C.)



Post signs in accordance with local utility and state requirements that reclaimed water is in use. Signs may be available from the reclaimed water purveyor. Some courses also notify golfers of the use of reclaimed water on scorecards or at the first tee.

Any course using reclaimed water must identify all nearby potable wells that could be affected by reclaimed water moving through the water table. Mandated setbacks (usually 75 feet) must be observed.

Obtain information at the time of contracting, and at least annually, about the quality of the reclaimed water to be delivered.

Account for the nutrients in reuse water when making fertilizer calculations. Knowing the nitrate levels in reuse water can reduce your fertilizer purchases. The application of 1 inch of reuse water containing 20 ppm nitrogen (N) adds about 0.104 lbs N per 1,000 ft^2 (4.5 pounds of N per acre) to the soil. If you irrigate 40 inches per year, that computes to about 4.15 lbs. per 1,000 ft^2 (ppm x inches x .0052 = lb. N/1,000 ft^2).

Users of reclaimed water should test the water regularly for TDS Sodium and bicarbonate buildup in the soil affect turf health and can lead to unnecessary maintenance.

System Design

Irrigation system design is a complex issue and should be handled by trained professionals. These professionals should use existing standards and criteria such as the FDEP Standards for Landscape Irrigation in Florida, as well as manufacturers' recommendations, to design the most appropriate system for a location.

The References section contains a list of sources for current standards and criteria. In many communities, construction and design documents and permits require the signature and seal of a licensed design professional.

The irrigation design for a site depends on several factors, including location, soils, landscape vegetation, water supply, and water quality. An irrigation system needs to be designed to meet a site's peak water requirements. However, it should also be flexible enough to adapt to various water demands and local restrictions.

Operating pressure must be designed not to exceed the source pressure. Design operating pressure should account for low pressure during periods of high use (i.e., mornings) and for project buildout when all of a development's landscape is in place. Irrigation systems designed to service both turf and landscape areas should have enough zones to meet each area's individual water needs. Emitter precipitation rates throughout the system must be selected so that the ability of the soil to absorb and retain the water applied is not exceeded during any one application. The irrigation design should also account for the extra water that is periodically needed to leach salt buildups caused by poor-quality irrigation water.

An irrigation system consists of four main components, as follows:

Water supply—this consists of a water source, pump, filters, and valves (including backflow valves)

Water conveyance—this is made up of a mainline, manifold, lateral lines, and spaghetti tubes and isolation valves

Distribution devices—these include impact, oscillating, and rotary sprinklers; sprayheads; and microirrigation emitters. Smaller heads (sprays and small rotors) can be used for special areas such as tee tops and bunker faces to deliver extra water efficiently when it is needed

A control system

The design must account for different site characteristics and topographies. The proper design and installation of the components listed above optimizes their use and decreases any off-site impacts. To meet peak water use demands and have enough flexibility to reduce supply for different demand requirements, irrigation systems need to be designed with various control devices, including rain shutoff devices and/or soil moisture devices, and with backflow prevention to protect the water source from contamination.

Water conveyance systems should be designed with thrust blocks and air-release valves to prevent system damage. Water conveyance pipelines, which are always color-coded purple for reclaimed water systems, should provide the appropriate pressure required for maximum irrigation uniformity, and distribution devices should be designed for optimum uniform coverage. Isolation valves should be installed between holes, so that a leak can be repaired while the rest of the course is still being irrigated. It may seem obvious, but a distribution system should not be designed to irrigate nonplanted areas (such as driveways, cart paths, parking lots, roads, sidewalks, roof overhangs, and natural buffer zones). An irrigation system should also be designed differently for play and nonplay areas.

Irrigation for Play Areas

Irrigation for play areas should contain the following elements:

- **Computerized control systems** should be installed on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head. By adjusting the watering times based on actual site conditions for each head and zone, water can be conserved and used most efficiently. Appropriate cutoff devices should be installed so that line breaks do not cause a pump to run excessively, or improper valve alignment does not cause a pump to overheat.
- **Weather stations** help superintendents adjust irrigation run times based on current local meteorological data that are recorded and downloaded to the irrigation computer. Some stations automatically compute the daily ET rate and adjust preselected run times to meet the turf's moisture needs. Weather stations, however, do not replace the human factor. Recorded ET rates can be manually adjusted to reflect wet and dry areas on the course to ensure the maximum watering efficiency. Install rain switches, as required by Florida law, to shut down the system if enough rain falls in a zone. Soil moisture sensors will circumvent schedules if soil moisture is already adequate.

- **Pump stations** should be sized to provide adequate flow and pressure. They should be equipped with control systems that protect distribution piping, provide for emergency shutdown due to line breaks, and allow maximum system scheduling flexibility.
- **Variable frequency drive** pumping systems should be considered if dramatically variable flow rates are required, if electrical transients (such spikes and surges) are infrequent, and if the superintendent has access to qualified technical support.
- **Heads and nozzles** should be selected to maximize the uniformity of coverage. The proper spacing of heads during course design and construction is critical. Equipment should be designed and installed following manufacturers' and professional designer specifications. Improper overlap leads to dry spots that require extra watering, so that other areas are overwatered.
- **Tee tops** may be designed so that the only maintained turf is on the tee top and slopes. Plantings of native grasses around teeing grounds, where applicable, provide an effective alternative ground cover. Such tees should have fully adjustable or part-circle heads installed to apply water only where needed.

If new plant material needs irrigation to become established on the slope areas, the heads can be adjusted to provide the necessary water and then returned to tee top-only coverage. The same principle can be applied to narrow fairways, bunker complexes, and the banks of lakes, ponds, and other waterbodies.

- The irrigation of **greens and green surrounds** should be designed to provide inward and outward sprinkler coverage for maximum efficiency and turf maintenance. With single-head coverage around the greens, the slopes are often watered unnecessarily, which wastes water.
- Additionally, **operational control of each head** around the green is preferred over systems that provide total green or zone irrigation control. Individual head control increases irrigation flexibility by allowing for wind correction, watering localized dry spots, and meeting other special local needs.
- **Provide separate irrigation zones for slopes and areas surrounding greens.** Irrigation heads need to be strategically placed to minimize the amount of water applied to surrounding bunkers. The soils used for these areas may be heavier and poorly drained, compared with the modified soils in putting greens. Surrounds may hold water better and may not need to be irrigated as frequently as a well-drained green.
- **Roughs** should be considered separate zones. At least one water management district (South Florida Water Management District [SWFWMD]) does not make an allowance for watering roughs in the permit calculations for golf courses in Water Use Caution Areas.

The image at the right illustrates a typical irrigation head configuration for a putting green. The two irrigation heads — one inner head for irrigating the putting surface for normal watering and one outer head for watering the green slopes, etc. during normal irrigation. Generally, a quick-coupler valve (not shown) is also located on each green complex to allow for plugging in a large hose for hand watering hot spots.

Typical system at green

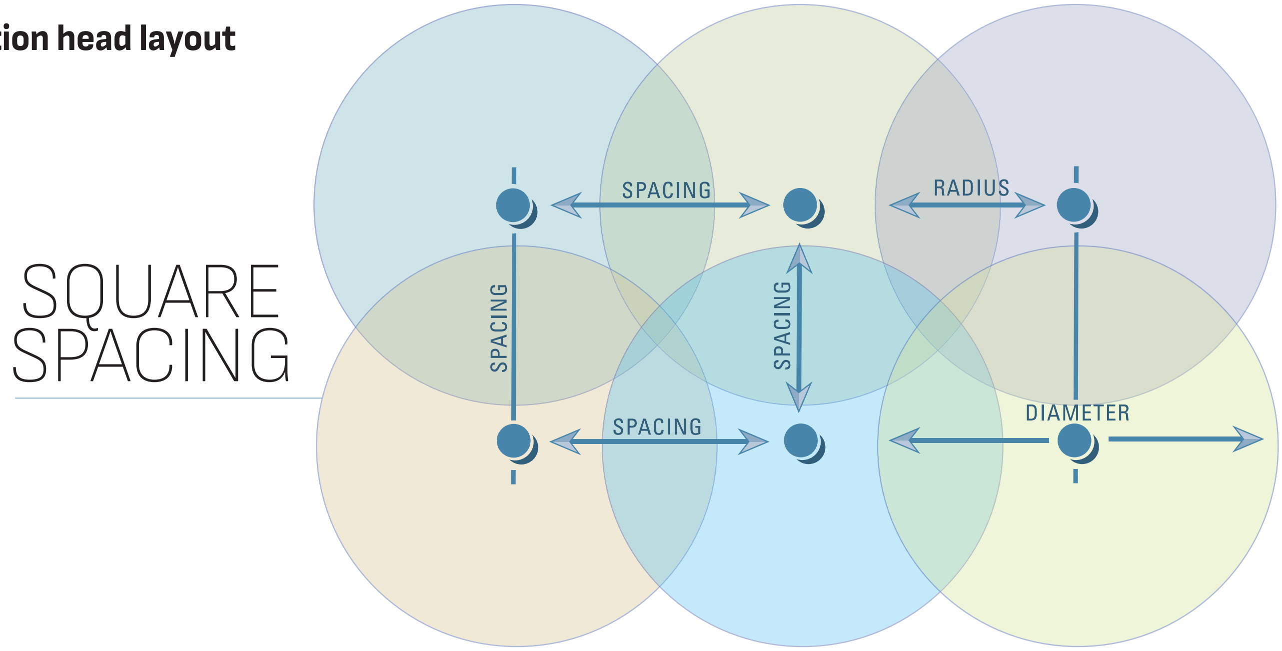
Watering bunkers can result in sand erosion, wet shots for the players, and algae and weed encroachment, and wastes valuable water resources. Bunker slopes, however, do need to be irrigated. Some extensive sand areas, although designed as nonirrigated spaces, may have automatic sprinklers installed to wet the sand. These are used only during extreme wind conditions to prevent sand blowout.

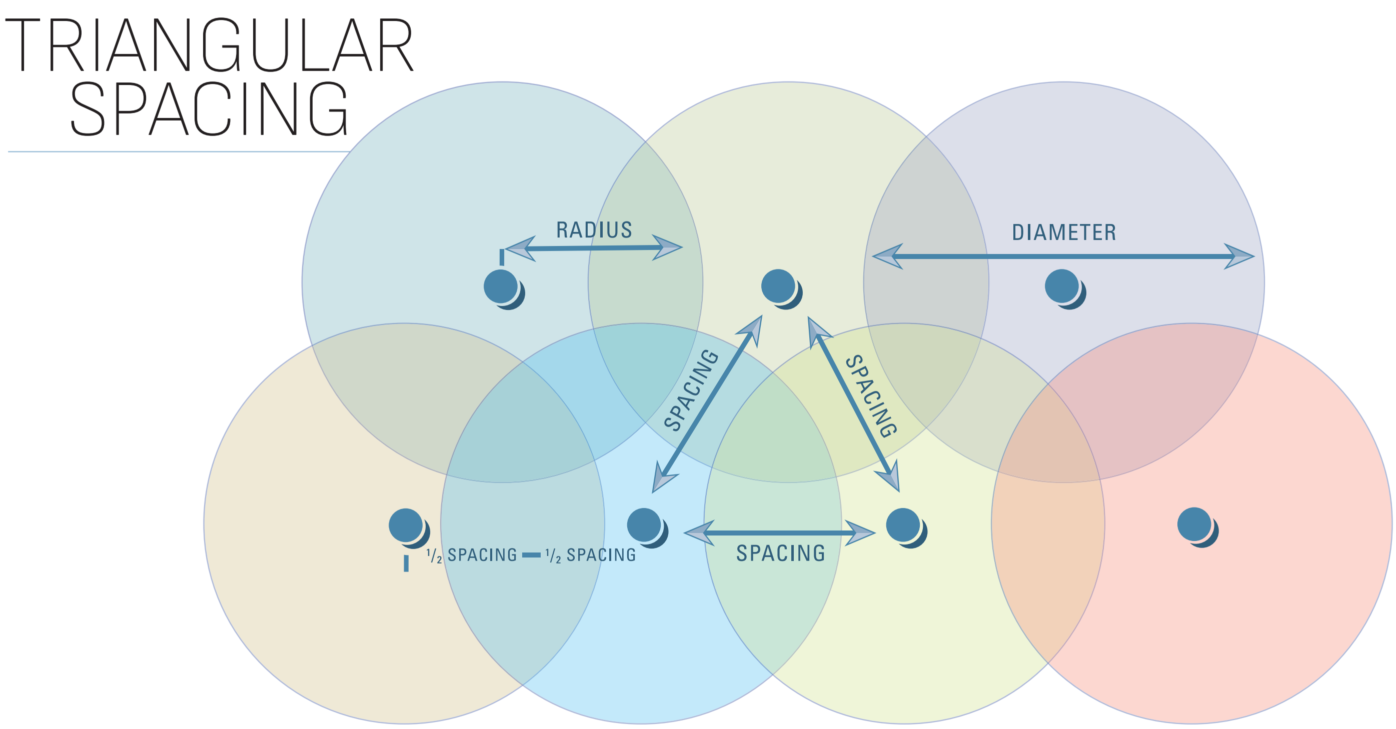
To ensure optimum uniformity, permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations. Typically, this spacing is based on average wind conditions during irrigation. If this information is not available, guidelines such as those in Table 1 can be used. For variable wind directions, triangular spacing is more uniform than square spacing. Practical experience may suggest closer spacing than the guidelines. However, spacing should not exceed the percentages in Table 4.1. After the system is constructed and operating, periodic "catch can" uniformity tests should be performed (see the chapter on Irrigation Management). The diagram below Table 4.1 shows two different irrigation head layouts.

TABLE 4.1: Irrigation Spacing

WIND	SQUARE COVERAGE	TRIANGULAR COVERAGE
Miles Per Hour	Percentage of Diameter Coverage	
0-5	55%	60%
5-10	50%	55%
10+	45%	50%

Irrigation head layout





Irrigation for Nonplay Areas and Landscape Plantings

Nonplay areas include aesthetic turf around clubhouses, landscaped garden areas, and out-of-bounds or border areas. Landscaping should follow the practices in Florida Green Industries: *Best Management Practices for Protection of Water Resources in Florida* (Available: https://ffl.ifas.ufl.edu/professionals/BMP_manual.htm). Consult local authorities on water restrictions for irrigation. When mature, many of these areas, if planted with the ***Right Plant, Right Place*** motto in mind, may require little supplemental irrigation. In these cases, temporary systems may be installed while the plants are becoming established and then removed when the plants are mature. In general, nonplay areas should be irrigated like any high-quality landscape using Florida-friendly landscaping principles.

Irrigation systems operate most efficiently if they minimize evaporation during spraying and from plant foliage. Plants do not use water applied to the foliage. The most efficient and effective watering method for nonturf landscaping is microirrigation, which includes drip-and-trickle irrigation and spray jets. Microirrigation supplies small quantities of water directly to the mulch and soil through plastic tubing on or below the ground surface. Low-pressure emitters (that is, nozzles that drip, spray, or sprinkle) are attached to the plastic tubing and slowly release water into the soil around a plant. Wetting only the root zone saves water, because less water is lost through wind and evaporation.

Microirrigation equipment flow rates are given in gallons per hour (gph), rather than the gallons per minute (gpm) used for conventional irrigation equipment. Despite the difference in flow rates, caution should be used in determining zone run times. The amount of water applied can be quite high, because the water is being applied to each plant, within a small area.

When microirrigating, you need to know what kind of emitter to install in a given location. There are various types of equipment, including individual point source emitters, in-line tubing (emitters that are factory installed in tubing), or microsprays.

When drip emitters are used in some of Florida's sandier soils, water has very limited lateral movement from the emitter. For this reason, they are not practical for watering turf in Florida.

Individual drip emitters (point source) provide water to individual plants using .25-inch poly tubing. Where plantings are dense, then in-line tubing is more appropriate than individual emitters. Microsprays are appropriate for plants that require higher amounts of water, or where the emitters need to be visible for maintenance. Because drip emitters are sometimes placed under mulch or buried in the soil, if clogging

occurs it is difficult to detect. Because the action of drip emitters is not readily apparent, it is also hard to know whether a system is irrigating excessively due to a hole in the tubing or some other problem. Regular inspection is required to make sure that the drip emitters, and the overall system, function as they should.

Regardless of the emitter style, clogging will likely be a problem if the water supply is not filtered before it enters the irrigation system. Filters are easily installed in any system. Water sources contain organic materials such as algae, which can dramatically increase emitter clogging. The injection of chlorine may be required to prevent the organic material from growing.

Irrigation System Design Best Management Practices:

The application rate must not exceed the ability of the soil to absorb and retain the water applied during any one application.

The design operating pressure must not be greater than the available source pressure.

The design operating pressure must account for peak use times and supply line pressures at final buildout for the entire system.

Distribution devices and pipe sizes should be designed for optimum uniform coverage. The first and last distribution device should have no more than a 10% difference in flow rate. This usually corresponds to about a 20% difference in pressure.

The system should be flexible enough to meet a site's peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions.

Distribution equipment (such as sprinklers, rotors, and microirrigation devices) in each zone must have the same precipitation rate.

Heads for turf areas should be spaced for head-to-head coverage.

Turf and landscape areas should be zoned separately.

The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic and growing conditions, and it should include the base ET rate for the particular location.

If required by the plant species that are present, the design should account for the need to leach out salt buildup from poor-quality water by providing access to fresh water. Otherwise, use species that tolerate these conditions.

Water supply systems (for example, wells and pipelines) should be designed for varying control devices, rain shutoff devices, and backflow prevention.

Water conveyance systems should be designed with thrust blocks and air-release valves.

Flow velocity must be 5 feet per second or less.

Pipelines should be designed to provide the system with the appropriate pressure required for maximum irrigation uniformity.

Pressure-regulating or compensating equipment must be used where the system pressure exceeds the manufacturer's recommendations.

Equipment with check valves must be used in low areas to prevent low head drainage.

Isolation valves should be installed between each hole.

Nonplanted areas, especially impervious surfaces, should not be irrigated.

Manual quick coupler valves should be installed near greens, tees, and bunkers so these can be hand watered during severe droughts.

Install part-circle heads along lakes and ponds.

Irrigation System Installation

Qualified, appropriately licensed, bonded, and insured professionals should handle irrigation installation. These individuals must follow the designer's plans and use existing standards and criteria (such as the FDEP *Standards for Landscape Irrigation in Florida*, and those of the American Society of Agricultural and Biological Engineers [ASABE], Florida Irrigation Society [FIS], Irrigation Association, U.S. Department of Agriculture—Natural Resources Conservation Service [USDA–NRCS], and/or the manufacturer's recommendations). The designer must approve any changes to the design.

To prevent system failures, waste, and property damage, construction materials must meet appropriate standards (such as the ASABE, American Society of Civil Engineers [ASCE], or American Society of Testing Materials [ASTM]). All construction practices should be planned and carried out using standard safety practices.

System Operation

Plants don't waste water, people do. Using proper irrigation system design, installation, water management, and maintenance practices provides a multitude of benefits. An efficient irrigation system translates into cost savings and protection of our water resources.

Irrigation management is the cornerstone of water conservation and reduced nutrient and pesticide movement. It includes both scheduling the amount of water applied and when, and maintaining system components, both to prevent and correct problems. Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excess water use that could lead to leaching and runoff. Plant water needs are determined by evapotranspiration rates, recent rainfall, recent temperature extremes, and soil moisture. Whenever possible, cultural practices should be used to minimize plant stress and the amount of water needed. For example, superintendents can use mowing, verticutting, nutrition, and other cultural practices to control water loss and to encourage conservation. The chapter on Cultural Practices provides more information on how turfgrass cultural practices influence water use rates and efficiency.

Irrigation System Installation Best Management Practices:

Only qualified specialists should install the irrigation system.

Construction must be consistent with the design.

The designer must approve any design changes before construction.

Construction and materials must meet existing standards and criteria.

Acceptable safety practices must be followed during construction.

Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.

Spare hydraulic tubing and electrical wiring should be installed during construction for rapid repairs in case of leaks, breaks, and short circuits.

Remote field controllers should be grounded according to code.

The owner should receive a copy of the as-built plans, operating manuals, and warranties, as well as written instructions on how to change the irrigation system's timers, clocks, and controllers.

When construction is completed, the site must be cleaned of all construction materials.

Water Restrictions

Florida's five regional water management districts may impose water restrictions based on aquifer levels, surface water flows, and rainfall shortages. Golf course owners are legally bound to abide by all restrictions placed on golf course irrigation. Failure to comply can result in punitive action by the districts.

It is also important to abide by the CUP/WUP granted to your property. Overpumping can damage water resources.

Watering restrictions generally allow supplemental watering for the establishment of new plantings and new sod, hand watering of critical hot spots, and watering in of chemicals and fertilizers as prescribed by the label or good stewardship practices. **For Water Shortage Rules and Criteria, contact your local water management district.**

It is in everyone's best interest to document actual watering practices — especially to show savings in water use over averages. Communication with the water management districts, golf course members, and the public should be maintained to explain what you are doing and why.

Irrigation Scheduling

Before a superintendent can properly develop an irrigation schedule, the system must be audited, or calibrated, so that the rate at which water is applied in each zone is known (see the section on System Maintenance in this chapter). Once the water delivery rate is known, determining when and how much to water is the next important step. Irrigation should not occur on a calendar-based schedule but should be based on ET rates and soil moisture replacement. Rain gauges are necessary measurement tools to track how much rain has fallen throughout the golf course. The use of soil moisture probes, inspections for visual symptoms such as wilting turf, computer models, and tensiometers may supplement these measurements. Computerized displays are available to help visualize the system.

Computerized irrigation display

Water loss rates decrease with reduced solar radiation, minimal wind, high relative humidity, and low air temperatures. A superintendent can take advantage of these factors by irrigating when conditions do not favor excessive evaporation. Irrigation should occur in the early morning hours before air temperatures rise and relative humidity drops. Irrigating at this time also removes dew from leaf blades and allows sufficient time for infiltration into the soil but does not encourage disease development.

Determining how much water to apply is the next step in water management. Enough water should be applied to wet the entire root zone. Wetting below the root zone is generally inefficient, since this is beyond a plant's range of access. Irrigating too shallowly encourages shallow rooting, increases soil compaction, and favors pest outbreaks. For golf greens and tees, the majority of roots are in the top 6 inches of soil. Irrigate to wet this depth unless the root zone extends deeper. For fairways and roughs, the top 12 inches of soil should become wet to supply sufficient water for plants and to encourage deep rooting. Soil moisture can be estimated by using a soil probe to feel the depth of the moisture and show the depth of the root zone.

Visual Symptoms

The presence of visual symptoms of moisture stress is a simple method used to determine when irrigation is needed. Moisture-stressed grass appears blue-green or grayish-green in color, recuperates slowly (longer than 1 minute) after one walks or drives across it, or wilts continuously. These symptoms occur when plant moisture is insufficient to maintain turgor. As a result, the plant rolls its leaves and wilts to conserve moisture. Certain areas or patches of turfgrass tend to wilt before others due to poor irrigation distribution, or to poorly developed or damaged root systems.

Waiting until visual symptoms appear before irrigating is a method best used for low-maintenance areas, such as golf course roughs and possibly fairways. Managers of golf greens cannot afford to wait until these symptoms occur, because unacceptable turf quality may result.

Predictive Models

Predictive models based on weather station data and soil types are also available. These are relatively accurate and applicable, especially as long-term predictors of yearly turf water requirements. Weather data such as rainfall, air and soil temperature, relative humidity, and wind speed are incorporated into certain model formulae, and soil moisture content is estimated. Models, however, are only as effective as the amount of data collected and the number of assumptions made. These models and programs should always be calibrated for local conditions, as they often use incorrect coefficients for Florida's climate and plant species. Accessible weather data must be available, as well as specialized computer equipment and programs. Computer programs allow for individual station settings to decrease or increase watering times for wet and dry areas. They also have "cycle and soak" features, so that water can be applied over several cycles and not puddle or run off.

Soil Moisture Probes

Soil moisture probes are now commonly used by golf course superintendents to measure soil moisture across a range of soil conditions. Newer versions of these instruments can also measure electrical conductivity (EC) indicating the level of salt in the soil and canopy temperature. Coupled with GPS technology and mapping software, golf course superintendents can easily identify areas of concern.

Irrigation Control with Feedback

Irrigation control with feedback simply means that the control system receives feedback from a single sensor or multiple sensors dispersed across the golf course. These may consist of soil moisture sensors or meteorological sensors that are used to calculate the ET demands of the plants under irrigation.

Irrigation with soil moisture sensors can consist of a sensor that has a user-adjustable threshold setting where the scheduled timer-based irrigation event is bypassed if the soil moisture content exceeds the threshold. This type of control is "bypass" control. The soil moisture sensor(s) should be installed in the root zone for each irrigation zone. If the sensor system only contains one soil moisture probe, then that probe should be installed in the driest irrigation zone of an irrigation system and all other irrigation zones should have their run times reduced to minimize over-watering. Frequent irrigation events can be programmed into the irrigation timer and the sensor will allow irrigation as conditions in the root zone dictate in response to rainfall and ET. The second type of soil moisture control is "on-demand" control where the soil moisture-based irrigation control system consists of a stand-alone controller and multiple soil moisture sensors. High and low limits are set so that irrigation only occurs within those limits. Currently, the "bypass" control devices are marketed for residential irrigation and "on-demand" devices are marketed for agricultural or large commercial systems. However, both strategies could be adapted to golf course irrigation systems.

Many types of soil moisture sensors have become commercially available. Newer sensors are capacitance or dielectric-based devices and rely on the ability of the soil to conduct electricity and the fact that this property is strongly correlated to soil moisture content. It is important to place these sensors in a representative location within the irrigated root zone. Since the sensors require wires for communication and power, the wires must be buried below aerification depths, and the locations of the sensors must be marked to prevent such damage. Excessive salt content in some irrigation water can also interfere with the accurate operation of some types of sensors.

Weather station

Evapotranspiration-based Control Systems

ET-based control systems have been available for many years. The oldest type, consisting of a full weather station that interfaces with a controller for a large, irrigated area, is common in golf course irrigation systems. However, a full weather station costs several thousand dollars and requires frequent maintenance for accurate measurements. ET is calculated based on the meteorological parameters measured by the weather station, and then the controller calculates a running soil water balance. Irrigation is scheduled automatically based on the application rate of the sprinklers in a particular irrigation zone and the calculated removal of water from the root zone.

The instruments on ET control systems should be periodically checked and their accuracy verified at least annually. In addition, an accepted method for the calculation of ET should be used along with the best available crop coefficients. One of the most widely accepted methods of ET calculation is the Penman-Montieth method. A standardized form of this equation has been proposed by the ASCE-EWRI Evapotranspiration in Irrigation and Hydrology Committee (ASCE, 2005). For the most accurate calculation of irrigation water requirements, rainfall should be measured onsite. In the future, technology such as OneRain Corporation's (onerain.com) high-resolution, gage-adjusted Doppler radar rainfall data may be used to provide spatially distributed irrigation scheduling.

Operating Older Systems

Not all golf courses are so fortunate as to have a computerized irrigation system, variable frequency drive (VFD) pump station, or weather station. Many existing courses have pump stations that maintain pressure through the use of hydraulic pressure-sustaining valves, which operate to maintain a constant downstream pressure in the piping system.

Golf courses with hydraulic pressure-sustaining valves are much more prone to irrigation pipe and fitting breaks due to surges in the system, creating more downtime for older systems. A good preventive maintenance program for this type of station is very important to keep it operating efficiently. Maintaining the air relief and vacuum breaker valves is particularly important. The installation of a VFD system can lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.

Time clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical time clocks cannot automatically adjust for changing ET rates, and therefore, staff have to adjust them frequently to compensate for the needs of individual turfgrass areas. The reliability of station timing depends on the calibration of the timing devices; this should be done periodically but at least seasonally.

It is important to keep in mind that, while new technology makes many tasks easier or less labor intensive, it is the principles discussed in this BMP manual that are important. These principles may be applied to any course at almost any level of technology. All of us can improve something by examining our operations from a different perspective, and the principles outlined here can help you to look at your operation from an environmental perspective.

Critical Irrigation Management Best Management Practices:

An irrigation system should be operated based only on the moisture needs of the turfgrass, or to water in a fertilizer or chemical application as directed by the label.

An irrigation system should be calibrated regularly to ensure that it is performing as designed by conducting periodic irrigation audits to check actual water delivery and nozzle efficiency.

An irrigation system should have rain sensors to shut off the system after ¼ to ½ inch of rain is received. Computerized systems allow a superintendent to call in and cancel the program if it is determined that the course has received adequate rainfall.

An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.

Each day the system should be monitored for malfunctions and breaks. It is also a good practice to log the amount of water pumped each day. These data can be useful in documenting watering needs and schedules during droughts.

Generally, granular fertilizer applications should receive ¼ inch of irrigation to move the particles off the leaves while minimizing runoff. Irrigation quantities should not exceed the available moisture storage in the root zone.

Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.

When possible, the irrigation schedule should coincide with other cultural practices (i.e., the application of nutrients, herbicides, or other chemicals).

Proper cultural practices such as mowing height, irrigation frequency, and irrigation amounts should be employed to promote healthy, deep root development and reduce irrigation requirements.

System Maintenance

Irrigation system maintenance on a golf course involves four major efforts:

1) Calibration or auditing
2) Preventive maintenance
3) Corrective maintenance
4) Recordkeeping

The recordkeeping is an essential part of the other three but is often overlooked. This manual also touches on system renovation.

Calibrating an Irrigation System

There are three levels of irrigation audits or evaluations: a visual inspection, a pressure/flow check, and a catch can test. The level chosen depends on how much detailed information is required *(see chart, next page)*. Irrigation audits should be performed by properly trained technicians.

First, if an irrigation system is in disrepair or coverage is obviously poor, then time is wasted doing a detailed catch can test. A visual inspection should first be conducted to identify any necessary repairs or corrective actions, and it is essential to make any repairs before carrying out other levels of evaluation. A visual inspection should be part of ongoing maintenance procedures.

Pressure and flow should be evaluated to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications. Pressure and flow rates should be checked at each head. The data can be used to determine the average application rate in an area, which is a fundamental parameter for irrigation scheduling.

Catch can tests should be run to determine the uniformity of coverage. Catch can testing provides the most detailed information on coverage and thus allows a system operator to accurately determine irrigation run times. The information gathered from this test also identifies areas where coverage is poor and a "redesign" option should be considered.

Catch can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency. However, due to time and budget constraints, this can be accomplished over an extended period. Annual testing results in a high-quality maintenance and scheduling program for the irrigation system.

LEVEL 1 VISUAL INSPECTION

With the irrigation system on, do the following:

- Inspect for mainline breaks
- Inspect for low pressure at the pump
- Inspect head-to-head spacing
- Inspect for interference with water distribution
- Inspect for broken and misaligned heads
- Make sure that the rain sensor is present and functioning
- Make sure that the backflow device is in place and in good repair
- Examine turf quality and plant health for indications of irrigation malfunction or need for scheduling adjustments
- Schedule documentation
- Make adjustments and repairs on items diagnosed during the visual inspection before conducting pressure and flow procedures.

LEVEL 2 PRESSURE AND FLOW TESTING

- Measure the pressure at each rotor with a pitot tube and pressure gauge, while simultaneously recording the flow rate at the pump station
- Identify and record the size of each nozzle
- Use nozzle sizes and operating pressure to check the manufacturer's specifications for the precipitation rate
- If all heads within a zone don't have matching precipitation rates, replace heads as needed
- Compute Average Application Rate (AAR) for a given area or group of heads:

$$\text{AAR (inches/hour)} = \frac{\text{Total gpm* x 96.3}}{\text{Total Area (sq. ft.)}}$$

**Total gallons per minute of all heads in irrigated area*

LEVEL 3 CATCH CAN TESTING

- Identify the areas to be tested and conduct a catch can test on all areas of each hole.
- Identify holes that represent the worst, best, and average for the following:

  Greens • Tees • Fairways
- Flag all heads.
- Evenly space 40 to 50 catchment containers throughout the test area.

  Testing run times:
  20 to 30 minutes or at least 5 rotations.
- Set up containers at night and then collect data in the morning.
- Measure and record volumes (in milliliters [mL]) collected from each container. Catch cans with direct-read mL measurements are available from the Irrigation Association. In addition, simple plastic tumblers can be used with rubber bands and wooden dowels. Measurements can be taken with a 100mL graduated cylinder available from any scientific supply company.

After all of the measurements have been taken, determine the effective application rate using the following three steps:

Compute the AAR using the information gathered from the pressure flow test, or use data from the catch can test with the following formula:

AVERAGE APPLICATION RATE (inches/hour)

$$AAR = \frac{\text{Average volume (mL)} \times 4.66}{\text{Diameter of catch can (inches)} \times \text{time (minutes)}}$$

Compute the distribution uniformity using the average volume of the low quarter of catch cans and divide by the average volume of all catch cans:

DISTRIBUTION UNIFORMITY (Lower Quarter)

$$DULQ = \frac{\text{Average volume of the lower quarter of catch cans}}{\text{Average volume of all catch cans}}$$

Compute the effective application rate by multiplying the average application rate by the distribution uniformity:

EFFECTIVE APPLICATION RATE (inches/hour)

EAR= Average application rate x distribution uniformity

Adjust the schedule based on the effective application rate, and implement all repairs needed to improve distribution uniformity.

The Irrigation Association website provides a webtool for identifying a certified professional irrigation auditor (Available: https://www.irrigation.org/IA/Certification/Hire-Certified/Find-a-Certified-Professional/IA/Certification/Find-a-Certified-Pro.aspx?hkey=d5c9649e-1170-4d09-8a78-401808ed0ccb). Additionally, the IA provides useful irrigation audit policies, procedures, and worksheets on their website (Available: https://www.irrigation.org/IA/Certification/Landscape-Certifications/CGIA/IA/Certification/CGIA.aspx).

Preventive Maintenance

Personnel charged with maintaining any golf course irrigation system face numerous challenges. This is particularly true for courses with older or outdated equipment. Good system management starts with good preventive maintenance (PM) procedures and recordkeeping. Maintaining a system is more than just fixing heads. It also includes documenting system- and maintenance-related details so that potential problems can be addressed before expensive repairs are needed. It also provides a basis for evaluating renovation or replacement options.

Preventive Maintenance Best Management Practices:

System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer's recommendations.

The system should be inspected daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. A visual inspection should be carried out for leaks, maligned or inoperable heads, and chronic wet and dry spot, so that adjustments can be made.

Systems need to be observed in operation at least weekly. This can be done during maintenance programs such as fertilizing or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation. This process detects controller or communications failures, stuck or misaligned heads, and clogged or broken nozzles.

Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source. Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.

Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.

Application/distribution efficiencies should be checked annually. Implement a PM program to replace worn components before they waste fertilizer, chemicals, and water.

Conduct a periodic professional irrigation audit at least once every five years.

Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.

Monitor pump station power consumption. Monthly bills should be monitored over time to detect a possible increase in power usage. Compare the power used with the amount of water pumped. Requiring more power to pump the same amount of water may indicate a problem with the pump motor(s), control valves, or distribution system. Quarterly checks of amperage by qualified pump personnel may more accurately indicate increased power usage and thus potential problems.

Monitor and record the amount of water being applied, including both system usage and rainfall. By tracking this information, you can identify areas where minor adjustments can improve performance. Not only is this information essential in identifying places that would benefit from a renovation, it is also needed to compute current operating costs and compare possible future costs after a renovation.

Document and periodically review the condition of infrastructure (such as pipes, wires, and fittings). If the system requires frequent repairs, it is necessary to determine why these failures are occurring. Pipe failures may not only be caused by material failure but could result from problems with the pump station. Wiring problems could be caused by corrosion, rodent damage, or frequent lightning or power surges. Control tubing problems could result from poor filtration.

Corrective Maintenance

Corrective maintenance is simply the act of fixing what is broken. It may be as simple as cleaning a clogged orifice, or as complex as a complete renovation of the irrigation system. For the smaller, day-to-day failures, BMPs simply call for timely action, maintaining the integrity of the system as designed, and good recordkeeping.

Corrective Maintenance Best Management Practices:

Replace or repair all broken or worn components before the next scheduled irrigation.

Replacement parts should have the same characteristics as the original components.

Document all corrective actions.

System Renovation

As maintenance costs increase, the question of whether to renovate arises. Renovating a golf course can improve system efficiencies, conserve water, improve playability, and lower operating costs.

System renovation starts with evaluating the current system's maintenance requirements and operating costs. Focusing on longer-term objectives may demonstrate that it is cost-effective to install a new system to reduce the accumulating and seemingly perpetual maintenance chores that older systems often require.

The process of identifying renovation needs starts with collecting as much information as possible about the system, including the following:

Gather all of the documentation collected as part of the PM program, along with corrective maintenance records. Correctly identifying problems and their costs helps to determine what renovations are appropriate.

Determine the age of the system. Irrigation systems, like any asset, do not last forever. Checking the dates on any as-builts and discussing the history of the course with other golf course personnel gives you a starting point.

Determine the age of the pump station, which is one of the single costliest items in a system. While a system's age in years provides some information, the number of operating hours is often a better indicator of life expectancy.

Understand the operations and options of the current control system. If the system has not been renovated, it probably doesn't have a state-of-the-art control system.

By trying to maximize the efficient use of the current system, three things should occur. First, you should recognize some improvement in system performance. Second, you should begin to develop a list of things that the current system doesn't accomplish, but that you would like a new system to do. Third, you should begin to gather the site information necessary for any renovation.

Identifying ways to improve system performance is only part of the information-gathering stage. Collecting information on the cost of maintaining the system is also important. This information should include the cost of pipe repairs, sprinkler repairs, control system repairs, and power consumption. Be sure to include labor costs and the costs of lost revenue, when appropriate.

After gathering as much information as possible, you will need to identify items that are beneficial to upgrade, including the following:

Updating control systems
Improving greens coverage
Improving tees coverage
Improving coverage on fairways and roughs
Repairing/replacing elements of the system infrastructure
Repairing/replacing the pump station
and all of the above.

As you begin to identify areas or reasons for upgrading, you will need to find appropriate professionals (such as architects and consultants) to assist in renovation planning. These professionals are necessary not only to assist in prioritizing goals, but also to develop plans, specifications, phasing recommendations, and project budgets. They can also help identify how much of the course needs to be closed and for how long, which is a crucial consideration

After a project has started, the involvement of current staff is essential. Understanding how a system was installed provides important information for developing an effective maintenance program. The fact that renovations have been completed does not indicate that the process of gathering information has ended. Continually documenting system performance is essential to maximize the effectiveness of the renovation.

SECTION 5

NUTRIENT MANAGEMENT

Proper nutrient management plays a key role in the reduction of environmental risk and increases course profitability.

Among other benefits, applied nutrients inflate the available pool of nutrients and allow turfgrass to recover from damage, increase its resistance to stress, and increase its playability. However, the increase in available nutrients also increases the potential risk of environmental impact. Nutrients may move beyond the turfgrass via leaching or runoff, which may directly impact the environment. Other organisms also respond to increases in nutrients and, in some cases, these organisms may deleteriously alter the ecosystem. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant uptake.

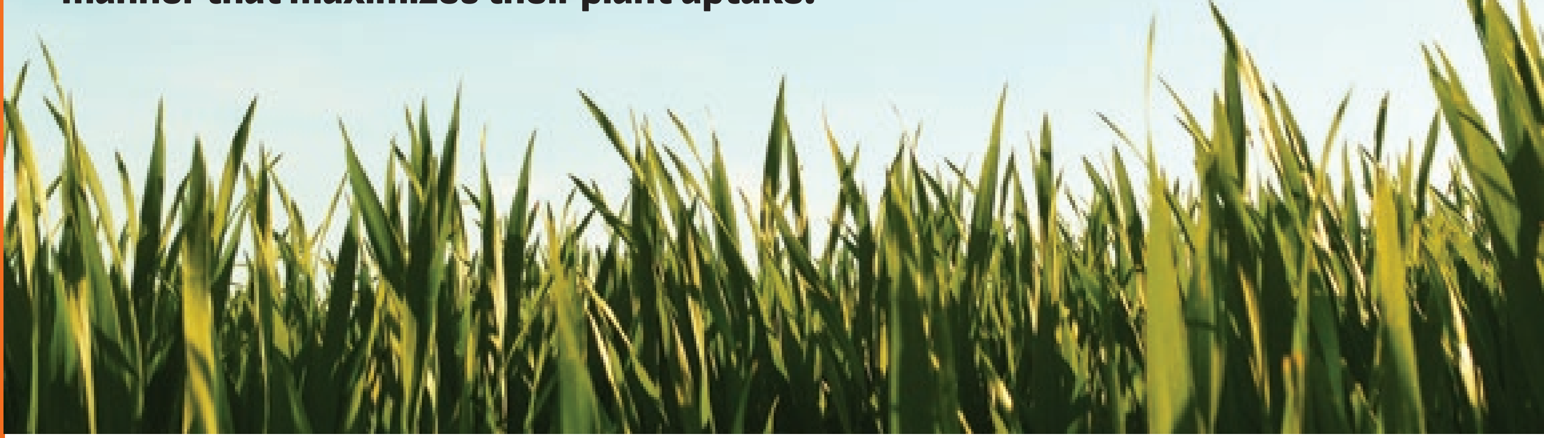


Photo by Clarisse Croset on Unsplash

Regulatory Considerations

Principles

The state of Florida has unique and delicate ecosystems consisting of waterways flowing above and below ground. Golf courses with healthy stand of managed turfgrass can serve as nature's best water filter for these systems. Florida golf course superintendents, through the proper use of nutrients, may ensure the positive impact turfgrass systems can have on the environment. Planning, practicing and recording applications, following the 4R's (Right Place, Right Time, Right Source, and Right Rate) and teaching others are key to achieving these environmental benefits. Rules and regulations have been put in place around the state regarding fertilizer use and applications. The goal of a Golf Course Superintendent is to not only be in compliance but to go above and beyond regulations with the Florida Golf Course BMP's.

It is the personal responsibility of Florida golf course superintendents to know, understand, and follow state and local laws pertaining to fertilizer and fertilizer applications. Golf course areas of play, the clubhouse, and main entrance may have restrictions and licensing specific to each area. Understand fertilizer. Know the laws. Follow the rules.

Soil Testing

Although it may not be an essential practice for the everyday maintenance of a healthy landscape, testing to determine the soil's chemical properties before installing turfgrass or landscape plants is recommended.

For Florida turfgrasses, soil testing can be used to diagnosis or manage issues associated with pH, salinity, sodicity, phosphorus (P), potassium (K), or magnesium (Mg). After initial soil testing, additional testing may be required only when fertility problems arise and the responses to fertilization are poor. For the effective management of nutrients, soil testing should be used in conjunction with tissue testing. Soil test recommendations are based on a correlation between the level of a given nutrient extracted from the soil and the anticipated turfgrass response. The amount of nutrients extracted by a particular extractant is only an index relative to turfgrass response, but because correlation response studies have not been conducted on Florida turfgrasses, the value of soil test recommendations is limited.

Methodology

The soil test and resulting recommendations are only as representative as the sample itself. Therefore, it is imperative that the soil sample be taken and handled properly. The sample should be obtained by taking 15 to 20 small plugs at a consistent depth randomly over the entire area where information is desired. Avoid any unusual areas or areas with specific, identifiable characteristics; these should be sampled separately. For turfgrass, since most of the roots are in the top 4 inches of soil, limit the sampling depth to 4 inches. For landscape plants, the sampling depth should be no more than 6 inches.

Place the plugs that have been collected into a plastic container, mix them thoroughly, and send approximately 1 pint of the mixed sample to the soil testing laboratory for chemical analysis. You should use the same laboratory on a continued basis to establish a historical log of your soil properties. Laboratories across Florida do not use the same extractant, and so if you change labs often you may be comparing results obtained by different methods, limiting your ability to draw conclusions from the results.


Soil core

Soil Test Interpretation

A soil analysis supplies information on a soil's nutritional status and can detect potential problems that limit plant growth. For Florida turfgrasses, a routine soil analysis supplies information on the soil pH, salinity, sodicity, P, K, and Mg status of the soil. Soil testing labs may analyze and provide recommendations for other variables such as nitrogen (N), calcium (Ca), sulfur (S), boron (B), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). However, these recommendations are not based upon current evidence and therefore following soil test recommendations for these elements is not a best management practice. Additionally, soil test recommendations based upon the basic cation saturation ratio (BCSR) method have been proven to be inaccurate and, therefore applying nutrients based upon the BCSR method is also not a best management practice. Many turfgrass managers have chosen to utilize the sufficiency level of available nutrients (SLAN) or the minimum level of sustainable nutrition (MLSN). These soil test interpretations are supported by evidence, but it is important to realize that the recommendations are based upon soil samples collected across a wide range of locations and soils. Thus, SLAN and MLSN recommendations are not specific to Florida and may greatly differ from Florida recommendations.

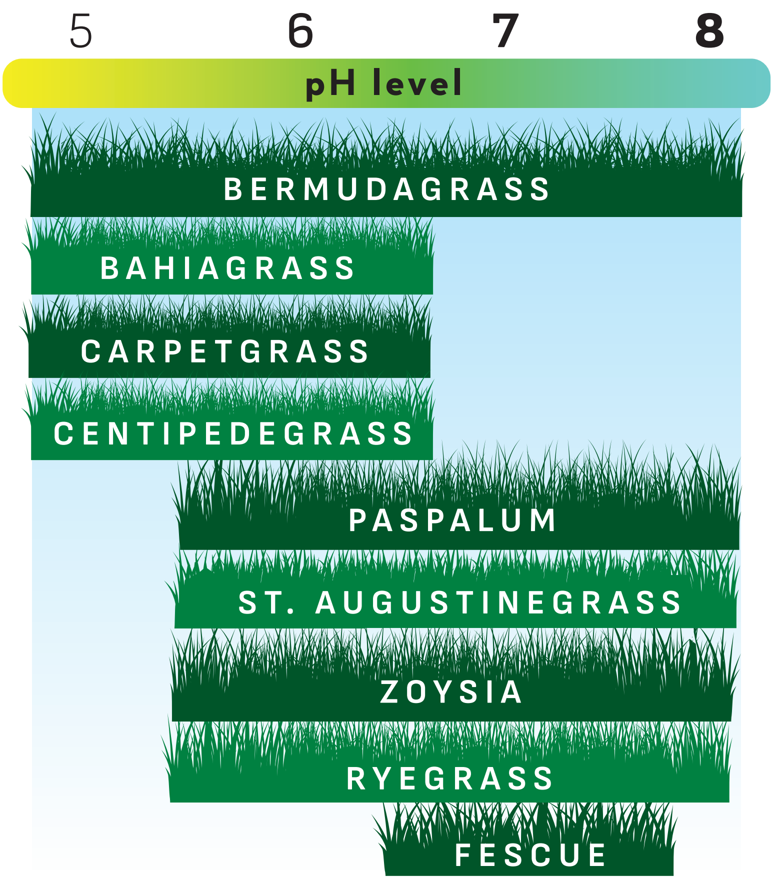
For example, MLSN values for P, K, and Mg are 21, 37, and 47 ppm and are, by definition, the minimum necessary to sustain good quality turfgrass. However, the MLSN P, K, and Mg values are greater than the values generated by UF/IFAS faculty under Florida conditions (P = 10, K = 30, and Mg = 20 ppm). When soil test values are below the MLSN but above UF/IFAS Mehlich III recommendations, applying P, K, and Mg based upon the MLSN recommendations would result in the application of nutrients when no response to those nutrients is expected. Thus, following the UF/IFAS soil test recommendations is the best management practice for Florida turfgrasses.

Soil Acidity

Soil reaction, or pH, is important because it influences several soil factors that affect plant growth. Soil bacteria that transform and release N from organic matter function best in the pH range of 5.5 to 7.0; certain fertilizer materials also supply nutrients more efficiently in this range.

Plant nutrients, particularly P, K, Ca, Mg, B, Cu, Fe, Mn, and Zn, are generally more available to plants in the pH range of 5.5 to 6.5. Often, these plant nutrients are more available to plants at pH values below 5.5 than in soils with pH values above 6.5. However, in certain soils, when the soil pH drops below 5.0, aluminum (Al) may become toxic to plant growth.

Turfgrasses differ in their adaptability to soil acidity. For example, centipedegrass and bahiagrass grow better in an acid environment (pH 5.0 to 6.0) than St. Augustinegrass or zoysiagrass, which grow best in near neutral or alkaline soils (pH 6.5 to 7.5).



Soil pH ranges for Florida turfgrasses

Soil Salinity

At high enough levels, soil salts deplete the turfgrass of moisture and can result in stressed and unacceptable turfgrass. Salts are introduced to turfgrass soils a variety of ways, including but not limited to irrigation water, effluent or reclaimed water, ocean spray, saltwater intrusion, and fertilizer. Soils may require remediation if the soil salt level exceeds the tolerance of the turfgrass being grown (Table 5.1).

TABLE 5.1: Salinity tolerance of warm season turfgrass species*

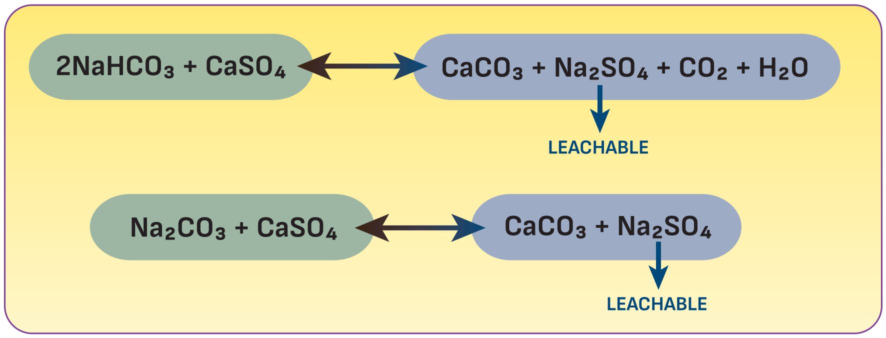
			Threshold ECe**		50% Growth Reduction ECe	
Common Name	Scientific Name	General Salinity Tolerance	Average	Range	Average	Range
			dS m^{-1}			
Bermudagrass, common	*Cynodon dactylon*	MT	4.3	0-12	21	12-32
Bermudagrass, hybrids	*Cynodon spp.*	MT	3.7	0-10	22	11-33
Carpetgrass	*Axonopus spp.*	VS	1.5	0-1	-	-
Centipedegrass	*Eremochloa ophiuroides*	VS	1.5	0-3	8	8-9
St. Augustinegrass	*Stenotaphrum secundatum*	T	6.5	0-18	29	22-44
Zoysiagrass	*Zoysia spp.*	MS	2.4	0-11	16	4-40

* Adapted from Carrow and Duncan (1998)

** ECe = electrical conductivity of the saturated-soil extract

*** MS = mildly sensitive, MT = mildly tolerant, T = tolerant, VS = very sensitive

The most effective method of reducing soil salts is to rely upon natural rainfall and/or low-saline irrigation. If clean water is not available, irrigate deeply with existing water to leach the salts remaining in the rootzone from prior irrigation cycles. Wetting agents may aid with moisture distribution but may also reduce infiltration rates. Despite claims, gypsum (CaSO4) will not remove salts and does little to increase percolation in Florida's sandy soils. Gypsum is a salt and, therefore, the application of gypsum increases salinity. However, gypsum can remediate sodium (Na)-related issues such as poor percolation resulting from deflocculated soils. However, Florida soils are predominately sands, which have a very poor capacity to retain Na and, therefore, Na-related soil problems are rare. However, gypsum has the additional benefit of reducing bicarbonates and carbonates, which can be toxic to many turfgrasses.



Bicarbonate (2NaHCO3) and carbonate (Na2HCO3) reductions following gypsum (CaSO4) application.

In locations where Na and/or bicarbonates are continually added to the turfgrass/soil system, remediation may, in some cases, require regular gypsum applications. On established turf, gypsum application rates range from 200–500 lbs. per acre. If your normal fertilizer contains filler, your fertilizer distributor should be able to replace the filler with gypsum. In this manner, gypsum applications would then be a regular part of your nutrient applications with very little appreciable increase in cost. This method may be less expensive than sole gypsum applications, but it will require more time to achieve the same remediation effect.

P, K, and Mg

For Florida turfgrasses, the Mehlich III extracted P, K, and Mg are categorized as 'sufficient' if the values are equal to or greater than 10, 30, and 20 ppm, respectively. Thus, in Florida, a soil test can tell you when not to apply P, K, and Mg, but a soil test cannot tell you how much to apply when the soil test value is below the critical soil level. This is due to the previously mentioned lack of calibration data between soil test nutrient levels and a measured response to the application of a given element. Some soil tests may recommend P, K, and Mg application rates based upon the conversion of parts per million to pounds per acre. Theoretically, this method would increase the existing soil level to the recommended minimum. Unfortunately, this method also has not been correlated with a measured turfgrass response; therefore, this method is not a best management practice. Rather than relying upon non-evidence-based soil test recommendations to apply P, K, and Mg, UF/IFAS utilizes the soil test minimum values in combination with known turfgrass responses (Table 5.2).

TABLE 5.2: UF/IFAS soil test recommendations for P, K, and Mg based upon the Mehlich III soil test extractant and documented turfgrass responses.

Nutrient	Critical Concentration	< Critical Concentration	> Critical Concentration
P	10	Apply 1 lb of P_2O_5/1,000 sq. ft. once.	No response to P expected
K	30	Tees, Fairways, Roughs: Apply K at ½ the rate of N with your normal N application Greens: Apply K at an equal rate of N with your normal N application	No response to K expected
Mg	20	Rate unknown	No response to Mg expected

For more information, see your county Cooperative Extension Service agent (for a list of local offices: https://sfyl.ifas.ufl.edu/find-your-local-office) or the publication, *Soil Testing and Interpretation for Florida Turfgrasses* (available: http://edis.ifas.ufl.edu/SS317); for specific information on the fertilization of different turfgrasses species grown on golf courses and athletic fields, see the publication, *Recommendations for N, P, K, and Mg for Golf Course and Athletic Field Fertilization Based on Mehlich III Extractant* (available: http://edis.ifas.ufl.edu/SS404).

Soil Testing Best Management Practices

Collect soil samples accurately and consistently to provide useful soil test information over time.

Divide the course into logical components such as greens, fairways, tees, roughs, etc., for each hole.

Collect 15 to 20 soil samples randomly from each section and blend together to provide a representative, uniform soil sample.

Collect soil samples from a consistent depth based on effective root depth/landscape use (4 inches).

Use the same lab/extractant for each test in order to compare soil test results over time.

Only use soil test results to manage pH, salinity, sodicity, P, K, and Mg.

In most case, you can reduce or eliminate the application of P, K, and Mg when Mehlich III soil test critical values are equal to or greater than 10, 30, and 20 ppm, respectively.

Keep soil tests from prior years to allow you to observe changes over time.

Tissue Testing

Because of the mobility of most essential nutrients for landscape plant and turfgrass growth in Florida soils, one of the best indicators of appropriate fertilization and plant health is tissue analysis. Since turfgrass is a perennial crop, historical logs of tissue composition can be used to fine-tune a turfgrass fertilization program for optimum plant growth and minimum environmental impact. Leaf analysis, along with appearance and soil analysis, can be used to diagnose the problems and the effectiveness of a fertilization program, especially for micronutrient deficiencies. Soil nutrient analysis provides an estimation of what will be plant available throughout the upcoming growing season, whereas tissue analysis offers a precise measurement of nutrients in the turfgrass leaf tissue at the time of sampling. Potential nutrient deficiencies can be detected with leaf analysis before visual symptoms appear. Leaf analysis may provide information on induced deficiencies and inferences on plant uptake.

Methodology

Clippings can be collected for tissue analysis during regular mowing. It is essential that the clippings be free of sand and fertilizer contamination. Do not harvest clippings

Turfgrass leaf tissue can be collected during normal mowing.

immediately after fertilization, topdressing, or any other cultural practice that results in significant mower pickup. Place approximately a handful of well-mixed clippings in a paper bag. Do not place the clippings in a plastic bag because the clippings may begin fermenting prior to drying.

If facilities exist at your location, dry the collected clippings at approximately 70° C (158° F) for 24 hours, and then mail them to your preferred analytical laboratory for analysis. If you do not have drying facilities, ship the samples, preferably overnight, to the analytical laboratory. Even if placed in a paper bag, if a sample is allowed to sit for more than a couple of days the tissue begins to ferment and the value of the sample for analytical purposes is lost.

Sample Contamination

Turfgrass clippings that have been recently sprayed with micronutrients for fungicidal or nutritional purposes should not be used for micronutrient analysis. Washing recently unsprayed clippings to remove soil and dust particles is recommended prior to sending the samples to the lab for analysis. If you wash one collection of clippings and not all, the nutritional analyses may not be comparable because the concentration of some nutrients, such as K, in tissue is highly mobile and a portion of the K may be removed during washing. Unwashed samples may appear to have a much higher concentration than the washed samples, and you may suspect a deficiency in the washed samples when in fact an adequate supply of K exists.

Interpretation of Results

At least five unique methods are used to interpret turfgrass tissue nutrient values. Four of these methods (critical nutrient range, diagnosis and recommendation integration system, compositional nutrient diagnosis, and Macy's concept) use yield to determine if a nutrient concentration is sufficient. Because obtaining maximum turfgrass yield is often not desirable, the use of these interpretations is questionable. However, if maximizing yield is of primary importance, then the interpretation based upon these methods can be useful in managing nutrient applications.

UF/IFAS turfgrass faculty use a fifth method, referred to as 'reference ranges.' Reference ranges provide the range of nutrients that exist within 95% of healthy turfgrass populations. Reference ranges are applicable to turfgrasses because it uses turfgrass quality as the primary metric rather than yield. UF/IFAS turfgrass faculty have developed reference ranges for St. Augustinegrass and fairway bermudagrass (Table 5.3). The two reference range values are the lower and upper 2.5 percentile of healthy turfgrass. As turfgrass nutrient concentrations approach these values, that nutrient becomes of greater concern of limiting turfgrass quality. Once a nutrient level drops below the lower 2.5 percentile, an application of that nutrient may be warranted. When nutrient concentrations exceed the upper 2.5 percentile, the turfgrass may be receiving excessive or toxic levels of that nutrient and a reduction in that nutrient may be recommended. However, other causes may need to be considered. If a change in fertilization is indicated, the adjustment should be reasonable.

The intent is to find the correct nutrient management level that maintains nutrient concentrations in turfgrass tissue within the reference range. This nutrient management strategy leads to proper fertilization and a reduction in possible adverse environmental and economic impacts.

TABLE 5.3: Nutrient ranges for warm-season turfgrass species

	Bermudagrass*	St. Augustinegrass*	Seashore Paspalum**	Centipedegrass**	Zoysia**
	%				
N	1.95-4.63	1.53-2.41	2.80-3.50	1.5-2.9	2.04-2.36
P	0.15-0.43	0.30-0.55	0.30-0.60	0.18-0.26	0.19-0.22
K	0.43-1.28	1.1-2.25	2.00-4.00	1.12-2.50	1.05-1.27
Ca	0.15-0.63	0.24-0.54	0.25-1.50	0.50-1.15	0.44-0.56
Mg	0.04-0.10	0.20-0.46	0.25-0.60	0.12-0.21	0.13-0.15
S	0.07-0.20	0.15-0.48	0.20-0.60	0.20-0.38	0.32-0.37
Na	0.05-0.17	0.00-0.17	–	–	–
	ppm				
Fe	29.99-131.23	8.32-137.16	50-500	102-221	188-318
Mn	6.82-29.78	47.53-183.17	50-300	35-75	25-34
Zn	15.60-44.96	30.93-73.73	20-250	17-40	36-55
Cu	0.00-15.17	0.0-15.79	5-50	2-7	2-4
B	0.00-16.32	0.69-9.05	5-60	5-10	6-11
Mo	–	–	0.5-1.0	0.14-0.30	0.12-0.30
Al	5.01-26.37	0.00-206.08	–	–	–

* Reference ranges — nutrient ranges of 95% of acceptable turfgrass in Florida.

** Sufficiency ranges (Bryson et al., 2014)

For more information, see your county Cooperative Extension Service agent or the publication, *Tissue Testing and Interpretation for Florida Turfgrasses* (available: https://edis.ifas.ufl.edu/ep539).

Tissue Testing Best Management Practices

Collect tissue samples during regular mowing.

Collect tissue prior to any potential contamination event. Events may include fertilization, topdressing, pesticide applications, etc.

Place tissue in paper bags, not plastic.

Allow tissue samples to air-dry at 70°C or mail overnight if possible.

Establish management areas and sample poor-quality turfgrass separately from higher-quality turfgrass.

Collect a tissue sample at the first sign of nutrient stress.

Sample tissue frequently to allow a more accurate assessment of your turfgrass nutrient status changes over time.

Sample tissue two to four times per year on greens and one to two times per year on tees and fairways. Keep tissue test results from prior years to allow you to observe changes over time.

Nutrition for Golf Course Turfgrasses

Efficient nutrient management programs are created with a fundamental understanding of the Florida fertilizer label, fertilizers, and the role of each nutrient in the plant. Some nutrients are sufficient in nature and do not require additional applications to achieve acceptable playing conditions, whereas other nutrients are limited in nature and may require regular applications to sustain acceptable turfgrass health. Additionally, many elements are not elements of environmental impairment, whereas other elements can alter our ecosystem, if improperly managed. This section provides the basic information necessary to make informed decisions regarding nutrient applications to Florida golf courses.

The Florida Fertilizer Label

Terms

Legally, in Florida, "fertilizer" means any substance that contains one or more recognized plant nutrients and promotes plant growth. Fertilizer "grade" or "analysis" is the percent by weight of N, P, and K guaranteed by the manufacturer to be in the fertilizer. Nitrogen is expressed as N, phosphate as P_2O_5, and soluble potash as K_2O. The percent sign is not used, but instead the numbers are separated by dashes, and the order is always N, P_2O_5, and K_2O (for example, 15-0-15).

Fertilizers are manufactured from a wide variety of materials to supply required plant nutrients. Once these materials are mixed, it becomes difficult to distinguish the materials present, and consumers may be unaware of what they are purchasing. To protect consumers, the Florida legislature enacted the first fertilizer law in 1889 and has amended it many times since enactment. These laws regulate the manufacture and sale of fertilizers in Florida.

Florida law requires that the manufacturer purchase and affix a label (Figure 5.4, next page) to each bag, package, container, or lot of fertilizer offered for sale in the state. The law requires that each label show specific information about the analysis and composition of the mixture or material.

FIGURE 5.4: The Florida Fertilizer Label

BRAND NAME		
GRADE X-X-X		
Guaranteed Analysis		
Total Nitrogen (N)		______%
______%	Nitrate Nitrogen	
______%	Ammoniacal Nitrogen	
______%	Other/Water Soluble Nitrogen	
______%	Urea Nitrogen	
______%	Water Insoluble Nitrogen	
Available Phosphate (P_2O_5)		______%
Soluble Potash (K_2O)		______%
Chlorine, (Cl) Not More Than		______%
______%	Magnesium as (Mg)	
______%	Water Soluble Magnesium as (Mg)	
______%	Chelated Magnesium (Mg)	
______%	Manganese as (Mn)	
______%	Water Soluble Manganese as (Mn)	
______%	Chelated Manganese as (Mn)	
______%	Copper as (Cu)	
______%	Water Soluble Copper as (Cu)	
______%	Chelated Copper as (Cu)	
______%	Iron as (Fe)	
______%	Water Soluble Iron as (Fe)	
______%	Chelated Iron as (Fe)	
______%	Zinc as (Zn)	
______%	Water Soluble Zinc as (Zn)	
______%	Chelated Zinc as (Zn)	
______%	Combined Sulfur as (S)	
______%	Free Sulfur as (S)	
Derived from: (Actual materials and in forms used in the fertilizer mixture, e.g., diammonium phosphate, urea, potassium chloride, magnesium sulfate, manganese nitrate, etc.)		
Manufactured by: Name (FXXXX) City, State & Zip		
Net Weight ______ lb		

Total Nitrogen

Nitrogen may be included in the form of nitrate-nitrogen, ammoniacal-nitrogen, water-soluble nitrogen, urea-nitrogen, and water-insoluble nitrogen. A statement of the percentage of each form present in the fertilizer must be given.

Water-insoluble nitrogen originally identified such natural organic materials as dried blood and tankage. Recently, however, many forms of water-insoluble nitrogen have been developed so that now any water-insoluble source is included in this figure. Insoluble sources may be materials such as urea-formaldehyde, isobutylidene diurea, magnesium ammonium phosphate, or other similar materials. The natural organic sources become available by microbial action that converts the N first to ammonium and then to nitrate. Some water-insoluble nitrogen forms are rendered insoluble by coating with sulfur or plastic-based materials, by chemical combination with other elements, or by inhibiting the activity of microorganisms that release the nitrogen from insoluble forms. Many of these sources are treated in such a way as to provide for a long continued release of nitrogen. The listing of source materials in which availability of nitrogen is controlled through slow hydrolysis of water-soluble organic compounds shall constitute a claim of slow or controlled release of a nutrient, and a guarantee for such nutrient sources is required.

Available Phosphoric Acid

Available phosphoric acid is the water-soluble plus the citrate-soluble phosphorus (soluble in weak acids). The soil solution is a weak acid, in which the citrate-soluble materials are readily made available for plant use. The guaranteed available phosphoric acid is the oxide equivalent of the actual phosphorus in the mixture. Elemental phosphorus makes up 44% of the amount of available phosphoric acid guaranteed in the mixture. The actual form of phosphorus is the mono-basic phosphate ion (H_2PO_4-), which is water soluble, or the dibasic phosphate ion (H_2PO_4-), which is citrate soluble. The terms "available phosphorus" or "available phosphate" may be used instead of "available phosphoric acid".

Soluble Potash

Soluble potash is the oxide equivalent of the potassium present in the mixture. Elemental K makes up 83% of the guaranteed soluble potash in the mixture. The actual form of K in the fertilizer is the potassium ion, K+. Soluble potash is that portion of the potash contained in fertilizer or fertilizer materials which is soluble in aqueous ammonium oxalate, aqueous ammonium citrate, or water, according to an applicable AOAC International method. All of the K guaranteed on a fertilizer label is soluble K, which implies that it goes into solution readily when applied to the soil and that it is immediately available for plant uptake. The term "soluble potassium" may be used instead of "soluble potash."

Total Available Primary Plant Nutrient

This is the sum of the total N, available phosphoric acid, and soluble potash. These are defined by the fertilizer law as the primary plant nutrients. The three figures, such as 10-30-10, are known as the guaranteed analysis of the material. The sum of these, the total available primary plant nutrient, makes up the grade of the mixture.

Chlorine, Not More Than

Chlorine must be stated as "not more than" because this element may be toxic and/or reduce quality and yields of many agronomic crops. Fortunately, turfgrasses have not been observed to respond negatively to normal levels of chlorine found in most fertilizers. However, it is required that the statement "chlorine, not more than" be placed on the label so that the purchaser is aware of the content of this material in the mix.

Derived From

The "derived from" statement lists the actual source materials used to create the fertilizer blend. In most cases, the value and influence of a fertilizer for a turfgrass is determined by a combination of the guaranteed analysis and the "derived from" statement. Thus, understanding the "derived from" statement is critical.

Secondary Plant Nutrients

The guaranteed analysis shall specify that secondary plant nutrients are present in elemental form. Magnesium, iron, zinc, copper, and manganese must be expressed as "total" and/or "water-soluble"/"soluble" depending upon the source materials formulated in the product. Chelated elements are guaranteed separately when a chelating agent is denoted in the derivation statement below the guaranteed analysis. Sulfur must be guaranteed as sulfur (combined) and/or sulfur (free) in the elemental form, depending upon the source material in the formulation.

A "derived from" statement is also required to give the sources of secondary elements contained in the mixture, such as magnesium sulfate and manganese sulfate. When a chelated form of a plant nutrient is claimed in addition to another form of the same element, the chelated portion shall be guaranteed separately.

Some fertilizer mixtures contain pesticides. These mixtures must have a yellow label with lettering in a contrasting color to be conspicuous. Only the pesticides allowed (by law) may be included in the mixtures and in amounts not to exceed the maximum allowed. The label must include the crops for which the pesticide(s) are recommended and directions for use. It must also include the required precautionary statements. It states the percent active ingredient by weight and states the actual number of pounds per ton in the mixture.

Slow- or Controlled-Release Nutrients

A slow-release fertilizer is defined as any fertilizer that releases its nutrients at a slower rate relative to a reference soluble fertilizer. When one or more slow- or controlled-release nutrients are claimed or advertised, the guarantees for such nutrients shall be shown as a footnote following the listing of source materials and shall be expressed as percent of the actual nutrient.

The listing of source materials providing slow- or controlled-release characteristics by controlling the water solubility of a naturally soluble material (as coating or occlusion) or through slow hydrolysis of water-soluble organic nitrogen compounds shall constitute a claim of controlled release nutrient, and a guarantee for such nutrient is required.

No guarantee, claim, or advertisement shall be made or required when a slow or controlled release nutrient is less than 15% of the total guarantee of that nutrient.

For more information on the Florida fertilizer label, see the publication, *The Florida Fertilizer Label* (available: http://edis.ifas.ufl.edu/ss170).

Macronutrients

Once the value of soil testing, tissue testing, and the fertilizer label is understood, a basic knowledge of the role and fate of applied nutrients in the turfgrass system is essential to efficient nutrient management. The primary macronutrients—nitrogen, phosphorus, and potassium (N, P, and K, respectively)—receive the greatest attention because they are typically deficient in soils and often require regular applications to sustain acceptable turfgrass. Golf and athletic turfgrass is responsible for only 5% of the total amount of N applied in Florida. Despite having a low N footprint, golf course superintendents must handle N with care to minimize any environmental risk. Excessive application of nutrients can lead to algal blooms and stimulate the growth of noxious plants in lakes and streams. This can reduce the amount of oxygen available for game fish such as bass and sunfish, while promoting less-desirable fish.

Nitrogen

THE ROLE OF NITROGEN

Nitrogen is one of the most important elements turfgrass managers apply to turfgrasses. Turfgrass almost always responds to N applications by increasing growth and green color. This predictable response is due to N supply and demand. In many cases, the soil supply of N is low and the turfgrass demand is high because N is required to create amino acids and proteins. In addition to affecting turf color and growth rate, N influences thatch accumulation, the incidence of diseases and insects, cold tolerance, heat and drought stress, nematode tolerance, lime requirements, and, most important to the player, putting speed. Turfgrass managers often measure N needs based on turf color, density, and/or clipping amount. However, it is the effect of N on other aspects of turfgrass management that often influences a superintendent's success or failure.

Improper N fertilization can have an undesirable effect on turfgrass rooting. Turfgrass, in general, uses carbohydrates stored in its roots to support shoot growth. These are replenished by products resulting from photosynthesis. If heavy amounts of N are used, excessive shoot growth occurs at the expense of roots. As a result, roots may not have enough recovery time to replenish their carbohydrates before being forced to support excessive shoot growth when N is reapplied. It has been observed that bermudagrass maintained at low N levels has up to twice as much root growth as that maintained at high levels.

In addition to forcing excessive shoot growth at the expense of root growth, improper N fertilization can also cause physiological changes such as cell-wall thinning, succulent tissue growth, and reduced root carbohydrate levels. Accordingly, increased susceptibility to stress makes the plant less hardy.

When plants are deficient in N, the initial leaf color is an overall pale yellow-green color, called chlorosis. Chlorosis reflects a reduction in chlorophyll production. Nitrogen is a part of chlorophyll and is thus essential in its manufacture. Chlorosis usually appears first on the lower (older) leaves, eventually changing to yellow as the deficiency symptoms progress to the newly-emerged leaves. In addition, the plant's growth rate and density may decrease, resulting in weak turf that has difficulty recovering from damage.

Other factors that also contribute to, or may cause, symptoms similar to those of N deficiency are a deficiency in nutrients such as iron, sulfur, or manganese. Florida's sandy soils, many of which are alkaline, often are lacking these elements. To the untrained observer, the symptoms appear similar to a lack of N. Compounding the problem are high populations of nematodes and soils with poor water-holding capacity; these can result in reduced rooting and increased water stress. Therefore, turf managers should determine the cause of chlorosis and turf thinning before indiscriminately applying a N or micronutrient fertilizer.

In general, N has a direct impact on turf growth and recovery from injuries such as divots or ball marks. However, the clipping matter produced can be a poor indicator of N needs. If adequate color and density are present, do not universally use clipping matter or weight to gauge N needs. If turf begins to thin or excessive damage occurs, turf growth and density may become relatively good indicators of N needs.

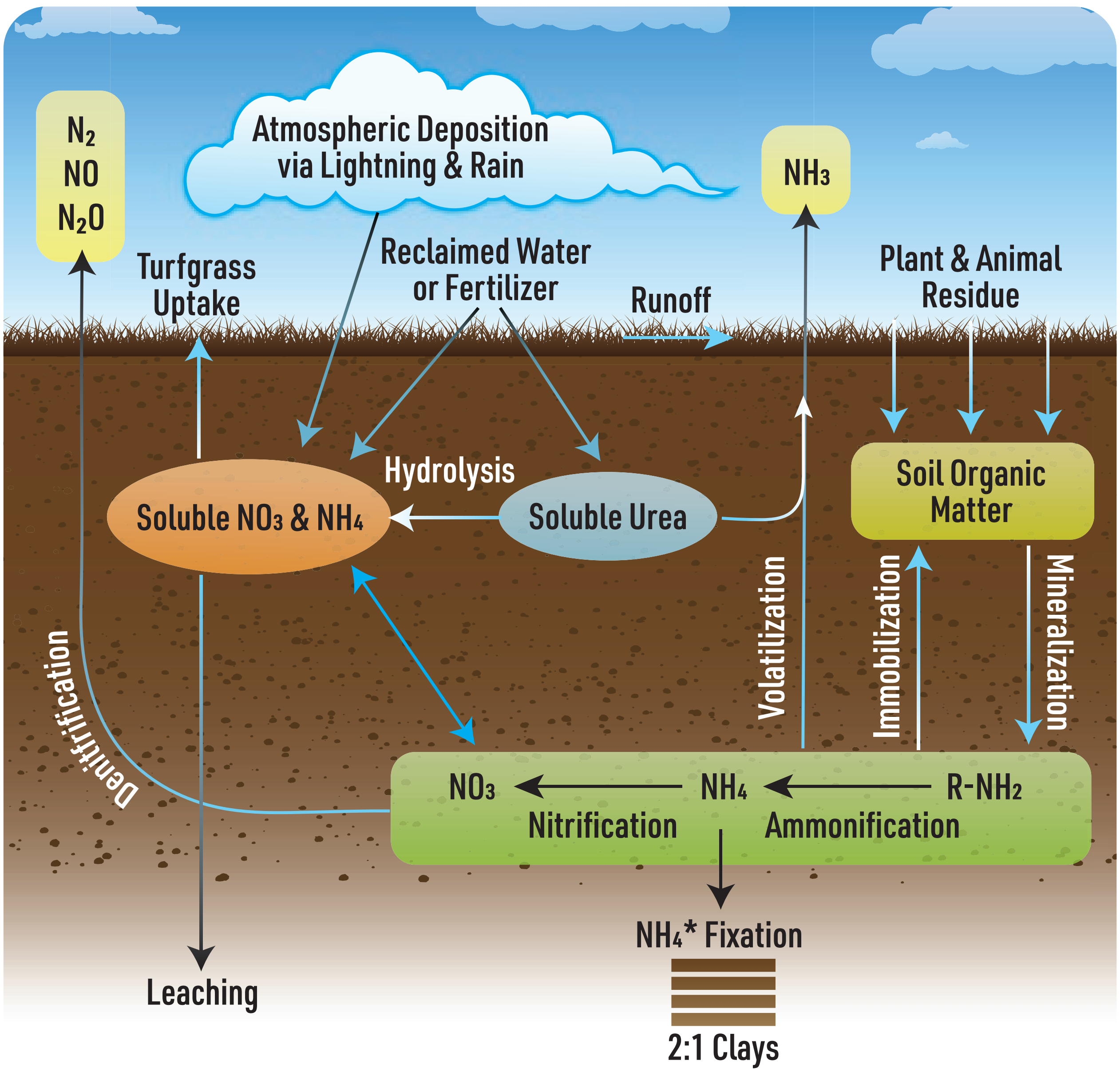
FATE AND TRANSFORMATION OF NITROGEN

Turfgrass Uptake

The objective of all N applications to turfgrass is sustainable turfgrass uptake and the resulting increase in turfgrass growth and health. Numerous factors may influence turfgrass uptake of N including but not limited to: turfgrass species, season, N type, N rate, and moisture management.

The percent of applied N recovered in turfgrass tissue can vary depending upon turfgrass species. Species that possess a greater density of roots deeper in the soil profile tend to take up greater amounts of applied N compared with turfgrasses with less dense root systems. Clearly, greater uptake occurs because a turfgrass with a greater quantity of roots has an increased chance for its roots to intercept and uptake N. St. Augustinegrass and bermudagrass have been documented to consume greater percentages of applied N than centipedegrass, bahiagrass, and zoysiagrass. Even cultivars within the same species may differ in their ability to consume applied N. Although the exact cause is not fully known, it is reasonable to postulate that the differences among cultivars is due to different levels of evapotranspiration (ET), dry matter production, or root masses, which would result in different amounts of applied N being consumed.

FIGURE 5.5: The nitrogen cycle in Florida turfgrass systems

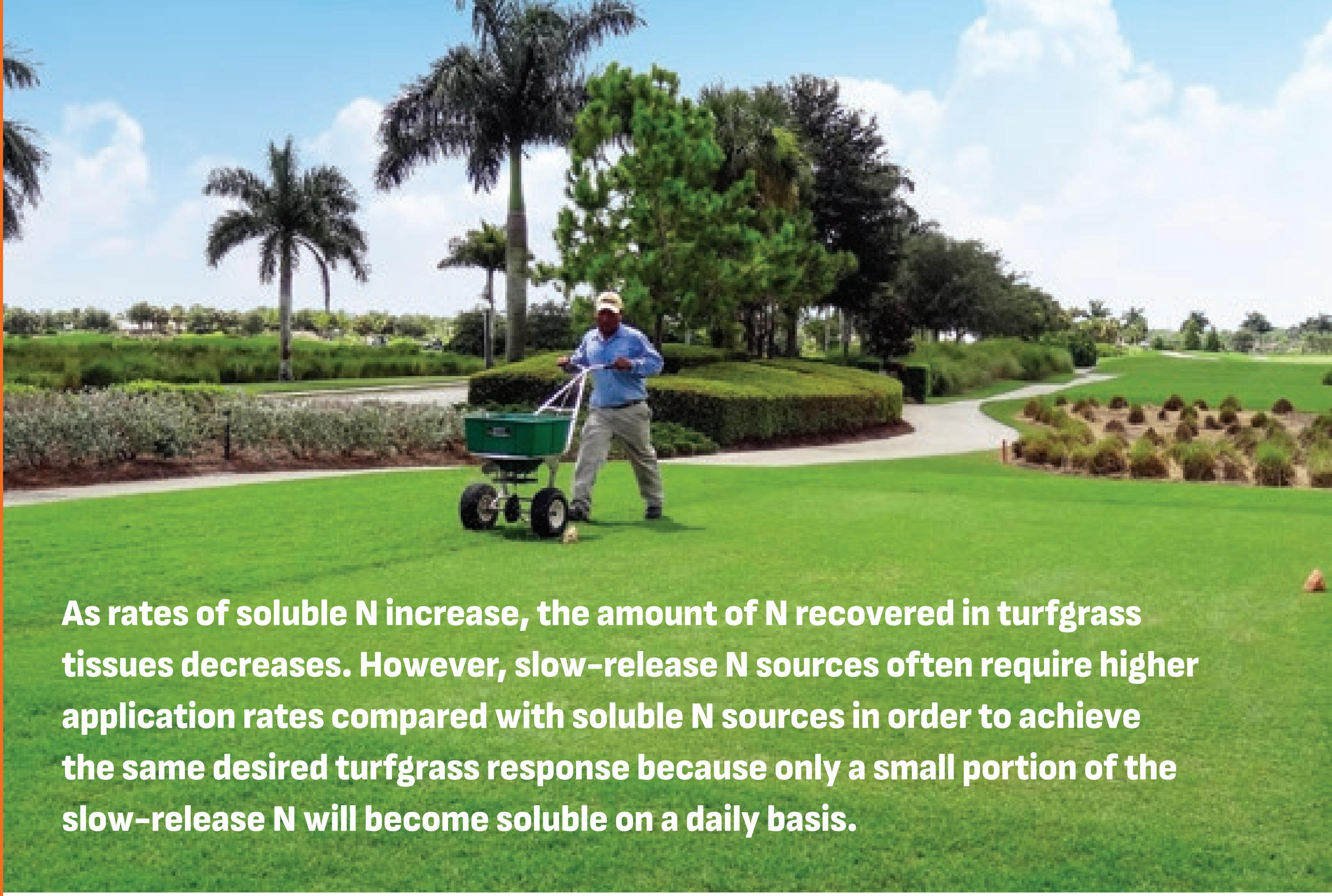


Like most plants, the change in climatic seasons can have a dramatic influence on plant growth and nutrient uptake. During the winter in northern Florida, most warm-season turfgrasses will exhibit a decrease in growth and may enter dormancy.

Even in southern Florida, reduced turfgrass growth will occur during the winter but true dormancy has not been reported. As turfgrass growth declines, the amount of N needed by the turfgrass also declines. Thus, consumption of applied N can be lower in the winter than in the summer. Nitrogen applications to dormant or semi-dormant turfgrass has not resulted in N leaching unless excessive rainfall occurs, thus the applied N will remain in the soil until the plant consumes it or until rainfall/irrigation moves the N beyond the rootzone. However, the agronomic advantages to applying N to dormant turfgrasses are low relative to the environmental risk. Thus, N applications to dormant and semi-dormant turfgrasses in Florida is not recommended.

Nitrogen fertilizers differ in their form of N and their release characteristics. These differences can lead to different quantities of N absorbed by turfgrass. Nitrogen applied as NH_4 may result in less N uptake than N applied as NO_3 due to the tendencies of NH_4 to volatilize and be lost from the soil/turfgrass system. A larger percentage of N from slow-release N fertilizers may be taken up by the turfgrass compared with soluble N sources. Soluble N is immediately available to follow any of the potential paths in the soil/turfgrass system including leaching and volatilization, while only small portions of N from slow-release N fertilizers become soluble at any given time. To this end, slow-release N fertilizers can increase N uptake by as much as 300% compared with soluble N sources.

A driving factor behind UF/IFAS nutrient recommendations to turfgrass is to apply the amount of N necessary to achieve a desired turfgrass response without applying more N than the turfgrass can consume at any given time. When UF/IFAS recommended N rates are followed, turfgrass uptake of applied N ranges from 40-68%. When small quantities of N are applied, very little N has an opportunity to escape turfgrass assimilation.



As rates of soluble N increase, the amount of N recovered in turfgrass tissues decreases. However, slow-release N sources often require higher application rates compared with soluble N sources in order to achieve the same desired turfgrass response because only a small portion of the slow-release N will become soluble on a daily basis.

Consequently, higher rates of slow-release N sources may result in greater percent uptake of applied N than lower rates. Additionally, a single application of slow-release N at a high rate may result in the same N uptake as soluble N applied as a split application. Therefore, slow-release N sources may be applied at higher rates than soluble N sources so long as the single application rate and total annual N applied do not exceed UF/IFAS recommendations.

Moisture management greatly influences plant uptake of applied N. Most N is taken up by the plant via the soil solution. Thus, when the soil water content exceeds the soil water holding capacity, N in the soil solution may be moved below the rootzone, which results in reduced plant uptake. On the other hand, when insufficient water is applied, the turfgrass may enter a state of drought-induced dormancy in which the turfgrass reduces water and N uptake in order to survive. Thus, careful consideration should be given to applying sufficient water to maintain acceptable turfgrass, but not applying more water than can be retained by the soil. Generally, rain sensor, soil water sensor, and evapotranspiration controllers apply water more effectively than automatically timed controllers.

Mineralization

Mineralization is the process through which soil microorganisms break down or transform organic matter, organic fertilizers, and some slow-release fertilizers to provide available ammonium and nitrate forms for plants. Mineralization is a three-step process involving aminization, ammonification, and nitrification. In aminization and ammonification, proteins, amines, and amino acids from organic matter or humus are converted to ammonium, a source of N used by plants. Ammonium nitrogen (NH_4^+) is then absorbed by plants or further transformed into nitrate (NO_3^-).

(c) Nitrification

The transformation of ammonium nitrogen to nitrate nitrogen is referred to as nitrification. Nitrification depends on environmental conditions that favor soil microbiological activity. Warm temperatures, adequate soil moisture, and soil oxygen are necessary for this activity. However, nitrification does not readily occur under extreme temperatures (e.g., below 40° F. or above 105° F.), in saturated or poorly aerated soil, in excessively dry soil, or in low-pH soil (< 4.8). Under these unfavorable conditions, microorganisms do not perform nitrification, and ammonium may accumulate. Ammonium nitrogen also may become toxic to turfgrasses grown under cool, low-light conditions, such as those in late winter or early spring.

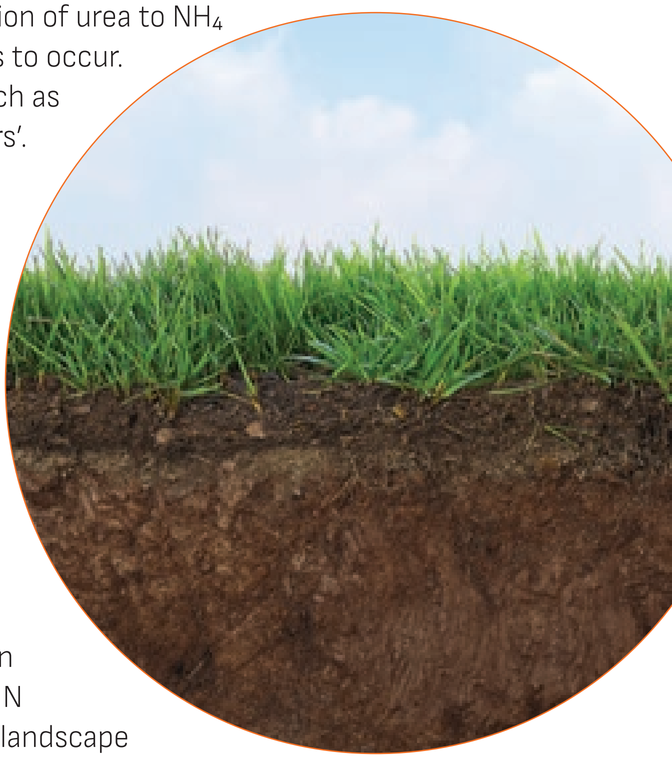
Nitrate nitrogen is readily soluble in water and may be repelled by negatively charged exchange sites of the soil components. Therefore, unless grasses rapidly use this form, it may be lost through leaching if excessive water is applied. This may especially be true during the winter months, when grass is not actively growing. In addition to nitrate and water, hydrogen ions (H^+) also are produced during nitrification, and a reduction in soil pH may be observed. This reduction is especially acute when a high rate of N is applied on sandy soils that are low in calcium. Such soils are poorly buffered against pH changes induced through the acidifying effect of nitrification.

Denitrification

Denitrification is the microbial conversion of NO_3 to N_2 gas. The conditions that favor denitrification are wet, organic soils containing NO_3. Similar to volatilization, denitrification converts N into a gas reducing the amount of plant available N and the amount of N available to move to non-target locations. Denitrification requires N to be in the NO_3 form, which is then reduced as oxygen is removed. Denitrification is greatly influenced by increased soil moisture, which results in an oxygen deprived soil and hastens the removal of oxygen from NO_3 by denitrifying bacteria. When soil oxygen levels drop below 2%, denitrification is increased. However, denitrification may still occur in aerated soils due to the saturation of internal soil microsites. Turfgrass studies designed to determine denitrification rates in Florida are limited. However, in sandy, well-drained soils, denitrification is normally low and accounts for <1% to 5% of applied N, but could approach 94% when soil temperature exceeds 30°C (86°F). Although already low in Florida turfgrass systems, denitrification may be further reduced by using nitrification inhibitors or slow-release N, which may reduce the amounts of NO_3-N in the soil. Nitrification inhibitors should contain either 2-chloro-6-[trichlor-omethyl] pyridine (Nitrapyrin) or dicanydiaminde (DCD) as these are the only two compounds that have reduced denitrification in field and laboratory studies. Similar to their effect on volatilization, slow-release N fertilizers may reduce denitrification by delaying the release of their N into the N cycle.

Volatilization

Volatilization is the conversion of N to ammonia. The factors influencing conversion of N to a gas include: quantity of soluble N as urea or ammonium, temperature, high soil pH, low soil moisture, and low cation exchange capacity. Nitrogen converted to ammonia is lost to the atmosphere and is no longer available for turfgrass uptake. While volatilization is a distinct disadvantage to the turfgrass, the loss of N as ammonia decreases the amount of N available to move into nearby water bodies via leaching or runoff. However, N volatilization may increase the amount of N returned to the earth via rainfall and atmospheric deposition. Because N is commonly applied as urea, volatilization can be a major contributor to N lost from turfgrass systems with losses ranging from <1% to as high as 60% of applied N. This percentage can be reduced by using a slow-release urea, urease inhibitors, or by irrigating the turf immediately after fertilization. Slow-release N sources are defined as any N source that releases its N at a slower rate compared with a reference soluble N source. Urease inhibitors slow the conversion of urea to NH_4 by inhibiting urease, the enzyme necessary for urea hydrolysis to occur. In so doing, the rate of volatilization can be reduced by as much as half. Urease inhibitors may be marketed as 'Nitrogen Stabilizers'. Numerous products marketed as urease inhibitors have been independently tested by land-grant institutions. Only the nitrogen stabilizers containing N-(n-butyl) thiophosphoric acid triamide (NBPT) or N-(n-propyl) thiophosphoric acid triamide (NPPT) have consistently reduced volatilization compared with urea alone. Slow-release N fertilizer also reduced volatilization not through urease inhibition, but by delaying the release of urea into the N cycle.

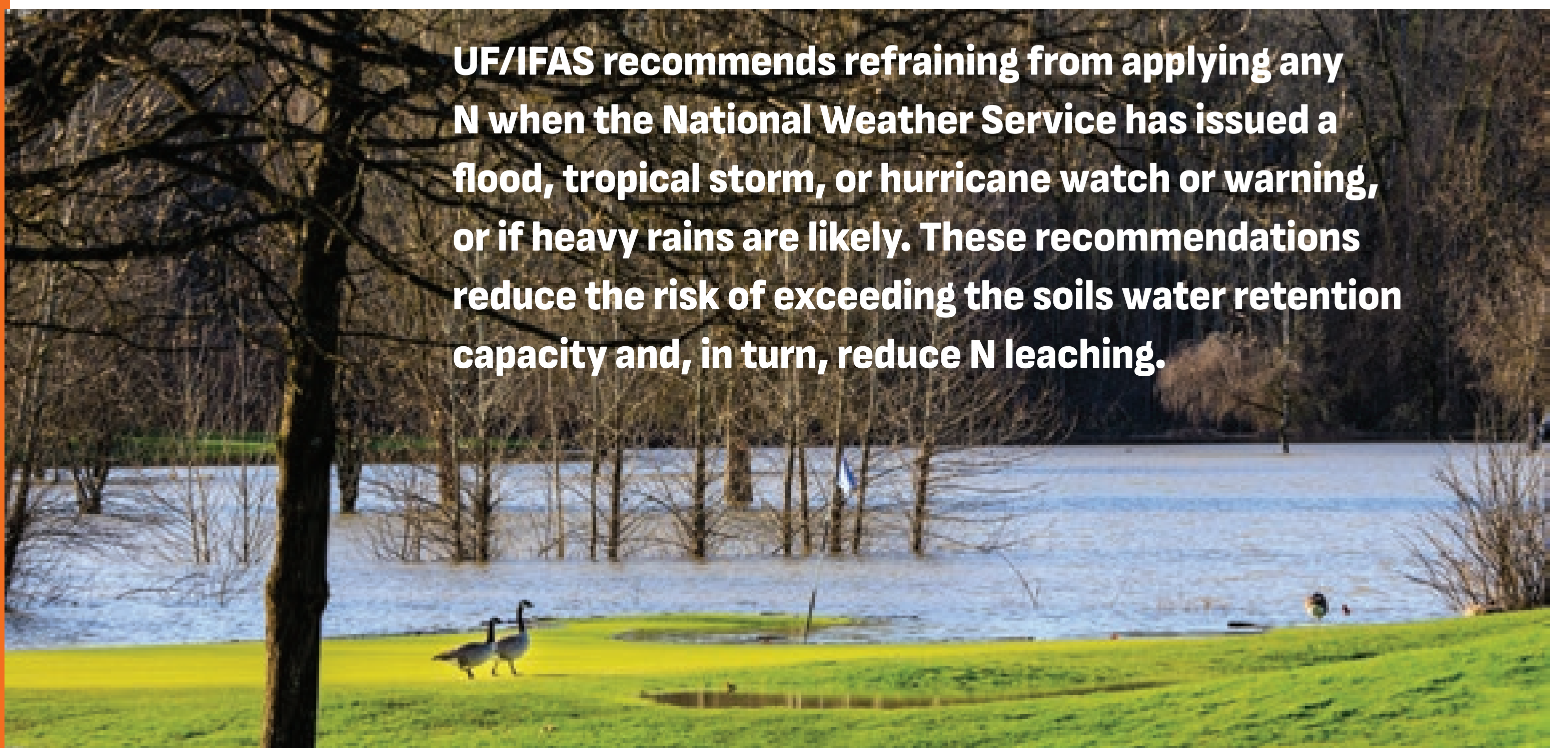


Leaching

Leaching is the process that moves soluble N below the rooting zone. Nitrogen leaching in turfgrass systems occurs at the moment soluble N moves below the deepest root. When turfgrass is fertilized according to UF/IFAS recommendations, N leaching is normally low and comparable to or less than other landscape plants. As with other fates of applied N, the exact amount of N that will leach is difficult to determine. However, it is possible that 0 to 55% of applied N could be leached, with the higher percentages occurring when UF/IFAS recommendations are not followed. When N leaching does occur, it is usually a factor of the turfgrass species, irrigation management, N source, N rate, or stressed turfgrass.

Direct comparisons of N lost through leaching related to turfgrass species indicate that less N leaches through 'Raleigh' St. Augustinegrass than 'Empire' zoysiagrass, 'Meyer' zoysiagrass, 'Emerald' zoysiagrass, centipedegrass, 'Tifway' bermudagrass, and common bermudagrass. The influence of turfgrass species on N leaching losses is largely a factor of the turfgrass root system. Deeper-rooted turfgrasses tend to reduce N leaching losses compared with shallow-rooted turfgrasses. Management practices that encourage deep rooting, such as deep, infrequent irrigation, are factors that shape UF/IFAS recommendations. Increased N leaching has been documented when N is applied within the first 60 days of planting sod. After the sod has been planted for 60 days, N leaching is reduced and is a result of increased root growth. Based upon these results, UF/IFAS recommends N applications to newly sodded turf commence 60 days after the sod has been planted. This recommendation allows the sod to develop a root system prior to fertilization and thus, minimizes the risk of N leaching.

The movement of water through the soil has a profound influence on N leaching. Once any nutrient becomes soluble in the soil solution, that nutrient is subject to the movement of water. Therefore, it is crucial to minimize any movement of water beyond the turfgrass rootzone. Increased water movement may be a result of excessive irrigation or fluctuations in rainfall due to changes in seasons, which may result in more water being applied to the soil than the soil can retain. Moisture sensor or ET-based irrigation is more effective than daily irrigation at applying the amount of water the turfgrass needs without exceeding the rootzone's water holding capacity. Throughout the year, N leaching can be highest in February–March, reduced in April–May, and the lowest in June–July. The reduction in N leaching from winter to summer is largely a factor of increased plant growth and increased ET, which reduce the amount of N in the soil solution and the amount of moisture in the rootzone, respectively. In each season, sensor-based irrigation can reduce N leaching by 2 to 28-fold that of daily irrigation.



UF/IFAS recommends refraining from applying any N when the National Weather Service has issued a flood, tropical storm, or hurricane watch or warning, or if heavy rains are likely. These recommendations reduce the risk of exceeding the soils water retention capacity and, in turn, reduce N leaching.

When applied according to UF/IFAS recommendations, soluble N applied to a healthy stand of turfgrass may not leach more N compared with N lost naturally from unfertilized turfgrass. Additionally, slow-release N sources further reduce N leaching losses compared with soluble N sources. Essentially, slow-release N sources delay the release of N into the N cycle (Figure 5.5). Over time, small portions of N are released, which increases the likelihood of plant uptake of applied N and decreases potential for N leaching losses. Blending soluble N sources with slow-release N sources also results in reduced N leaching losses. Generally, differences in N leaching losses among slow-release N sources are negligible assuming they are applied at the same time and rate. However, organic N sources and polymer-coated N sources may result in the least amount of N leaching losses compared with other slow-release sources. Enhanced efficiency fertilizers, such as nitrification and urease inhibitors, do not delay the release of N into the N cycle and, thus, result in similar N leaching losses as other soluble N sources.

Increasing the rate of applied N beyond the rate recommended by UF/IFAS can increase the risk of N leaching losses. UF/IFAS turfgrass nutrient recommendations take into account the turfgrass need for N and the potential impact on the environment. UF/IFAS nutrient recommendations are often 50–75% less than the amount of N necessary to increase N leaching losses above the natural environment applied to a healthy stand of turfgrass. Thus, current rates are considered conservative and exceeding these rates is unnecessary because any further increase in turfgrass growth or quality is minimal and could come at a cost to the environment.

As previously mentioned, N applied according to UF/IFAS recommendations to healthy, growing turfgrass has a low probability of leaching. However, when turfgrass is stressed, N leaching can increase. Normally, stresses manifest themselves as reductions in turfgrass density and growth, which correspond to a reduction in N uptake. These stresses are largely environmental and are caused by pests, late-season frosts, and changes in season. However, stresses can also be anthropogenic — caused by misapplications of nutrients or pest control products. When stresses occur, further applications of N may not cure the problem and may, in fact, exacerbate the problem and increase N leaching.

Runoff

Runoff is defined as the lateral movement of N beyond the target location. Runoff may occur above or below the soil surface but always occurs above the deepest root. Nitrogen lost via runoff may be influenced by topography, soil type, soil compaction, soil moisture, rainfall, and fertilizer type. Because Florida soils are predominantly sand-based and have a high water infiltration capacity, the movement of water across the soil surface is far less common than the movement of water into the soil. Thus, in Florida, runoff studies are less common than leaching studies because the few runoff studies that do exist report that little to no runoff occurs. In Florida, when N is applied on steep slopes subject to intense irrigation rates, N found in runoff has been reported to be less than 0.1% of that applied. This evidence does not discount the probability that runoff could occur under different conditions.

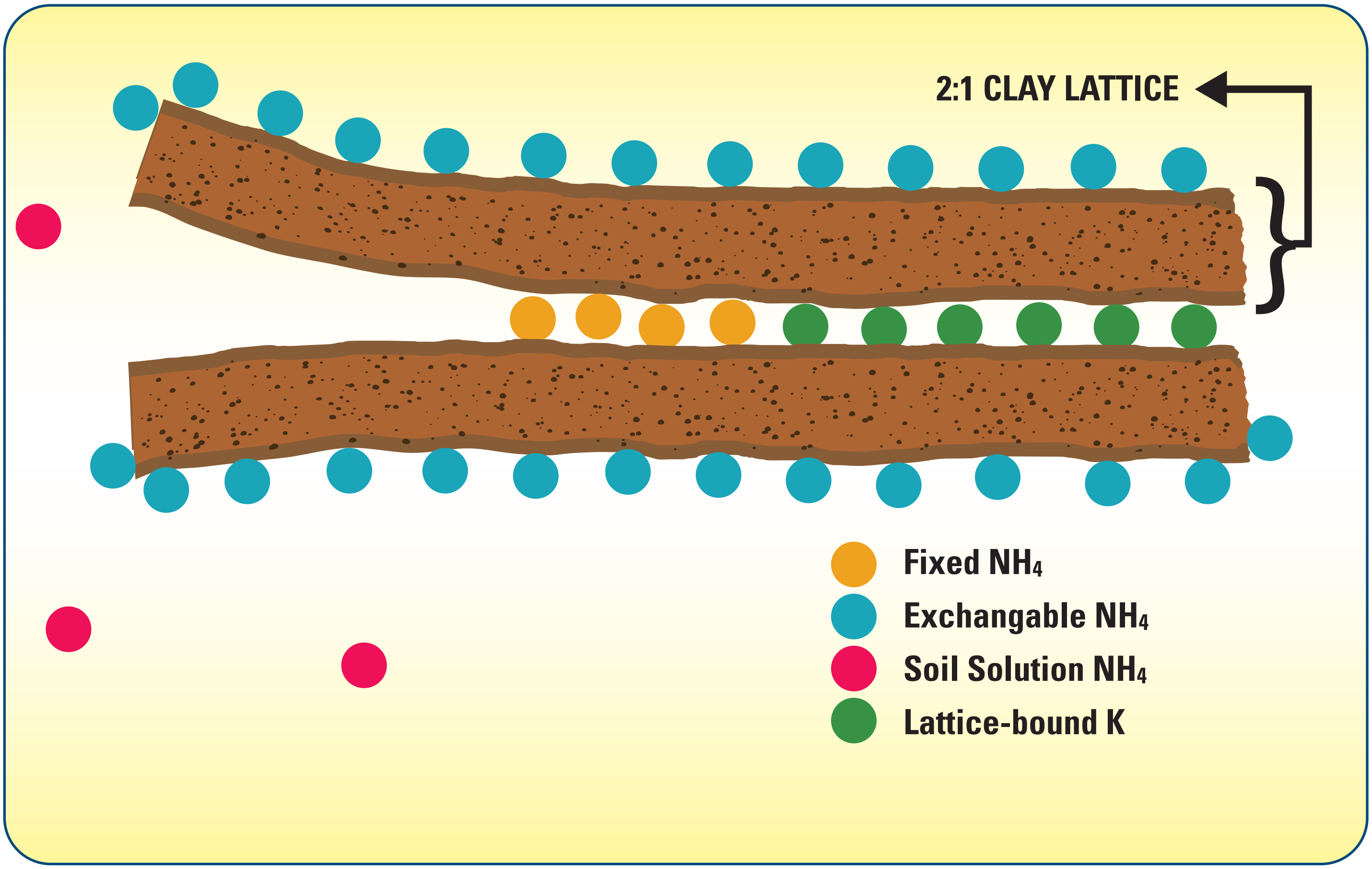
Soil Retention, Immobilization, and NH_4 Fixation

The amount of N stored in the soil is dependent upon many factors, particularly fertilizer type, fertilizer rate, time of year, soil moisture, soil pH, and rainfall. The majority of soil N exists as organic N in the form of organic matter or as N that has not been released from slow-release fertilizer granules. Technically, fertilizer granules are not a component of soil stored N. However, the process of measuring soil N will also measure N from any fertilizer granules that have not yet been released. The type and amount of slow-release fertilizer will directly influence this value. Once released from the slow-release form, N may remain in the soil via anion or cation exchange. The cation exchange capacity of most Florida soils is normally less than 3 milliequivalents of positive charge and the anion exchange capacity is normally too low to measure. In Florida soils, mineralized N, N applied as urea, or N applied as NH_4 can rapidly convert to NO_3 and, because NO_3 is an anion, it is not retained by the soil. Thus, soil storage of N via cation exchange is commonly less than 10% of applied N and can be less than 2%.

Nitrogen immobilization occurs when inorganic N is converted to organic N via microbial activity. An organic form of N is simply any form of N that is bound with carbon. Like plants, microbes require N to survive, and some portion of applied N will be consumed by microbes and converted into amino acids, proteins, or some other organic form used for growth by the microbes. While in an organic form, N is not soluble and therefore is unavailable for plant uptake or loss to a water body. Organic N will remain unavailable for plant uptake until the environmental conditions change to favor N mineralization. The percentage of applied N that becomes microbially immobilized in Florida turfgrass systems will vary according to numerous factors including soil moisture, pH, and soil temperature. Little, if any, research has been conducted to determine immobilization of applied N in Florida turfgrass systems. Thus, providing an estimation is difficult. However, research conducted on turfgrass in other climates report that N immobilization may range from 15 to 26%.

Ammonium fixation occurs when NH_4 enters the layers (lattices) of 2:1 clays (Figure 5.6), becoming unavailable for plant uptake. Ammonium fixation in Florida soils is believed to contribute very little to the overall fate of applied N for two reasons. First, the content of 2:1 clays in Florida soils is normally very low and, second, NH_4 normally converts to NO_3 very rapidly. The exact percentage of applied N to Florida turfgrasses that eventually is fixed by 2:1 clay minerals is unknown. However, evidence from other agronomic systems indicates the percentage is less than 5%.

FIGURE 5.6: The ammonium ion may become bound between clay layers and be rendered unavailable for turfgrass uptake. This phenomenon is rare in Florida due to a lack of clay in most Florida soils.



Nitrogen Fertilizer Sources

Healthy turfgrass can be produced using virtually any N fertilizer. The primary difference between N sources is their cost, their release characteristics, and their influence on environmental risk. Understanding how certain N sources should be blended and applied is an essential component in an efficient nutrient management plan. In many cases, N sources are applied without regard to their release characteristics. This is an improper practice and increases the risk of negative environmental impact. Each N source (particularly slow-release forms) is unique and therefore should be managed accordingly. Applying a polymer-coated urea in the same manner one would apply a sulfur-coated urea greatly reduces the value of the polymer-coated urea. Similarly, applying 2 pounds of N from ammonium sulfate may cause burning, while applying 2 pounds of N from certain polymer-coated ureas may not provide the desired turfgrass response. Rate, application date, location, and turfgrass species all should be included in your nutrient application decision.

Soluble Nitrogen Sources

Soluble or quickly available N sources result in rapid shoot growth and greening. These occur approximately 2 to 5 days after application, peak in 7 to 10 days, and taper off to their original levels in 3 to 6 weeks, depending on the application rate and subsequent amount of water applied.

Except urea, soluble N sources have salt-like characteristics. They dissolve readily in water to form cations and anions. The greater availability of these ions corresponds to a greater burn potential for the fertilizer. Burn potential can be lowered by making applications only to dry turfgrass when air temperatures are cooler than 80° F. Watering in soluble N immediately following application further reduces the chance of burning plant tissue. Other disadvantages of using soluble N sources can be minimized by applying small amounts frequently. Rates at or below ½ lb. N per 1,000 ft^2 minimize these problems but increase application frequency and treatment costs.

Advantages and Disadvantages of Soluble Nitrogen Sources

ADVANTAGES:

- ✓ Rapid initial color and growth response
- ✓ High in total nitrogen
- ✓ Odorless
- ✓ Help to maintain satisfactory nitrogen levels if applied frequently in small amounts
- ✓ Minimum temperature dependence for availability
- ✓ Low cost per unit of N
- ✓ Versatile—can be applied in granular or liquid forms

DISADVANTAGES:

- × High potential for foliar burn, especially at higher rates and temperatures
- × Potential undesirable growth surge
- × Relatively short residual turfgrass response may be observed
- × Greater potential for N loss from volatility, leaching, and runoff

Urea

Urea is one of the most widely used N sources due to its relatively low cost and high solubility. It is formed by reacting ammonia gas and carbon dioxide. Once applied, urea is hydrolyzed and in the presence of urease is converted to ammonium carbonate. This ammonia form of N is prone to volatilization. If left on the surface and exposed to heat from the sun, the ammonium carbonate decomposes into ammonia and carbon dioxide resulting in N volatilization. Research has shown that as much as 70% of surface-applied urea can be lost through volatilization. The easiest and simplest way to avoid this volatile N loss is to irrigate with .25 to .5 inch of water shortly after urea application. Urea is nonionic when solubilized and thus will not be retained by the soil. To this end, urea-N readily leaches, especially when subjected to excessive irrigation or rainfall.

Urea has a quick initial release rate of short duration and a low foliar burn potential. Urea-based fertilizer programs for putting greens should therefore involve light applications (< ½ lb. N per 1,000 ft^2) made frequently (e.g., every 2 to 4 weeks) to reduce these potential losses.

Ammonium or Nitrate Salts

Ammonium sulfate, ammonium nitrate, ammonium phosphate, potassium nitrate, and calcium nitrate are other commonly used, water-soluble N sources, collectively referred to as inorganic salts. Once the ammonium fertilizers solubilize in soil, ammonium ions can be adsorbed by the negatively charged clay or organic matter. As with urea, soil bacteria convert this ammonium to nitrate, which is the main form available to plants. Unlike ammonium sulfate and phosphate, potassium nitrate and calcium nitrate fertilizers do not need to undergo conversion by bacteria because their N source is already in nitrate forms.

FIGURE 5.7: Ammonium sulfate applied to putting greens using particle sizes > SGN 90 can result in mottled, tip-burn.

Ammonium sulfate is perhaps the most common ammonium salt used on Florida turfgrasses. The application of ammonium sulfate results in a reduction in soil pH because the ammonium sulfate molecule [$(NH_4)^2SO_4$] contains eight hydrogen ions that are released during nitrification. The sulfate component of ammonium sulfate has no influence on pH because the sulfur is already in the oxidized form. Care should be taken during and after the application of ammonium sulfate, especially to greens. Proper particle size should be selected for the specific turf area, i.e., SGN ≤ 90 for greens, SGN ≤ 170 for tees and approaches, SGN ≤ 240 for fairways and roughs) and approximately 0.1 – 0.2 inches of water should be applied after the application. Improper particle size and moisture management can result in a significant burn and a mottled appearance (Figure 5.7).

Diammonium phosphate (DAP) is especially common in fertilizers used for fairway and rough applications that require P because the substrate combines N and P in a single material and tends to be less expensive than the equivalent amount of N and P blended as separate raw materials. The disadvantage of DAP is the soil pH will initially increase, which will result in a portion of the P binding with Ca and becoming unavailable. The pH will eventually decrease but the bound P will remain unavailable. This pH increase can be avoided by using monoammonium phosphate (MAP), which results in a decrease in pH, which is normally advantageous on Florida soils that typically exhibit pH values above 7.0.

TABLE 5.8: Guaranteed analysis, salt index, and acidifying effect of common raw materials used in granular and liquid fertilizer blends for turfgrasses.

			N-P-K	Other Nutrients	Salt index	Relative Acidifying Effect
N	Soluble	Ammonium Nitrate	34-0-0		105	59
		Ammonium Sulfate	21-0-0		69	110
		Diammonium Phosphate	18-46-0		34	64
		Monoammonium Phosphate	10-50-0		30	56
		Calcium Nitrate	15-0-0			-20
		Potassium Nitrate	13-0-44		74	-26
		Sodium Nitrate	16-0-0		100	-29
		Urea	46-0-0		75	84
	Slow-Release	Urea Formaldehyde	38-0-0			
		Methylene Urea	40-0-0			
		Isobutylidene Diurea	31-0-0			57
		Polymer-coated Urea	Variable			80
		Sulfur-coated Urea	Variable			110, variable
		Biosolids	Variable		3.5	10
		Natural Organics	Variable		3.5	10
	Liquids	Methylene Urea	28-0-0			
		Triazone	28-0-0			
		Ammonium Polyphosphate	10-34-0			
		Ammonium Thiosulfate	12-0-0			
	Sprayable Powders	Methylene Urea	41-0-0			
		Urea Formaldehyde	38-0-0			
P	Soluble	Ordinary Superphosphate	0-20-0		8	0
		Concentrated Superphosphate	0-46-0		10	0
		Phosphoric Acid	0-55-0			
		Superphosphoric Acid	0-72-0			
		Monoammonium Phosphate	11-48-0		30	56
		Diammonium Phosphate	18-46-0		34	64
	Slow-Release	Natural Organics	Variable			
		Polymer-Coated	Variable			
K	Soluble	Potassium Chloride	0-0-62		116	0

TABLE 5.8 (continued)

			N-P-K	Other Nutrients	Salt index	Relative Acidifying Effect
		Potassium Sulfate	0-0-52		46	0
		Potassium Magnesium Sulfate	0-0-022		43	0
		Potassium Nitrate	13-0-44		74	-26
	Slow-Release	Polymer-Coated	Variable			0
Ca	Soluble	Limestone (calcitic)	0-0-0	Ca = 40		-20
		Limestone (dolomitic)	0-0-0	Ca = 21; Mg = 13	74	-26
		Hydrated Lime	0-0-0	Ca = 54	100	-29
		Gypsum	0-0-0	Ca = 23	75	84
		Calcium Nitrate	15-0-0	Ca = 24		
		Ordinary Superphosphate	0-20-0	Ca = 20		
		Concentrated Superphosphate	0-46-0	Ca = 13		
Mg	Soluble	Limestone (dolomitic)	0-0-0	Ca = 21; Mg = 13		
		Magnesium Oxide	0-0-0	Mg = 55		
		Magnesium Sucrate	0-0-0	Mg = 45		
		Magnesium Sulfate	0-0-0	Mg = 10		
	Slow-Release	Kieserite	0-0-0	Mg = 18		
		Polymer-Coated	Variable	Mg = Variable		
Fe	Soluble	Iron Sulfate	0-0-0	Fe = 20		
		Iron EDTA	0-0-0	Fe = 10		
		Iron DTPA	0-0-0	Fe = 10		
		Iron EDDHA	0-0-0	Fe = 5		
	Insoluble	Iron Sucrate	0-0-0	Fe = 55	8	0
		Iron Oxide	0-0-0	Fe = 75	10	0
	Liquid	Iron Gluconate	0-0-0	Fe = Variable		
		Iron Glucoheptonate	0-0-0	Fe = Variable		
		Iron Citrate	0-0-0	Fe = Variable		
		Iron Polysaccharide	0-0-0	Fe = Variable		
Mn	Soluble	Manganese Sulfate	0-0-0	Mn = 27		
		Manganese EDTA	0-0-0	Mn = 12		
	Insoluble	Manganese Sucrate	0-0-0	Mn = 35		
		Manganese Oxide	0-0-0	Mn = 68		

Slow-release Nitrogen Sources

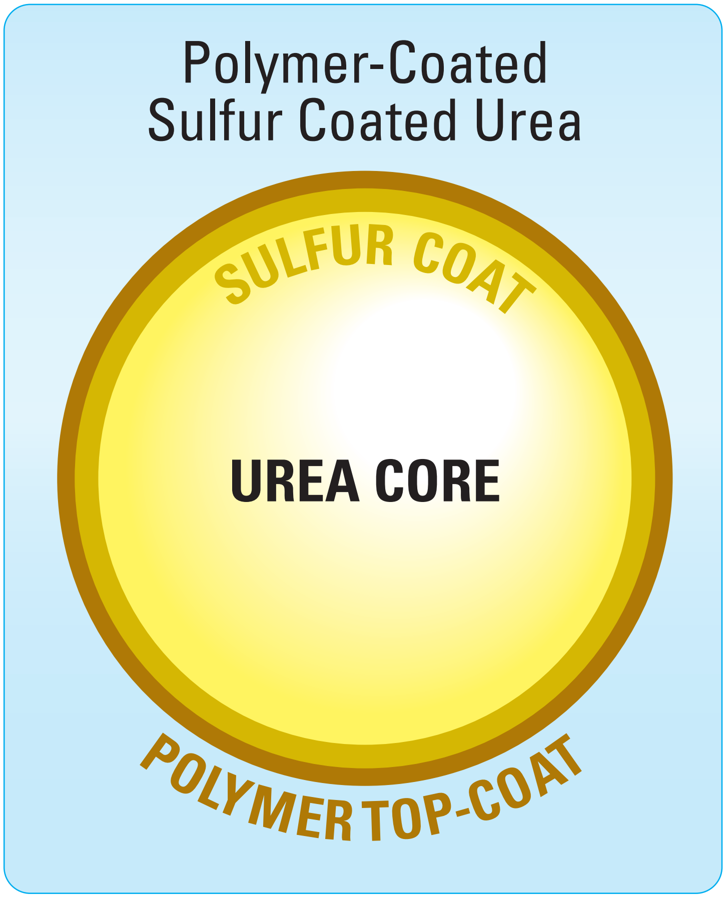
In an attempt to overcome some of the disadvantages of soluble N sources, fertilizer manufacturers have developed an array of slow- or controlled-release products (Table 5.8, previous pages). These generally provide a more uniform growth response and longer residual plant response. They also have less potential for N loss and allow a higher application rate than readily soluble sources. In addition, their burn potentials are lower because of their low salt index values. The application rate at which these sources release N may vary with fertilizer timing, source, temperature, moisture, pH, and particle size.

The drawbacks of slow-release N sources include high per-unit cost and slow initial plant response. Most sources also are not adaptable to liquid application systems. Turfgrass managers should understand the various N sources and conditions favoring N release before formulating their yearly fertilizer program.

Coated N fertilizers consist of urea or other soluble sources that are coated with a semipermeable barrier. Their release rate is slow because the coating prevents the wetting of the soluble N source. Release rates depend on coating degradation or the physical integrity of the coating. Other controlled-release fertilizers are created by a reaction between urea with isobutyraldehyde (IBDU) or formaldehyde (urea-formaldehyde). Release rates depend on water hydrolysis or the microbial degradation of the product.

Sulfur-Coated Urea

Sulfur-coated urea (SCU) is formulated by moving granulated or prilled, preheated urea pellets through a stream of molten sulfur using a rotating drum. SCU is usually further coated with a sealant and/or conditioner. As SCU evolved, many sealants have been used to protect the sulfur coating from cracking before application. Talcum powder and wax have been used for many years. However, in recent years, the price of polymers has been reduced, and it has become economically feasible to now use polymer coatings in place of wax. Thus, SCUs may be referred to as polymer-coated sulfur coated urea. However, this polymer coating has not changed the release mechanism of urea from the coating. According to the Association of American Plant Food Control Officials (AAPFCO), the release mechanism is still defined as catastrophic eruption. Granules of SCU slightly differ from one another, which results in water entering the particles at different rates. Once water enters the particle, pressure builds inside, and the sulfur shell cracks. Once the release begins, it is quite rapid which explains the release category 'catastrophic eruption'. Therefore, although the release is rapid, SCU appears to release N slowly due to the variability in the coating among different particles.



SCU can be applied on greens if the granule is ~90 SGN or smaller, but this is no longer common practice. Since the turn of this century, fertilizer manufactures produce very little greens-grade SCU due to a lack of demand. SCU applied during the winter months may produce a mottled turfgrass appearance, particularly on greens.

SCU has little effect on soil salinity but can reduce soil pH slightly due to the sulfur coating. The sulfur coating also is a sulfur source for plants. Sulfur-coated urea is less costly than many other coated, slow-release N sources. Leaching and volatilization losses generally are low, assuming that excessive moisture is not applied. The N content of SCU ranges from 32 to 43%, depending on the thickness of the sulfur coating.

Plastic/Resin-Coated Urea

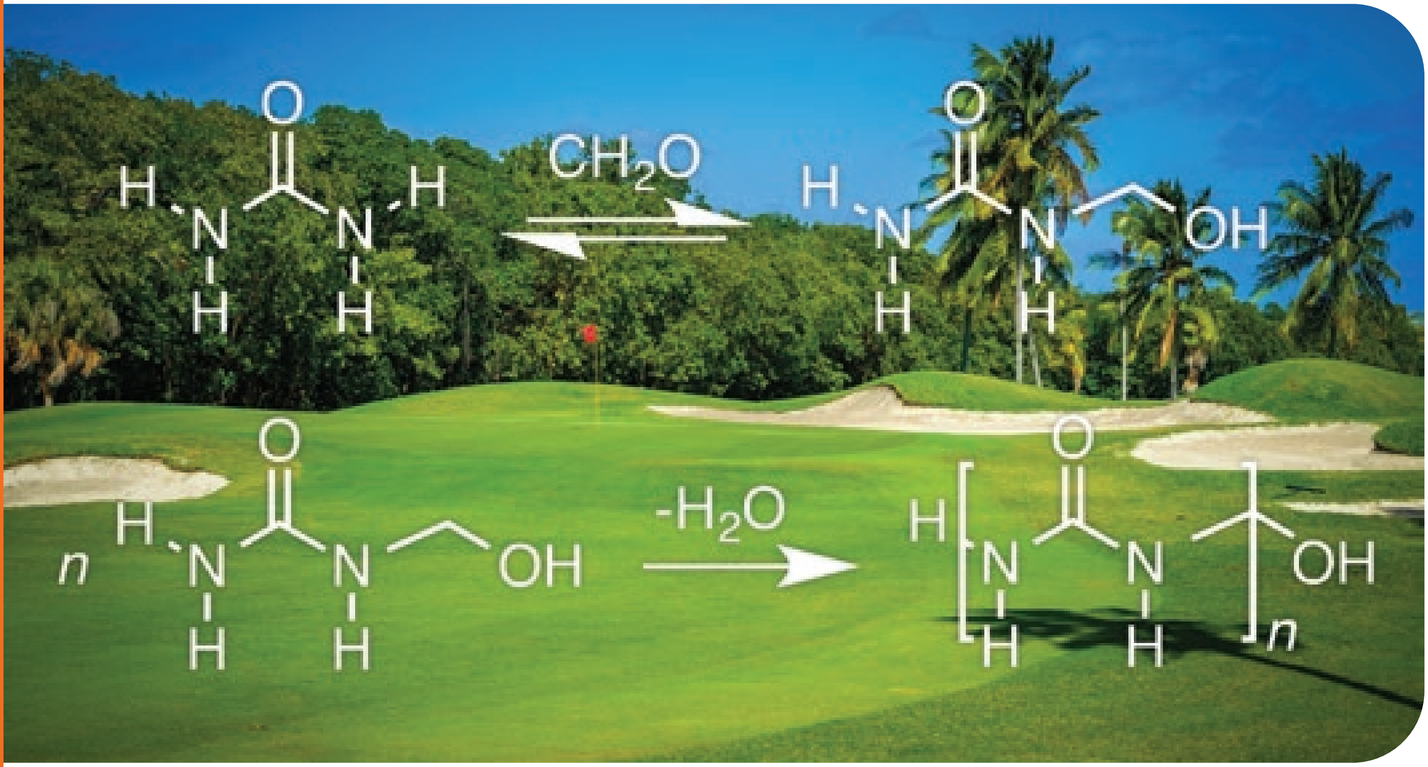
Beginning in the early 1990's, resin-coated (or polymer-coated) urea became available to the turfgrass market. Resin-coated fertilizers rely on osmosis rather than coating imperfections to release N. Low concentrations of salts on one side of the resin or plastic membrane allow the diffusion of high salt concentrations to the other side through the coating. As the fertilizer particle swells, internal pressure either causes the pellet to crack open, releasing the urea, or the urea is forced out through the pores. Since the coating is semipermeable, N is time released. Polymer-coated urea (PCU) is similar to resin-coated urea, but the coating does not swell or crack. Instead, the substrate moves through the porous polymer by osmotic diffusion. Release rates generally vary from 70 to 270 days, depending on the thickness of the coating and dissolution of water into the prill. Soil temperature also influences the release rates of coated materials, since the release is by diffusion. The diffusion rate is temperature mediated. Thus, the polymer-coated materials tend to release N more slowly in the cool season than in the warm season. The major disadvantage of polymer coating is that it costs more than other slow-release fertilizers.

Isobutylidene Diurea

Isobutylidene diurea (IBDU) is formed by reacting isobutyraldehyde with urea in an acid solution. The resulting product contains 31% N, 90% of which is water insoluble. In the presence of water, IBDU hydrolyzes back to urea and butyric acid. IBDU's nitrogen release rate is predominantly affected by soil moisture and particle size, and is not as dependent on temperature. With IBDU, an optimum pH range for N release is between 5 and 8, with a significant rate reduction occurring outside these ranges. Nitrogen release is independent of microbial activity. Therefore, IBDU nitrogen is released more readily during cool weather compared with other slow-release sources. The influence of IBDU on soil salinity and pH is minimal. Due to production costs, in the early 2000's manufactures reduced the production of IBDU and, as a result, IBDU has been essentially eliminated from the turfgrass market.

Ureaformaldehyde

Ureaformaldehyde (UF) is a generic designation for several methylene urea polymers that are formed by reacting urea with formaldehyde. These products have varying-length polymers of methylene urea, ranging from water-soluble molecules to highly water-insoluble molecules, to provide controlled N release. The smaller the ratio of urea to formaldehyde, the longer the chain of polymers formed. As polymer lengths and the number of longer polymers increase, solubility decreases, and N is released more slowly. Ureaformaldehyde fertilizers contain a minimum of 38% N and are commercially available as Nitroform™, Nutralene™, Ureaform™, and Blue-Chip™; several additional methylene urea materials are marketed under other trade names.



All UF products depend on microbial breakdown for N availability. Therefore, environmental conditions favoring microbial activity (e.g., warm temperatures > 13° C / 55° F), neutral soil pH, and adequate soil moisture and oxygen) promote N release. Conversely, low temperatures, acid soils, and low soil oxygen inhibit N release from UF. Unlike IBDU and SCU, where N is released into soil as urea, N from UF is released as ammonium. Shorter-chained, water-soluble polymers are readily digestible by soil microorganisms and release N in a relatively short time. Longer-chained polymers contain water-insoluble N, which is more slowly digested by soil bacteria. A lag in N availability may occur when using UF.

As with any N source, UF losses by mower pickup can be significant, especially immediately after application. Grass catcher baskets can be removed to allow clippings and fertilizer granules to return to the soil surface.

The losses of N by leaching and volatilization are less for UF than for readily available N sources. Over time, UF sources are about equal to soluble sources in terms of N use efficiency. Under conditions favoring leaching and volatilization, however, UF sources often are more efficient. Labor costs for applying fertilizer also must be weighed, since UF applications are less frequent. Soil pH or salinity are little affected by UF, and its burn potential is low.

Several new liquid materials that have better slow-release characteristics are now commercially available for foliar feeding and fertigation. These allow heavier rates to be applied less frequently without undesirable surges in growth or color. In addition, these slow-release materials minimize turf foliar burn potential. These solutions are generally composed of mixtures of short-chain methylene ureas, triazones, amines, and soluble urea. They are generally marketed as 28 to 30% N solutions containing about 30% soluble urea. In general, the responses observed for the various materials are very similar and generally last for no more than 60 days.

Natural Organic N Sources

Natural organic N sources often result in healthy stands of turfgrass similar to those managed with synthetic N sources. Natural organics usually involve various levels of compost or waste (either human or animal) materials. Manure, biosolids, bone meal, humates, and composted plant residues are traditional sources of natural organic N. The advantages of these substances include a low burn potential due to limited water-soluble N, little effect on pH, low leaching losses, and the presence of other nutrients in the materials. The physical condition of soils, especially sandy soils, may improve with their use.

Some considerations before using these sources include their low N content and slow N release during cool weather due to reduced microbial activity. Natural organic N sources are usually the least expensive N source on a price per ton basis but are commonly the most expensive N source on a price per pound of N basis. Large amounts of material may be needed to apply the same rate of N from a synthetic soluble N source. Therefore, natural organic fertilizer can be 2-16 times more expensive than soluble sources, depending upon how the cost comparison is conducted.

Natural organic fertilizers should not be used as the sole source to supply all the N required by the turfgrass (i.e., 1 pound of N per 1,000 sq. ft. per application). Nearly all natural organic fertilizers not only contain N, but also contain P. Because the N and P are in approximately the same concentration (5-4-0, 6-2-0, etc.), when natural organics are applied to meet N requirements, the amount of P that is applied greatly exceeds the amount of P required by the turfgrass. Excess application of P has been documented to increase P leaching. Therefore, natural organic fertilizers should be applied based upon the rate of P, applied as a supplemental N source, or applied as an alternate filler source to lime in fertilizer blends.

Natural organic N sources may be difficult to store and to apply uniformly, especially when the turf is already established. Some natural organic sources produce objectionable odors after application and contain undesirable salts, heavy metals, and weed seeds. Natural organic sources such as manures and composted crop residues should not be used on golf greens because of potential hindrances to soil drainage resulting from the large amounts of material applied.

For more information on N fertilizer sources for turfgrasses, see the publication: *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: http://edis.ifas.ufl.edu/LH014).

Phosphorus

Phosphorus (P) is a common component of many turfgrass nutrition programs. P has many functions within the plant including energy transfer. Florida soils contain large quantities of total P and, although total P has little to no relationship with plant available P, most Florida soils also contain an adequate supply of plant available P.

THE ROLE OF PHOSPHOROUS

Phosphorus has many functions in the plant, but the most essential function is energy transfer. Energy obtained during photosynthesis is stored in compounds and transferred to other parts of the plant. When these high-energy molecules adenosine diphosphate or adenosine triphosphate (ADP and ATP) are split, a relatively large quantity of energy is liberated and used for various metabolic processes. Essentially every metabolic process in turfgrass development requires P.

Phosphorus is absorbed by the plant as either $H_2PO_4^-$ or HPO_4^{2-} (often referred to as orthophosphate or ortho-P) with the former more prevalent at low soil pH and the latter more prevalent at high soil pH. Small amounts of organic P may be absorbed by the plant but the quantity and importance of organic P for turfgrasses is limited due to the instability of organic P compounds in the presence of active microbes.

Phosphorus deficiency in turfgrass can appear different from other nutrient deficiencies. P deficient turfgrass may actually appear darker green, particularly on the older leaves. When darker green leaves are observed in conjunction with reduced growth, P deficiency may be the cause. The darker green leaves are a result of an increased concentration of chlorophyll partly due to the reduction in growth. If P deficiency progresses, older leaves may appear purple, which is a result of excess anthocyanins, a pigment normally associated with ripening of some fruits including blueberries.

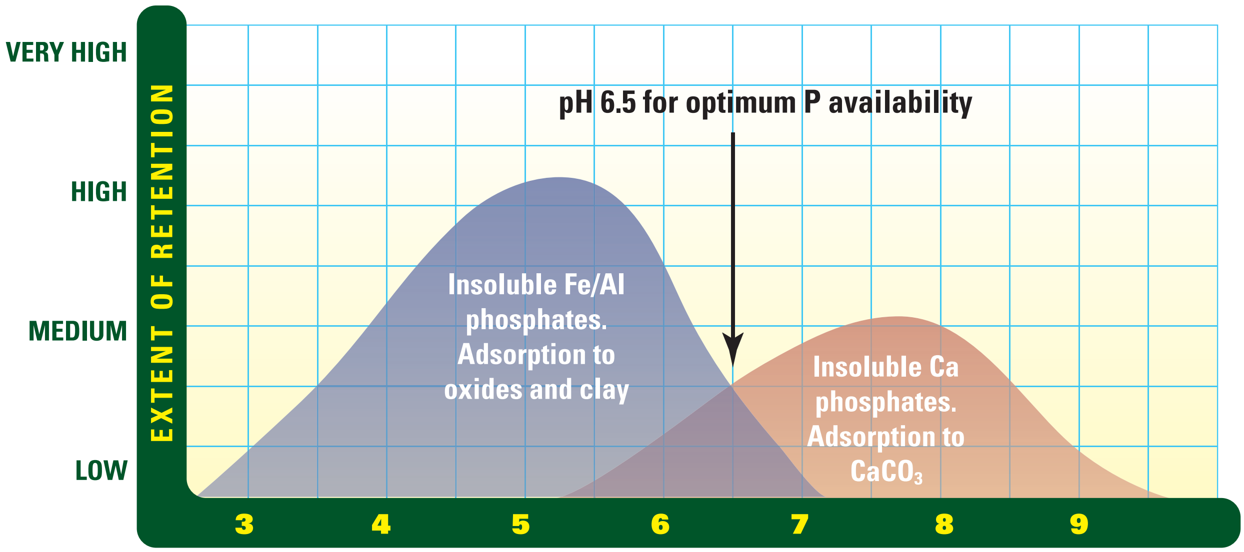
Particularly during the early stages of development, P is associated with increased root growth. During these early stages, the turfgrass has a high demand for energy and very little ability to supply P due to insufficient root growth. Thus, applications of P during turfgrass establishment increase root production and turfgrass establishment. Special care should be given to the N:P ratio during putting green establishment. A ratio of 5:2 has been shown to increase establishment compared to a 1:0 N:P, whereas further increases of P above a 5:2 N:P may decrease establishment. The increase in turfgrass establishment through the application of P is also a function of the initial soil P value. As we will discuss, soil test P levels are of little use except to indicate when P should not be applied. This holds true even during establishment.

Although the exact soil P level required to establish turfgrasses on Florida soils remains unknown, P fertilizer applied during turfgrass establishment on soils with medium or high P levels (≥ 50 ppm) have resulted in no improvement in turfgrass establishment.

Soil Phosphorus

Total P in most Florida soils is quite high, but total P has very little influence on the portion of P that is plant available. The concentration of P in the soil solution can be very low relative to total P with reported concentrations often less than 0.05 ppm. Regardless, most Florida soils contain an adequate supply of available P to sustain acceptable turfgrass health with some exceptions. Turfgrasses grown on putting greens often encounter stresses that are atypical of fairways. These stresses are often alleviated with the application of P and, thus, the use of P for putting green turfgrasses is often higher than fairways. Available P is highest in soil solution when the pH is between 5.0 and 7.2 with maximum turfgrass uptake occurring at a soil pH of 6.5 (Figure 5.9). Below 5.0, P precipitates with Fe or Al and falls out of solution. Above 7.2, P may bind with Ca and become unavailable for plant uptake. Bound to these secondary minerals of Fe, Al, and Ca, P may again become plant available through dissolution if the soil pH remains between 5.0 and 7.2. The strong influence soil pH has on plant available P is one reason soil testing is a critical part of managing turfgrass systems. Phosphorus in soil solution may be adsorbed onto the surface of secondary minerals. This process, known

FIGURE 5.9: Soil pH influences P solubility. (Stevenson, *Cycles of Soil*, p. 250, 1986)



as adsorption, renders the P unavailable for plant uptake but the P is still available to return to the soil solution via desorption. This adsorption/desorption process is very similar to the retention of cations through cation exchange, with P being returned to soil solution as concentrations decrease through plant uptake or precipitation.

Soil organic matter contains between 1% and 3% P. The majority of P in organic matter is organic-P, although a small fraction is already in the ortho-P (plant available) form. Organic-P must be mineralized into ortho-P by soil microbes in order for the P to become plant available. After mineralization, the P is in an inorganic form and may be taken up by the turfgrass or returned to its original organic form via immobilization by other soil microbes. Mineralization and immobilization are soil process mediated by soil microbes and, thus, any environmental variable (such as pH, soil moisture, soil temperature, etc.) that influences soil microbial activity will influence P-mineralization and immobilization. Phosphorous mineralization rates have been documented to increase during the warmer summer months compared to the cooler winter months. Thus, for turfgrasses growing on soils with appreciable organic matter, less P fertilizer may be necessary during the summer months than the winter months. This dynamic is more magnified in the northern part of Florida where temperature fluctuations between winter and summer are far greater than that of south Florida.

Soil Testing for Phosphorus

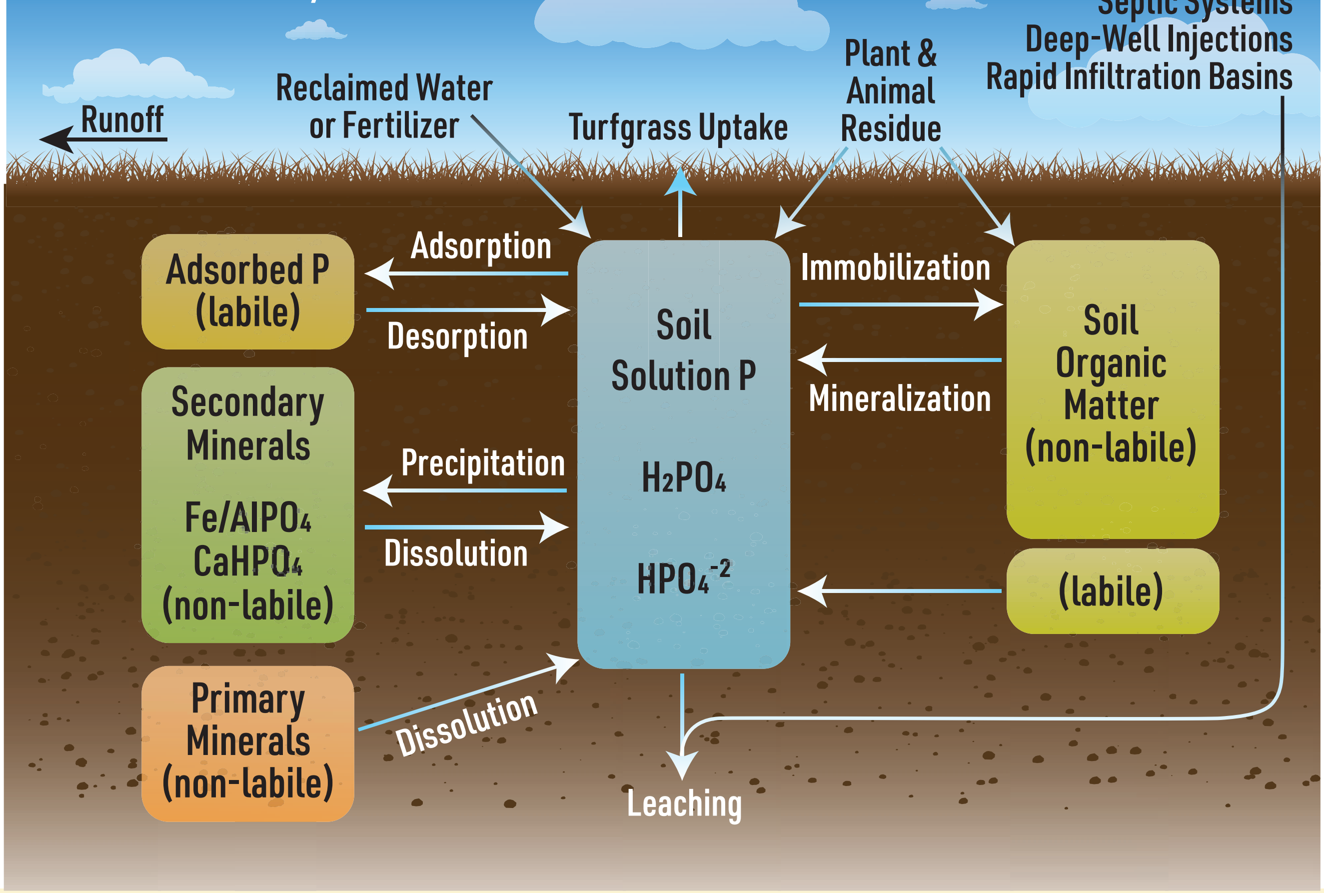
Phosphorus soil tests for Florida turfgrasses has limited use. Soil test P values are often not calibrated to a turfgrass response, thus, applying specific amounts of P based upon a soil P test has been proven unreliable. However, soil test values may be used to indicate when P should not be applied. A Mehlich III soil test value of ≥ 10 ppm indicates a turfgrass response to P is unlikely and, therefore, P may be omitted from nutrient applications without concern for a reduction in turfgrass health or growth. When Mehlich III soil test values are below 10 ppm, P may be warranted, but the exact amount of P one should apply is difficult to estimate because soil test P values and a response to applied P have not been calibrated, as previously mentioned.

Sandy soils, such as those under many golf greens, lack iron (Fe) or aluminum (Al) and do not form insoluble P complexes. Under these conditions, P is more available at a lower pH. In alkaline soils (pH > 7.5), calcium forms insoluble complexes with P to render it unavailable as dicalcium phosphate ($CaHPO_4$). Applied P becomes less soluble over time and thus unavailable for plant uptake.

Fate of P

Soil reactions with P are very different than soil reactions with N (Figure 5.10). In the case of N, the primary source and sink of N is the atmosphere, whereas the source and sink of P is the soil itself. Potassium may dissolve from primary and secondary minerals or enter the soil solution via mineralization from organic matter.

FIGURE 5.10: The P cycle in Florida soils



Many Florida soils are rich with P; in fact, Florida is one of the world's largest sources of phosphate rock. Once P has entered the soil solution, P may again become unavailable for plant uptake by precipitating into a secondary mineral or through immobilization by soil microbes.

When surface applied, P readily binds with Fe and Al at low pH and Ca at high pH. Thus, pH management highly influences the availability of P for turfgrass uptake. As one may expect, pH management also influences off-site movement of P. However, leaching and runoff of P do not readily occur except under specific conditions. Such conditions include soluble P applications to uncoated sands, soluble P applications immediately prior to a significant rain event, or natural organic fertilizer that is applied based upon the rate of N rather than P. Phosphorus runoff is very rare but occurs when excessive rainfall results in soil erosion. The soil itself will have some P bound as secondary or primary minerals and can move off-site. Because healthy turfgrass is a deterrent to erosion, maintaining healthy turfgrass or other ground cover on slopes that lead to waterbodies can significantly reduce P runoff.

Depending on the golf course's physical and chemical soil composition, conditions may allow for the accumulation of phosphorous over time from fertilizer sources containing phosphate. Phosphorous can also be sourced naturally from the soil. Additionally, accumulation of P can build-up via stormwater runoff into nearby lakes and ponds. Phosphorous can become problematic for shallow lakes. The accumulation of P is often referred to as "Legacy-P". Legacy-P can be a sink or source, where P is bound in sediment and accessible to plant uptake.

The build-up of P in soils and surface water sediment can have prolong damaging effects to water quality. Phosphorous pathways may include mobilization in an aqueous solution to underground or surface waterbodies via stormwater runoff. Depending on the location in Florida, P is often a limiting nutrient in freshwater systems and is responsible for triggering algae blooms and other aquatic burst of growth.

Accumulation of legacy-P in waterbodies over time can become a sink, a holding area for P. Depending on pH, P can be bound by iron and aluminum complexes, or precipitate out of water solution bound by Ca. If pH conditions reach 7 (neutral), it can translocate in solution back into living systems. Uniquely, P can recycle within an aquatic system for years at a concentration that can result in a cycle of rapid overgrown plant tissue called "Eutrophication" resulting in low dissolved oxygen levels followed by aquatic animal and plant death. Other legacy-P systems can act as a trickle feeder, delivering dissolved P downstream, often resulting in eutrophic situations.

Once P is in the lake system, it can be very challenging to capture and remove. Shallow lake systems biologically process P once it has entered a waterbody. Therefore, it is very important to apply P only when tissue and soil tests recommend it.

Advanced soil testing analysis can assess sandy soil P assimilation capacity. This is important for understanding how much P can be stored in the soil before it becomes an environmental risk. Phosphorus Saturation Ratio (PSR) can be calculated to determine P loss risk. The PSR can alert the superintendent to changes in the soil that may risk the movement of P into the environment via surface and sub-surface flow.

Tissue Testing for Phosphorus

Tissue testing is a valid method to determine whether P is limiting turfgrass health. Phosphorus concentrations in turfgrasses will vary depending upon the species and cultivar (Table 5.3). As previously mentioned, UF/IFAS utilizes reference ranges to determine the nutrient concentrations within 95% of acceptable turfgrass. When P concentrations fall below or exceed 95% of the acceptable range, P applications should be adjusted up or down, accordingly.

The true value of turfgrass tissue analysis for P is to indicate when P should not be applied. The lower P reference range for bermudagrass and St. Augustinegrass in Florida is 0.15% and 0.3% on a dry weight basis, respectively. When turfgrass P concentrations are greater than these values, P applications should be limited. When tissue P concentrations are below these values, an application of P may be warranted and the amount of P to apply should follow current UF/IFAS recommendations for establishing turfgrasses, which is no more than 1 pound of P per 1,000 sq. ft.

P Fertilizer Sources

When naturally available soil P is too low to meet the turfgrass needs, P may be applied as one of numerous P fertilizers. Nearly all P sources used in turfgrass management originated from mined P, usually apatite (a form of calcium phosphate). Once applied to the soil, P sources will have vastly different reactions in the soil. In most soils, P is immobile and the solution concentration of P is highly dependent upon pH and P source, thus, an understanding of P source reactions is essential to maximize the efficient use of applied P.

Ordinary and Triple Superphosphate

Mined apatite is reacted with either sulfuric or phosphoric acid to form ordinary or triple superphosphate (OSP and TSP, respectively). OSP and TSP have a guaranteed analysis of 0-20-0 and 0-46-0, respectively. Both are highly water soluble and reduce the soil pH around the fertilizer particle to approximately 1.5. Thus, OSP and TSP are good sources of P on the high pH and calcareous soils of Florida. Conversely, if the soil pH is already near 5.0, OSP and TSP would be poor choices because the soil pH would be reduced below 5.0 resulting in a larger percentage of applied P becoming bound by Al or Fe.

Monoammonium and Diammonium Phosphates

Both monoammonium (MAP) and diammonium phosphate (DAP) are manufactured by reacting ammonia with phosphoric acid. MAP and DAP have guaranteed analyses of 11-48-0 and 18-46-0, respectively. MAP is less acidifying than OSP and TSP but the soil pH directly around the fertilizer particle will still be around 3.5. Thus, MAP is a good choice for high pH soils.

DAP is the most used fertilizer on earth and is a good choice for acidic soils because the application of DAP results in a pH of 8.5 immediately around the fertilizer granule. When DAP is applied to high pH, calcareous soils, the P is immediately bound by Ca to form dicalcium phosphate and the N will volatilize because ammonium is highly soluble and easily converted to ammonia gas. Overtime, the soil pH will return to the initial soil pH due to the conversion of ammonium to nitrate (nitrification). However, in the time required to reduce the soil pH back to its initial level, much of the P and N will have been lost to precipitation and volatilization, respectively. When soil pH exceeds 6.5, volatilization of N from DAP can exceed 30% of applied N and can be 5x greater than that of MAP and 2x greater than that of urea and ammonium sulfate. Thus, DAP should not be used on high pH, calcareous soils. Unfortunately, DAP is regularly applied to Florida turfgrasses without consideration of soil pH because the cost of N and P in DAP results in a less expensive fertilizer blend than other combinations of N and P. This perceived savings is not valid due to the quantity of N and P that is lost after application on high pH soils.

Liquid Phosphorus

Phosphorous may also be applied as a liquid or as a foliar spray. Liquids are applied in water at 80 gallons per acre or higher, whereas foliar sprays are designed to remain on the leaf surface and are applied at lower rates near 40 gallons per acre. In either case, P in liquid form is usually as phosphoric acid. The ammoniated P sources previously mentioned may also be used as a liquid, but phosphoric acid is more common because it only contains P and it tends to be the least expensive liquid source. The P concentration of liquid P fertilizers vary greatly because the phosphoric acid must be diluted in water and may be blended with other components, particularly N and K.

Organic Phosphorus

Most, if not all, natural organic fertilizers are manufactured from plant, animal, or municipal wastes and contain a component of P. Typical P concentrations of organic fertilizers range between 1% and 7%. Organic-P fertilizers contain both inorganic and organic-P with the ratio of inorganic-P to organic-P varying widely depending upon the source. However, on average, P in organic fertilizers is roughly 50% organic and 50% inorganic. Thus, half of the total applied P would immediately contribute to soil solution P whereas, the remaining organic-P requires mineralization to be converted to a plant-available form.

Natural organic fertilizers are often viewed more favorably than synthetic fertilizers due to a perceived reduction in environmental risk. However, evidence indicates that natural organic fertilizers may increase environmental risk compared to synthetic fertilizers with respect to P. Caution should be taken when using natural organic fertilizers to minimize the risk of P leaching and/or runoff. When natural organic fertilizers are applied at rates sufficient to meet N needs, more P is applied than the turfgrass can use leading to excess P lost to the environment. Thus, natural organic fertilizers should be applied as a supplemental N source or applied based upon the rate of P, without exceeding UF/IFAS recommendations.

For more information on P sources for turfgrasses, see the publication: *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: http://edis.ifas.ufl.edu/LH014).

Potassium

Potassium is an essential element not usually associated with a prominent, easily seen response in a plant's shoot color, density, or overall health. K does help a plant overcome some of the negative effects of excessive N fertilization, such as decreased stress tolerance to cold, heat, drought, diseases, and wear. K is often called the "health" element, since an ample supply of K increases a plant's tolerance to these stresses. Keep in mind, the positive influence K has on stresses has only been measured in cases where the turfgrass was deprived of K and became K deficient. When turfgrass is regularly supplied with K, additional K has not been shown to further enhance the turfgrass resistance to cold, heat, diseases, or drought stresses.

Potassium is directly involved in maintaining the water status of a plant, the turgor pressure of the cells, and the opening and closing of the stomata. As the K concentration increases in a plant, the tissue water content increases and the plant becomes more turgid, since K regulates the stomatal opening. This is because K provides much of the osmotic pressure necessary to pull water into plant roots and thus improves a plant's drought tolerance.

K Deficiency Symptoms

Potassium deficiency symptoms include the interveinal yellowing of older leaves and the rolling and burning of the leaf tip. Leaf veins finally appear yellow, and margins look scorched. The turfgrass stand loses density, with spindly growth of individual plants. Potassium is a mobile element within plants and thus can be translocated to younger, meristematic tissues from older leaves if a shortage occurs.

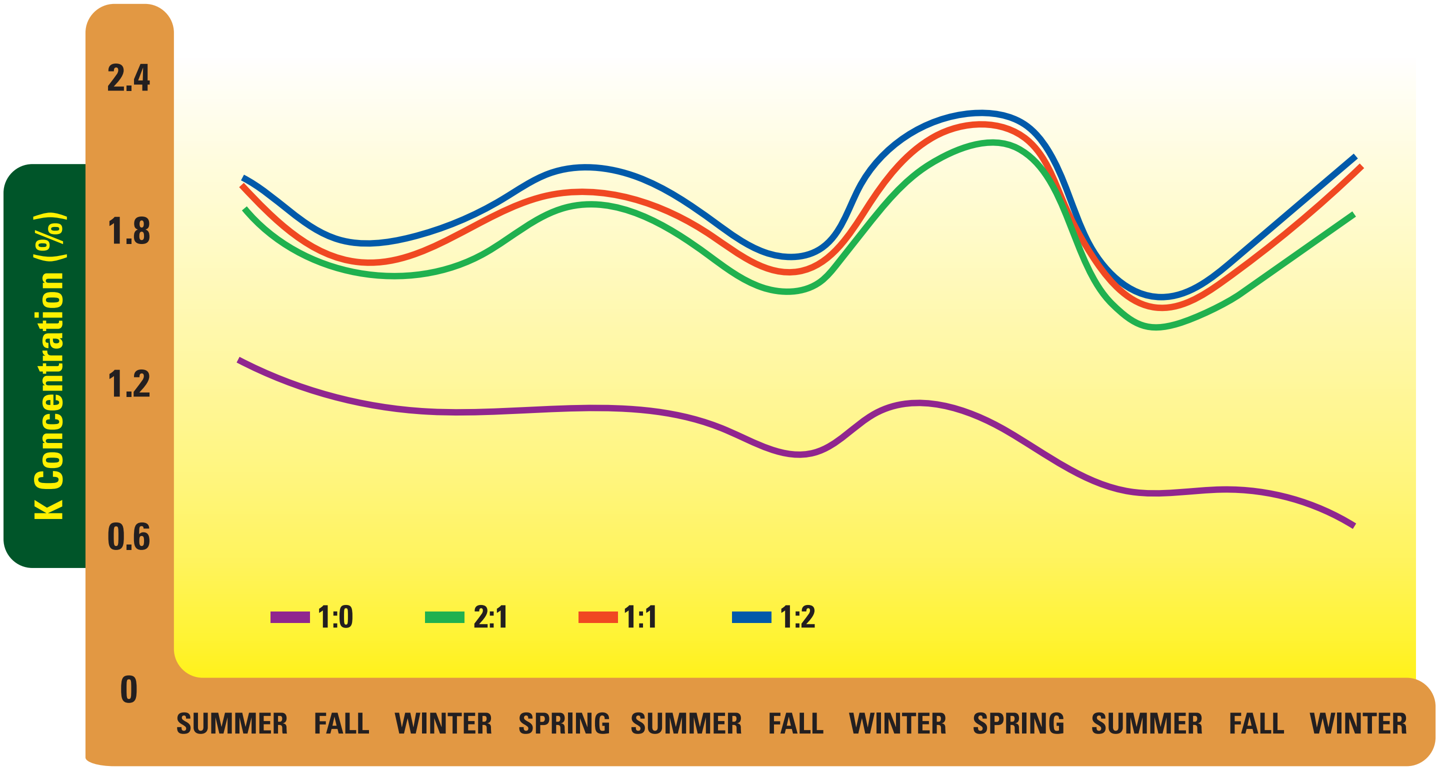
K Tissue Testing

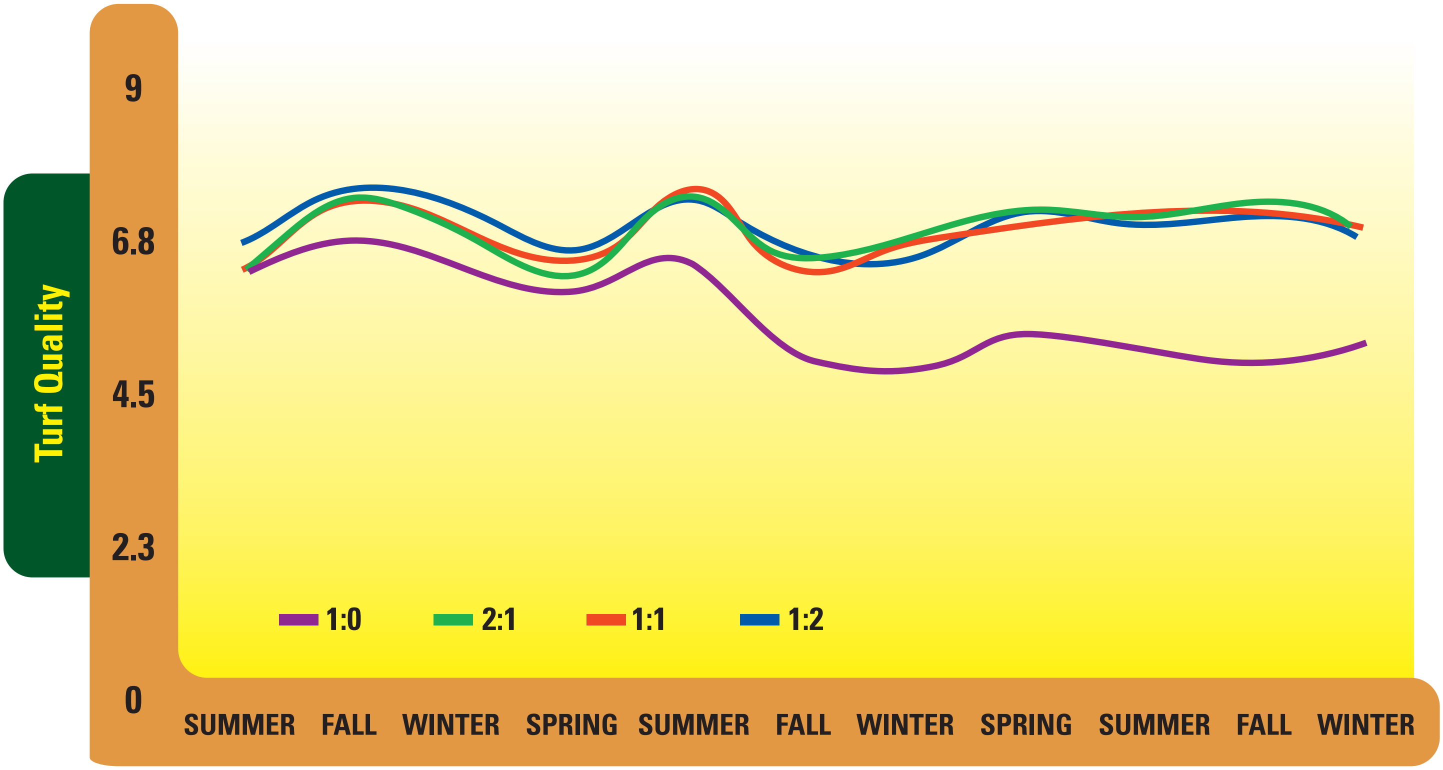
Measuring the K concentration of turfgrass leaf tissue may help indicate when K is limiting turfgrass health. Turfgrass leaf K concentrations will vary according to species. The current reference ranges for bermudagrass and St. Augustinegrass are 0.43–1.28 and 1.10–2.25% on a dry weight basis, which represent the K concentration that exists within 95% of acceptable turfgrass. Reference ranges for each bermudagrass cultivar have not yet been developed. As K concentrations approach the lower ranges, K is more likely to limit turfgrass health and, thus, a K application may be warranted. It is important to remember that an inverse relationship exists between K, Mg, and Ca in plants. As K levels increase, Mg deficiencies are the first to show, while at higher concentrations, Ca deficiencies occur. A similar but opposite relationship can occur in saline soils, where Ca, Mg, or Na ions compete with K for plant uptake.

K Soil Testing

Soil test K levels ≥ 30 ppm indicate a turfgrass response to K is unlikely. When soil test K levels are < 30 ppm, K should be applied at the rates described below. Keep in mind, because K easily leaches, K should be applied with each N application to minimize any opportunity for K deficiency. To that end, soil testing for K is usually not necessary so long as you are following the K recommendations described in the following section.

FIGURE 5.11: For maximum K-use efficiency, K should be applied to fairways, tees, and roughs with normal N applications at ½ the rate of N.





K Application Rates

K should be applied regularly to reduce the chances of K deficiency that can occur due to K leaching in Florida's sandy soils. Because of the additional stresses typically encountered on putting greens, K should be applied at a rate equal to the rate of N and be applied on the same application interval as N. For other areas of the course, K should also be applied at the same time as N but the rate of K should be ½ the rate of N. Exceeding a 2:1 N:K ratio on fairways, tees, roughs, and approaches will not increase turfgrass quality or turfgrass tissue K (Figure 5.11, previous page).

K Fertilizer Sources

Potassium fertilizer often is referred to as "potash." The soluble K content of a fertilizer is expressed as K_2O. Turfgrass response or (in most cases) lack of response to K is the same regardless of the type of K source applied. Therefore, the choice of which K source to use is based upon your needs and budget.

Potassium fertilizer, a.k.a. "potash"

Potassium Chloride

Potassium chloride is sometimes referred to as muriate of potash or KCl. On Florida golf courses, KCl is the most common K fertilizer because it is usually the least expensive K source. Care should be taken to water-in KCl after applications because KCl also has the highest burn potential of any K source fertilizer (per pound of fertilizer) (Table 5.3).

Potassium Sulfate

When burn potential is a concern, potassium sulfate should be used in lieu of KCl because the burn potential of potassium sulfate is less than ½ that of KCl.

Potassium Magnesium Sulfate

Potassium magnesium sulfate may be referred to as Sul-Po-Mag (SPM), or sulfate of potash magnesia. As the name suggests, SPM is both a source of K and Mg. Although SPM has a low burn potential per pound of fertilizer, SPM has the highest burn potential per pound of K.

Potassium Nitrate

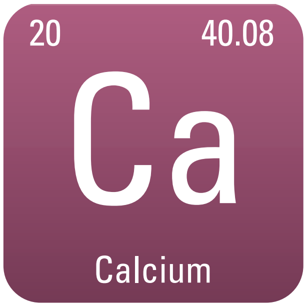
Potassium nitrate is often referred to as Pot-Nit. Like SPM, potassium nitrate is a multi-nutrient product supplying both K and N.

Slow-Release Potassium

Sulfur and polymer-coated K sources are the only available sources of slow-release K. K never enters into a molecular compound in plants or animals, thus, slow-release, organic K sources do not exist. The K substrate may be any soluble K source, but the substrate is normally KCl because KCl is the least expensive granular K fertilizer. The burn potential of coated K is much lower than their uncoated, soluble K counterparts because only small amounts of K are released into the soil/turfgrass system at any one time. Sulfur and polymer-coated K fertilizers release their K in the same manner as coated N sources. However, unlike coated N sources, an enhanced turfgrass response to slow-release K sources relative to soluble K sources has not been documented.

Secondary Plant Nutrients

Calcium



Calcium (Ca) is the dominate cation in all soils of agronomic importance. Florida soils are naturally high in Ca because much of the parent material that formed Florida soils is comprised of limestone. Consequently, Ca deficiency in Florida turfgrasses is extremely rare, and the probability of observing a direct Ca response on any part of the golf course is very low. Applying Ca fertilizers to artificially increase soil Ca above the level necessary for proper plant growth normally does not result in an increase in plant uptake because Ca uptake is genetically controlled. Regardless, many superintendents purchase and apply Ca in both granular and liquid forms. The objective of this section is to explain the function of Ca in turfgrasses, to describe situations where the Ca applications would or would not be of value in golf course management, and to identify Ca sources.

Function of Calcium in Turfgrasses

Calcium is absorbed by the turfgrass as Ca^{2+} and, under normal conditions, turfgrass receives sufficient quantities of Ca^{2+} from the soil without the need to apply Ca-fertilizers. Calcium is required for cell membranes to function properly and serves to bind phospholipids or membrane proteins. Most Ca in turfgrasses is found in cell vacuoles or serves as a structural component of cell walls. Calcium activates some enzymes but inhibits others. Calcium cannot enter phloem tissues, which are required to translocate nutrients while inhibiting others throughout the plant. Thus, deficiency symptoms, although exceedingly rare, will appear on newer leaves/tissues first. Deficiency may appear as twisted or deformed tissue in roots, stems, or leaves where cell division occurs. Leaf blades may appear rose to brown and the lead tips and/or margins may wither.

Soil Testing for Calcium

Applying Ca based upon a soil test recommendation is not a best management practice. Soil testing for Ca is of little value because the extractant dissolves Ca compounds, which would not otherwise be plant available. As importantly, soil test correlations between Ca soil test values and a turfgrass response to applied Ca do not exist for Florida soils. The use of base saturation (BCSR) to interpret soil Ca is not supported by evidence, has been widely rejected by land grant institutions, and is not a best management practice. Additionally, the application of Ca has been shown to provide no beneficial effect on turfgrass grown on calcareous putting greens.

Soil pH and Bicarbonates

Soil acidity and bicarbonate management are the primary purposes of Ca applications to Florida turfgrasses. The application of gypsum does not increase soil pH like limestone despite both materials containing Ca. It is limestone's counterion (CO_3^-) that increases pH and because gypsum contains SO_4^{-2} rather than CO_3^-, no increase in pH will occur.

The application of gypsum may lower pH if the soil pH is initially high due to the presence of Na. The turfgrass response, if any, would likely be due to the increased biological activity that typically accompanies a reduction in pH — i.e., increased microbial activity and increased micronutrient availability. However, a turfgrass response to such a scenario has not been documented in Florida.

Direct toxicity to bicarbonates has been documented but tolerance limits for most turfgrasses remains unknown. In most cases, bicarbonates are a concern due to their ability to bind with Ca and Mg and leave behind soluble Na. Additionally, water low in Na and dissolved salts but high in bicarbonates may result in unacceptable pH levels (>8.0). The application of gypsum will reduce the presence of bicarbonates.

Salt Remediation

Gypsum is a salt and, therefore, the application of gypsum does not remediate salt-affected turfgrass and, in fact, may exacerbate salt-related problems.

Calcium Sources

Irrigation Water

One of the most common Ca sources for irrigated turfgrass is the irrigation water itself. Because much of our water is sourced from aquifers, ponds, and lakes, Ca content of irrigation water is commonly in excess of 40 ppm. Therefore, for every 1 million gallons applied, you would also be applying 40 gallons of Ca.

Lime

Limestone is the most common source of lime because limestone is inexpensive and readily available. Limestone is comprised of calcium carbonate ($CaCO_3$) and it is one of the least expensive Ca sources available for turfgrass use. However, lime may also be burned lime, hydrated lime, or dolomitic lime. Each lime source has a different capacity to neutralize acidity and increase pH. Lime should be used as a Ca source when soil pH falls below the suggested pH range for the turfgrass being grown. If soil pH is already greater than the suggested range, gypsum should be the preferred Ca source in place of lime.

Limestone, an inexpensive and readily available source of lime, should be used when soil pH falls below the range for the turfgrass being grown.

Gypsum

The application of gypsum may enhance soil permeability in clay-textured saline soils. High sodium levels cause dispersion of clays and often results in poor drainage. Gypsum can alleviate sodic soils by replacing Na with Ca on the soils exchange sites which enhances soil structure and increases soil permeability. However, Florida soils naturally have little to no structure due to their high sand content. Florida's sandy soils and high rainfall also enables Na to be easily leached without the application of gypsum. Thus, the application of gypsum to turfgrasses grown on Florida soils has little to no influence on soil structure.

Since gypsum's primary use is in clay-textured soils, it is of little use in the sandy soils of Florida.

Calcium Chelates

Some lime and gypsum sources may contain a chelating or complexing agent such as lignosulfates, citrates, gluconates, or plant extracts. These additives are designed to increase the solubility and availability of Ca for plant uptake. When the soil pH is low (< 5.5), the use of calcium chelates on Florida soils may increase pH more effectively than non-chelated Ca sources. However, very few Ca chelates have been tested and confirmed to increase pH more efficiently than non-chelated Ca. Under normal Florida conditions, Ca is naturally solubilized from the soil and remains soluble in the soil for extended periods. Therefore, fertilizer additives intended to increase Ca solubility are normally not necessary. The release of Ca from a fertilizer source may vary depending upon the particle size, density, and structure.

Calcium Nitrate

Calcium nitrate has a guaranteed N and Ca analysis of 15% and 19%, respectively. The product is normally applied based upon the nitrogen component and consequently, any turfgrass response is likely due to nitrogen. However, if the soil pH is below a suggested turfgrass range, calcium nitrate will increase pH and supply nitrogen in a single application.

Magnesium

Magnesium (Mg) exists in soils primarily as Mg^{2+} and is an essential element for all plants. Because Mg is often applied to turfgrasses in both granular and foliar forms, it is essential to understand the function of Mg in the plant, the dynamics of Mg in the soil, and the forms of Mg fertilizers.

Function of Magnesium in Turfgrasses

The primary function of Mg in turfgrass is to serve as the central atom in the chlorophyll molecule. As much as 25% of Mg taken up by plants is used for this purpose. Other functions of Mg in turfgrasses include enzyme activation, stabilization of ribosomes during protein synthesis, and is a key component of ATP and NADPH, which are used to store and transfer energy during phosphate transfer. Mg is mobile within the plant; thus, deficiency symptoms typically appear as a chlorosis on older leaves first.

Soil Magnesium

The earth's crust is comprised of 1.93% Mg, but the majority of this Mg is bound in primary and secondary minerals and is not available for plant uptake. Mehlich III extractable Mg in unfertilized Florida soils typically ranges from 20–40 ppm. Because it is positively charged, Mg can be retained on the soil's cation exchange sites (CEC). However, the benefit of this retention may be quite low in Florida soils because many Florida soils are predominantly sand and have a low CEC. Unlike Fe and Mn, Mg remains soluble in Florida soils for extended periods. Thus, the use of Mg chelates to enhance Mg solubility has limited value. Additionally, the application of other cations, such as Ca in fertilizers or Na in reclaimed water, has a tendency to replace Mg on exchange sites, which can exacerbate Mg leaching and lead to Mg deficiency in turfgrasses.

Soil Testing for Magnesium

Soil testing can only be used to indicate when Mg applications are not necessary. A Mehlich III Mg value of 20 ppm or greater indicates that a turfgrass response to Mg is unlikely. Because under normal Florida conditions many Florida soils already contain > 20 ppm Mg, Mg applications are generally not necessary. Below 20 ppm Mehlich III Mg, a turfgrass response to Mg may occur but the amount of Mg to apply is unknown because Mg calibration responses have not been determined. Other methods of interpreting soil test Mg values are commonly used, such as the BCSR. However, as previously mentioned, the BCSR has been determined to be inaccurate and should not be used in turfgrass management.

Magnesium Fertilizer Sources

Magnesium Sulfate

Also known as Epsom's salt, Mg sulfate has an analysis of 10% Mg and appears as a white, angular particle or prill, and it is 100% water soluble. It is a common Mg fertilizer because it can be spread or sprayed and it is normally less expensive than other Mg fertilizers on a pound of Mg basis.

Sulfate of Potash Magnesia

Sulfate of potash magnesia (often referred to as SPM) provides both K and Mg in a single fertilizer. SPM can be more expensive than Mg sulfate per pound of Mg but, because it also contains K, the cost of the fertilizer is offset because the applicator does not need to pay for additional K. SPM is manufactured in numerous forms including brown prills and pink crystals and the variety of particle sizes allows SPM to be applied to nearly any turfgrass including putting greens and fairways. Typical analysis is 22% K and 10% Mg.

Dolomite

Dolomite is calcium-magnesium carbonate and is usually used as a liming source rather than a Mg source. Dolomite analyses can vary but a typical analysis is 18% Ca and 10% Mg. The use of dolomite as a Mg source on soils with a pH > 6.5 is not recommended for turfgrasses due to the further increase in pH. In contrast, turfgrass grown on low pH soils that are documented as Mg deficient may respond more favorably to dolomite than to calcium carbonate.

Keiserite

Keiserite ($MgSO_4 \cdot H_2O$) is a natural occurring mineral possessing 17% Mg and is obtained during the mining of potash ore. Few, if any, turfgrass fertilizers contain kieserite, but kieserite is included in some landscape fertilizers that may be inadvertently applied to turfgrass. As with most minerals, kieserite must weather in order to release Mg. To this end, kieserite has been documented to provide extended release of Mg compared to soluble Mg sources. The influence of kieserite on Florida turfgrasses has not been investigated, thus, its value relative to other Mg fertilizers is unknown.

Magnesium Oxide

Mg oxide (MgO) contains 56% Mg and is applied to Florida turfgrasses in the form of frits (homogenous granules of metal oxides). Because Mg is in the oxide form, the solubility of Mg in MgO is extremely low. Studies have shown that MgO does not increase Mehlich III Mg levels in soils. The use of MgO and all forms of MgO (hydroxides, frits, sucrates, etc.) to supply Mg to turfgrass is not a best management practice.

Magnesium Sucrate

Mg sucrate is manufactured by pelletizing MgO powder into a black or dark-red granule. Although the granules rapidly disperse in water, this dispersion only forms a suspension of undissolved particles and, thus, Mg remains mostly insoluble. Magnesium sucrate has been studied on turfgrass in central and north Florida and does not increase turfgrass quality or color relative to untreated turfgrass.

Magnesium Chelates

Mg may be chelated for use on soils or as a foliar spray. Limited information exists on chelated Mg for turfgrasses, however, evidence indicates that chelated Mg may result in the same turf response and soil solubility as non-chelated Mg. Under normal Florida conditions, non-chelated Mg will remain soluble in soils for many weeks after application, which implies the addition of a chelating agent is unnecessary.

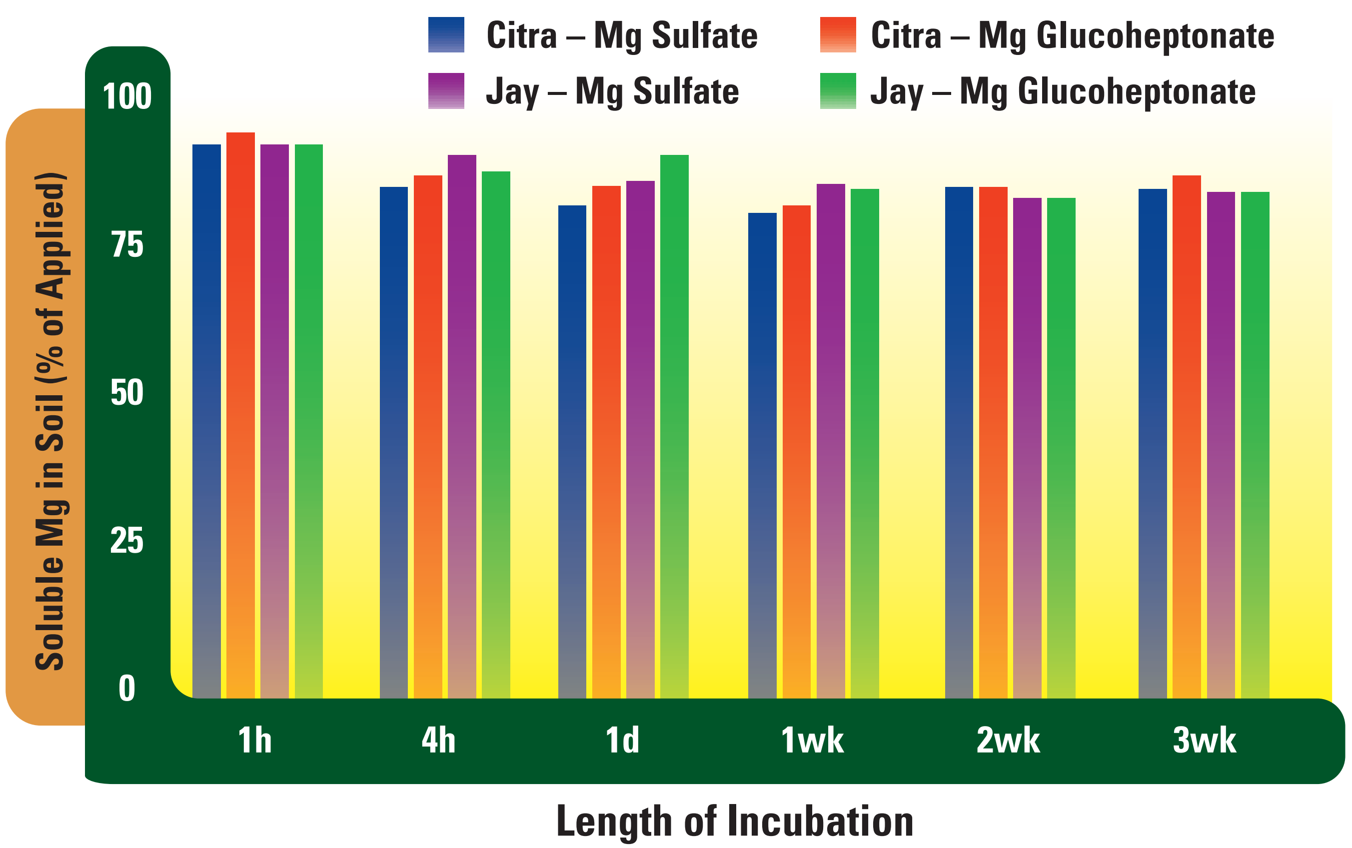
Organic Magnesium

Some natural organic fertilizers such as municipal biosolids may contain small amounts of Mg. The value of this Mg in turfgrass management is difficult to determine because most organic Mg sources also contain nitrogen and/or phosphorus, which also increases turfgrass greening and can obscure the influence of Mg. Organic Mg may become plant available through mineralization and be taken up by the turfgrass. However, this dynamic has not been adequately investigated in Florida turfgrasses and, therefore, the value of using organic Mg remains unknown.

Turfgrass Response to Magnesium

A turfgrass response to Mg in Florida has been documented but responses are uncommon. When a response occurs, the turfgrass usually appears darker green with little to no increase in growth. UF/IFAS research on Mg is limited, but recent findings indicate that the soil may provide adequate Mg to sustain acceptable turfgrass, and further addition of Mg via fertilizers may be of little value. When Mg is desired, current evidence indicates foliar Mg may be a more effective Mg source than granular, although both granular and liquid soluble Mg sources will remain soluble and, therefore, plant available in Florida soils for many weeks after application (Figure 5.12).

FIGURE 5.12: Soluble Mg fertilizers will remain soluble in soils for many weeks after application despite chelation.



Sulfur

Sulfur is essential for selective amino acid production. It is used for building blocks of proteins and also reduces the incidence of disease. Sulfur content in leaf tissue ranges from 0.15 to 0.50% of the dry weight.

The sulfate anion (SO_4^{-2}) is the primary available form found in soil solution. Like nitrate, the sulfate ion can leach from soil. Sulfur deficiency in Florida turfgrasses is exceedingly rare because many common fertilizers contain sulfate as the counterion to the element of interest, such as Fe sulfate, Mg sulfate, ammonium sulfate, etc. When deficiencies occur, they are more likely to occur where grass clippings are removed, excessive watering occurs, and sandy soils predominate. Deficiency symptoms include an initial light yellow-green color in the leaves, with the yellowing most pronounced in younger leaves, as sulfur is mobile in plants. Older leaves become pale and then turn yellowish-green in interveinal areas. Leaf tips are scorched along the margins. Bermudagrass grown in sandy soils has been shown to respond to sulfur applications.

Over 90% of available sulfur exists in the organic matter, which has a nitrogen-to-sulfur ratio of approximately 10 to 1. Deficiencies may occur when the ratio is greater than 20 to 1 or at a high soil pH (> 7.0). Sulfur may be precipitated as calcium sulfate ($CaSO_4$), whereas at lower pH levels (< 4.0), the sulfate anion may be adsorbed by aluminum and/or iron oxides. Turf clippings with a high nitrogen-to-sulfur ratio (> 20 to 1) decompose slowly and may slow thatch biodegradation. Microorganisms require sulfur to decompose plant residues.

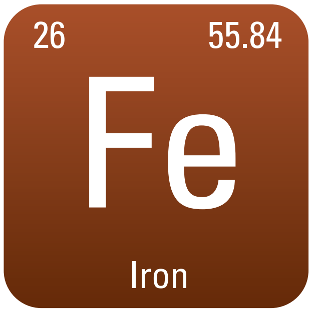
In poorly drained, waterlogged soils where soil oxygen is exhausted, sulfate-reducing bacteria can convert SO_4^{-2} and sulfur-containing organic matter to toxic hydrogen sulfide (H_2S). Excessive applications of elemental sulfur also may encourage the buildup of hydrogen sulfide in greens where excessive irrigation is practiced, or drainage is poor. Insoluble sulfides also may form by reacting with soil iron.

Turf soils containing toxic levels of hydrogen sulfide or iron sulfate are acidic and commonly form a black layer several inches below the soil surface. They typically are characterized by a distinct hydrogen sulfide (e.g., sewer or rotten egg) smell. Low soil oxygen also can reduce levels of manganese, copper, and iron, resulting in gray and blue colored subsoils. This often occurs in poorly drained soils and in greens receiving excessive irrigation. The black layer can usually be controlled by proper water management and aeration.

Micronutrients

Micronutrients are just as essential as the macronutrients but required in relatively smaller amounts. Many soils in the United States supply sufficient levels of micronutrients. In other cases, enough micronutrients are supplied in fertilizers as impurities. In Florida, however, with its sandy and peat or muck soils, pockets of high-pH and phosphorus-containing soils, poor drainage, and periods of extended, heavy rainfall, micronutrient deficiencies may occur but are rarely confirmed for any micronutrients other than Fe and Mn.

Fe and Mn are the only micronutrient fertilizers that have been documented to provide a turfgrass response in Florida. Fe should be applied only as a foliar spray at between 1–5 lbs. of Fe per acre. Granular Fe chelates may result in a turfgrass response but often require multiple applications of ≥ 20 lbs. per acre. Mn may be applied as either a foliar or granular application but a response to Mn is uncommon from either source. The lack of turfgrass response typical from either granular Fe or Mn is due to the rapid soil oxidation of Fe and Mn. Within 1 hour of soil contact, approximately 99% of Fe and 50% of Mn may become oxidized and unavailable for turfgrass uptake. Foliar applications of these micronutrients are readily taken into the plant through the leaves and avoid soil contact, therefore resulting in a more consistent response.



Managing micronutrient applications based upon soil testing is not a best management practice. As previously stated, for Florida turfgrasses, soil testing is useful in managing pH, salinity, and provides critical minimum values for P, K, and Mg.

Iron

Iron is commonly applied using granular or foliar sources to enhance turfgrass color. Iron applications can result in darker green turfgrass but may result in no turfgrass response at all. Understanding the dynamics of Fe both in the plant and in the soil could greatly enhance your nutrient management programs and recommendations.

Role of Iron in Turfgrasses

Turfgrass can appear darker green after an Fe application because the supply of Fe from the soil is low and the demand for Fe in the plant is high. Iron is needed in numerous photosynthetic functions, including activation of enzymes that catalyze chlorophyll synthesis, maintenance of thylakoid membrane (the site of the light-dependent photosynthesis reaction) structural integrity, and the transfer of electrons during photosynthesis. Be aware that although several nutritional elements may result in darker green turfgrass, the roles of most elements within the plant are not interchangeable with one another. Thus, the application of Fe will not cure N deficiency.

Iron is immobile in the plant (i.e., does not move from one plant tissue to another) and, thus, deficiency appears on younger leaves first. Iron deficiency is commonly observed in Florida in the spring following N fertilizer applications. This phenomenon can occur on any turfgrass but usually occurs only on bahiagrass, centipedegrass, and St. Augustinegrass. This can be frustrating because the N application should have resulted in a greener turfgrass but in fact, the turfgrass may appear more chlorotic in places. The most likely explanation is that during the winter months, the rate of turfgrass shoot and root growth declines. In north Florida, growth may cease altogether whereas in south Florida, growth may slow down.

Nitrogen applied during the spring encourages turfgrass growth and, in turn, increases the demand for Fe. This demand for Fe cannot be met because turfgrass root growth is still limited in the spring and, thus, the ability to take up Fe is low resulting in chlorotic leaf blades. Cool, wet soils tend to exacerbate this chlorosis. As soil temperatures increase, the quantity of turfgrass roots increases resulting in greater uptake of Fe and a decrease in Fe deficiency symptoms. Springtime occurrences of Fe deficiency are more common in central and north Florida than in south Florida and normally dissipate within a few weeks. Otherwise, turfgrass Fe chlorosis can be minimized by applying foliar Fe at a rate between 1–5 lbs. of Fe per acre (Figure 5.13).

FIGURE 5.13: Bermudagrass showing response to foliar iron (each dark green rectangle) compared to granular Fe or no Fe (all remaining rectangles).

Soil Iron

Iron makes up about 5% of the earth's crust but most of this Fe is bound in primary or secondary minerals and is unavailable for plant uptake. Compared with other cations in the soil solution, available Fe concentration is usually very low and is commonly lower than necessary to meet plant requirements. So how does turfgrass acquire Fe if the available Fe is insufficient? Turfgrass exudes natural chelating compounds known as phytosiderophores that complex Fe and renders the Fe available for plant uptake. Even with the ability to chelate soil Fe, turfgrasses may not receive sufficient Fe to achieve the desired green color expected by many superintendents. In these cases, Fe fertilizers can be used to enhance turfgrass greening.

The availability of Fe in soils is dependent upon soil moisture, soil pH, soil temperature, and organic matter content. As soil moisture increases, the quantity of Fe available for plant uptake also increases because the rate of Fe oxidation is much lower when oxygen is limited. This may seem advantageous but limited oxygen also negatively influences turfgrass root growth. Thus, a moist soil that is not too dry or too wet is ideal. Iron remains soluble for no more than a few minutes in aerated solutions of pH 7.0 or higher. This does not imply that Fe is always soluble when soil pH is below 7.0. The dominant plant-available form of Fe in soils is ferrous Fe (Fe^{2+}) and because Fe^{2+} reacts directly with oxygen (O_2) in an aerated soil solution, little, if any, soluble Fe will be available for turfgrass uptake until the soil pH falls below 4.0. Low soil temperatures may limit Fe uptake by reducing phytosiderophores production or by increasing bicarbonate accumulation, which precipitates soluble Fe as $FeCO_3$. Humic and fulvic acids found in soil organic matter may increase Fe solubility. In short, Fe acts as a catalyst for the oxidation of organic matter by O_2, which increases the amount of Fe^{2+} in soil solution. This reaction occurs despite the presence of O_2 in soil solution, thus Florida soils with appreciable organic matter should be less prone to producing Fe deficient turfgrass.

Soil Testing for Iron

Iron applications should not be based upon soil test Fe levels. Most soil testing labs will test for Fe, but do not provide a fertilizer recommendation. This is because the concentration of Fe changes rapidly in most aerated soils and thus, by the time the applicator receives the recommendation, the soil Fe levels would likely be different from the initial soil concentration. In addition, soil test calibrations used to predict a response to the application of Fe have not been established on Florida soils.

Iron Fertilizer Sources

Iron Sulfate

Iron sulfate is perhaps the most common soluble granular Fe source for turfgrasses. Iron sulfate typically has an analysis of 20% Fe and appears as a white or light greenish blue, angular particle or prill, and it is 100% water soluble. Both granular and foliar forms of Fe sulfate are used in turfgrass management, but only foliar Fe sulfate has resulted in a positive turfgrass response in Florida. Granular Fe sulfate must dissolve into the soil solution and be taken up by the roots. During this process Fe sulfate reacts with water to form an Fe hydroxide (Figure 5.14). This oxidation process is extremely rapid resulting in as much as 95% of the applied Fe becoming unavailable within one hour of soil contact. In addition, if the oxidation process occurs on surfaces such as cart paths or roads, a reddish brown stain will occur (Figure 5.15). Because these stains are formed chemically, they are difficult to remove. Therefore, Fe sulfate should be applied as a liquid to the turfgrass foliage rather than applied to the soil.

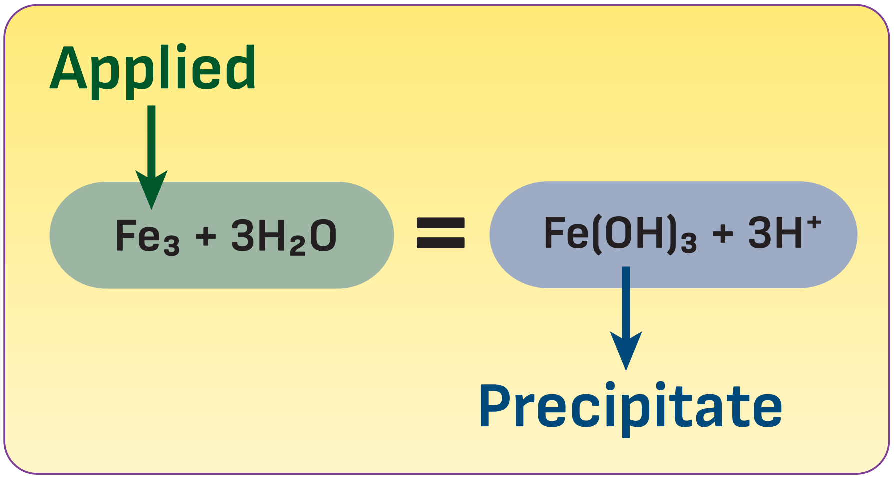


FIGURE 5.14: Iron applied to soil rapidly oxidizes and becomes unavailable for plant uptake. If applied as a foliar spray at 1–5 pounds of Fe per acre, Fe sulfate generally improves turfgrass color for up to 4 weeks. The longevity of response is a function of the amount of Fe applied, the amount of N applied, and the time of year. Exceeding 5 pounds of Fe per acre increases the probability of leaf burn and may temporarily turn the turfgrass leaves black. Foliar Fe cannot be used to cure chlorosis resulting from N deficiency. Iron cures Fe deficiency and N cures N deficiency.

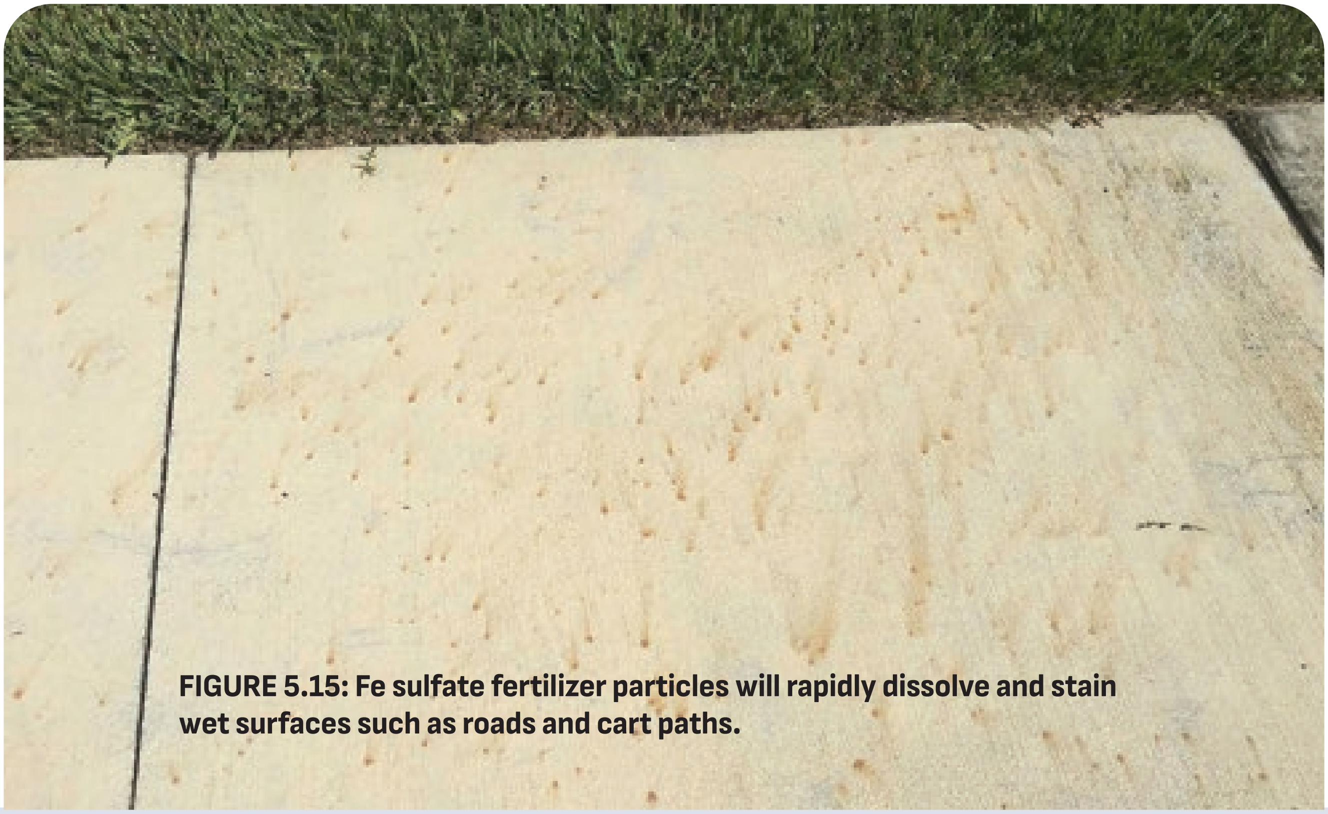


FIGURE 5.15: Fe sulfate fertilizer particles will rapidly dissolve and stain wet surfaces such as roads and cart paths.

Iron Humate

Iron humate is the bi-product of water treatment facilities that produce potable water from humate-rich river water. The material is normally a dark brown to black granule and has a guaranteed Fe analysis of 14%. Iron humate is approximately 30% water soluble with the remaining Fe being in a slowly available form. Over a two-year period in two Florida locations, a single application of 20 pounds of Fe (as Fe humate) per acre resulted in no improvement in bermudagrass color or quality. Although a portion of the Fe is slowly available, the Fe still must solubilize into the soil solution before plant uptake can occur. Because the Fe is not chelated, the Fe entering the soil solution will oxidize similar to Fe sulfate.

Iron Oxide

Iron oxide is the end product of Fe weathering, and more than 99.5% of Fe within Fe oxide is water insoluble. The product is normally a black, angular, very hard granule and guarantees 50% or more Fe. No turfgrass response to Fe oxide has been observed in research studies. Iron oxide should not be used as a turfgrass fertilizer in any of its forms.

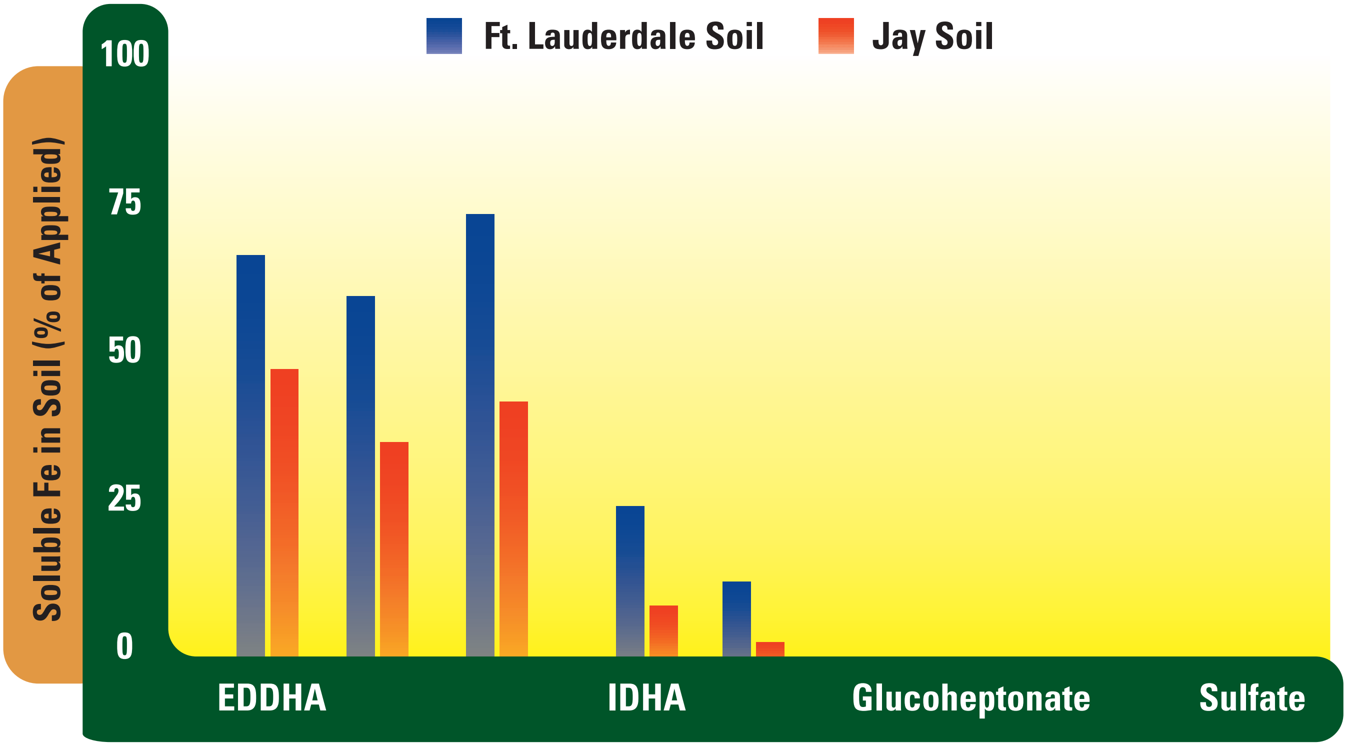
Iron Sucrate

Iron sucrate is manufactured by pelletizing powdered Fe oxide using a sugar, usually molasses. The product is normally a spherical, black prill and guarantees 50% or more Fe. Although the prills readily disperse in water, Fe sucrate is not water soluble. The dispersion forms a suspension in water, but the fine particles remain insoluble. Turfgrass research using Fe sucrate clearly shows that Fe sucrate does not improve turf quality, growth, or color.

Iron Chelates

Chelation is the process of making an insoluble metal soluble by surrounding the molecule with an organic complex. Many Fe chelates exist for use on turfgrasses but only ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), and ethylenediaminedi-o-hydroxyphenlyacetic

FIGURE 5.16: Solubility of Fe sources one day after application to Jay and Ft. Lauderdale soils.



acid (EDDHA) are documented to result in turfgrass responses when applied to the soil. EDTA, DTPA, and EDDHA may also be applied as a foliar spray and common guaranteed analysis range between 5% and 10% Fe. A relatively new chelate to the turf market is N-(1,2-Dicarboxyethyl)-D,L-aspartic acid (IDHA). After 1 day of soil contact, IDHA resulted in an increase in soluble Fe in Florida soils compared to Fe sulfate (Figure 5.16, previous page), but the influence IDHA has on turfgrass color has not been determined. Other Fe chelates such as gluconate, glucoheptonate, and citrate applied as foliar sprays commonly improve turf color, but they do not increase the availability of Fe in the soil. Keep in mind that high application rates of Fe chelates, especially Fe EDTA, can be phytotoxic to some landscape plants.

Powder-Coated Iron

Some fertilizers may be blended with a component of very fine Fe powder added when the fertilizer is being blended. This powder attaches to each fertilizer particle, which greatly increases the uniformity of Fe distributed across the turfgrass. The Fe powder may be derived from Fe sulfate, Fe oxide, or Fe chelate. Each of these powder-coated Fe sources have been tested on Florida turfgrass and none have increased turfgrass color or quality compared to untreated turfgrass. In the case of Fe sulfate and Fe oxide, the lack of response is due to the same soil chemical reactions that limit Fe solubility from conventional Fe fertilizers (Figure 32). In the case of powder-coated Fe chelates, the reason no response has been observed is unknown. However, it is likely that the amount of Fe chelate required to induce a response is greater than the amount of Fe chelate that can be applied via this coating method. Until a turfgrass response to powder-coated Fe is confirmed in Florida, the use of powder-coated Fe is not an evidence-based practice.

Organic Iron

The value of organic Fe in fertilizers such as Milorganite® or municipal biosolids is difficult to evaluate because most organic Fe sources also contain N and/or phosphorus (P). Separating the influence of Fe from the influence of N and P is very difficult and, thus, a real response to organic Fe has not yet been documented on Florida turfgrasses.

Manganese

25 54.94
Mn
Manganese

Manganese is similar to Fe in many ways. Manganese is commonly applied using granular or foliar sources to enhance turfgrass color. Supplemental applications of manganese may enhance turfgrass greening but may also result in no turfgrass response.

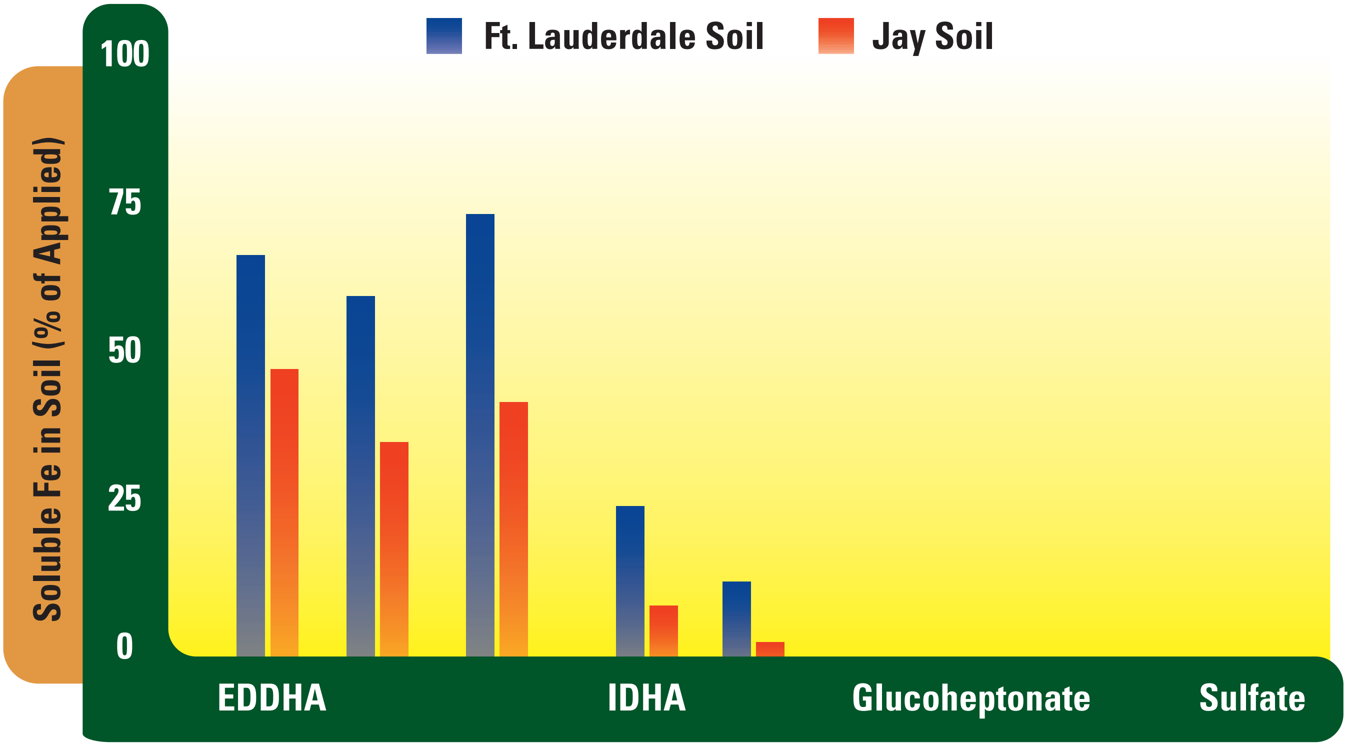
Role of manganese

Manganese influences the rate of photosynthesis and is a cofactor for ~35 enzymes. Lignin biosynthesis requires Mn and in the absence of Mn, thylakoid membranes begin to degrade resulting in a loss of chlorophyll.

Soil Manganese

The majority of Mn in Florida soils is unavailable for plant uptake and exists in various minerals or in organic matter. As organic matter mineralizes, small amounts of Mn will enter the soil solution where the Mn will come into contact with dissolved oxygen and oxidize to form one of several species of Mn oxides. This reaction also occurs following Mn fertilization. Within one hour of soil contact, approximately 50% of applied Mn as sulfate or glucoheptonate may be rendered insoluble through oxidation (Figure 5.17, next page). The remaining Mn may remain soluble throughout the next several weeks.

FIGURE 5.17: Solubility of Mn sources from 1 hour to 3 weeks after application to soils from Jay and Citra, Florida.



Soil Testing for Manganese

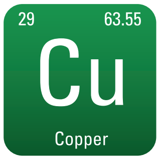
Soil testing for Mn in Florida turfgrass systems is unreliable because the concentration of Mn changes rapidly between sampling and analysis.

Turfgrass Response to Manganese

Fairway and greens-height bermudagrasses have shown responses to applied Mn in Florida. In each case, the response was described as enhanced greening with no increase in growth. Both foliar and granular forms of Mn can alleviate Mn-deficiency symptoms although foliar Mn may be more effective than granular because granular Mn may be rendered unavailable through soil oxidation.

Role of Boron

Boron is primary found in the cell wall and likely plays a role in the cell wall's structural integrity.



Role of Copper

Copper is a component of plastocyanin required for photosynthesis and is a cofactor for several enzymes.

Role of Zinc

Zinc is a structural component of enzymes, is required for protein synthesis, and influences carbohydrate metabolism.

42 95.94 Mo Molybdenum

Role of Molybdenum

Molybdenum role is primarily related to N metabolism but also is a structural component of enzymes.

17 35.45 Cl Chlorine

Role of Chlorine

Chlorine is required for the oxygen evolving reaction of photosynthesis and is likely required for cell division in leaves and shoots.

Chelates

Chelates, chelating agents, or sequestering agents are cyclic structures of a normally insoluble metal atom bonded with an organic component. They are soluble in water. Commercially available sequestered metallic ions are iron, copper, zinc, manganese, and magnesium. Organic compounds with the ability to chelate or sequester these metallic ions include EDTA, DTPA, cyclohexanediaminetetraacetic acid (CDTA), EDDHA, and IDHA. A plant can absorb the soluble chelate forms of the metal ions. The only chelates that have been documented to increase the solubility of micronutrients in Florida turfgrass soils are EDTA, DTPA, CDTA, EDDHA, and IDHA. Liquid fertilizers may contain other chelates such as glucoheptonate, gluconate, lignosulfate, and citrate. These compounds are chelates according to the AAPFCO because the compounds form a stable molecule that does not precipitate in a basic solution. However, these compounds are not soil chelates because they do not increase the soil solubility of the element they carry.

Other Beneficial Elements

Research conducted in Florida indicates that silicon may be beneficial to some turfgrasses. Disease incidence, particularly grey leaf spot, may be reduced by the application of silicon to turfgrasses growing in soils low in soluble silicon. Silicon is thought by some to increase green speeds by stiffening the leaf blade. This notion has been tested on TifEagle greens and no supporting evidence was found. On each of eleven occurrences when Si was applied to TifEagle putting greens, no increase in ball roll was documented.

Nonessential Elements

Aluminum, arsenic (As), and Na are generally considered nonessential elements for turfgrass growth and development. They become toxic when levels are excessive and should not normally be applied in supplemental fertilizers. Toxic concentrations of Al, As, and Na in leaf tissue are unknown but the upper reference range for Al and Na provides a reasonable estimation (Table 5.3). Some published research indicates that sodium may be essential at some level for bermudagrass and other C_4 plants.

Soil pH

Soil pH has many effects on plants but probably influences them most by affecting the availability of important nutrients. For example, pH values < 5.0, aluminum, iron, and manganese are highly soluble. High levels of aluminum can reduce plant uptake of phosphorus, calcium, magnesium, and iron. At pH values > 7.0, nutrients such as iron, manganese, copper, and zinc are less soluble and therefore relatively unavailable for plant uptake—although molybdenum (Mo) availability actually increases with high pH. The availability of phosphorus and boron also may be hindered by a soil pH value greater than 7.
In parts of south Florida, marl may become mixed with surface organic soils or peat. These normally

acidic organic soils thus become neutral or even alkaline due to the liming action of the marl. Many of the peat or muck sod farms in south Florida are on soils with marl intermixing. These soils are almost always low in magnesium, potassium, phosphorus, copper, and zinc.

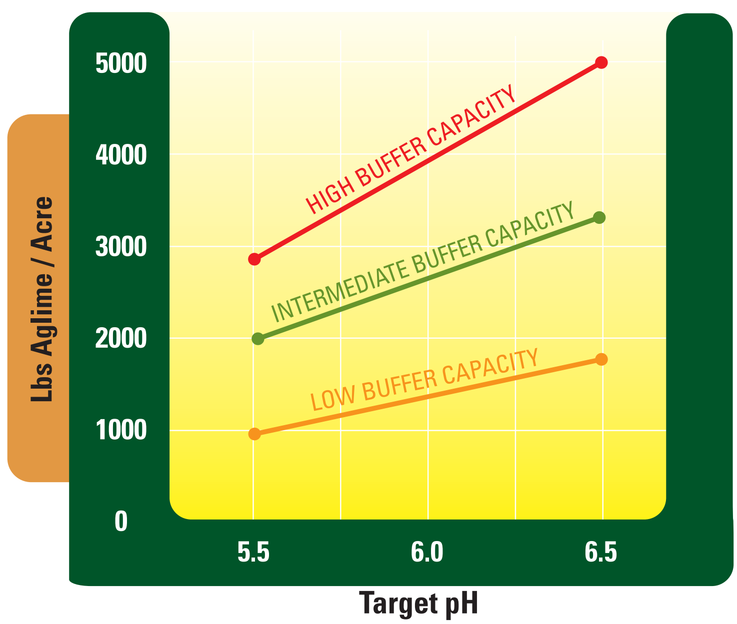
Except in some coastal areas, most Florida soils are naturally acidic. Liming acidic soils to a pH of 6.5 has numerous positive effects on the soil and on turfgrass growth and quality. The beneficial effects of liming acidic soils include the following:

- **Increased turfgrass growth and quality**
- **Decreased thatch buildup**
- **Increased retention and reduced leaching of fertilizer elements**
- **Increased rooting density and depth**
- **Optimum availability of nutrients**
- **Increased activity of beneficial soil organisms**
- **Amelioration of toxic elements in the soil**
- **Better soil structure and tilth**

Soil pH should be monitored by annual soil testing. Intensively managed and artificially constructed areas such as putting greens may require more frequent testing. Whenever soil pH drops below 6.0, lime should be applied in sufficient amount to raise the pH to 6.5. A general rule of thumb for liming sandy soils with low buffering capacity, such as those in Florida, is to apply 1 ton of lime per acre to raise the pH 1 unit (Figure 5.18). However, liming based on laboratory recommendations is more precise and should be used whenever possible. Samples should be sent to a soils lab that uses the Adams-Evans (A-E) method for predicting liming requirements. The UF—IFAS Extension Soil Testing Laboratory (ESTL) uses the A-E method and recommends it. Ideally, the pH of Florida soils should never be allowed to drop below 5.5 unless recommended by the ESTL for the specific crop being grown.

Pulverized calcitic or dolomitic limestone with a calcium carbonate equivalent (CCE), or neutralizing power, of 90 or greater is recommended for liming turfgrass on golf courses. Dolomitic limestone is the preferred product for soils that are low in magnesium. Pelletized products reduce the dust associated with the application of liming materials and flow more easily through spreading equipment, resulting in a more uniform application.

FIGURE 5.18: Effects of buffering capacity on lime requirements



Soil pH Best Management Practices

To increase soil pH, apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca_2+ and neutralizes acidity.

To lower soil pH, use products containing elemental sulfur, such as sulfur or sulfur-coated urea; or use ammonium sulfate.

In some cases, using injection pumps into irrigation water to address pH can be beneficial.

Nutrient Management

Fertilization programs for golf course grasses require sufficient nutrients for optimum health and performance turfgrass but must also protect Florida's fragile environment. Trying to improvise one fertilization schedule that encompasses all courses within the state is unrealistic. Players' expectations, budget constraints, the soils used in construction, and location all influence the inputs each course must use when determining a sound fertility program. Sometimes, this is intensified by the high, and often excessive, standards demanded by professional players. Club members often place undue pressure on their superintendents to provide lush conditions that drive up costs and risk wasting or harming natural resources.

There is great concern about nitrate-nitrogen leaching into ground water and the phosphorus and nitrogen impacts on surface waters in the state of Florida. Both local and state agencies have been examining the fertilization practices of golf courses. Excessive and unnecessary fertilization should be avoided to prevent water contamination and the possible penalties faced by those deemed to be the source of water pollution.

Additionally, Florida receives abundant rainfall that, at times, exceeds the ability of the soil to retain moisture in the root zone. This may lead to runoff into surface waters or leaching through the soil to ground water. Consequently, do not apply fertilizer when the National Weather Service has issued a flood, tropical storm, or hurricane watch or warning, or if heavy rains are forecast in the next 24 hours. While only about 3 to 5% of Florida rain events exceed two inches, caution should always be used to avoid runoff or leaching from saturated or compacted soils or in other high-risk situations.

The following provides an overview of fertility recommendations for most courses and special situations in the state. Each course, however, should follow the fertility program that best suits its situation. For general information on the fertilization of Florida turfgrasses, see the publication, *General Recommendations for Fertilization of Turfgrasses on Florida Soils* (available: http://edis.ifas.ufl.edu/LH014).

Fertilization Program for Golf Greens

Timing

Determining how much and how often fertilizer should be applied depends on several factors. Each golf course superintendent should consider the quantity and scheduling of fertilizer to be applied during the year. Fertilization programs should provide adequate levels of essential nutrients to sustain growth and acceptable turfgrass health. Improper timing and/or rates of fertilizer application influence the stress tolerance and recuperative ability of turfgrasses. In addition, disease occurrence and severity often are closely linked to the amounts and timing of fertilization programs. For example, dollar spot (*Moellerodiscus* and *Lanzia* spp.) disease often is associated with low nitrogen levels in turfgrass plants. A fertilizer application containing quick-release nitrogen often allows the turfgrass to outgrow these disease symptoms, thus eliminating the need for fungicide applications. In contrast, the excessive fertilization of overseeded grasses such as ryegrass (*Lolium* spp.), roughstalk bluegrass (*Poa trivialis*), and bentgrass (*Agrostis* spp.) often promotes the occurrence of brown patch (*Rhizoctonia* spp.) and pythium (*Pythium* spp.) diseases.

Proper fertilization improves disease and stress tolerance of turfgrass, but also provides disease-free and stress-free turf, but also an acceptable playing surface. Excessive fertilization with nitrogen is not only agronomically detrimental but drastically slows ball roll and draws complaints from players. Exceptions, such as certain high-traffic greens and tees (e.g., Par 3s) or newly constructed greens, require more nitrogen fertilization to promote turf recovery from ball marks and concentrated traffic, and to facilitate grow-in.

The timing of fertilization may be based on the minimum and optimum temperatures necessary for turfgrass growth. Minimum temperatures for warm- and cool-season shoot growth are about 55° and 40° F., respectively, while warm- and cool-season roots may grow at temperatures as low as 50° and 33° F., respectively. Optimum temperatures for warm- and cool-season shoot growth are about 80° to 95° F. and 60° to 75° F., respectively, while optimum temperatures for warm- and cool-season roots are 75° to 85° F. and 50° to 65° F., respectively. If temperatures are outside the growth range of the grass, slow-growing plants use fertilizer applications inefficiently.

Nitrogen Rates

Because of year-round play, the range of annual N needs for Florida golf greens is higher than that typically used in many other landscape settings. However, quality putting surfaces can be maintained without excessive N rates. Courses with high traffic and elevated demands from serious amateur and tournament players use more N than public courses with modest traffic. The most important factor in the environmental fate of N application to turfgrass is not the total amount applied annually but rather, the amount applied in any single application and therefore available to leach or run off to surface waters before being used by the plants. Frequent "spoon-feeding" of greens is the most effective method of avoiding accidental N losses to the environment. The nitrogen content in reclaimed water used for irrigation should be included in these calculations.

Frequency

To maintain acceptable color and density during periods of active growth, sand-based bermudagrass golf greens need approximately ½ to 1.0 lb. N per 1,000 ft^2 per month. Higher application rates can lead to other problems. Excessive thatch can quickly accumulate, putting speeds are slower since more leaf area is produced, and a decrease in turfgrass rooting may result. During the rainy season, these rates may cause excessive leaching and runoff due to the severity of Florida's frequent thunderstorms. Use local weather forecasts to take advantage of breaks in the rainy weather to apply nutrients so they may be absorbed before the rains start again.

Prescription Fertilization

Whenever practicable, fertilization should be based on the specific needs of each individual green at a given time, recognizing that — even when constructed of uniform root zone materials — localized conditions will impact nutrient levels.

Nitrogen Sources

The source of N used to fertilize golf greens affects the amount applied. Usually, a combination of soluble and insoluble sources is recommended to provide uniform grass growth and reduce N leaching. Ureaformaldehyde (Nitroform) and sulfur-coated urea often are used to provide slow-release N, whereas a soluble source is used for rapid response. Other considerations involving N sources include higher costs for slow-release and natural organic sources compared with soluble sources, the salinity hazard of ammonium nitrate and ammonium sulfate, and the acidifying effects of ammonium sulfate and ammonium phosphate.

Except for slow-release materials, N should never be applied in excess of 1 lb. per 1,000 ft^2 in any one application, and then only when appropriate soils and healthy turfgrass preclude leaching. Small amounts (½ lb/1,000 ft^2 soluble N) frequently applied are preferred, since this produces a higher-quality turf, reduces growth flushes, and minimizes leaching potential. In most cases, a high-quality turfgrass can be maintained for a 90-day period without flushes of growth or drastic changes in color when slow-release sources are used. Additionally, slow-release N sources leach less than soluble ones.

Other Elements

Potassium (K) often is called the "health" element. Without a readily available supply of K, turfgrasses may be more susceptible to environmental and pest stresses. Root growth also is related to K availability. Unfortunately, K does not readily remain in the turfgrass root zone, especially in greens constructed predominately with sandy soils. Therefore, it should be applied to golf greens nearly as frequently as N, at between one-half to equal the N rate.

Soil phosphorus (P) levels tend not to fluctuate as readily as N or K. Golf greens constructed of uncoated sands, and sand greens that have a pH less than 5.0, may leach P readily. In such situations, soil P levels should be monitored frequently, and P source fertilizers applied only when soil P levels become deficient.

Micronutrients

Soil testing should be used to determine the soil pH and adjusting the soil pH to approximately 6.5 will reduce the chances of observing micronutrient deficiencies. The remaining micronutrient values and/or recommendations on a soil test should not be used to apply micronutrients. Deficient soil concentrations of micronutrients for Florida turfgrasses are unknown and have not been calibrated with a specific soil extractant and a given turfgrass response. However, because Fe and Mn commonly increase turfgrass color and quality, Fe and Mn are the only micronutrients that should be regularly applied. Mn may be applied in either a granular or foliar form, but Fe should only be applied in foliar form. Fe and Mn may be applied at rates between 1–5 lbs. per acre. Both Fe and Mn may result in turf 'blackening' as rates increase above 5 lbs. per acre. The 'blackening' occurs as the metal is oxidized on the leaf surface, but the turf normally grows through this response within 1–2 weeks.

Tees

Tees, like greens, should be fertilized sufficiently to sustain vigorous recuperative growth. Tees, in general, are maintained almost as intensively as golf greens. This is especially true for tees constructed with a sand-based profile and for Par 3 tees that receive excessive traffic and damage from club divots. For most Par 4 and Par 5 tees, the fertilization program can be reduced to approximately one-half that for golf greens. For Par 3 tees, the fertilization program should range between three-fourths of or equal to that for greens. K applications should be approximately one-half of N applications, except where clippings are removed or when sand-based tees are constructed. In such cases, K application rates may need to equal those of N.

Fairways and Roughs

Fairways generally are maintained with lower fertilizer inputs than golf greens. Clippings are returned during mowing, resulting in the recycling of more nutrients, and heavier native soils are usually used for fairways. In addition, higher mowing heights promote deeper rooting, and less irrigation is applied that may leach soil nutrients. N fertilization rates should range between 130 and 260 lbs. per acre per year. P may be required when Mehlich III soil test decline below 10 ppm. K should be applied at the same time as N at ½ the rate of N.

Fertilizers

Fertilizer applications should begin with the first flush of new turf growth. These are supplemented throughout the year with N and K, as needed, to maintain desirable color, leaf texture, density, and recuperative ability. In general, applications are made every 5 to 8 weeks on high-maintenance courses and every 10 to 12 weeks on low-maintenance courses through the spring and summer. The last fertilization should be made approximately 1 month before anticipated frost in north Florida. Fertilization should continue in south Florida or on overseeded fairways to maintain desirable color. Be careful not to over-apply, because the slower-growing turf is less able to use the applied material.

For specific information on the fertilization of different turfgrass species grown on golf courses and athletic fields, see the publication, *Recommendations for N, P, K, and Mg for Golf Course and Athletic Field Fertilization Based on Mehlich III Extractant* (available: http://edis.ifas.ufl.edu/SS404).

Grow-In

Grow-in, or the establishment of turfgrass, is one of the most intensive phases in turfgrass management. Historically, in order to promote rapid establishment, large amounts of N and water were applied during the 10- to 12-week grow-in period, when the largest amount of environmental impairment may take place. Research has shown that this does not have to be the case. By regulating the rate of N applied according to the level of establishment of the turfgrass—i.e., applying less nutrients when the turfgrass coverage is low and gradually increasing the rate of nutrients as the turfgrass establishes—one can reduce N leaching losses by as much as 25%. Also, by properly selecting the N source—i.e., including some slow-release or organic N sources in the fertilizer mixture—the rate of N loss through leaching can be reduced. For installation of fresh-cut sod which has been fertilized within 45 days of harvest, N or P fertilizer should not be applied until at least 14 days after sodding. This does not apply to grow-in from seeding or sprigging. These practices delay the full establishment of the turfgrass by as much as 14 days, but through the proper selection of application rates and N fertilizer sources, N leaching losses can be reduced to less than 10% of the applied N during the entire 12-week grow-in period, even with the increased rates of irrigation that are typically required. Combinations of soluble, organic, and slow-release N sources produce a healthy and vigorous stand of turfgrass during grow-in. The incorporation of fertilizer nutrients in the grow-in root-zone sand/peat mixture does not result in more rapid establishment of turfgrass but does result in more total N, P, and K leached. Some golf course construction firms have used sand only as a root-zone mix. Sand-only greens have a higher propensity to leach N and P and are slower to become established. Great care should be exercised when establishing turfgrasses on sand-only greens.


Photo courtesy USGA

Phosphorous is very important during grow-in. In general, turfgrasses respond better to P fertilization during grow-in than at any other time during their growth cycle. If the root-zone mix does not contain adequate levels of P for root development, turfgrass establishes slowly and has a poorly developed system. Extreme care should be exercised when fertilizing with P during grow-in. When establishing turfgrass on sands containing low levels of P and sesquioxide/clay coatings, P may leach. Apply P when Mehlich III soil test values fall below 10 ppm.

Potassium is also very important during turfgrass establishment for healthy turfgrass growth and root development. Sandy soils are typically low in K and require K fertilization. Fortunately, K is not considered an element of environmental impairment; thus, K fertilization may not have an environmental impact, but salt buildup in the root-zone mix and the depletion of a natural resource are two reasons to monitor the soil test K level and apply only the amount required for optimum turfgrass growth. Generally, turfgrasses do not respond to K when Mehlich III soil test values are greater than 30 ppm. Maintaining an optimum soil pH for turfgrass health through proper liming results in maximum K retention by media cation exchange sites in the root zone.

Fertilizer Loading

Load fertilizer into application equipment away from wells or surface waterbodies. A concrete or asphalt pad with rainfall protection is ideal, as it permits the easy recovery of spilled material. If this is not feasible, spread a tarp to collect spillage. Where dedicated facilities are not available, loading at random locations can prevent a buildup of nutrients in one location. **It is not recommended to load fertilizers on a pesticide CMC because of the potential for cross-contamination.** Fertilizers contaminated with pesticides may cause turf damage or generate hazardous wastes. Many pesticide carriers are hydrocarbon-based and they may react with oxidizers in spilled fertilizer materials.

Clean up spilled material immediately. Collected material may be applied as fertilizer. The area can be cleaned by sweeping or vacuuming (or by using a shovel or loader, if a large spill), or by washing down the loading area to a containment basin specially designed to permit recovery and reuse of the washwater. Washwater generated should be collected and applied to the turf. **Discharging this washwater to waterbodies, wetlands, storm drains, or septic systems is illegal.**

Figure 5.18 shows unsafe and safe fertilizer storage practices (left and right photos, respectively).

FIGURE 5.18: Fertilizer: left, no cover, open spills; right: good practices, inside storage

Fertilizer Application

Calibration

The only way to accurately know how much fertilizer is actually being applied is to calibrate your application equipment. Calibration should be done in accordance with the manufacturer's recommendations, or whenever wear or damage is suspected to have changed the delivery rate. For granular materials, it may be necessary to recalibrate whenever using a new material with different flow characteristics. Sprayers and metering pumps on liquid systems also need to be calibrated regularly.

Granular Application

Granular fertilizer is usually applied with a rotary spreader. When applying it near waterways, cart paths, or other non-target areas, always use a deflector shield to prevent inappropriate fertilizer distribution. Maintain a 'Ring of Responsibility' of at least 3 feet when using a deflector shield, 10 feet if no shield is used, even if no other Special Management Zone is defined. If fertilizer is deposited on cart paths, parking lots, or other impervious surfaces, sweep or blow the material into the turf where it can be properly absorbed and will not run off into storm drains or waterbodies. Drop spreaders may be used occasionally, but they may cause mechanical damage to the coatings of slow-release fertilizers.

Foliar Feeding

Foliar feeding and liquid fertilization involve the use of a soluble nutrient form for plants. Nutrients are used more rapidly, and deficiencies corrected in less time than conventional soil treatments. However, the response is often temporary. Due to the small amounts required, micronutrient applications have traditionally been the most prominent use for foliar sprays.

Foliar feeding involves using low fertilizer rates (e.g., 1/8 lb. nitrogen or iron per 1,000 ft^2) at low spray volumes (e.g., 1/2 gal. per 1,000 ft^2). Low nutrient and spray volumes minimize costs and supplement the normal fertilization program with nutrients absorbed directly by turfgrass leaves.

At higher spray volumes, (e.g., 3 to 5 gals. per 1,000 ft^2), the fertilizer is washed off the leaves. This is called liquid fertilization. With liquid fertilization, fertilizers and pesticides often are applied together. Although the initial spray equipment for liquid application costs more, it usually is less expensive to apply in the long run than granular fertilizer.

The application of micronutrients, Fe being a notable example, is commonly employed with foliar fertilization. All micronutrients are metals except boron and chloride. With the exception of molybdenum, the availability of most micronutrients declines with increasing soil pH. Chloride is unaffected by soil pH. Micronutrient fertilizers are generally more expensive than macronutrient materials. The application rates for micronutrients usually are low enough so that foliar applications are feasible. One potential problem when zinc, iron, manganese, and copper are added to clear liquid fertilizers is that precipitation often occurs as a reaction with phosphates. Chelates of the metal micronutrients can be mixed with liquids without causing precipitation.

Nitrogen may be added to many micronutrient products to stabilize the solution. Micronutrient solutions can retain elements at higher temperatures and become supersaturated. Upon cooling, micronutrients in the solution may precipitate out, forming insoluble compounds. Urea has been shown to help prevent precipitation, and it also gives the turf a small color boost.

Advantages and Disadvantages of Foliar Fertilization

Advantages:

No particle segregation, as is common with granular fertilizers.

Micronutrients avoid soil contact through direct absorption by leaves.

Increased application uniformity especially for low-rate products such as micronutrients.

Fertilization provides water-soluble forms of nutrients.

Co-application with pesticides is possible.

Disadvantages:

Sufficient amounts of nutrients may be difficult to apply while avoiding leaf burn.

May be more expensive than granular fertilizers.

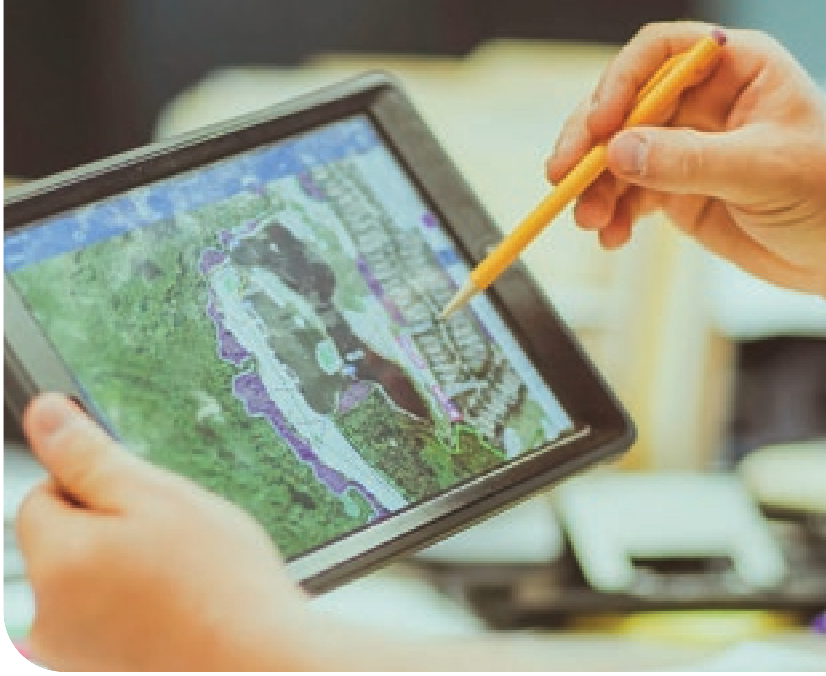
Requires additional labor due to the increased applications.

Some solutions may salt out at lower temperatures.

Frequent applications at low rates may be necessary because turf response is temporary and low rates prevent leaf burn.

Precision Application

Precision application refers to the use of automated application equipment using global positioning system (GPS) data and detailed mapping to apply precise amounts of a product to a specific area. This may reduce overall fertilizer (or pesticide) use by customizing the application to the particular characteristics at a given location and may be accurate to within one or two feet. Typically, standard spreading equipment applies the same amount everywhere. In order to ensure that enough is applied to troublesome spots, overapplication may occur in many other areas.



Fertigation

Fertilizer application through an irrigation system is termed fertigation. This ideally combines the two operations to use resources and labor more efficiently. Frequent light applications (e.g., spoon-feeding) of fertilizer are metered into irrigation lines and distributed along with irrigation water through sprinkler heads. Since most of the applied irrigation water and fertilizer enters the soil and is not retained on the foliage, fertigation is not synonymous with foliar fertilization. Nitrogen, potassium, and micronutrients are often applied in this manner. Fertigation is usually considered a BMP in Florida because it minimizes the potential for leaching. It helps maintain even color and growth, minimizes color surges that result after heavy granular applications, and reduces the labor costs associated with frequent applications of granular forms.

Application through a simple irrigation delivery system is probably the best. This consists of a fiberglass or plastic storage tank with a visual volume gauge, a filter, and an adjustable, corrosive-resistant pump to inject fertilizer into the main irrigation line. If a centrifugal pump is used for irrigation, drawing fertilizer into the suction side of the irrigation pump can eliminate the injector pump, so that some fertilizer is applied at each irrigation event. If the injection pump supplies fertilizer at a constant rate, it is important that the irrigation system is well balanced, with each zone covering approximately the same amount of land area so the fertilization rate is also constant—except for areas where it is desirable to fertilize at a heavier rate. Proportioning systems have been developed that keep a constant ratio between the volume of liquid fertilizer injected and the volume of irrigation water applied.

To operate the system, the amount of N and other nutrients that are desired per unit of turf area per unit of time (e.g., lbs. N per 1,000 ft^2 or per acre applied per month) must be determined. Then, by knowing the concentration of the fertilizer solution, the rate at which the injection pump must operate can be determined. This rate can be adjusted, if necessary, to compensate for unusually high or low amounts of rainfall that affect irrigation needs. The visual gauge on the fertilizer tank helps determine how well the fertilization schedule is being maintained, since the period needed to empty the tank (e.g., a week, a month) can be determined in advance. Heavily used areas such as tees and greens often require higher N rates than fairways. Various methods can be devised to increase the rate of fertilizer applied by irrigation systems on these areas. Such complications, however, may cause excessive work and problems. In most cases, it seems best to use fertigation to supply a uniform rate of N to the entire golf course and traditional granular means to augment fertilization on the relatively small, heavily used green and tee areas.

Best Management Practices

The objective of all nutrient applications is to maximize plant uptake and the corresponding desirable response.

Follow UF/IFAS N application rates.

Apply nutrients when turfgrass is actively growing.

Apply slow-release N fertilizers at the appropriate time of year to maximize the products' release characteristics. For example, an application of slow-release N to warm-season turfgrasses in fall may not be as effective as the same application applied in early summer because of the prolonged release time in fall.

N application rates from slow-release materials should take into consideration the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.

Putting greens require more nutrition than other areas due to the extra stresses imposed by mowing heights, traffic, etc.

Tees and landing areas require more nutrients than fairways and roughs because they suffer heavy traffic and constant divot damage.

Fairways and roughs often require fewer nutrients than other locations because of their increased height of cut, less damage, and clipping return.

Exercise caution when applying nutrients during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff.

During establishment, use appropriate rates and products to minimize N loss due to increased water applications, increased nutrients rates, and reduced root mass.

Be aware of the different types of spreaders and understand the advantages and disadvantages of each.

Use the appropriate spreader for the chosen fertilizer.

Calibration reduces environmental risk and increases profitability.

Proper fertilizer storage, loading, and clean-up reduce environmental risk.

Avoid applying fertilizer to soils that are at, or near, saturation or following rain events that leave the soils wet.

Do not apply fertilizer when the National Weather Service has issued a flood, tropical storm, or hurricane warning, or if heavy rains are forecast in the next 24 hours.

When using fertigation, ensure that irrigation heads are properly aligned and adjusted to ensure no nutrient-loaded irrigation water is being applied to lakes and wetlands.

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SECTION 6

CULTURAL PRACTICES FOR GOLF TURF

Cultural practices have a significant impact on turfgrass growth and playability. **Certain cultural practices such as mowing, verticutting, and rolling are necessary to provide good playability, while others, such as aerification, are needed to enhance turfgrass health. This chapter discusses the need for each practice and lists methods for cultivating turf for improved playability while decreasing water loss and encouraging environmental protection.**

Mowing

Mowing is the most basic yet most important cultural practice a superintendent can use to maintain desirable turf. Mowing affects other cultural practices and many aspects of turf quality, such as density, texture, color, root development, and wear tolerance. Failure to mow properly usually results in a weakened stand of turfgrass with poor density and quality.

Turfgrasses used on golf courses can be mowed close to the ground, since their terminal growing points (crowns) are located at or just below the soil surface. In contrast, upright-growing dicot plants have their meristematic (growth points) tissue at the top or tip of their stems. Consequently, mowing removes this growing point, and many upright dicot weeds are thus easily eliminated from frequently mowed turf.

Mowing affects turfgrass growth habit. Frequent mowing increases tillering and shoot density. Mowing decreases root and rhizome growth, resulting from food reserves being used for new shoot tissue development at the expense of root and rhizome growth after mowing. Improper mowing exacerbates this problem. If the correct mowing height and frequency are used, the turfgrass does not go through a stress period from the immediate loss of top growth and can recover more quickly. Infrequent mowing results in alternating cycles of elevated crowns followed by scalping and the further depletion of food reserves. Remember, stressed turfgrass results in a weaker plant that is more vulnerable to drought, insects, and disease, requiring more pesticides.

Mowing Height

Mowing height refers to the height of top growth immediately after the grass is cut. Determining this height accurately can be misleading to inexperienced mower operators. Often height is adjusted and checked on a level surface such as a worker's bench or roadway, and is thus referred to as the "bench setting." However, when operated, the mower wheels ride on top of the turfgrass canopy, and as a result, the actual height of cut is higher than the bench setting. Conversely, when a mower is operated on soft ground or when a thick, spongy thatch layer is present, the mower cuts lower than the bench setting, often resulting in undesirable scalping.

Variables Influencing Mowing Height

Many factors influence the mowing height of grasses. Mowing heights for golf course turf are governed by the grass variety and its intended use. For example, golf greens are normally mowed below 1/4 inch to provide the smooth, fast, and consistent playing surface that golfers desire. Ultradwarf bermudagrass varieties like TifEagle, Mini-Verde and Champion can tolerate lower mowing heights than older varieties like Tifdwarf. Understanding genetic limitations of your particular turfgrass can help reduce turfgrass stress and the need to apply plant protectants. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and other abiotic and biotic stressors.

Table 6.1 lists the recommended mowing heights for the different areas of a golf course and the species of turfgrass being managed; Table 6.2 shows the recommended mowing heights for lawn and common area grasses. Shoot and leaf tissue are the sites of photosynthesis. Any removal of this tissue strongly influences the physiological and developmental condition of a turfgrass plant. If grass is mowed too low or too infrequently, crown damage can occur, and excessive photosynthetic tissue is removed. This results in off-colored turf with a low recuperative potential.

TABLE 6.1: Recommended golf course mowing heights, by area

	GREENS REGULAR MAINTENANCE	GREENS TOURNAMENT PLAY	COLLARS AND APPROACHES	TEES	FAIRWAYS	ROUGHS
Bermudagrass	0.110"–0.250"	0.090"–0.125"	0.375"–0.500"	0.250"–0.500"	0.375"–0.600"	0.750"–2.000"
Seashore paspalum	0.110"–0.125"	0.090"–0.125"	0.375"–0.500"	0.375"–0.500"	0.375"–0.500"	1.00"–1.500"

*Golf course mowing heights vary within these ranges and may temporarily vary outside these ranges due to numerous factors, including weather, budget, season, tournaments, member expectations, and a variety of other agronomic considerations such as the turf growth rate, cultivar being grown, soil type, age of turf, shading, pest outbreaks, rooting depth, thatch management, grow-in, and overseeding.

TABLE 6.2: Recommended mowing heights for lawn and common area turfgrasses

ZOYSIAGRASS	ST. AUGUSTINEGRASS	BAHIAGRASS	CENTIPEDEGRASS	CARPETGRASS
0.5"–2.5"	2.5"–4"	2.5"–4"	1"–2"	1"–2"

Root-to-Shoot Ratio

If plants are mowed too low, their roots require a substantial amount of time to provide the food needed to produce shoot tissue for future photosynthesis. Turfgrasses have a ratio of root-to-shoot tissue that is optimum to support growth and development. If turfgrass is mowed too low all at one time, the ratio becomes imbalanced, with more roots available than the plant physiologically requires. This excessive root mass is then sloughed off. Until the plant has time to regenerate new shoot tissue, it becomes weak and more susceptible to environmental and pest stresses. Root growth is least affected when no more than 30 to 40% of the leaf area is removed at one mowing.

Root Growth

A direct relationship exists between mowing height and root depth. As the mowing height is reduced, a corresponding reduction in root depth occurs. Less root depth is needed to support less top growth when the mowing height is lowered. This is why golf greens, with shallower roots, need to be watered and fertilized more frequently than other playing surfaces. Roots (plus lateral stems) are where carbohydrate reserves are stored. Therefore, shallow roots on a putting green also mean that leaves and shoots have minimal carbohydrate reserves to draw from when the plants are stressed.

Shade

Under shady conditions, grass leaves grow more upright to capture as much of the filtered sunlight for photosynthesis as possible. As a result, the mowing height for grasses grown under these conditions needs to be raised at least 30%. If mowed continuously short, grasses grown under shaded conditions gradually thin due to the lack of sunlight needed for photosynthesis.

To reduce irrigation, fertilization, and pesticide inputs, it is recommended that greens be mowed as high as the clientele will allow. Also, research suggests that applying the plant growth regulator trinexapac-ethyl (Primo™) to shaded turf improves turf health.

Mower Type

Mowing height is also influenced by the mower type being used. Rotary and flail-type mowers cut best at heights above 1 inch and are used primarily in roughs and out-of-play areas. Conversely, reel mowers cut best at heights below 1 inch and are used on most golf course play areas including greens, tees, and fairways.

Season

The season of the year may also influence mowing height. In early spring, turfgrasses have a more prostrate (horizontal) growth habit. They can be mowed at lower heights of cut without the detrimental impacts that might occur during other seasons of the year. Close mowing in early spring controls thatch, increases turf density, removes excess residues or dead leaf tissue, and promotes earlier green-up. Green-up is hastened because close mowing removes top growth and dead tissue that shade, and thus cool, the soil surface. If more solar radiation reaches the soil surface, it warms up more quickly than if the top growth is allowed to remain tall. In summer, when days are longer, grasses have a more upright growth habit and are healthier if the mowing height is raised to compensate for it. A higher mower setting at this time also increases turf rooting, reducing water needs and stresses imposed by increased nematode activity. In fall, the mowing height may also need to be raised to reduce the chance of low-temperature damage during winter (in north Florida) and to provide a cushion for grass crowns in winter where bermudagrass is dormant.

Environmental Stresses

Mowing height should be increased on putting greens during more stressful periods, particularly during prolonged cloudy weather. Increase mowing height as high as the golfing clientele will allow. If cutting heights are selected based strictly on desired green speed, consider a higher height and implementing a rolling program. It is also important to raise mowing heights on all playing surfaces during periods of drought. Higher mowing increases root depth and improves the turf's ability to take up water and nutrients.

Mowing Frequency

Mowing frequency often is a compromise between what is best for the turf and what is practical for the sport. The growth rate of the turfgrass should determine the frequency of cut. The growth rate is influenced primarily by mowing height, the amount and source of nitrogen fertilizer applied, and the season or temperature. Higher amounts of nitrogen result in faster top growth, necessitating an increased mowing frequency. Raising the mowing height reduces cutting frequency, helping to compensate for faster growth.

One-Third Guideline

The traditional guideline is to mow often enough so that no more than one-third of the top growth is removed at any one time. Removing more than this amount decreases the recuperative ability of grass due to the extensive loss of leaf area needed for photosynthesis. A reduction in photosynthesis can result in the weakening or death of a large portion of the root system, since carbohydrates in roots are then used to restore new shoot tissue. Consequently, root growth may stop for a while, since the regeneration of new leaves (shoots) always takes priority over sustaining roots for food reserves following severe defoliation.

To determine how much growth to allow, multiply the height of cut (HOC) by 1.5. For example, if the HOC is 0.5 inch, the calculation is as follows:

$$0.5'' \times 1.5 = 0.75''$$

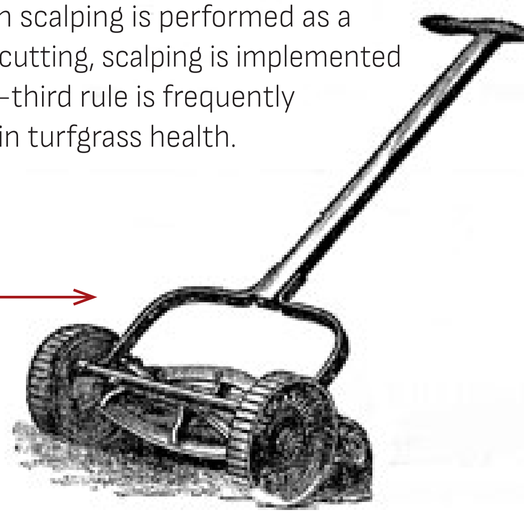
The grass should be allowed to reach 0.75 inch and then mowed. Thus, 0.25 inch of clippings is removed (one-third) and 0.5 inch of verdure (fresh green vegetation) remains (two-thirds).

Scalping

If turfgrass becomes too tall, it should not be mowed down to the intended height all at one time. Such severe scalping may stop root growth for extensive periods. Also, scalping reduces turf density, increasing the potential for weed establishment. Tall grass should be mowed frequently and the height gradually reduced with each mowing until the desired height is reached. The exception is when scalping is performed as a summertime cultivation practice, particularly on golf course roughs. Like verticutting, scalping is implemented to remove excess stem/leaf material and improve uniformity, but if the one-third rule is frequently violated, the result is usually gradual thinning and a disappointing reduction in turfgrass health.

Mowing Equipment

Mowing equipment has continued to increase in sophistication since the scythe was invented. **The first reel mower was developed in 1830** by Edwin Budding, a textile engineer, who adapted the rotary shear that was used to cut carpet nap. Early mowers were operated using hand or animal power, but these were eventually replaced by gasoline- and diesel-powered units. Today a vast array of mower types is available, with varying levels of sophistication and a wide range of costs.



Reel Mowers

Reel mowers consist of blades attached to a cylinder known as a reel. As this cylinder rotates, grass leaves are pushed against a sharp, stationary bedknife and clipped. A reel mower that is properly adjusted cuts grass as cleanly as a sharp pair of scissors and produces better-quality results than other types of mowers. Reel mowers also require less power, consume less fuel, and, therefore, are more efficient to operate than rotary or flail mowers. In fact, reel mowers use up to 50% less fuel per acre of cut than rotary mowers when used at the same mowing speed.

Reel mowers do have some disadvantages, most notably their inability to mow grass maintained above approximately 1.5 inches and to cut coarse-textured turf. Similarly, tall seedheads, weeds, and tough seed stalks are not cut efficiently with reel mowers. Reel mowers, especially hydraulically driven ones, are more expensive than other mowers and usually require a higher level of maintenance and skill to adjust and operate.

Rotary Mowers

Rotary mowers are an impact-type cutting mower. They have blades that are horizontally mounted to a vertical shaft that cuts grass by impact at a high rate of speed. The key to success with rotary mowers is to maintain a sharp, balanced blade. Rotary mowers cut grass like a machete. As long as the blade is sharp and balanced, the quality of cut is acceptable. A dull mower blade shreds leaf blades instead of cutting them, and leaf tips become jagged and frayed. When leaf tissue is mutilated by an unsharpened rotary blade, wounds heal slowly, and greater water losses occur through evaporation since the vascular tissue exposed to the environment is increased. Mutilated tissue also provides invasion points for diseases. This can increase the need for pesticides or fertilizers. If blades are nicked from hitting hard objects, they should be ground or filed to restore the original cutting edges.

Rotary mowers have the advantage of being relatively inexpensive and more versatile than reel mowers. They can be used to cut very tall or coarse-textured grass, tough weeds and seed stalks, while reel mowers cannot. Rotary mowers may also decrease herbicide use in golf course roughs by making weed seedheads less conspicuous. They also can be more easily maneuvered than reel mowers to trim around trees and buildings, and generally have lower initial costs and simpler maintenance requirements.

One disadvantage of rotary mowers is their inability to provide a quality cut at heights lower than one inch. Rotary mowers are not usually designed to follow the surface contour as exactly as a reel mower. Therefore, at close mowing heights, the rotary mower is more likely to scalp turf as it travels across small mounds or ridges that often compose the turf surface. Rotary mowers are also dangerous if hands or feet are accidentally placed under the mowing deck while the blade is operating. Because the blades rotate at a high speed, they can turn any rocks or tree limbs that they encounter into dangerous projectiles.

Flail Mowers

Flail mowers, another impact-type cutting unit, have a number of small blades (knives) attached to a horizontal shaft. As the shaft rotates, the knives are held out by centrifugal force. Cut debris from flail mowers is cut repeatedly until it is small enough to escape the close clearance between the knives and mower housing.

The advantages of flail mowers include their ability to cut tall grass into finely ground mulch and the ability of each blade to recoil upon impacting rocks or other heavy/buried objects without damage to the mower. Unlike rotary mowers, they do not create a dangerous projectile if they strike a hard object such as a rock or tree limb. The disadvantages include the flail mower's inability to provide a close, high quality cut and the difficulty of sharpening the small, numerous knives. Flail mowers are most often used on low-maintenance utility turfgrasses, such as roughs or out-of-play areas, that are mowed infrequently and do not have a high aesthetic requirement.

Equipment Care

Equipment care is almost as important as initially choosing the right mower. Routine maintenance such as lubrication, oil changes, blade sharpening, tune-ups, belt adjustments, and proper cleaning are important in extending the useful life of equipment and in lowering operating costs. Accurate records need to be maintained and observed to help pinpoint the costs of operation and to justify the purchase of new equipment. In addition, proper storage should be available to minimize the exposure of equipment to weather, to prevent accidents, and to maintain security. When a job is finished, the unit should be cleaned and stored in a clean, dry, and secure area.

Mowing Patterns

The mowing patterns imposed by operators can influence both the aesthetic and functional characteristics of a turfgrass surface (top right). Aesthetic qualities are influenced by differing light reflections that occur in response to shifts in mowing direction. These shifts often result in alternating light- and dark-green strips that are generally more pronounced when walk-behind reel mowers are used, compared with triplex-riding mowers. Double-cutting at right angles produces a checkerboard appearance of light- and dark-green strips, as if two different nitrogen fertility levels or grasses had been used.

Mowing directions should not be repeated over the long term, even though this may produce alternating color differences. If turf is mowed repeatedly in the same direction, the grass leans or grows in the direction in which it is cut. This horizontal orientation of grass foliage in one direction is called "grain" (bottom right). Grain results in an uneven cut,

Mowing pattern

Grain on putting green

Photo courtesy USGA

a streaked appearance, and a poor-quality putting surface on golf greens. The ball tends to follow the grain. When a different grain is encountered, the ball reacts by altering its path slightly.

Varying the pattern of successive mowings easily prevents grain, encourages the upright growth of the shoots, minimizes the amount of leaf surface that the rolling golf ball encounters, and increases a green's putting speed and accuracy. The mowing patterns or directions of golf greens should be changed daily and cleanup laps routinely reversed or skipped. Often a rotating clock pattern is followed for mowing directions and is changed daily. Similarly, fairways should be mowed side to side and diagonally as well as longitudinally to minimize wear, compaction, and grain development.

Mowing continually in the same direction also scalps the same high spots and increases compaction and rutting by mower wheels. In addition, turning the mower at the same location and in the same direction encourages severe wear and soil compaction.

Grass Clippings

Clippings are a source of nutrients. They contain 2 to 4% nitrogen based on dry weight and also significant amounts of phosphorus and potassium. If clippings are removed, additional fertilizer must be applied to compensate for these nutrients. Removing clippings can pose environmental and budgetary concerns, since municipal landfills no longer accept them. Emptying the catcher or raking the clippings also requires additional time and labor. Under normal conditions, clippings should be allowed to fall back to the turf. They should be removed only when they are so heavy that they smother the grass or interfere with the playing surface, such as on golf greens.

By following the one-third guideline on mowing frequency, large amounts of clippings are not deposited at one time. Soil organisms that naturally break down grass clippings with enough time to decompose them before the clippings accumulate. If excessive growth occurs because of heavy nitrogen fertilization or excessive scalping, natural decomposition may not be able to keep up with the amount of clippings deposited. A thatch problem may develop under these conditions.

Clippings collected from golf greens should be disposed of properly to prevent undesirable odors near play areas and to prevent fire hazards that can occur when clipping piles accumulate. One option is to compost the clippings. Develop compost piles by alternating layers of clippings with a mixture of soil and nitrogen fertilizer. When composted, the clippings can then be used as ground mulch in flower beds or inaccessible mowing areas. If not composted, the clippings should be dispersed so that piles do not form.

Turfgrass Cultivation Practices

Cultivation practices are an important part of turfgrass management. Heavily used areas such as golf course greens often deteriorate due to compacted soil, thatch development, and excessive use. Soil problems from active use are usually confined to the upper 3 inches of the turf.

Unlike annual crops, which are periodically tilled to correct such problems, turf managers do not have the opportunities for such physical disturbances without destroying the playing surface. Over the years, however, a number of mechanical devices have been developed that provide a degree of turfgrass cultivation with minimum disturbance to the turf surface. Cultivation is accomplished by aerification, vertical mowing, spiking, and topdressing.

Aerification

Aerification is the practice of inserting "tines" into the playing surface to create an opening for increased air and water movement. Aerification can be done using solid tines that create holes in the playing surface to improve air exchange and water infiltration with minimal surface disturbance or with "coring" tines that remove small cores or plugs of soil from the turfgrass surface, which provides the added benefit of reducing soil compaction.

Holes are normally 0.25 to 0.75 inches in diameter; their depths and distances vary depending on the type of machine used, forward speed, degree of soil compaction, and amount of soil moisture present. Traditional aerating machines penetrate the upper 2 to 4 inches of soil surface, with cores spaced on 2- to 6-inch centers. Recent innovations in aerification equipment provide options for creating holes to depths greater than 10 inches and diameters ranging from 0.125 to 1 inch.

Generally, the benefits of aerification far outweigh any detrimental effects. Turf managers must decide which option is best to solve the existing problem. The following common problems limiting turf growth may be improved by aerification:

Excessive soil compaction
Waterlogged soils
Black layer development
Standing surface water
Dry spots
Excessive thatch development
Poor root growth

Soil Compaction

One of the primary goals of core aerification is to relieve soil compaction, which occurs when mineral particles are pressed close together. This results from excessive or concentrated traffic, especially when soil is wet. Soil compaction reduces oxygen (porosity) levels in the soil. A soil should be composed of at least 25% air, on a volume basis, but compacted soil has as little as 5% (Figure 6.3).

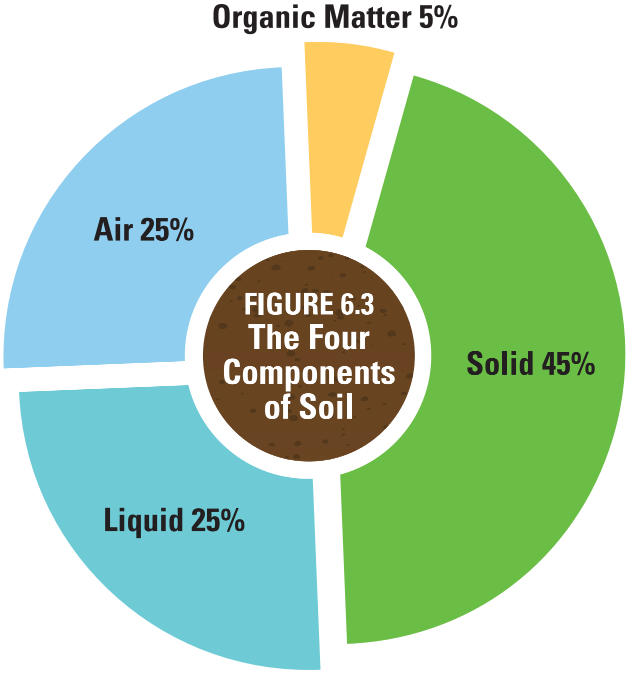


FIGURE 6.3 The Four Components of Soil

Root function decreases under compaction due to the lack of oxygen needed for respiration and the buildup of toxic gases such as carbon dioxide. Also, roots may be unable to physically penetrate such a tightly packed soil mass. New roots are often abundant along the sides of the aerification holes, indicating the need for increased soil oxygen.

Advantages and Disadvantages of Aerification

Advantages:

Relieves soil compaction.

Allows deeper, faster penetration of water, air, fertilizer, lime, and pesticides into the root zone.

Allows for the atmospheric release of toxic gases (e.g., carbon dioxide, carbon monoxide) from the root zone.

Improves drainage, helping to dry out saturated soils and prevent the formation of puddles.

Improves water penetration into dry or hydrophobic soils (e.g., relieves localized dry spots).

Penetrates the soil layers that develop from topdressing with dissimilar materials.

Provides thatch control by stimulating the environmental conditions that promote healthy soil microorganism activity for thatch decomposition.

Increases rooting by constructing a medium more conducive to active root growth.

Disadvantages:

Can temporarily disrupt or damage playing quality.

Increases turf surface desiccation as roots are exposed.

Produces coring holes that provide a better habitat for cutworms and other insect pests.

Compacted soil surfaces also reduce water infiltration and percolation. Dry soils in compacted areas are difficult to rewet. Conditions such as localized dry spots often develop, especially in areas with a high sand content. This encourages the overwatering of adjacent areas. Conversely, compacted, saturated soils may not drain excessive water and often turn into mud with continued use. Such soils often remain wet for extended periods and become covered with an undesirable layer of algae or moss. The success of highly maintained turfgrass areas such as golf greens depends largely on the superintendent's control of soil moisture content.

The best method for preventing compaction is to build greens and tees with a predominately sandy soil and proper surface drainage. Compaction is much more likely on fine-textured soil than on a coarser, sandy soil. Usually a coarse-textured soil consisting of 80% or more sand is necessary to achieve the desired results. Soil containing a significant amount of clay (> 30%) or silt (> 5%) is unacceptable for golf green construction. All soils should be tested by an accredited soil laboratory before use. Proper surface contouring and subsurface drainage in the form of perforated drainage pipes also hasten the removal of excessive surface water. For putting greens, the USGA formulated a construction method that provides good drainage and resistance to compaction. Created in 1960, it is still one of the most prevalent methods for constructing golf course putting greens today. This method is discussed in the publication *USGA Recommendations for a Method of Putting Green Construction* (available: https://archive.lib.msu.edu/tic/usgamisc/monos/2018recommendationsmethodputtinggreen.pdf).

Reducing or redirecting traffic also relieves soil compaction. For example, the correct placement of cart paths and sidewalks is important. Cart paths should normally be a minimum of 8 feet wide to allow two-way cart traffic and larger maintenance vehicles, such as tractors and trucks, an adequate passageway. Barriers such as curbs should be used adjacent to high-traffic areas such as tees and greens to prevent carts straying from the path.

Traffic should be minimized or prevented when soil is wet. Water in the soil acts as a lubricant. Traffic during these periods further increases soil compaction, reducing turfgrass growth and vigor. Regulate traffic after heavy rains, and avoid mowing with large, heavy units. Use wide turf tires on all equipment to help distribute the weight of the vehicles over a larger area than is allowed by regular tires.

Core aerification usually softens hard, compacted turfgrass surfaces. This is especially true when the spacing between holes does not exceed 2 inches. Aerifier tines should penetrate a minimum of 3 inches deep. This depth should be varied between aerifications to minimize the development of any compacted layering. Coring is most effective when soils are moist but should never be performed when soils are saturated.

Thatch Management

Putting greens can accumulate thatch and organic matter quite aggressively in Florida's warm climate. Some thatch and organic matter are necessary for nutrient/water retention and good playability, but excessive amounts reduce root growth, encourage disease, and create undesirable playing conditions.

Core aerification removes small cores of thatch and organic matter, and subsequent sand topdressing is incorporated to dilute the existing material. Putting greens should be core aerified several times each summer to properly manage thatch accumulation. Various aerifier tine diameters and spacings affect the percentage of putting surface impacted.

Thatch from putting green root zone

Dry Spots

Localized dry spots are areas—usually ranging from one to several feet in diameter—that become very hydrophobic and repel water. This is most pronounced during hot, dry weather and with sand-based greens that have excessive thatch accumulation. Aerifying with small-diameter tines (< 0.5 inch) on close spacing (< 2 inches) allows better water infiltration. The routine use of granular or liquid wetting agents or surfactants applied to the dry spots in combination with aerification is also helpful. Solid "quad-tines," followed by wetting agent treatments, can alleviate dry spots with minimal disruption to the putting green surface.

Types of Aerifiers

Many types of core aerifiers or cultivators are available. Most fall into one of two categories: vertical- or circular-motion units. Vertical-motion core cultivators provide minimal surface disruption and are the preferred choice on closely mowed surfaces such as golf greens. Vertical units have the drawback of being relatively slow due to the linking of vertical and forward operations. However, their speed and ease of operation have improved.

Circular-motion cultivators have tines or spoons mounted on a drum or metal wheels. The tines or spoons are forced into the soil as the drum or wheels turn in a circular motion. Hollow drum units remove extracted cores from the soil surface, while other units deposit cores back directly onto the surface. Circular-motion cultivators are preferred for aerifying large areas, since the rotating units can cover more ground in a given period than vertical-motion cultivators. However, they disrupt the turf surface more and do not penetrate as deeply as vertical-motion cultivators. Weights are often placed on top of these cultivators to increase penetration depth.

High pressure water and air injection systems are now commonly used to improve soil aeration but have limited impact on alleviating soil compaction. Sand injection cultivation is used mostly on putting greens and is used to supplement conventional core aeration programs. Sand injection cultivation is more costly than conventional core aeration but takes less time to recover and is less disruptive to the playing surface. Recent advances in mechanization allow the quick and easy windrowing of soil cores and their subsequent mechanical removal. Cores should be removed on putting greens, since organic matter removal/dilution is much more important on greens than on other playing surfaces.

Core Removal

Aerifiers with hollow tines cut and bring a soil core to the surface, leaving a hole or cavity. A commonly asked question is whether to remove the cores that result from aerifying. For turf areas other than golf or bowling greens, it is most practical to leave the holes open. Cores also do not have to be removed if thatch control, temporary compaction reduction, or air and chemical entry are acceptable and the underlying soil is adequate.

If the root-zone mixture (soil) present is acceptable, then the cores should be broken up by lightly verticutting or dragging the area with a mat, brush, or piece of carpet. The remaining debris should be blown off or picked up with a

Harvester picking up cores

follow-up mowing. Before dragging the soil cores, they should be allowed to dry enough so that they easily crumble between the fingers. If the cores are too dry, they are hard and not easily broken up. If too wet, they tend to smear and be aesthetically undesirable.

Frequency of Cultivation

The frequency of core cultivation should be based on the traffic intensity that the turfgrass is exposed to, and on the soil makeup, hardness of the soil surface, and degree of compaction. Areas receiving intense daily traffic—such as golf greens, approaches, landing areas, aprons, and tees—require a minimum of 2 to 4 core aerifications annually. Additional aerifications may be needed on exceptionally small greens where traffic is more concentrated, on areas of heavy soils high in silt and/or clay that do not drain well, or on soils exposed to saline or effluent water. Such areas may need aerification with smaller-diameter tines (0.38 inch or less) every 4 to 6 weeks during the active growing months. Failure to maintain an aggressive aerification program in these situations may result in poorly drained soils, thin grass stands, and continued problems with algae.

Less-intense traffic areas should be aerified as needed. Most golf course fairways should be aerified twice yearly, with the first aerification timed in mid-spring once the grass is actively growing and the chance of a late freeze has passed. The second aerification should be in late summer. If the area is to be overseeded with ryegrass, then the second aerification should be timed approximately 4 to 6 weeks prior to seeding. Aerification is not recommended within 6 to 8 weeks before the first expected frost in north Florida, in order to allow enough time for warm-season grasses to recuperate before cold weather ceases its growth.

Solid tines are sometimes used for coring instead of hollow tines. Creating holes by forcing solid tines into the turf is called "shatter-coring." Solid tines do not remove soil cores and may compact soil along the sides and bottoms of the holes more severely than hollow tines. Areas receiving solid tine aerification will probably benefit only temporarily.

Solid tines do not disrupt the playing surface as much as hollow tine cultivation. This is an advantage during the winter months, when the growth rate of warm-season grasses has ceased or been reduced. Using solid tines in the winter months temporarily reduces compaction and softens the green with minimal disruption of the putting surface.

Warm-season grasses should only be aerified with hollow tines when the turf is actively growing and is not subjected to heat, cold, and water stress. Topdressing and irrigation immediately following aerification may reduce desiccation potential but may not be totally effective during periods of high temperatures.

Deep Aeration

Advances in aerification technology provide turf managers with a wider choice of aerification strategies. One involves deep tine cultivators that are able to extract a 0.75- to 1-inch diameter core to a depth of 8 to 12 inches. Deep cultivator units enable the superintendent to relieve the soil compaction layer that develops when traditionally used aerifiers penetrate constantly to 3 inches. Soil profiles consisting of many undesirable layers that develop with the use of different materials for topdressing are also penetrated. This enhances water penetration, soil aeration, and rooting. For greens, an undesirable soil profile can be improved by topdressing with desirable soil following deep aerification.

Photo courtesy USGA

Another implement is the deep drill aerifier. Drill bits of varying lengths and diameter are drilled into the turf, leaving a small cast of soil on the surface around each hole. This soil is usually then dragged back into the turfgrass canopy. The biggest advantage of the deep drill aerifier is the ability to provide a deep hole with the least disruption to the playing surface. These units, however, are relatively slow running and are generally more expensive to operate, since a high degree of mechanization and numerous drill bits are needed. Since a core is not physically extracted, the soil brought to the surface is difficult to remove.

Deep aerification creates more surface damage than shallow depth models. The initial expense also prevents many clubs from purchasing a unit, since it is more of a renovation tool than a regularly scheduled maintenance practice. These units are generally available for rental or contract use, however, or several clubs may choose to share the cost of purchasing a unit. Care must be used when aerifying golf greens built to the specifications outlined by the USGA, so as not to penetrate the 2- to 4-inch coarse sand layer, or 4-inch gravel layer, that is located 12 to 14 inches deep. This violates the concept that greens maintain a "perched" water table for the turfgrass to be grown in.

Some golf courses still possess a Toro Hydroject™, a machine that uses high-pressure water injection. Fine streams of high-velocity water are injected over the turf surface, resulting in minimal surface disruption. Play is not disrupted by these aerification holes as it is by traditional machines. These high-pressure units are also beneficial because they wet hydrophobic soils, such as localized dry spots. The disadvantages are the initial high cost and the need for a water source at all aerification sites. The units may be less effective on heavy soils where the high-pressure water stream cannot adequately penetrate. In addition, thatch control is minimal and sand cannot be incorporated back into the green's profile, since the holes produced are not large enough. The hole spacing and penetration depth are, however, adjustable through multiple pulses, the changing of nozzle spacing, or varying speed. Water injection cultivation should supplement, not replace, traditional core aerification.

Slicing and Spiking

Two other cultural practices, slicing and spiking, help relieve surface compaction and promote better water penetration and aeration. A slicer has thin, V-shaped knives bolted at intervals to the perimeter of metal wheels that cut into the soil. The turfgrass canopy is sliced with narrow slits about 0.25 inch wide and 2 to 4 inches deep. Slicing can be performed much faster than coring and does not interfere with turf use, since there is no removal of soil cores; thus, no cleanup is necessary after the operation. Slicing is also performed on fairways and other large, trafficked areas during stress periods, when coring may be too injurious or disruptive. However, it is less effective than coring and is most effective when used in conjunction with coring. As with coring, slicing is best accomplished on moist soils.

A spiker has an effect similar to that of a slicer, but penetration is limited to approximately 1 inch, and the distance between perforations along the surface is shorter. For these reasons, and because spiking causes less surface disruption than coring, spiking is practiced primarily on greens and tees. A spiker is used to break up soil surface crusting, break up algae layers, and improve water penetration and aeration. Solid tines are associated with a spiker, and holes are punched by forcing soil downward and laterally. This results in some compaction at the bottoms and along the sides of the holes. Since only minor disruptions of soil surfaces occur, spiking and slicing can be performed more often (e.g., every 7 to 14 days) than core aerification (e.g., every 4 to 8 weeks).

Vertical Mowing (Verticutting)

A vertical mower has a series of knives vertically mounted on a horizontal shaft. The shaft rotates at high speeds, and the blades slice into the turf and rip out thatch and other debris.

Depth

Vertical mowing meets different objectives, depending on the depth of the penetrating knives. Grain is reduced on putting greens when the knives are set just to nick the surface of the turf. Shallow vertical mowing on tees and fairways breaks up cores following aerification, facilitating a topdressing effect. The deeper penetration of knives stimulates new growth when stolons and rhizomes are severed and removes accumulated thatch. Vertical mowing is also used to prepare seedbeds before overseeding.

The desired depth of thatch removal determines blade depth when dethatching is the objective. Vertical mowing should reach the bottom of the thatch layer, and preferably the soil surface beneath the thatch layer should be sliced. Dethatching is an aggressive practice that is not recommended on most golf course putting greens, due to increased disease susceptibility and time needed for recovery. There is a limit to the depth that blades should be set, or excessive removal of turf roots, rhizomes, stolons, and leaf surface may occur. For example, blades should be set at a depth to cut just stolons and no deeper if new growth stimulation is the objective. Vertical blade spacing for thatch removal in bermudagrass should range from 1 to 2 inches for maximum thatch removal with minimal damage.

Frequency

The rate of thatch accumulation dictates the frequency of vertical mowing. Vertical mowing should begin once the thatch layer on golf greens exceeds 0.25 to 0.5 inch. Shallow vertical mowing should be completed at least once per month for non-overseeded bermudagrass greens. Some of the ultradwarf bermudagrasses may require even more frequent shallow vertical mowing to prevent excessive thatch accumulation. Be sure to verticut in different directions, just as with regular mowing.

Interchangeable vertical mower units are available for many of today's triplex greens mowers. This equipment allows for frequent vertical mowing and simultaneous debris collection. For light surface grooming, the vertical blades on greens mowers should be set only to nick the surface of the turfgrass canopy so the surface is not impaired. By conducting frequent vertical mowing, the severe vertical mowing needed for renovation may be avoided.

Large turf areas are vertically mowed by using units that operate off a tractor's power takeoff (PTO). Such units have heavily reinforced construction and large, thick (approximately 0.25-inch) blades that can penetrate to the soil surface.

Grooming and Brushing

A miniature vertical mower can be attached in front of the reel cutting unit of greens mowers to lightly groom putting green turf. Likewise, brush attachments can be used in conjunction with daily mowing. These units improve the playing surface by standing up leaf blades before mowing, thus reducing surface grain. Slicing stolons also stimulates new shoot development, and thatch near the surface is removed.

Topdressing Frequency and Amounts

The frequency and rate of topdressing depend on the objective. Following coring and heavy verticutting, moderate to heavy topdressing helps to smooth the surface, fill holes, and cover exposed roots resulting from these two processes. Irregular play surfaces or soil profile renovation require frequent and relative heavy topdressing. Rates ranging from 0.125 to 0.25 inch (2 to 4 cubic yards of soil per 5,000 ft^2) are suggested. However, if the capacity of the turf to absorb the material is limited, less material should be used to prevent smothering the turf.

If the objective of topdressing is to change the characteristics of the underlying soil, then a heavy topdressing program following numerous deep core removal operations over a period of years is required. If thatch management is the main objective, then the rate of thatch accumulation governs the amount and frequency of topdressing. A thatch layer of 0.25 to 0.5 inch on golf greens is desirable, but it is necessary to dilute this layer with sand. The relatively thin thatch layer cushions (holds) the approaching golf shot better and also helps to protect turfgrass crowns from traffic. When thatch is not excessive (≤ 0.5 inch), approximately 1 cubic yard per 5,000 ft^2 of topdressing is suggested at least once per month during the growing season. If over time this relatively light rate is not maintaining or reducing the thatch layer, then the frequency of application and the topdressing rate should be increased.

If the thatch layer exceeds 0.5 inch, then coring or deep verticutting is required to remove a portion of the thatch material. This should be followed with heavy topdressing. A distinct thatch (stem) layer greater than 0.5 inch that does not contain any sand must be prevented or eliminated. Such thatch layers either become hydrophobic (repel water) or create a perched water table at the surface that encourages roots to remain in the thatch layer and not grow down into the soil. In either situation, the turfgrass stand is more susceptible to pests, mechanical damage, and environmental stresses.

Topdressing

Topdressing adds a thin layer of sand to the turf surface that is then incorporated by dragging or brushing it in. On newly established turf, topdressing partially covers and stabilizes the newly planted material, smooths gaps that result from sodding, and minimizes turfgrass desiccation. Topdressing is performed on established turf to smooth the playing surface, control thatch and grain, promote recovery from injury, and possibly change the physical characteristics of the underlying soil. Unfortunately, many superintendents have reduced the number of coring and topdressing procedures on putting greens in recent years due to complaints that these practices disrupt play. However, these are sound, fundamental agronomic practices that are necessary to maintain an optimal bermudagrass putting surface. If eliminated, the quality of the putting green will diminish over time.

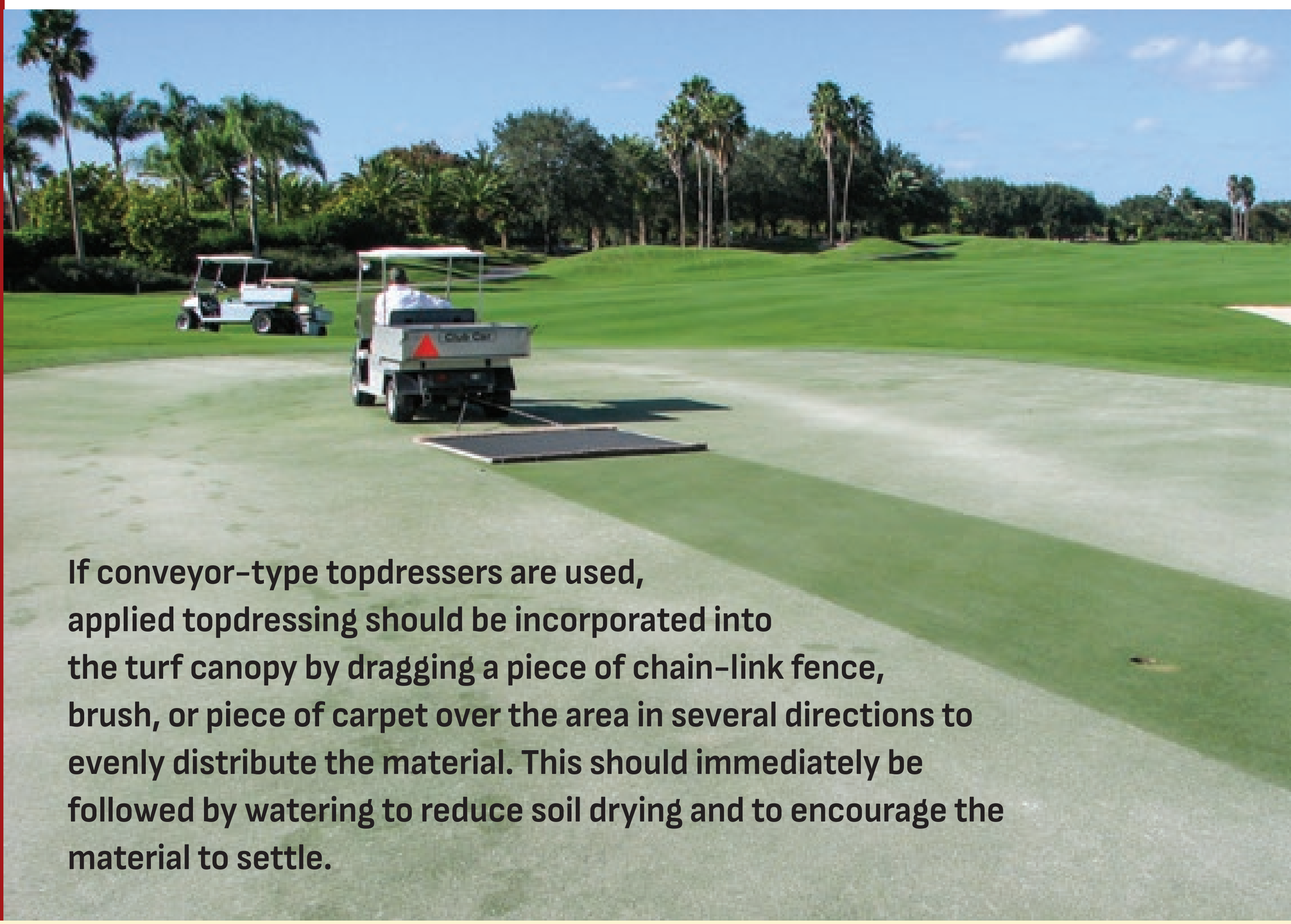
If the objective of topdressing is only to provide routine smoothing of the playing surface, then light, frequent topdressings are suggested. The surface irregularities of the green are reduced and the area is somewhat leveled when a mat is used to drag sand into the turf canopy following topdressing. Topdressing with 0.5 to 1 cubic yard per 5,000 ft^2 of green surface every 2 to 4 weeks provides a smoother, truer playing surface. Light topdressing is also performed approximately 10 to 14 days prior to major club tournaments to increase green speed and provide a smoother putting surface. In addition, frequent, light topdressing should be applied to new greens every 2 to 4 weeks to cover stolons and to smooth the surface, until complete coverage or the desired smoothness is achieved.

Topdressing Materials

Deciding what material to use for topdressing is one of a superintendent's most important long-term management decisions. Using unsuitable materials can be disastrous and can ruin the integrity of initially well-built facilities. This usually occurs when the topdressing material used is finer in particle size than the size used in constructing the green.

Only weed-free materials should be used for topdressing. If the material's origin is not known, or if it has been piled and exposed over time, fumigation is highly recommended before use. Washed sands may not need sterilization before use but should be closely inspected to determine whether this is needed. Excess topdressing material should be properly stored to keep it dry and uncontaminated. Covered soil bins, sand silos, or polyethylene covers provide good storage conditions until the material is used.

When the underlying soil of the play surface (green or tee) is unsatisfactory, it must be determined whether to rebuild or try to slowly change its composition through aggressive coring and topdressing. If the soil problem is severe, then reconstruction should be considered. With the introduction of deep core aerifiers, the process of changing the underlying soil characteristics may be expanded. Deep coring once per year followed by heavy topdressing with desirable sand can improve poorly draining greens. Between these corings, conventional aerification and topdressing should still be performed. Over several years, the use of this technique can radically improve the soil characteristics of the playing area.



If conveyor-type topdressers are used, applied topdressing should be incorporated into the turf canopy by dragging a piece of chain-link fence, brush, or piece of carpet over the area in several directions to evenly distribute the material. This should immediately be followed by watering to reduce soil drying and to encourage the material to settle.

If a topdressing program is chosen to improve the soil, then the next question is what material to use. Fine-textured soils high in clay and/or silt predominate on most undesirable playing surfaces. A coarser soil texture, most notably sand, is introduced to improve water percolation and aeration. Current trends involve frequent topdressing with medium-fine (0.25 to 1.0 millimeter [mm]) sand. This size is usually coarse enough to change soil texture and fine enough to be easily worked into the turf surface. It is not so fine, however, as to seal the surface and impede air and water movement. A competent soil-testing laboratory should test the sand in question before a superintendent attempts to slowly change the root zone of a green or tee by this method.

The most commonly observed problem is the formation of various alternating layers of soil when different topdressing materials are used over time. The differences in textural characteristics between layers of sand and organic matter result in poor root growth, caused by physical barriers, the lack of oxygen, the entrapment of toxic gases, microperched water tables, and dry zones. Once these layers have formed, aggressive vertical mowing and coring are required to correct the problem. Aerification holes should extend at least 1 inch below the depth of the deepest layer. The use of deep-tine or deep-drill aerifiers often is required to reach these desirable depths. Shallow spiking or coring above the layering is of questionable benefit.

Rolling a putting green

Rolling

Rolling has become common practice in today's management of golf course putting greens. Some routinely roll (i.e., daily) while others roll prior to a tournament to provide a smoother, faster playing surface.

Two types of rollers are used: first, a set of three that replaces the mowing units on a triplex mower, and second, a stand-alone unit that has a driver facing perpendicular to the direction the machine moves. This machine must be loaded and unloaded from a trailer at each green.

Benefits

Limited research provides some guidelines on the expected increase in ball speed after rolling. Rolling once the morning before a tournament increases the speed of a green approximately 10%. However, to increase the speed by 20%, greens need to be rolled a total of four times. Rolling two or three times increases the speed between 10% and 20%.

Limitations

Any time pressure is applied to a soil surface, compaction may result. Therefore, to minimize the potential of compaction from rollers, use the lightest roller(s) available. Roller weight does not appear to influence resulting ball speed but may influence the degree of resulting compaction. Rollers also should be used only on greens consisting primarily (80%) of sand and less than 10% silt or clay.

To further prevent compaction problems and to reduce labor costs, roller use is encouraged only during major tournament play and not as a routine daily practice. Rolling should also never be attempted when the soil is saturated, because moisture acts as a lubricant, raising the risk of increasing soil compaction. Extra aerification to relieve any soil compaction may be required.

Winter Overseeding / Colorants

Golf is played year-round in Florida. However, the warm-season turfgrasses generally slow their growth (south Florida) or cease growth altogether (north Florida) in the winter months due to cooler temperatures and shorter days. Winter overseeding, the practice of establishing a temporary cool-season grass into the base turfgrass for improved winter color and playability, has long been the accepted practice.

Overseeding increases the need for daily watering and routine mowing, and can also cause significant thinning of the base turfgrass during the spring transition. Each golf course should evaluate whether overseeding is worth the increased requirements for natural resources and labor.

Due to the significant cost and the negative consequences of overseeding, some golf courses choose to apply pigments, paints, or dyes to certain playing surfaces, instead of overseeding them, as it requires fewer resources than overseeding and is a more environmentally responsible alternative.

Overseeding

Fertilizers used 4 to 6 weeks prior to overseeding should be low in nitrogen and high in potassium. Maintaining low nitrogen levels at this time minimizes warm-season turfgrass' competitiveness with overseeded grasses but allows it to retain enough vigor to withstand the overseeding process. Adequate potassium promotes tolerance to cold, wear, and diseases.

Seedbed Preparation and Fall Transition

Proper seedbed preparation ensures that seedling roots are in contact with the soil and not perched above it, where they are susceptible to drought and temperature stress. Thatch greater than 0.5 inch associated with the base grass prevents good seed-to-soil contact and therefore should be reduced before overseeding.

Nitrogen fertilization should be reduced or completely stopped 3 to 4 weeks before overseeding to minimize competitive bermudagrass growth. Excessive growth at the time of overseeding provides competition for the germinating seed. It may also predispose the warm-season turfgrass to winter injury.

Cultivate the soil by coring 4 to 6 weeks prior to overseeding to alleviate soil compaction and to open the turf. If growing an ultradwarf bermudagrass, cultivate no less than 6 weeks prior to overseeding to allow adequate time for recovery. Allow the cores to dry and pulverize them by verticutting, power raking, or dragging. Coring is performed in advance of the actual overseeding date to allow the coring holes to heal over, thus preventing a speckled growth pattern of winter grass.

Grass Selection for Overseeding

The primary grasses used for overseeding in Florida are perennial ryegrass and roughstalk bluegrass (*Poa trivialis*). Annual ryegrass, intermediate ryegrass, creeping bentgrass, and fine (chewings, creeping red, or hard) fescue are used to a lesser extent. The grasses and mixtures most widely used on golf greens and tees are improved cultivars of roughstalk bluegrass seeded alone, or in mixtures with perennial ryegrass or fine fescue. Fairways are seeded predominately with a perennial ryegrass cultivar. Each grass has advantages and disadvantages.

Photo courtesy USGA

Post-planting Maintenance

Irrigate lightly to carefully moisten the soil surface without puddling or washing the seed into surrounding areas. Three or four light irrigations per day may be needed until the seedlings become established. Once germination begins, the seed cannot be allowed to dry out or the stand will be thinned. If seed washes into concentrated drifts following intense rains or heavy irrigation, a stiff-bristled broom should be used to redistribute it. The use of preemergence herbicides helps reduce the emergence of overseed in unwanted areas. Once grass is established, gradually reduce watering frequency to decrease disease potential.

Mow greens at a 0.5-inch height when the new stand reaches 0.67 to 0.75 inches. Gradually lower the cutting height to 0.31 inch over a 2- to 3-week period. Use a sharp mower to avoid uprooting the seedlings. On golf greens, walk-behind reel mowers are preferable to triplex mowers, which are heavy. Once the grass is well established, mowing heights gradually can be reduced to the desired height, and the heavier triplex mowers then can be used. On tees and fairways, initiate mowing when the grass reaches 1 to 2 inches. This allows time for seedling turf to root. Tees and fairways usually are maintained at 0.5 inch and 0.75 inch in height, respectively.

Photo courtesy USGA

Do not fertilize with nitrogen (N) immediately before or during overseeding and grass establishment, because excessive N may encourage excessive warm-season turfgrass competition and increase disease potential. Nitrogen fertilizer also influences the appearance of overseeded grass and the spring recovery of bermudagrass. Adequate levels of phosphorus and potassium, however, should be maintained for good plant growth. Begin to fertilize shortly after shoot emergence (2 to 3 weeks after seeding for perennial ryegrass) and continue until cold weather halts warm-season turfgrass growth. Normally, 0.25 to 0.5 lb. N per 1,000 ft^2 every 2 to 3 weeks with a soluble N source (e.g., urea, ammonium sulfate), or 1 lb. N per 1,000 ft^2 per month with a slow-release N source (e.g., PCU, SCU, reacted products, biosolids) is adequate to promote desired growth without overstimulating growth and encouraging disease. More frequent applications using lower rates may be needed if the recovery time from traffic or weather damage is slow. Whenever possible, traffic should be minimized during overseed establishment. Hole locations and tee markers should be moved daily.

Applications of phosphorus, potassium, manganese, and iron should be considered during winter. These nutrients provide desirable color without stimulating excessive shoot growth. Soil phosphorus levels and rates should be determined by soil testing. Potassium should be applied at one-half the rate of N. Iron generally is applied every 3 to 4 weeks as ferrous sulfate at 2 oz. per 1,000 ft^2. Manganese can be applied as manganese sulfate at 0.5 to 1 oz. per 1,000 ft^2 in 3 to 5 gallons of water.


Pythium blight on overseeded green

Once the overseeded grass becomes established, the chance of severe disease is reduced. Dollar spot often occurs when N levels are too low. It is easily reduced by applying a small amount (0.125 to 0.25 lb. N per 1,000 ft^2) of a quick-release N source. Brown patch and Pythium blight may occur on greens that drain poorly, or during continuous wet periods. Excessive amounts of soluble nitrogen also can trigger these diseases. This is especially true during the periods of heavy, uninterrupted foggy weather that often occur in Florida during the winter. Turf managers should constantly monitor the weather forecast and be ready to apply an appropriate fungicide if these conditions are forecast.

Maintain low fertilizer application rates in late winter through early spring to reduce overseeded grass vigor. When the warm-season, base grass regrowth is observed, restore fertilizer applications. Many herbicides are available that can be used as transition aids that can selectively kill the overseed grass. Some have achieved overseed removal by withholding irrigation for a period of time. This is not advisable as it can lead to warm-season turfgrass desiccation leading to injury.

Pigments, Paints, and Dyes

Applying various colorants to turfgrass provides the aesthetics (green color) and playability without the surface disruption, costs, and negative consequences associated with overseeding. However, there are some potential negatives with this approach. Depending on the level of winter play, the turf generally thins out in late winter/early spring which can negatively impact spring regrowth and putting quality. Furthermore, those using colorants indicate that putting speeds can become very fast which may limit hole placement on greens with steep slopes.

There are many turf colorants in the marketplace each offering unique marketing claims. The use of these products requires some experimentation. Application techniques with onsite equipment needs to be refined. Further, application frequency is dynamic — if the turf is growing even slightly, the colorants will be mowed off and reapplication will be necessary.

An excellent resource on using turf colorants can be found here:
https://content.ces.ncsu.edu/guide-to-using-turf-colorants

Shade and Tree Management

In general, most turfgrasses grow best in full sun. Excessive shade reduces photosynthesis, and moisture does not evaporate as quickly. Also, trees reduce air circulation, resulting in stagnant air. High heat and humidity quickly build in such areas. Whether from decreased sunlight or air circulation, the result is weaker turf that is more prone to disease and pest problems than turfgrass grown in sunnier areas. Tree limbs and roots should be pruned yearly to reduce competition for sunlight, water, and nutrients with bermudagrass turf. A UF-IFAS website dedicated specifically to pruning is: http://hort.ufl.edu/woody/pruning.shtml. Where possible, trees should be removed from around closely mown areas such as tees and greens to maintain good turf growth. A UF–IFAS website on landscape plants, at http://hort.ufl.edu/woody/, is a good source of information on all aspects of tree and shrub care.

Best Management Practices for Turfgrass Growth in Shade:

Increase mowing height: This allows for more leaf area to intercept as much available light as possible. In addition, leaf blades are longer and narrower in the shade, and a lower cutting height excessively reduces leaf length, which is not good for the grass. Increased mowing height also promotes deeper rooting, which is one of the key mechanisms of stress tolerance for turfgrasses.

Reduce fertilizer applications: Grass grows more slowly in a shaded environment, reducing its fertility needs. Too much nitrogen fertilizer depletes carbohydrates and produces a weaker turf system. If a normal yearly application is 4 lbs. N per 1,000 ft^2, apply only 2.5 to 3 lbs. to turf growing in the shade. Limit any single fertility application to no more than 0.5 lb. N per 1,000 ft^2 at any one time.

Adjust irrigation accordingly: If the irrigation system covers an area that is partially shaded and partially in sun, consider removing the sprinkler heads from the shaded areas and irrigate by hand when rainfall is inadequate. Not only does overirrigation waste water and potentially leach pollutants, but the slower evapotranspiration (ET) rate in shaded areas can lead to fungal or other disease and pest problems.

Reduce traffic: Shaded turf is more easily injured by traffic and may not be able to recover adequately. Also, traffic in shady areas may damage a tree's roots, causing the tree to decline or die.

Increase air circulation: Very few fungi can infect dry leaves. Where a green is "boxed" or "pocketed" by trees or other obstructions to the point where air circulation is inhibited, surface moisture builds up due to decreased air flow. This may lead to increased fungal disease, algae, or other problems. Both the root zone and the leaf tissues are susceptible to excessive moisture problems. To address this on an existing course, fans are often used to dry out the soil and increase ET by providing a 3- to 4-mile-per-hour breeze at the surface.

SECTION 7

LAKE AND AQUATIC PLANT MANAGEMENT

Golf course lakes/ponds (for the rest of this section "lake") are present for many reasons. They may be natural or man-made. They may serve many purposes including, but not limited to: water hazards for the golfers, provide water for irrigation, aesthetics, fish and wildlife, and/or for storm water holding and treatment. Most provide multiple services at the same time.

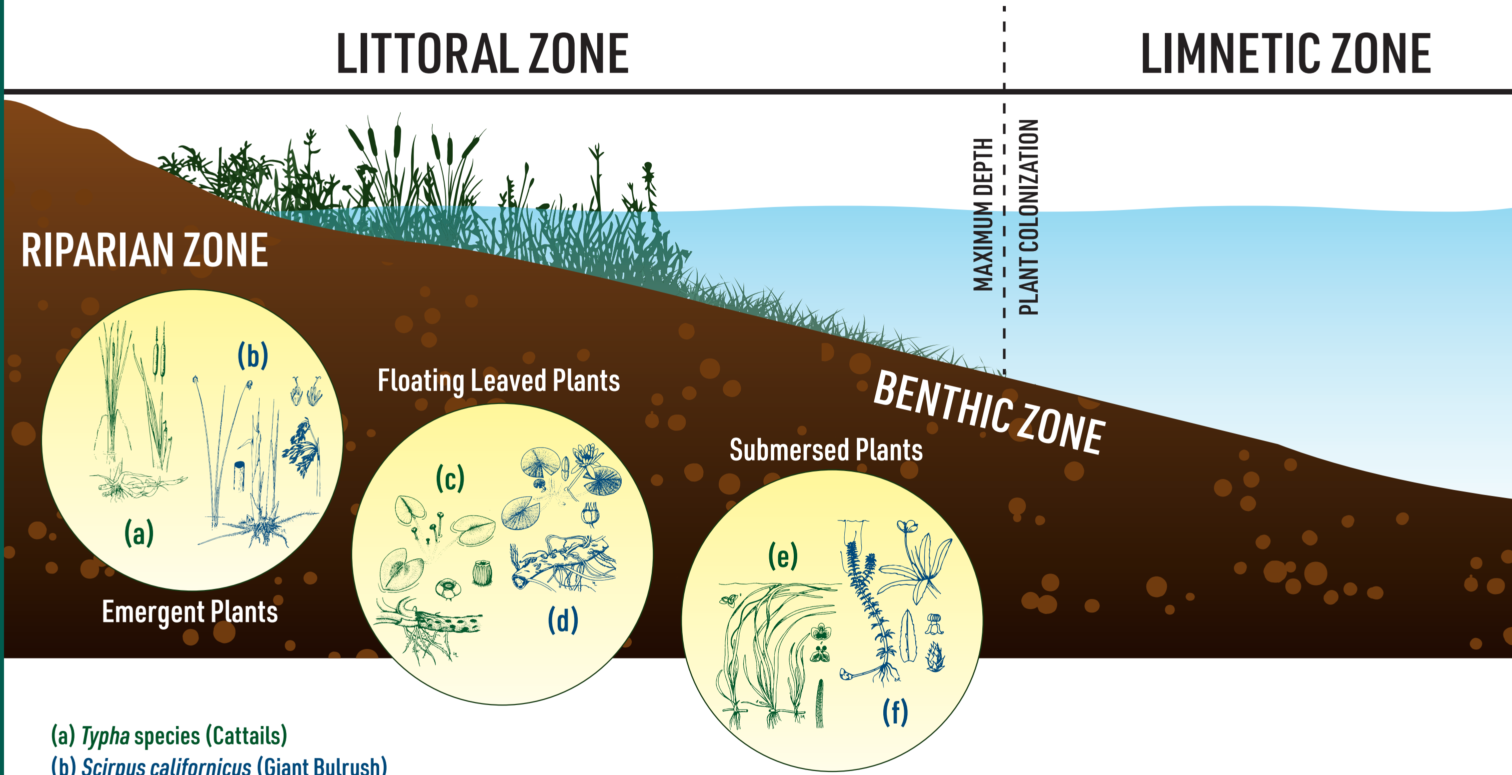
Each lake has its own watershed, which is the area surrounding the lake that drains into the system. Within the watershed, there are terrestrial plants, and near the water body, a lakeshore generally supports a variety of herbaceous and woody vegetation that can be referred to as a riparian zone. Most Florida golf course stakeholders favor lake banks with open views of sparkling clear water, distinguished by neat edges of closely mowed turf or hardscape retaining structures. However, maintaining such a highly artificial system requires intensive management and may not be possible because of the natural conditions of the lake. Understanding the limitations of individual systems, natural lake processes, and incorporating them into the design and management of a lake can create significant benefits and reduce operational costs.

Lakes have four major ecological zones. These are the riparian zone, littoral zone, limnetic zone, and benthic zone (see Figure 7.1, next page):

RIPARIAN ZONES can be described as a buffer to the lake, which are composed of strips of grass, shrubs, and/or trees surrounding a lake and separating it from upland areas. They can slow the velocity of stormwater entering a lake allowing it to filter into the soil and recharge the ground water aquifer. Slowing the velocity also helps filter out pollutants and trap sediments (soil, grass clippings, leaves, etc.) carried by the stormwater runoff. Riparian zones also offer valuable wildlife habitat especially for nesting aquatic birds. These buffers are above the high-water mark and should be unfertilized and left in a natural state if possible to prevent nutrients and/or sediments from entering into the lake. If herbaceous and woody vegetation cannot be maintained, then the turf should be mowed 2 to 3 inches higher than the main fairway to act as a filter and buffer to nutrients/sediments moving toward the lake.

THE LITTORAL ZONE is the transitional area between the riparian zone and the open water where sunlight still penetrates to the bottom of the lake (approximately 1% of ambient light) and aquatic plants can survive. Ideally, it should have a slope of about 1 foot vertical drop to 6 to 10 feet of horizontal width, but this may vary with the size, shape, and morphology of the lake. In the littoral zone, there are three main zones of aquatic plants including emergent plants (rooted plants emerging into the air),

FIGURE 7.1: Diagram of a pond/lake's major habitat zones



floating leaved plants, and submersed plants. Many lakes also have floating plants that drift back and forth in the lake with the wind. This zone is crucial to a lake's health because the aquatic plants in this area not only take up nutrients themselves, they decrease wave action, stabilize bottom sediments, reduce shoreline erosion, and provide habitat for many types of organisms.

THE LIMNETIC ZONE is the open water zone dominated by free-floating algal populations. Algal abundances are determined by the nutrient concentrations (primarily phosphorus and nitrogen) that generally limit algal growth. The limnetic zone, or open water zone, usually comprises the largest volume of water in the lake.

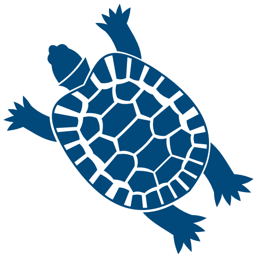
THE BENTHIC ZONE is the area at the bottom of the lake, deeper than light will penetrate for plant growth and is comprised of sediment. It is typically nutrient enriched, highly organic, and has a high demand for dissolved oxygen. The benthic zone functions as habitat for epifaunal organisms that live on the sediment surface and infaunal organisms that spend all or part of their life cycle within the sediments. These organisms are important because they consume dead plankton and other organic matter and are an important part of the food base for fish and wildlife.

Riparian and littoral zone of Little Santa Fe Lake in Alachua County

Individual lakes have several distinct defining characteristics. Their background geology and soil fertility, watershed area, size, shape, and depth may all affect how lakes respond to various environmental inputs. Most lakes on a golf course are relatively small and somewhat shallow. This can lead to high variability in multiple factors including nutrient concentrations, algal/plant abundances, temperature, water clarity, dissolved oxygen concentration, and others. This high variability generally causes many management challenges often due to high abundances of aquatic plants and unsightly algae that may lead to decreases in oxygen concentrations and possibly fish kills.

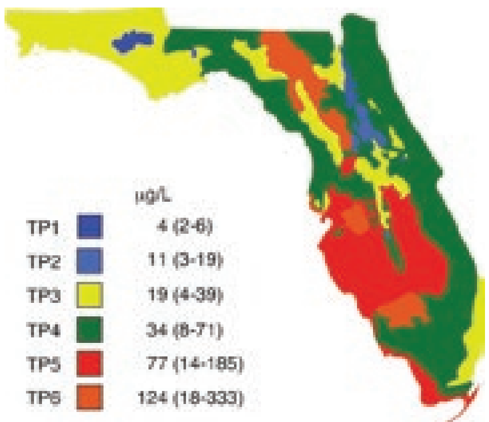
No matter what their purpose, golf course lakes can also provide sustainable aquatic ecosystems for aquatic insects, fish, frogs, turtles, birds, and other wildlife. Therefore, it is important to develop a comprehensive lake management plan that not only allows a lake to continue to function as it was originally designed, but also protects water quality and prevents undesirable changes that could lead to significant restoration costs. Successful lake management must include a clear statement of goals and priorities to guide the development of the BMPs necessary to meet those goals. ***Some of the challenges facing superintendents in maintaining the quality of golf course lakes are as follows:***

- **nutrient and algal concentrations**
- **dissolved oxygen concentrations**
- **aquatic plant abundance**
- **sedimentation**
- **fish and wildlife**

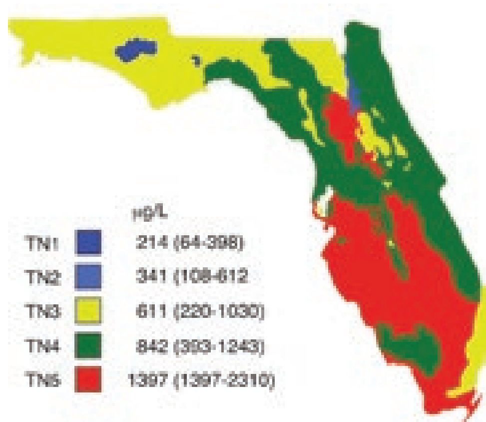


Nutrient and Algal Concentrations

Phosphorus and nitrogen concentrations in water generally limit algal abundance in lakes and algal abundance limits the water clarity. In Florida, phosphorus is the nutrient most likely to limit the growth of the algal population and any anthropogenic increases in phosphorus will cause increases in algal abundance that will also cause decreases in water clarity. The background nutrient concentrations are mostly dependent on the geology in which the lake is located. If lakes are located in low-nutrient sandy soils, like those in the Ocala National Forest, the lakes will be nutrient poor with low algal abundance and high-water clarity. If lakes are located in nutrient-rich soils, like areas around Lakeland, Florida where they mine phosphorus, the lakes will be nutrient rich with high algal abundance and low water clarity. Florida LAKEWATCH (https://lakewatch.ifas.ufl.edu) staff have used statewide lake data to define nutrient zones in Florida that are used to define background nutrient concentrations for lakes (Bachmann et al. 2012).



Total Phosphorous Zones



Total Nitrogen Zones

Maps showing the phosphorus and nitrogen zones and the concentrations listed are the upper 90th percentile value for each zone and are the proposed numeric criteria for TP and TN from Bachmann et al. (2012).

The management of nutrient concentrations in lakes is generally the most important management activity for a lake because increases in nutrient concentration above background levels can change the entire ecology of the lake. For this reason, Florida Department of Environmental Protections has been tasked by the State Legislature, with setting surface water quality standards (https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-302). Monitoring lake water chemistry on a regular basis is recommended to determine if lakes are meeting water quality standards, especially for nutrients.

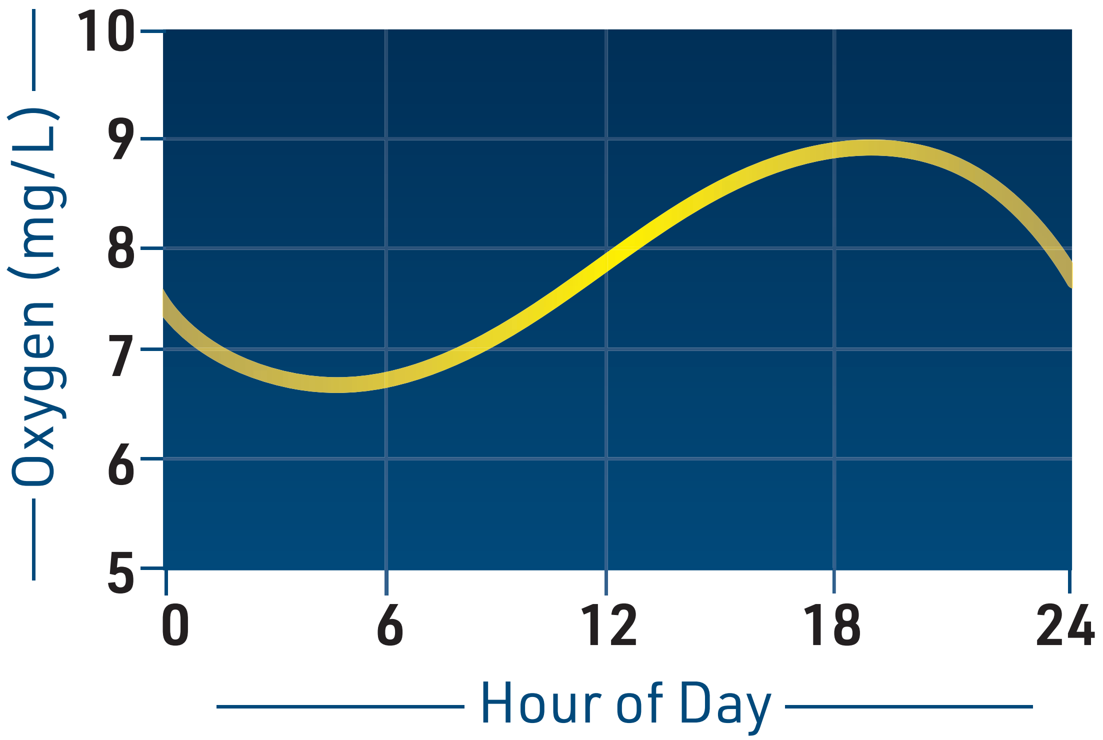
Lake Best Management Practices:

- **Maintain buffer zones to prevent or reduce stormwater nutrients from entering the lake.**
- **Install berms and swales to capture sediments and associated nutrients before they enter into a lake.**
- **Make sure fertilizer applications are not conducted too close to the lake, i.e., leave fertilizer free zones.**
- **Do not put grass clippings/leaf material into a lake, as they also contain nutrients.**
- **Regularly monitor lakes for nutrient concentrations to make sure nutrients are not increasing over time.**

Dissolved Oxygen

The atmosphere we breath is approximately 20% oxygen. In lake water, the maximum amount of dissolved oxygen (saturation) primarily depends on water temperature, with warm water able to hold less oxygen than colder water. This is important because many fish kills occur in the summer when water is hot and oxygen saturation levels are the lowest. In Florida lakes, dissolved oxygen commonly ranges from 5 ppm to 9 ppm. Most fish show stress if dissolved oxygen concentrations fall below 3 ppm and fish kills begin occurring at levels below 2 ppm for sustained periods.

Chart of dissolved oxygen concentrations in a lake over a 24-hour period



Oxygen enters lake water from two sources: 1) the major source of oxygen entering the lake is the result of photosynthesis from green plants (primarily algae), 2) a less important method is from diffusion into water from the atmosphere. Oxygen levels are reduced in lake water when it is consumed by organisms living in the lake, including bacteria that decompose organic matter in the sediments and suspended in the water. Oxygen levels naturally rise during the day as sunlight drives the photosynthesis process and decline at night as organisms including plants consume oxygen through respiration. Excessive oxygen depletion and resulting fish kills are usually caused by one or more of the following factors:

Algae

Large blooms of algae in nutrient rich lakes can cause severe oxygen depletions when they consume more oxygen than they are producing in a 24-hour period. This occurs most often during hot cloudy weather, which minimize photosynthesis during the day when hot water holds less oxygen. When phytoplankton/free-floating algal levels are high enough to limit visibility to a foot or less, there is a danger of oxygen depletion.

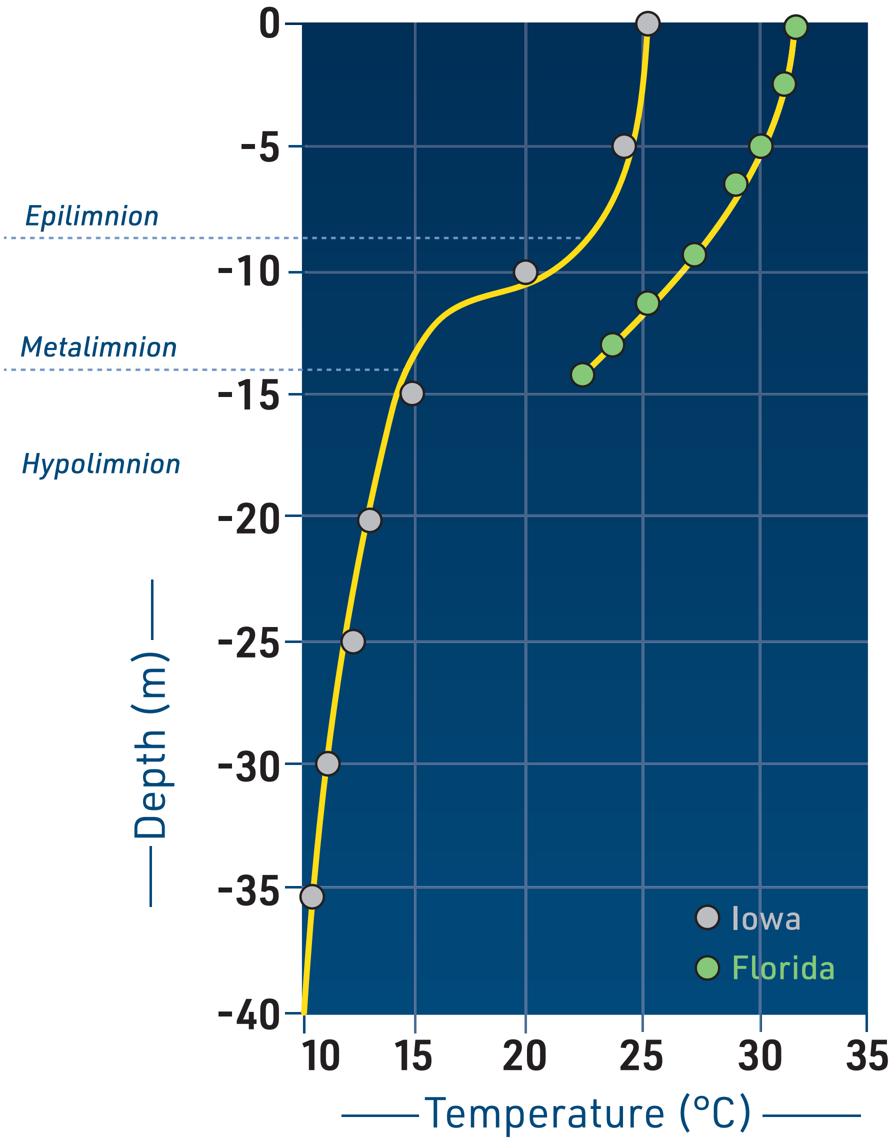
Phytoplankton

Phytoplankton populations can expand rapidly maintaining high abundances, but they can also die rapidly. Such large die-offs cause rapid oxygen depletions as oxygen production ends, bacteria consume and degrade the now-dead phytoplankton and consume the remaining oxygen in the water through respiration. Die-offs can be caused by sudden drops in temperature, other natural factors, and by heavy algicide applications to a lake.

Turnover

A lake "turnover" can also result in rapid decreases in oxygen levels. In the summer, water in a lake can stratify with warm water on the surface and cooler water below. The temperature differences keep the surface and bottom water from mixing. Thus, the lower water often has very little oxygen because there is no light for photosynthesis and there is no connection to the air for diffusion of oxygen to occur. Turnovers occur during rapid cooling of the surface water — perhaps by a cold rain or strong wind breaking down this stratification, mixing the deeper oxygen-poor water with surface water, and bringing the overall dissolved oxygen concentration down to levels that may cause fish kills. Such turnovers occur most frequently in deeper (over 8 feet) lakes.

Chart showing temperature stratification for a northern Iowa and Florida lake during summer.



In Florida, nutrient rich productive lakes, less than 6 feet in depth, can be difficult to keep oxygenated. Because they are shallow, light penetrates much of the water column and promotes aquatic plant and algae growth. These shallow lakes also heat up quickly, often reaching more than 90 or 95°F, limiting the maximum amount of oxygen that the water can hold. Thus, hot and humid summer weather provides a worst-case for potential fish kills. Artificial aeration, particularly at night when aquatic organisms, including aquatic plants and algae, are consuming oxygen, can help to maintain higher oxygen concentrations, thus preventing or minimizing possible fish kills.

Surface and bubbler artificial aeration in ponds

Aquatic Plants

As mentioned above, there are three aquatic plant zones in a lake with four main aquatic plant types:

1) **emergent plants** (rooted plants emerging into the air)
2) **floating leaved plants** (plants that live in two extremely different habitats: the bottom of the plant lives in the water, and the top of the plant lives in air)
3) **submersed plants** (plants that grow completely under the water), and
4) **floating plants** that are not rooted to the bottom but get their nutrients completely from the water and drift back and forth in the lake with the wind.

Common emergent plants include bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), reeds (*Phragmites* spp.), spikerushes (*Eleocharis* spp.), maidencane (*Panicum hemitomon*), pickerelweed (*Pontederia cordata*), and duck potato (*Sagittaria lancifolia*). A common exotic emergent plant that is one of the hardest to control is torpedograss (*Panicum repens*).

Maidencane (*Panicum hemitomen*) in Little Santa Fe Lake, Alachua County, Florida.

Common floating leaved plants include waterlilies (*Nymphaea* spp.), spatterdock (*Nuphar* spp.), and watershield (*Brasenia* spp.).

Fragrant water lily (*Nymphaea odorata*) in Cowpen Lake, Alachua County, Florida.

Submersed plants are a diverse group that includes quillworts (*Isoetes* spp.), mosses (*Fontinalis* spp.), muskgrasses (*Chara* spp.), stoneworts (*Nitella* spp.), and numerous vascular plants. Many submersed plants, such as widgeon-grass (*Ruppia maritima*), various pondweeds (*Potamogeton* spp.), coontail (*Ceratophyllum demersum*), bladderwort (*Utricularia* spp.), and tape-grass (*Vallisneria* spp.), are native to the United States. Others like hydrilla (*Hydrilla verticillata*) are exotic and cause some of the worst aquatic weed problems.

Coontail (*Ceratophyllum demersum*)

Common floating plants include duckweeds (*Lemna* spp.), mosquito fern (*Azolla caroliniana*), water meal (*Wolffia columbiana*), and water fern (*Salvinia* spp.). Larger floating plants include water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*), which are the top targets for aquatic plant management in Florida.

Water hyacinth (*Eichhornia crassipes*)

Plants are vital to the functioning of lakes and serve various beneficial roles, such as producing oxygen, stabilizing sediments and shorelines, and providing fish and wildlife habitat.

However, on golf courses, lakes are constructed for many different purposes and aquatic plants often interfere with these purposes and need to be managed. It is important to remember that Florida law (F.S. 369.20) requires all persons intending to control or remove aquatic vegetation from the waters of the state to obtain a permit from the Florida Fish and Wildlife Conservation Commission's (FWC) Invasive Plant Management Section unless an exemption for the activity has been provided in statute or rule (http://myfwc.com/license/aquatic-plants).

In developing an aquatic plant management strategy, it is important to know the intended uses of a waterbody, the site's physical attributes and location, the ecology of the invasive or weedy species present, and other environmental considerations. As with other pest problems, the principles of Integrated Pest Management (IPM) should be used. IPM incorporates a variety of methods and techniques, including cultural, biological, chemical, mechanical, and structural strategies to control the pest problems. However, prevention is better than a cure, and the first steps in prevention are to use best management practices like proper turfgrass fertilization, proper mowing, maintaining unfertilized buffer strips, and good lake design. When prevention is not enough, and an aquatic plant problem needs to managed, there are many different approaches and tools to be considered.

One of the preferred approaches to plant management, used in Florida to manage floating plants such as water hyacinth and water lettuce, is called maintenance control. Florida law (Chapter 369.22, F.S.) defines maintenance control as "a method of managing exotic plants in which control techniques are utilized in a coordinated manner on a continuous basis in order to maintain a plant population at the lowest feasible level." Often herbicides are the major tool used in a maintenance control program and even though herbicide applications occur more frequently, the overall amount of herbicide used is much lower than what would be used to treat an out-of-control infestation. By keeping plant biomass and production at a low level, maintenance control also reduces sediment deposition. All these benefits make maintenance control an excellent approach to managing invasive aquatic plants.

The diversity of lake types dictates that aquatic plant managers carefully choose the most appropriate method or combination of methods (IPM) to manage aquatic plants for each individual situation. The effectiveness and benefits of methods used for controlling the pest plant must be weighed against potential impacts on non-target plants and animals and impacts on water uses such as irrigation and stormwater management. The following methods for managing aquatic weeds are most often used:

Physical removal including hand removal, mechanical removal and dredging.

Habitat alteration including water level manipulation, benthic barriers, and nutrient limitation.

Biological control including insects, pathogens, triploid grass carp, and tilapia.

Herbicides including contact herbicides, systemic herbicides, broad-spectrum herbicides, and selective herbicides.

Physical Removal

Simply weeding by hand may be all that is necessary to remove small amounts of vegetation that interfere with fairways, golf cart paths, and bridges. Of course, hand removal is labor intensive and must be repeated routinely. It can be effective in preventing a new weed from becoming established when first observed. The practicality of this simple and effective method will depend on availability of labor, the regrowth or reintroduction potential of the vegetation, and the level of control desired.

Specialized machines are available in many sizes and with several different accessories for removing aquatic vegetation in a variety of situations. Small machines are practical for limited areas, and large machines, in combination with transports and shore conveyors, are suitable for large, whole-lake operations. In certain circumstances, such as cutting boat trails through dense stands of vegetation, mechanical removal has several advantages over other methods. Immediate control can be achieved

Aquatic plant harvesting, Center for Aquatic and Invasive Plants (CAIP) University of Florida, Institute of Food and Agricultural Sciences.

in small areas., allowing areas to be used immediately, whereas in areas treated with herbicides, water-use restrictions may apply. Mechanical removal minimizes the objectionable dead and dying vegetation that may be associated with other methods. However, several disadvantages limit the use of mechanical removal for aquatic weed control in many regions. It usually costs more and is slower and less efficient than other methods, and there are high maintenance and repair costs for the machinery. Shallow water and obstructions render some water bodies unsuitable for mechanical removal operations. Plant fragments easily drift to infest new areas. Mechanical removal disturbs sediments and temporarily increases turbidity. A suitable area for disposal of harvested plants must be available. Finally, this method is imprecise and may remove wildlife (e.g., small fish, snakes, newts, frogs, and turtles) and desirable vegetation along with the weeds.

In extreme cases of overgrown aquatic vegetation, conventional or specially adapted dredging machines may be used to remove vegetation and associated sediments. Dredging is expensive, especially if a nearby disposal site is not available. The secondary environmental effects of dredging can be quite drastic, and therefore permits from regulatory agencies must be acquired before a dredging operation can begin.

Habitat Alterations

Water-level manipulation refers to the deliberate raising or lowering of water levels to control aquatic vegetation. Raising the water level drowns plants, and lowering the water level exposes them to freezing, drying, or heat. This method is limited to lakes with appropriate water control structures.

Most plants need nitrogen, phosphorus, and carbon to grow. Theoretically, reducing at least one of these nutrients could keep aquatic plants from growing to an objectionable level. However, unless the lakes are extremely oligotrophic (nutrient poor), the sediment will contain sufficient levels of nitrogen, phosphorus, and carbon to sustain abundant rooted aquatic plants.

Biological Control

Biological control is the purposeful introduction of organisms, such as insects and pathogens, to keep the growth of problem plants in check. Biocontrol agents have to be released into the problem plant's range to help suppress its growth. Small numbers of biocontrol agents are released so that they can

Alligatorweed (*Alternanthera philoxeroides*) and alligatorweed flea beetle (*Agasicles hygrophila*)

increase to a point where they control the problem plant and are in balance with the target plant, so a self-perpetuating population is established. The first aquatic weed target for biocontrol in Florida was alligatorweed (*Alternanthera philoxeroides*). Three host-specific South American insects were found and eventually released. These include the alligatorweed flea beetle (*Agasicles hygrophila*), which was released in 1964; the alligatorweed thrip (*Amynothrips andersoni*), which was released in 1967; and the alligatorweed stem borer (Vogtia malloi), a moth, which was released in 1971. These insects are very effective and usually suppress the growth of alligatorweed below problem levels.

Grass carp (*Ctenopharyngodon idella*)

Triploid grass carp (*Ctenopharyngodon idella*) are the most commonly used and effective biological control agent for aquatic plants currently available. The success of grass carp is also the primary reason this biocontrol agent is so controversial. If stocked at a high enough density, grass carp can remove virtually all aquatic vegetation in a lake for a decade or longer. Because of the fear that grass carp could escape and reproduce in open waters, most states that allow grass carp for aquatic plant control require that they be sterile triploid fish. Triploid species have three sets of chromosomes instead of the normal two, which makes them infertile. Many management agencies are currently attempting to use low stocking densities of grass carp (2—5 per acre) in combination with herbicides to control nuisance aquatic plants, while maintaining certain levels of aquatic vegetation. Because of the dynamic nature of aquatic systems and the inability to determine mortality rates of grass carp after stocking, this technique is unpredictable and should only be used with the understanding that the end result may be the total eradication of all aquatic plants in the water body. A permit is required to stock triploid grass carp in Florida. Permit forms and additional information can be obtained from the FWC.
(available: http://myfwc.com/wildlifehabitats/invasive-plants/grass-carp/)

Tilapia are tropical species that can suppress growth of softer aquatic vegetation such as filamentous algae and bladderwort (*Utricularia* spp.) when stocked at high density (300 per acre). Two species of tilapia have been considered for aquatic weed control. The blue tilapia (*Oreochromis aurea*) feeds entirely on algae (planktonic and filamentous), but does not readily consume larger, coarser vegetation. The redbelly tilapia (*Tilapia zillii*) feeds on larger submersed vegetation rather than algae. However, both species reproduce rapidly and consume not only vegetation but many small animals that are important

Blue tilapia (*Oreochromis aureus*).

food sources for desirable fish populations. Therefore, use of tilapia can have unwanted environmental consequences. In Florida, only blue tilapia, Nile tilapia (*Oreochromis niloticus*), and their hybrids can be legally stocked into lakes located east and south of the Suwannee River.

Herbicides

Herbicides are the most common tool used for aquatic plant control. Most people asked to define "herbicide" would come up with "weed killer." Weed scientists define herbicides more precisely as chemicals used for killing plants or severely interrupting their normal growth processes. For the aquatic plant manager, herbicides are useful tools that, if used properly, can safely, efficiently, and inexpensively manage aquatic vegetation. An herbicide formulation consists of an organic (carbon-containing) or inorganic active ingredient, an inert carrier, and perhaps adjuvants/surfactants (wetting or spreading agents). Herbicides must be registered by the Environmental Protection Agency (EPA) for use in the United States. There are about 200 herbicides (active ingredients) currently registered in the United States. Currently, only 16 are labeled for use in aquatic sites: bispyribac, carfentrazone, copper, 2,4-D, diquat, endothall, flumioxazin, fluridone, glyphosate, hydrogen peroxide, imazamox, imazapyr, penoxsulam,

Controlling emergent vegetation with glyphosate in ponds located at Fisheries and Aquatic Sciences, University of Florida, Institute of Food and Agricultural Sciences.

sethoxydim, topramezone, and triclopyr. Of the 16 herbicides, only fluridone is exclusive to aquatic use. All other compounds are also used in terrestrial environments. Some of these can be used on food (glyphosate on Roundup Ready crops, carfentrazone and triclopyr on rice) and some in forestry and on rights of way (glyphosate, triclopyr, 2,4-D, and imazapyr). With all of these terrestrial and aquatic uses, it remains very important to use only those compounds that are labeled for aquatic use. Use of an herbicide that does not specify aquatic sites on the label is a violation of the law.

All herbicide containers must have attached to them a label that provides instructions for storage and disposal, uses of the product, and precautions for the user and the environment. The label is the law. It is unlawful to alter, detach, or destroy the label. It is unlawful to use an herbicide in a manner that is inconsistent with or not specified on the label. Note that aquatic weeds that are not specified on the label may be treated, and application methods not mentioned on the label may be used as long as they are not prohibited on the label. It is unlawful to transfer an herbicide to an improperly labeled container. Misuse of an herbicide is a violation of federal and state law. Herbicides, used in water contrary to label directions, may make water unfit for fishing, irrigation, swimming, or domestic use.

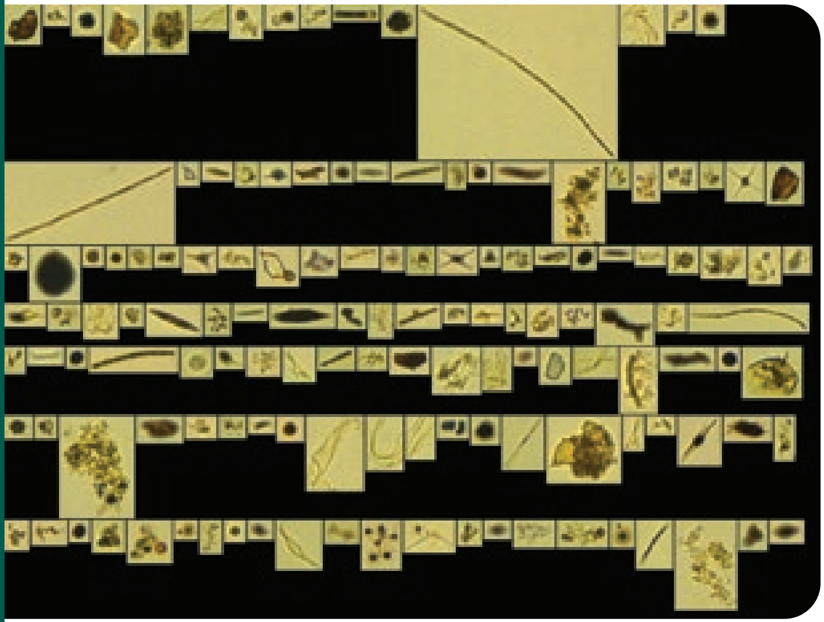
Managing Aquatic Plants

Plant managers choose the best method and tools for each aquatic plant management project according to the target plant, waterbody type and uses, wind, temperature, water depth, and other factors such as efficiency and cost-effectiveness. Vegetation is managed differently for different purposes. Special practices may be required in permitted stormwater management lakes. In lakes with littoral plantings, problem plants should be selectively controlled without damaging the littoral shelves. Some permits stipulate certain control methods that may not be used. Therefore, before using an algicide, herbicide, or grass carp in a permitted surface water detention lake, it may be necessary to check with a water management district official to determine permit requirements. If water from the pond is used for irrigation, waiting periods for using the water for irrigation required by the herbicide label must be followed. The herbicide label must be consulted as the legal guideline. The management of vegetation for certain combinations of benefits may be mutually exclusive, and certain compromises may have to be made. The removal of aquatic weeds from state waters requires an aquatic plant removal permit from FWC (additional information is available at http://www.myfwc.com/license/aquatic-plants/).

A comprehensive lake management plan should include strategies to control the growth of nuisance vegetation that can negatively affect a lake's water quality and treatment capacity. These plants generally fall into two categories: suspended phytoplankton and filamentous algae, and plants (emergent, floating leaved, floating, and submersed).

Suspended Algae

Green and turbid water, caused by abundant phytoplankton, results from high levels of nutrients, particularly nitrogen and phosphorus, in the water. Fertilizers and reclaimed water are common sources of nutrients on golf courses. The reduction of nutrient inputs to the lake water is the best long-term solution to chronic phytoplankton problems. Properly functioning buffer zones and littoral zones may reduce nutrient inputs before they reach open water and stimulate algal growth. EPA-approved lake dyes that reduce light infiltration and algal photosynthesis may be helpful. Aeration alone may help correct certain problems associated with phytoplankton abundance, but it may also resuspend nutrients causing more intense algal blooms.



Multiple pictures of suspended algae species sampled in Bear Lake, Seminole County Florida using Fluid Imaging Technologies (FlowCam).

If other methods are not feasible, an algaecide containing endothall, copper, or hydrogen peroxide can be used to temporarily reduce phytoplankton blooms. Fish mortality is likely to occur after algaecide application, because the decay of treated phytoplankton by bacteria consumes oxygen, and oxygen is no longer being produced by the phytoplankton, which is the primary source of oxygen in lake water. There is a greater potential for fish mortality when water temperatures are high. Oxygen depletion is less likely to be a problem with an algaecide containing hydrogen peroxide than one with copper or endothall. Phytoplankton are very resilient and will quickly reoccur if suitable conditions for growth prevail. The use of an algicide will be a continual activity especially during the peak growing season. Copper products are also a concern to environmental agencies because copper is persistent in the environment and highly toxic to many fish and other aquatic animals at exposure levels near those used to control algae, especially in water with low alkalinity.

Filamentous Algae

Filamentous algae are one of the most common and difficult problems in lakes. Unlike suspended algae, filamentous algae can obtain nutrients both from lake water and sediments where filamentous mats rest. Therefore, these algae are difficult to control even after reducing nutrient inputs to pond. Filamentous algae problems may be fewer if the pond is heavily vegetated with macrophytes but that leads to other problems. As with phytoplankton, dyes and aeration may help. However, some problems with filamentous algae may still occur. It is best to keep filamentous algae to a minimum by frequent physical removal and/or the frequent application of algaecide to small areas of algae (spot treatment). As with suspended algae, treating an entire pond with an algaecide to kill filamentous algae is likely to cause fish mortality due to the lowering of oxygen in the water.

Matted blue green filamentous algae in a pond located at Fisheries and Aquatic Sciences, University of Florida, Institute of Food and Agricultural Sciences.

Emergent Plants

Many emergent plants can become problems especially in shallow lakes where light can reach the bottom in most of the lake. Exotic emergent vegetation, such as torpedograss, can often begin in upland turf areas and extend into the water making thick mats that are difficult to treat with herbicides, thus making it one of the most difficult to control aquatic plants. Some emergent plants that are considered natives, such as cattails and primrose willow and/or even duck potato, also find an open pond bank a great place to become established and expand, reducing the plant diversity of a healthy system. These plants must be kept at manageable levels with proper herbicides on a regular basis (maintenance control).

Torpedograss (*Panicum repens*)

Submersed Plants

While submersed plants, such as bladderwort, provide certain wildlife benefits, they can become objectionable in small lakes if allowed to grow out of control. Because they can derive nutrients from both the water and sediments, rooted submersed plants can proliferate under all but very low-nutrient conditions.

Most submersed plants can be selectively controlled with herbicides without permanently damaging littoral shelves. Triploid grass carp can be used to some extent to keep submersed weeds under control with minimal damage to desirable emersed plants, but it is usually best to get the problem under control with at least one herbicide application and then maintain control using grass carp.

However, the effects of stocking grass carp in lakes are unpredictable. Desirable vegetation may be damaged, or acceptable control may not be achieved. It is difficult to remove grass carp from a lake, but it may be necessary to remove some grass carp if beneficial plant loss is noted. Thus, it is prudent to begin by stocking the fish in low numbers and adding more if needed. While triploid grass carp are sterile so that uncontrolled population expansions should not be an issue, barriers are required at lake outfalls to ensure that the fish stay where they are stocked.

Floating Plants

The most common floating plants that can become problems include water-hyacinth (*Eichhornia crassipes*), water-lettuce (*Pistia stratiotes*), duckweed (*Lemna* spp., *Spirodela* sp., *Landoltia* spp.), watermeal (*Wolfia* sp.), water fern (*Salvinia minima*), and mosquito fern (*Azolla caroliniana*). Floating

Water lettuce (*Pistia stratiotes*)

plants, like algae, are the greatest problem under high-nutrient conditions. Therefore, limiting nutrient runoff from artificial sources may reduce the problem. Small numbers of invasive, non-native plants such as water-hyacinth and water-lettuce can be hand removed or spot treated with herbicide on a regular basis. Triploid grass carp can be used to help keep duckweed, water fern, and mosquito fern under control in lakes, but their effectiveness is unpredictable and they may damage littoral plantings over time. Therefore, if grass carp are used, they should be stocked at low rates initially, and littoral shelves should be monitored so that these fish can be removed if necessary.

Sedimentation

Excess sedimentation usually results from upstream erosion or the buildup of decaying organic matter. As with nutrients, maintaining good buffer strips and creating berms and swales can capture many sediments before they enter a lake. Excessive nutrients can also result in excessive aquatic plant

Sediment (muck) accumulation in ponds located at Fisheries and Aquatic Sciences, University of Florida, Institute of Food and Agricultural Sciences.

growth, algal growth, and other problems that contribute to muck build up. As aquatic plants and algae grow and die, they sink to the bottom and form an organic muck. If this occurs faster than bacteria can degrade the material, the muck can build up over time, leading to odors and clumps of floating muck buoyed by gases. The muck may be sucked into irrigation systems. These sediments can build up to the point where a lake's water storage capacity is significantly reduced, and dredging may be necessary. Excess sediments also smother benthic organisms, reducing food resources available to other aquatic species. In addition, sediments often build up high levels of cadmium, lead, nickel, and/or toxic substances, including herbicides (e.g., copper) and other pesticides. The disposal of these sediments may be subject to regulation, and application to turf may cause damage from residual herbicides.

Fish and Wildlife

As development associated with urban growth continues to alter and degrade natural habitats, created habitats in urbanized landscapes may become increasingly important for the conservation of fish and wildlife. Unlike many types of developed landscapes, golf courses usually include large amounts of green space with multiple lakes. Therefore, golf courses may provide unique opportunities for creating fish and wildlife habitat in urbanized landscapes that should be exploited. While most lakes on a golf course are not managed primarily for fish and wildlife, considering these aspects when managing lakes provides an opportunity to promote conservation ethics while improving local community support.

SUMMARY

This brief summary cannot cover all of the aspects of lake and aquatic plant management that have been researched and described in the primary literature. However, for more information on individual lake management topics, Florida LAKEWATCH has created the following information circulars for management purposes (https://lakewatch.ifas.ufl.edu/extension/information-circulars/).

Florida LAKEWATCH. 1999. A beginners guide to water management-The ABCs, Descriptions of commonly used terms. Information Circular #101. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/101_ABCs_2004copy.pdf

Florida LAKEWATCH. 2000. A beginners guide to water management-Nutrients. Information Circular #102. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/102_NUTRIENTS_FINAL_2004copy.pdf

Florida LAKEWATCH. 2000. A beginners guide to water management-Water clarity. Information Circular #103. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/103_WATER_CLARITY_3rd_2004-copy.pdf

Florida LAKEWATCH. 2001. A beginners guide to water management-Lake Morphoometry. Information Circular #104. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/104_MORPHOMETRY_2nd_ED_2004.pdf

Florida LAKEWATCH. 2001. A beginners guide to water management-Symbols, Abbreviations & Conversion Factors. Information Circular #105. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/105_SYMBOLS_ABBREV_2004copy.pdf

Florida LAKEWATCH. 2003. A beginners guide to water management-Bacteria. Information Circular #106. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/106Bacteria.pdf

Florida LAKEWATCH. 2003. A beginners guide to water management-Fish Kills. Information Circular #107. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/107FishKills.pdf

Florida LAKEWATCH. 2004. A beginners guide to water management-Color. Information Circular #108. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/108Color.pdf

Florida LAKEWATCH. 2004. A beginners guide to water management-Oxygen and Temperature. Information Circular #109. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/109OxygenandTemperature.pdf

Florida LAKEWATCH. 2007. A beginners guide to water management-Fish Communities and Trophic State in Florida Lakes. Information Circular #110. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/110FishCommunitiesandTrophicState.pdf

Florida LAKEWATCH. 2007. A beginners guide to water management-Aquatic Plants in Florida. Information Circular #111. Department of Fisheries and Aquatic Sciences, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/111AquaticPlants.pdf

Florida LAKEWATCH. 2017. A beginner's guide to water management-Muck: Causes and Corrective Actions. Information Circular #112. Program of Fisheries and Aquatic Sciences, School of Forest Resources and Conservation, University of Florida/Institute of Food and Agricultural Sciences. Library, University of Florida. Gainesville, Florida. Available: https://lakewatch.ifas.ufl.edu/media/lakewatchifasufledu/extension/circulars/112Muck.pdf

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Bachmann, R. W., Bigham D. L., Hoyer M. V., Canfield D. E, Jr. 2012. A strategy for establishing numeric nutrient criteria for Florida lakes. Lake Reserv Manage. 28:84–92.

SECTION 8

INTEGRATED PEST MANAGEMENT

Integrated Pest Management (IPM) is a year-round activity on Florida's golf courses. The state's temperate to subtropical/tropical climate — which is marked by high temperatures, abundant moisture, and year-round growing conditions — makes it prone to increased pest activity.

To grow healthy turfgrass in Florida, it is important for golf course superintendents to know what IPM is and how to implement it for each pest group (arthropods, nematodes, diseases, and weeds). They must be well-versed in pest identification, understand pest life cycles and/or conditions that favor pests, and know about all possible methods of controlling pests.

Integrated Pest Management

IPM is a method of combining proper plant selection, correct cultural practices, the monitoring of pest and environmental conditions, the use of biological controls, and the judicious use of pesticides to manage pest problems. Under Florida law (Chapter 482, F.S.), IPM is defined as the following:

> *...the selection, integration, and implementation of multiple pest control techniques based on predictable economic, ecological, and sociological consequences, making maximum use of naturally occurring pest controls, such as weather, disease agents, and parasitoids, using various biological, physical, chemical, and habitat modification methods of control, and using artificial controls only as required to keep particular pests from surpassing intolerable population levels predetermined from an accurate assessment of the pest damage potential and the ecological, sociological, and economic cost of other control measures.*

The philosophy of IPM was developed in the 1950s because of concerns over increased pesticide use, environmental contamination, and the development of pesticide resistance. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of exposure to people, animals, and the environment. Its main goal, however, is to reduce pesticide use by using a combination of tactics to control pests, including cultural, biological, genetic, and chemical controls.

Cultural controls consist of the proper selection, establishment, and maintenance (such as mowing/pruning, fertilization, and irrigation) of turf and landscape plants. Keeping turfgrass healthy reduces its susceptibility to diseases, nematodes, weeds, and insects, thus reducing the need for chemical treatment.

Cultural Control Best Management Practices:

Prevent introducing pests by using certified plant material, destroy infested/infected plants (sanitize), and exclude pests.

When possible, increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed seed germination.

Stimulate or increase root growth if root-feeding pests are detected (e.g., through aeration, fertilization).

Time irrigation to avoid excess moisture or drought stress and minimize the duration of leaf wetness.

Remove dew during disease-conducive periods.

Wash mowers to avoid spreading pathogens and weeds.

Allow turf to dry before mowing.

Manage thatch by adjusting fertility levels, mechanical removal, topdressing, or other means.

Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.

Avoid outdoor lighting or use sodium-vapor lightbulbs during peak mole cricket flight periods, from dusk to 2 hours after dusk. If unavoidable, anticipate increased mole cricket pressure in turf below lights.

Biological control involves the release and/or conservation of natural enemies (such as parasites, predators, and pathogens) and other beneficial organisms (such as pollinators). Natural enemies (including ladybird beetles, green lacewings, and insect-parasitic nematodes) may be purchased and released near pest infestations. However, the golf course landscape can also be modified to attract natural enemies, provide habitat for them, and protect them from pesticide applications. For example, in out-of-play areas, flowering plants provide insect parasitoids and predators with habitat and food resources, which then forage for turfgrass insect pests on nearby in-play turf areas.

Biological Control Best Management Practices:

Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide beneficial organisms a refuge.

When possible, use insecticides that are selective for the target pest and safer for beneficial arthropods (e.g., reduced-risk insecticides).

Avoid widespread applications of broad-spectrum, contact-toxic insecticides when possible.

Install diverse flowering plants in out-of-play areas adjacent to managed turf to attract predatory and parasitic insects and promote biological control of turfgrass insect pests.

Release or promote insect-parasitic nematodes or parasitoid wasps to naturally suppress soil-dwelling pests like mole crickets and white grubs.

Genetic controls rely on the breeding or genetic engineering of turfgrasses and landscape plants that are resistant to key pests. Such resistance may increase a plant's tolerance of damage, or weaken or kill the pests. Pests may also develop more slowly on partially resistant plants, thus increasing their susceptibility to natural enemies or "softer" pesticides. Selecting resistant cultivars or plant species when designing a golf course is a very important part of IPM. Although superintendents often work with established plant material, they can still recommend changes. Every opportunity should be taken to educate builders, developers, landscape architects, plant producers, and others on which plants are best suited to golf courses.

Chemical controls include a wide assortment of conventional, broad-spectrum pesticides and more selective, newer chemicals, such as microbial insecticides and insect growth regulators. IPM does not preclude the use of pesticides, but it does promote the use of the least toxic and most selective alternatives when chemicals are necessary. Pesticides are only one tool used against pests and should be used responsibly and in combination with other, less-toxic control tactics.

Chemical Control Best Management Practices:

Integrate pesticide use into a pest management plan that is based on the proper diagnosis and identification of pest problems, documents pest abundance, ensures that the pest is in a susceptible life stage, and considers feasible cultural management options first.

Especially for insecticides aimed at soil insects, irrigate turfgrass before and/or after an application, in accordance with the label.

Avoid broad-spectrum pesticides when possible to conserve beneficial insects.

Test new pesticides on a small area on the golf course before widely using them.

Manage pesticide resistance by rotating pesticides with different modes of action, as appropriate.

Preventively apply appropriate fungicides where diseases are likely to occur and when conditions favor disease outbreaks.

Preventively apply pesticides only in areas where severe damage previously occurred, was documented, and can be reasonably expected again.

Avoid applying herbicides when they could contribute to plant stress and lead to greater damage from a secondary pest problem.

When determining which products are available for use by turfgrass managers, and when and how to use them, refer to the following UF/IFAS Extension Publications:

- *Insect Pest Management on Turfgrass* (available: https://edis.ifas.ufl.edu/ig001)
- *Turfgrass Disease Management* (available: https://edis.ifas.ufl.edu/lh040)
- *Nematode Management for Golf Courses in Florida* (available: https://edis.ifas.ufl.edu/in124)
- *Weed Biology and Management in Turf Series* (available: https://edis.ifas.ufl.edu/topic_series_weed_biology_and_management_in_turf)

Other relevant publications include *Pesticide Formulations* (available: https://edis.ifas.ufl.edu/pi231) and *Pesticide Calibration Formulas and Information* (available: http://edis.ifas.ufl.edu/WG067). Online searches for University of Florida extension publications can be made at http://edis.ifas.ufl.edu/advsearch.html. Also, consult with UF/IFAS extension agents or faculty, chemical distributors, product manufacturers, or independent turf or golf course maintenance consultants.

The basic steps of an IPM program are as follows:

1. Identify key pests and key plants. Know which pests are associated with the turf species and cultivars being managed.

2. Determine the pest's life cycle and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).

3. Use cultural, mechanical, or physical methods to prevent problems from occurring (for example, prepare the site and select resistant plant cultivars), reduce pest habitat (for example, practice good sanitation and carry out pruning and dethatching), or promote biological control (for example, provide nectar or honeydew sources for natural enemies).

4. Decide which pest management practice is appropriate and carry out corrective actions. Direct control where the pest lives or feeds. Use properly timed preventive chemical applications only when your professional judgment indicates that they are likely to control the target pest effectively, while minimizing the economic and environmental costs.

5. Determine if the "corrective actions" reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.

Written Plans and Record Keeping

It is essential to develop a written IPM plan and to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures. Record keeping is required to comply with the federal Superfund Amendments and Reauthorization Act (SARA, Title III), which contains emergency planning and community right-to-know legislation. If restricted-use pesticides (RUPs) are used on the golf course, certain record-keeping requirements apply.

Best Management Practices:

Document, identify, and record key pest activities on key plants and locations.

Determine the pest's life cycle and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).

Determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.

Observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so intelligent decisions can be made regarding how damaging they are and what control strategies are necessary.

Monitoring and Scouting

Monitoring, or scouting, is the most important element of a successful IPM program. It enables you to monitor for the presence and development of pests throughout the year. By observing turf conditions regularly (daily, weekly, or monthly, depending on the pest) and noting which pests are present, intelligent decisions can be made regarding how damaging they are and what control strategies are necessary.

Keep in mind that pests may be present for some time before damage occurs or is noticed. It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures. Look for the following when monitoring:

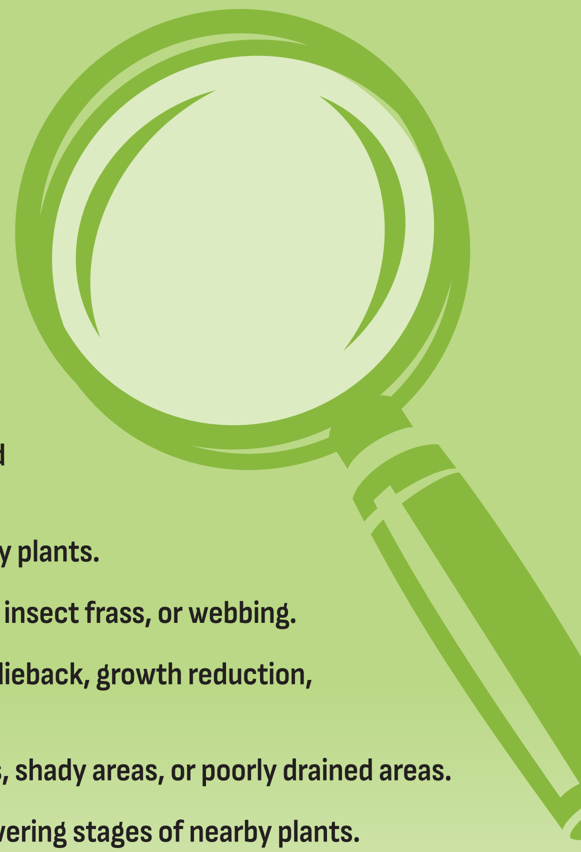
What are the signs of the pest?
These may include mushrooms, animal damage, insect frass, or webbing.

What are the symptoms?
Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.

Where does the damage occur?
Problem areas might include the edges of fairways, shady areas, or poorly drained areas.

When does the damage occur?
Note the time of day and the year, and the flowering stages of nearby plants.

What environmental conditions are present at the time of damage?
These include air temperature and humidity, soil moisture, soil fertility, air circulation, and amount of sunlight.



Best Management Practices:

Train personnel to observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so intelligent decisions can be made regarding how damaging they are and what control strategies are necessary.

Train personnel to recognize different pests, determine the pest's life cycle, and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).

Train personnel to determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.

Train personnel to document, identify, and record key pest activities on key plants.

Look for signs of the pest. These may include mushrooms, animal damage, insect frass, or webbing.

Identify the symptoms of the pest. Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.

Determine the damage. Problem areas might include the edges of fairways, shady areas, or poorly drained areas.

Document when the damage occurred. Note the time of day, year, and flowering stages of nearby plants.

Map pest outbreaks locations to identify patterns and susceptible areas for future target applications and ultimate pesticide reductions.

Sampling

Common sampling methods for pests include soil samples; soap flushes or drenches; and blacklight, pheromone, and pitfall traps. Before collecting and submitting turf samples for identification, visit the following UF—IFAS Web site for direction on which resources to use: https://plantpath.ifas.ufl.edu/extension/plant-diagnostic-services. These include the Plant Disease Clinic (available: http://edis.ifas.ufl.edu/sr007), Insect Identification Service (available: http://edis.ifas.ufl.edu/SR010), and Nematode Assay Laboratory (available: http://entnemdept.ufl.edu/nematology-assay-lab/). The Rapid Turfgrass Diagnostic Service was designed and implemented for managers of high quality turfgrass in Florida for very fast turnaround (available: http://turf.ufl.edu/rapiddiag.shtml).

Pest Thresholds — Using economic thresholds for key pests is common in agricultural commodities. However, using economic thresholds is more challenging on golf courses because the golf industry is sensitive to aesthetic damage, and golfers are often intolerant of anything that could affect the appearance or playability of turfgrass. Therefore, pest control measures are typically based on experience and site-specific information (site use, visibility, history, and pest density). Increased education of golfers and maintenance personnel could raise their tolerance of minor aesthetic damage without compromising plant health, play, and aesthetics.

Pests

Diseases

Turfgrasses are managed at the edge of their adaptations to create suitable surfaces for playing golf in Florida. Various groups of plant pathogens can disrupt play by damaging the intensely managed turf, if conditions are conducive to disease. As some superintendents note, the tolerance of golfers for disease damage is generally inversely proportional to what they pay to use the course. In other words, the more they pay, the better they expect the course to look.

No measure can completely eliminate the threat of turfgrass disease on a golf course. However, turfgrass managers have several tactics and tools that can reduce the likelihood of disease. A superintendent's budget, turfgrass species and cultivars, and membership expectations dictate what options are available.

The first rule is to minimize plant stress by optimizing cultural management programs. Cultural factors that can influence turfgrass stress and the likelihood of disease problems include organic layer (thatch) management, fertility programs, water management, and mowing height selection. Healthy, well-managed turfgrass is less likely to develop disease problems. Diseases that do occur are less likely to be severe because healthy turf has better recuperative potential than stressed, unhealthy turf. Successful superintendents find a balance between membership expectations and the edge of their turf's adaptation.

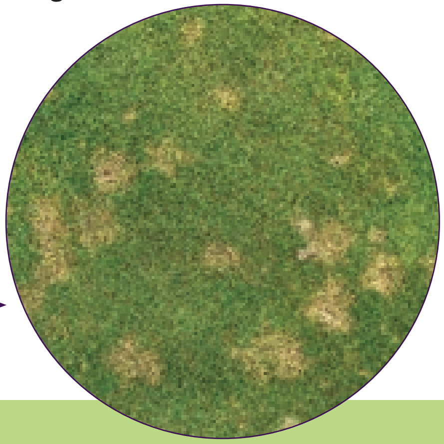
Many excellent fungicide products are labeled for use on golf courses and marketed to superintendents. Fungicide use should be carefully integrated into an overall management strategy for a golf course. In general, plant diseases are difficult to manage once symptoms are severe in an area, and fungicides are most effective when used in preventive programs. The appropriate (most effective) preventive fungicide should be applied to susceptible turfgrasses when unacceptable levels of disease are likely to occur.

Determining when and where diseases are likely to occur requires an understanding of the potential disease problems for a particular turfgrass cultivar and knowledge of the impact that environmental variables such as temperature, sunlight, airflow, relative humidity, and leaf wetness have on disease outbreaks. Because this type of prediction is difficult, and even veteran superintendents and plant pathologists cannot predict all disease outbreaks, curative treatments are sometimes necessary. Fungicide labels generally call for higher rates and shorter intervals when treating diseased turfgrass curatively. Selecting the appropriate fungicide product is very important for efficient and effective curative treatment and depends on a correct disease diagnosis.

No one fungicide product is effective against all common turfgrass pathogens. Also, for some turfgrass injuries and disorders (not caused by a pathogen), the symptoms resemble those of disease. Some turfgrass diseases are fairly obvious, and others can cause a range of overlapping symptoms that makes correctly diagnosing the problem difficult. Plant disease diagnostic services are available from the University of Florida and private laboratories. To avoid using the wrong product, ask your fungicide company sales representative, turfgrass consultant, or county agent for diagnostic lab confirmation to make sure the best fungicide product for your situation is applied. For a list of potential fungicides, see the publication, *Turfgrass Disease Management* (available: http://edis.ifas.ufl.edu/LH040).

The most problematic of the golf turf disease problems include the following:

- Bermudagrass decline and take-all root rot caused by *Gaeumannomyces graminis* var. *graminis*
- *Pythium* root rot and blight of warm-season turfgrasses
- *Helminthosporium* leaf spot and melting out caused by *Bipolaris* spp.
- Leaf and sheath spot, caused by *Waitea circinate* var. *zeae*
- Large patch disease caused by *Rhizoctonia solani*
- Dollar spot caused by *Clarireedia monteithiana* (formerly *Sclerotinia homoeocarpa*)
- Fairy ring caused by various *basidiomycete* fungi



Best Management Practices for Turfgrass Diseases

Correctly diagnose the diseases causing symptoms of concern. This often involves sending samples to diagnostic clinics.

Ensure that proper cultural practices that reduce turfgrass stress are used.

Correct conditions that produce stressful environments for the turf (for example, improve airflow and drainage, reduce or eliminate shade).

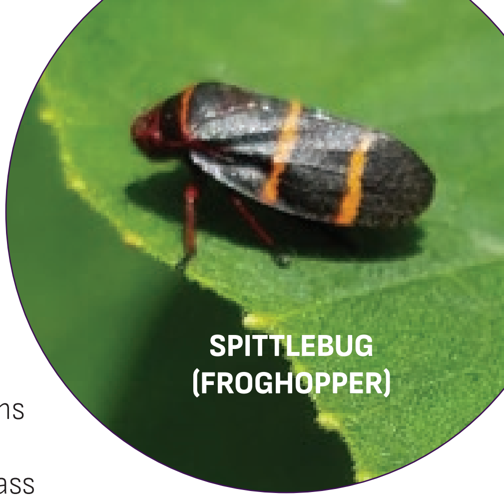
Fungicide use should be integrated into an overall management strategy for a golf course.

Select appropriate (effective) fungicides to prevent spread of specific diseases that are diagnosed when unacceptable levels of disease are likely to occur.

Preventively apply appropriate fungicides where diseases are likely to occur and when conditions favor disease outbreaks.

Record and map disease outbreaks and identify trends that can help guide future treatments and focus on changing conditions in susceptible areas to reduce disease outbreaks.

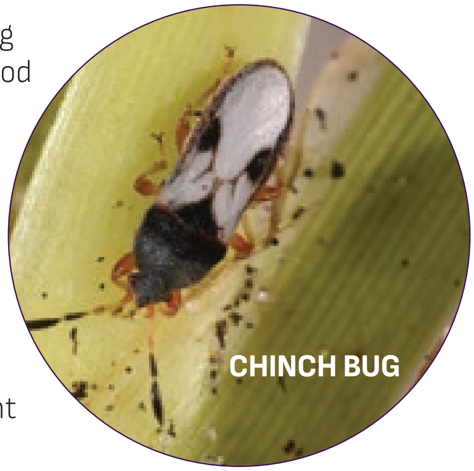
Arthropods


SPITTLEBUG (FROGHOPPER)

Many arthropods (especially insects and mites) occur in turfgrasses and ornamental plantings located on golf courses. Most are beneficial (e.g., pollinators, decomposers, and natural enemies) or aesthetically attractive (e.g., butterflies), while others may be nuisance pests or actually reduce plant health. Arthropods can cause various types of damage to turfgrass depending on their abundance and density, and where they attack the plant. Major root-feeding pests in Florida include mole crickets, white grubs, billbugs, and ground pearls. Arthropods that commonly feed on leaves or stems include tropical sod webworm, fall armyworm, grass looper, greenbug aphids, chinch bugs, spittlebugs, bermudagrass scale, Rhodesgrass mealybug, Tuttle mealybug, and bermudagrass mite. Arthropod pests with piercing—sucking mouthparts (e.g., aphids, chinch bugs, scale insects, mealybugs, mites, and spittlebugs) withdraw nutrients from plants and cause leaf chlorosis, browning, and dieback. Insects with chewing mouthparts (e.g., mole crickets, white grubs, billbugs, and caterpillars) partially or completely remove above- or below-ground plant tissue. Nuisance pests may not directly damage turfgrass but can be abundant during short periods, make mounds or castings (e.g., earthworms), nest in sand traps (e.g., cicada killer wasps) or electrical equipment, or affect human or animal health (e.g., red imported fire ants, stinging wasps, fleas, and ticks).


GREENBUG APHID

Florida's warm and humid climate, long growing season, and diversity of plants are ideal for arthropod growth, development, and survival. Several insects that have only one generation per year in the northern United States may have multiple generations in Florida. Thus, pest management decisions should be made based on regionally-specific information on pest life cycles, behavior, and susceptible life stages. Early pest detection and identification are vital to any IPM program. Turf should be inspected as often as practical, especially in areas that tend to become reinfested each year. All employees should be trained to spot potential problems while performing their assigned duties. Specimens can be sent to several different University of Florida and private identification labs.


CHINCH BUG

IPM is useful against most arthropod pests of turfgrass. It is both a practice and strategy to keep pest populations below damaging levels with minimal nontarget effects. When possible, it is important to identify which factors might predispose areas to unwanted arthropod pests and then modify those factors before using pesticides. For example, some golf course practices that enhance playability (e.g., using floodlights at night) can attract flying beetles, moths, and mole crickets that will reproduce and feed on turf in those areas. Low-lying areas that remain wet can be expected to have increased pressure from insects like mole crickets and white grubs. Cultural practices, such as mowing, dethatching, and aerating may help to mechanically kill some pests or reduce their habitats. Leaving roughs and driving ranges as untreated refuges for natural enemies, providing flower or nectar sources for parasitic flies or wasps, or applying insect-parasitic nematodes or pathogens to infested turfgrass are a few more sustainable arthropod pest management strategies in an IPM program.


BILLBUG

Insecticides are effective tools if they are accurately selected, timed, and targeted against a pest's appropriate life stage. Products within several chemical classes are available to superintendents, and product manufacturers continue to create new chemical classes and modes of action for use in turf and ornamentals. However, there have been documented instances of insect pests in Florida turfgrasses developing resistance to an insecticide, including neonicotinoids, pyrethroids, organophosphates, and carbamates. Therefore, resistance management must be a part of an IPM program. Resistance is likely to develop if products in the same chemical class or those that have the same mode of action are repeatedly used without rotation. Risk is even more heightened if the target insect has several generations per year, has limited dispersal, and it can reproduce and develop quickly. For these reasons, chinch bugs, aphids, mealybugs, scale insects, and mites are more likely to become resistant than mole crickets, caterpillar pests, or white grubs.

For more information, see the publication, *Insect Pest Management on Turfgrass* (available: https://edis.ifas.ufl.edu/ig001) or see the Insecticide Resistance Action Committee (IRAC) Web site (available: http://www.irac-online.org/).

Photo courtesy USGA

Insect Best Management Practices:

Ensure that proper cultural practices that reduce turfgrass stress and increase resistance to pests are being used.

Plant pest-resistant or pest-tolerant species and varieties when possible.

Create areas of diverse flowering plants adjacent to managed turfgrasses to attract predatory and parasitic insects and promote natural pest control.

Be familiar with the key pests associated (or not associated) with plants being managed so that you can anticipate pest problems, more easily diagnose damage, and be prepared to control arthropod pests more effectively.

Correct conditions that produce stressful environments for the turf or harbor arthropod pests (e.g., improve airflow, reduce thatch, improve drainage).

Correctly identify the insect or mite. This often involves a hand lens or microscope, being familiar with mouthparts and damage, knowing key pests, or sending samples to diagnostic clinics.

Regularly survey turf and ornamental plantings for signs and symptoms of arthropod pests.

Detection of a pest does not warrant insecticide application. Also consider pest density, damage, life stage, and time of year.

When possible, apply selective, reduced-risk insecticides to control pests with minimal non-target effects on beneficial arthropods that also live in turfgrasses or on ornamental plants

Avoid widespread applications of broad-spectrum, contact-toxic insecticides when possible.

Use insecticides to control insect pests and miticides to control mite pests.

Apply at least three different IRAC insecticide classes in sequence before re-applying a chemical class that has already been used (e.g., A-B-C-A, not A-B-A, A-B-B, or A-A-A).

Record and map arthropod pest outbreaks and identify trends that can help guide future treatments.

Nematodes

Plant parasitic nematodes have long been known to adversely affect turfgrass health. However, as many of the highly effective nematicides used in the past 25 years have been withdrawn from the market, nematode management on turfgrasses has become increasingly difficult. Plant parasitic nematodes are microscopic roundworms (unsegmented), usually between 1/64th and 1/8th inch (0.25 and 3 mm) in length. These obligate parasites feed on living plant tissue using a hollow stylet (mouth spear), with which they puncture cell walls, inject digestive juices into the cells, and draw the liquid contents from the cells. By debilitating the root system, plant parasitic nematodes cause turf to be less efficient at assimilating water and nutrients from the soil making the turf more susceptible to environmental stresses. Additionally, weakened turf favors pest infestation, especially troublesome weeds that necessitate herbicide applications.

Plant parasitic nematodes are classified according to their feeding habit as ectoparasitic or endoparasitic. Ectoparasitic nematodes always live outside roots and feed only on tissues they can reach from outside the roots. Because they are exposed in the soil, ectoparasites generally respond better to nematicides than endoparasites. Endoparasitic nematodes spend at least part of their life cycles inside the roots on which they feed and are either migratory or sedentary. Migratory nematodes move freely in, through, and out of root tissues, while sedentary nematodes spend most of their life cycles in a single permanent feeding site within a root. Because they are protected within roots, endoparasitic nematodes are typically more difficult to manage with nematicides and are easily spread in infested plant material.

Photo courtesy USGA

Nematode damage to turfgrass

Because they have an irregular distribution, areas of nematode-damaged turf usually are irregular in shape and vary in size. Affected turfgrass plants often appear wilted, and the shoots often turn yellow and eventually brown. Over time, turf in the affected areas thins out and, with severe infestations, may die. The roots of turfgrasses under nematode attack may be very short and club-shaped with few, if any, root hairs; or they may appear dark and rotten.

Although plant parasitic nematodes may be active, healthy turfgrass growing in fertile, moist soil during favorable weather often perseveres. Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses, including drought, high temperatures, low temperatures, and wear. When nematode activity is suspected, an assay of soil, thatch, and turfgrass roots is recommended to determine the extent of the problem. Often, tolerance to nematodes can be promoted by reducing additional stresses on the turf. However, in many cases nematicides need to be applied to achieve the desired turf quality. The application of a nematicide on golf course turf should always be based on assay results.

For more information, see the publication, *Nematode Management for Golf Courses in Florida* (available: http://edis.ifas.ufl.edu/IN124).

Nematode Best Management Practices:

When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem (available: http://entnemdept.ufl.edu/nematology-assay-lab/ *for instructions*).

The application of a nematicide on golf course turf should always be based on assay results.

Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.

Increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed-seed germination.

Reduce/eliminate other biotic/abiotic stresses when nematodes are compromising the root system and plant health.

Weeds

A weed is any plant out of place or growing where it is not wanted. For example, bahiagrass is considered a weed when growing in a pure stand of bermudagrass but is highly desirable when grown in a monoculture such as a golf course rough. In addition to being unsightly, weeds compete with turfgrasses for light, soil nutrients, soil moisture, and physical space. Weeds also are hosts for other pests such as plant pathogens, nematodes, and insects, and certain weeds can cause allergic reactions in humans.

YELLOW WOODSORREL

The most undesirable characteristic of weeds in turf is the disruption of visual turf uniformity that occurs when weeds with a different leaf width or shape, growth habit, or colors are present.

Broadleaf weeds such as yellow woodsorrel, spotted spurge, and dollarweed have leaves with a different size and shape than the desirable turf species. Smutgrass, goosegrass, vaseygrass, and thin paspalum grow in clumps or patches that also disrupt turf uniformity. In addition, large clumps are difficult to mow effectively and increase maintenance problems. The lighter-green color typically associated with certain weeds, such as annual bluegrass, in a golf green often distracts from the playing surface.

DOLLARWEED

Weed control for turf managers can be a difficult chore for several reasons. Florida, unlike most areas of the country, has a very mild climate with few freezes. As a result, many weeds traditionally thought of as annuals often behave as short-lived perennials, especially in central and south Florida. For example, year-round weed pressure can occur in Florida from annuals such as crabgrass and goosegrass, which in most sections of the country are killed by freezing temperatures. Florida's mild climate is also suitable for the growth of many subtropical and tropical weeds that are not found in other regions of the country.

Weed management is an integrated process where good cultural practices are employed to encourage desirable turfgrass ground cover, and where herbicides are intelligently selected and judiciously used. **A successful weed management program consists of:**

(1) preventing weeds from being introduced into an area
(2) using proper turfgrass management and cultural practices to promote vigorous, competitive turf
(3) properly identifying weeds
(4) properly selecting and using the appropriate herbicide, if necessary

Weed invasion often occurs in weakened turf. The major reasons for weed encroachment are reduced turfgrass quality and low density. **Weakened turf or bare areas results from:**

(a) the selection of turf species or cultivars not adapted to the prevalent environmental conditions
(b) damage from turfgrass pests such as diseases, insects, nematodes, and animals
(c) environmental stresses such as shade, drought, heat, and cold
(d) improper turf management practices, such as the misuse of fertilizer and chemicals, improper mowing height or mowing frequency, and improper soil aeration
(e) physical damage and compaction from excessive traffic.

Unless the factors that contribute to the turf decline are corrected, continued problems with weed encroachment can be expected. Proper weed identification is essential for effective management and control. Turf managers should be able to correctly identify at least the most common species for their geographic area. Since weeds often indicate fertilizer, drainage, traffic, or irrigation problems, correct weed identification can help turf managers to determine the underlying causes of certain infestations and correct them. For example, goosegrass indicates compacted soil, nutsedge suggests drainage problems, while red sorrel indicates low pH.


GOOSEGRASS

Identification begins with classifying the weed type. Broadleaves, or dicots, have two seed cotyledons (young leaves) at emergence and have netlike veins in their true leaves. They often have colorful flowers. Examples include clover, spurges, lespedeza, plantain, henbit, pusley, dollarweed, and matchweed. Grasses, or monocots, have only one seed cotyledon present when seedlings emerge from the soil. They also have hollow, rounded stems with nodes (joints) and parallel veins in their true leaves. Examples include crabgrass, tropical signalgrass, goosegrass, thin (bull) paspalum, and annual bluegrass. Sedges and rushes generally favor a moist habitat and have stems that are either triangular shaped and solid (sedges), or round and solid (rushes).

Weeds complete their life cycles in either one growing season (annuals), two growing seasons (biennials), or three or more years (perennials). Annuals that complete their life cycles from spring to fall are referred to as summer annuals. Those that complete their life cycles from fall to spring are winter annuals.

In the past, proper weed identification was difficult due to the lack of a suitable guide. Most guides pictured weeds in unmowed conditions or did not list all the important turf weeds. Currently there are many reference books available that provide detailed descriptions and color photographs of common weeds found in turf settings.


MATCHWEED

Weed Management Best Management Practices:

Proper weed identification is essential for effective management and control.

Select appropriate turf species or cultivars that are adapted to the prevalent environmental conditions to reduce weed encroachment that may lead to bare soils.

To prevent weed encroachment, adopt or maintain cultural practices that protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.

To reduce weed infestation, address improper turf management practices, such as the misuse of fertilizers and chemicals, improper mowing height or mowing frequency, and improper soil aeration, and physical damage and compaction from excessive traffic.

Proper fertilization is essential for turfgrasses to sustain desirable color, growth density, and vigor and to better resist diseases, weeds, and insects.

Avoid scalping; it reduces turf density, increasing weed establishment.

Weed-free materials should be used for topdressing.

Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.

Record and map weed infestations to help identify site specific issues for preventative actions.

SECTION 9

PESTICIDE MANAGEMENT

Before any pesticide product is sold or distributed in Florida, it must be registered by the U.S. Environmental Protection Agency (EPA) and Florida Department of Agriculture and Consumers Services (FDACS).

In any commercial pesticide product, the component that actually kills, or otherwise controls, the target pest is called an active ingredient. The product may also contain inert ingredients such as solvents, surfactants, and carriers. However, not all inert ingredients are harmless, and they may be controlled or regulated because of environmental or health concerns. The EPA regulates the use of pesticide products based on their active ingredients, but also reviews and limits the use of inert ingredients based on their toxicity.

Regulation

The U.S. Congress has mandated that the EPA regulate the use and disposal of pesticides in this country. Through its Office of Pesticide Programs, the EPA regulates pesticide use and disposal under two federal statutes. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), administered by the EPA, governs the licensing or registration of pesticide products. This act was last amended by Congress in 1988. FIFRA, as amended in 1972, authorizes cooperative enforcement agreements between the EPA and the state's lead pesticide regulatory agency. In 1978, FIFRA was amended to give state governments the primary enforcement responsibility, subject to oversight by the EPA, for pesticide-use violations.

The Federal Food, Drug, and Cosmetic Act (FFDCA) authorizes the EPA to establish tolerances for pesticide residues in raw and processed foods. The Food and Drug Administration (FDA) of the U.S. Department of Health and Human Services monitors and enforces these tolerances.

State regulatory agencies may set local standards, but they can be no less stringent than those established by the EPA. Because of the unique environmental conditions present in Florida, state regulations have been adopted that are more strict than the federal guidelines for the use of certain pesticides. FDACS is the lead state agency that, in cooperation with the EPA, enforces existing state and federal statutes to ensure that pesticides are registered, used, and disposed of properly. FDACS also analyzes field samples of soils and water to determine if pesticide residues are at acceptable levels in environmental samples.

Four main programs within FDACS carry out these responsibilities:

(1) pesticide registration
(2) pesticide enforcement
(3) scientific evaluation
(4) laboratory analysis

Depending on the specific pesticide use, a registrant must supply the EPA with the results of a battery of environmental fate and toxicity studies. These studies are performed primarily by private laboratories that follow strict good lab practices (GLPs) and QA/QC measures. Only after the registrant has met all the EPA guidelines and the risk assessment is complete can a registrant receive a federal registration for a pesticide product.

Several states, including Florida, require an additional review before a pesticide can be sold and distributed within the state. FDACS scientists review the behavior of a pesticide under Florida conditions which may be atypical compared with much of the rest of the United States. Florida's high annual rainfall, year-round cropping, Karst topography, and sandy soils are only a few of the conditions that must be considered in evaluating a pesticide's risk to surface water and ground water quality, threatened and endangered species, and Florida citizens. All new pesticides are reviewed before the Pesticide Registration and Evaluation Committee (PREC) for registration. This committee comprises members from the Florida Department of Health (FDOH), Florida Department of Environmental Protection (FDEP), Florida Fish and Wildlife Conservation Commission (FFWCC), and FDACS. If unreasonable risks are suspected, the manufacturer may be required to provide additional data, perform field tests under Florida-specific conditions, and/or impose risk mitigation measures.

Pesticides registered for use in Florida carry a label that provides, among other information, the maximum allowed application rates; approved application methods and times, crops, sites, and pests; and directions for safe and effective use. State and federal laws require the use and disposal of pesticides according to the label.

Pesticide Regulation Best Management Practices

Only apply pesticides that are legally registered at all levels of jurisdiction.

Only apply pesticides that are legally registered for use on the facility (for example, do not apply pesticides labeled for agricultural uses even though they may have the same active ingredient).

Apply according to manufacturer recommendations as seen on label.

Licensing Requirements for Pesticide Use in Golf Course Maintenance

Some federal or state regulation covers practically anyone who manufactures, formulates, markets, and uses any pesticide. Laws regarding pesticide use (Chapter 487, F.S.) require that golf course superintendents using restricted use pesticides (RUPs) obtain a RUP applicator license from FDACS. A licensed applicator may supervise up to 15 unlicensed pesticide handlers. County Cooperative Extension Service offices statewide provide training and exams, and most exam study manuals are available at a nominal cost from the UF/IFAS Extension Bookstore at (800) 226–1764 or at http://www.ifasbooks.com. A person aspiring to become licensed is not required to attend a training program but may choose to self-study for the exams. A list of counties that offer all exams is available at http://www.freshfromflorida.com/Business-Services/Pesticide-Licensing/Pesticide-Applicator-Licenses. To find out the exam schedule for a specific county Cooperative Extension Service office, contact that particular office. A list of the offices with telephone numbers, addresses, and maps is available at https://directory.ifas.ufl.edu/googleearthdisplay?pageID=1. For more information contact the FDACS Bureau of Licensing and Enforcement at (850) 617-7870.

Continuing Education and Applicator Training

Once an applicator has successfully passed the examinations, continuing education units (CEUs) or retesting are necessary for renewal. FDACS requires those holding the Ornamental and Turfgrass Pest Control category to earn a total of 16 CEUs: 4 in core and 12 in the category. UF/IFAS and industry associations such as the Florida Golf Course Superintendents Association and the Florida Turfgrass Association offer many training opportunities each year. These events provide learners with practical information on pesticide safety, scouting, cultural practices and IPM, equipment calibration and maintenance, and record keeping. Pesticide application is where the rubber meets the road, so to speak, and applicator training is key to safe and effective use. For training information, contact your local extension agent or the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392-4721 (available: https://pested.ifas.ufl.edu/).

Record Keeping

The Florida pesticide law requires certified applicators to keep records of applications of all RUPs. To meet your legal responsibility and to document your management practices, you need to maintain accurate pesticide application records. Florida regulations require that information on RUPs be recorded within two working days of the application and maintained for two years from the application date. The required records must be made available upon request to FDACS representatives, USDA authorized representatives, and licensed health care professionals. A simple-to-use recordkeeping form is available at http://www.freshfromflorida.com/content/download/2990/18861/Suggested%20Pesticide%20Recordkeeping%20Form.pdf.

Florida law requires that you record the following items to comply with the RUP recordkeeping requirement:

- *Brand or product name*
- *EPA registration number*
- *Total amount applied*
- *Location of application site*
- *Size of area treated*
- *Crop/variety/target site*
- *Month/day/year and start and end times of application*
- *Name and license number of applicator (if applicator is not licensed, record his/her name and his/her supervisor's name and license number)*
- *Method of application*
- *Name of the person authorizing the application, if the licensed applicator does not own or lease the property.*

Florida law also require application information on organo-auxin herbicides (e.g., 2,4-D) and plant growth regulators (general or restricted use) to a land or surface area greater than 5 cumulative acres within a 24-hour period. For a land or surface area less than 5 cumulative acres within a 24-hour period, only wind speed and direction readings are required. The suggested format for recording this information is available at http://forms.freshfromflorida.com/13328.pdf.

The publication, *Pesticide Record Keeping* (available: http://edis.ifas.ufl.edu/PI012), provides additional information on pesticide record keeping.

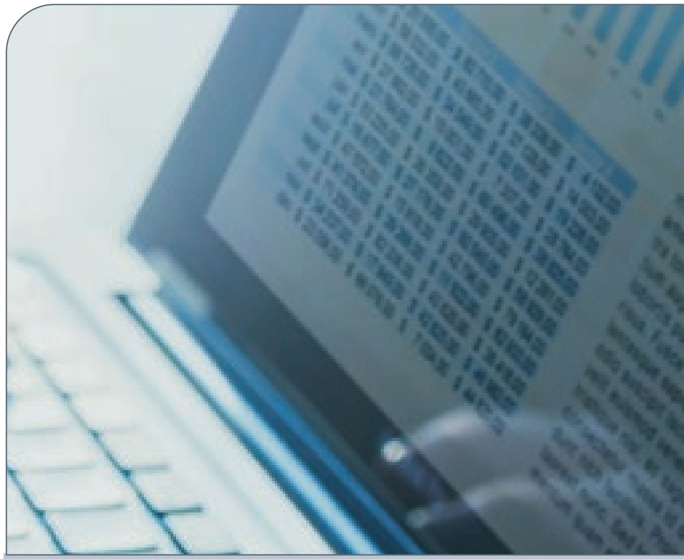
In addition to the records required by law for RUP use, IPM principles suggest that you keep records of all pest control activity, so that you may refer to information on past infestations or other problems to select the best course of action in the future. There is no time limit on these records, because the longer they go back, the more helpful they are.

These records will help you to do the following:

- *Evaluate past pest control practices*
- *Improve pest control practices*
- *Predict future pest problems*
- *Predict future results*
- *Develop more accurate pest control budgets*
- *Minimize pesticide use and costs*
- *Maximize pest control efficiency*
- *Reduce the risk of pesticide resistance*
- *Avoid pesticide misuse*
- *Reduce pesticide inventory and storage requirements*
- *Provide proof of label and IPM compliance in the event of a lawsuit*

Such records should include the following:

- *Plant being treated*
- *Location and area treated*
- *Stage of plant development*
- *Pest being treated,*
- *Stage of pest development*
- *Severity of infestation*
- *Beneficial species present*
- *Air temperature*
- *Wind speed and direction*
- *Rainfall and soil moisture level*
- *Other pertinent environmental conditions*
- *Time of day and date*
- *Recent previous attempts to control*
- *Basis of selection for treatment used*
- *Pesticide name (if used)*
- *Trade name and manufacturer*
- *Type of formulation*
- *Lot number*
- *Percent active ingredient*
- *Application rate (per acre or 1,000 ft^2)*
- *Type of equipment used*
- *Results of treatment*



Record Keeping Best Management Practices

Keep and maintain records of all pesticides used to meet legal (federal, state, and local) reporting requirements.

Use records to monitor pest control efforts and to plan future management actions.

Use electronic or hard-copy forms and software tools to properly track pesticide inventory and use.

Develop and implement a pesticide drift management plan.

Keep a backup set of records in a safe, but separate storage area.

Pesticides and Water Quality

Because Florida's climate favors the growth of many harmful insects, nematodes, weeds, and plant diseases, golf courses are typically dependent on pesticides for turfgrass management. In Florida, concern about the presence of pesticides in the environment and the threat they pose to surface water and ground water quality is significant. The careful use of pesticides to avoid environmental contamination is an important aspect of golf course management and is desired by both superintendents and the general public. This section discusses factors affecting the behavior of pesticides in soil and water, and how pesticides should be selected and used to prevent environmental contamination.

Surface Water and Ground Water Resources

Surface waters are those we can see on the surface of the earth, including lakes, rivers, streams, wetlands, estuaries, and even the oceans. They are replenished by rain, runoff, the upwelling of ground water, and the lateral discharge of ground water. Ground water, the source of water for wells and springs, is found underground, within cracks in bedrock or filling the spaces between particles of soil and rocks. The ground water layer in which all available spaces are filled with water is called the saturated zone. The dividing line between the saturated zone and overlying unsaturated rock or sediments is called the water table.

Water entering the soil gradually percolates downward to become ground water if it is not first taken up by plants, evaporated into the atmosphere, or held within soil pores. This percolating water, called recharge, passes downward through the root zone and unsaturated zone until it reaches the water table. Effective programs for ground water protection focus primarily on the recharge process, because this controls both the quantity and the quality of water reaching the saturated zone.

The quantity of recharge in any location depends on the amount of precipitation or irrigation, runoff, soil storage, evapotranspiration, the type of soil, and the site's topography and geology. Seasonal fluctuations occur in the quantity of recharge, leading also to fluctuations in the depth of the water table. Florida is known for its high annual rainfall; however, these rain events are often seasonal. During the dry season, shallow wells can run dry and also cause some springs, wetlands, and small streams to dry up due to a falling water table. Recharge is the only natural means of replenishing ground water supplies, and the water table drops if the amount of water lost exceeds the amount of recharge.

Behavior of Pesticides in Soil and Water

Once a pesticide is applied to turfgrass, a number of environmental fate processes may occur (Figure 9.1). The pesticide may be taken up by plants or ingested by animals such as insects and earthworms or by microorganisms in the soil. It may move downward in the soil and either adhere to particles or dissolve.

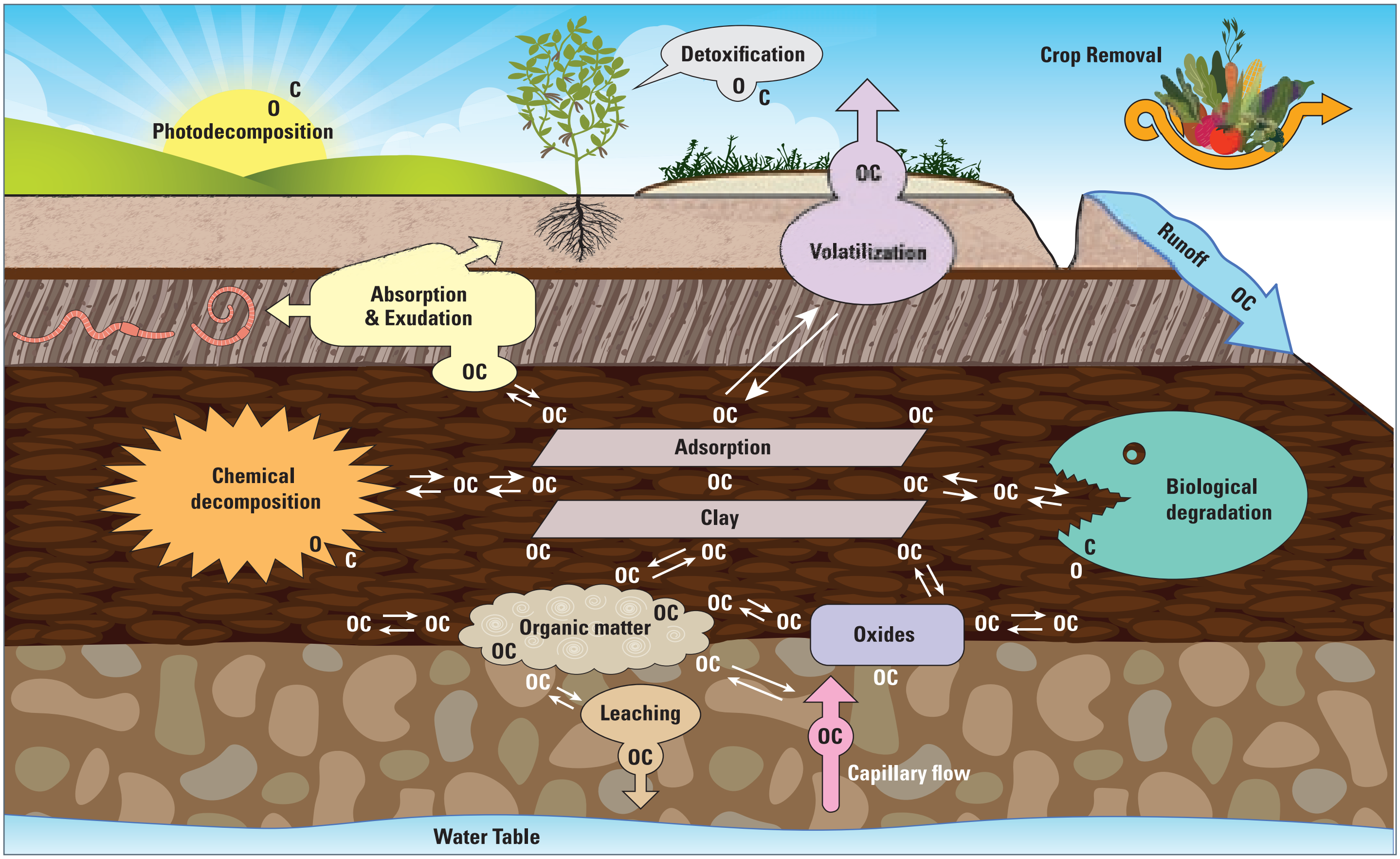


FIGURE 9.1: Pathways of pesticide loss (based on Rao and Hornsby, 1993; adapted from Skrotch and Sheet, 1981)

The pesticide may volatilize and enter the atmosphere or break down via microbial and chemical pathways into other, less toxic compounds. Pesticides may be leached out of the root zone or washed off the land surface by rain or irrigation water. Although the evaporation of water at the ground surface can lead to the upward flow of water and pesticides, in most Florida soils, this process is likely not to be as important as downward leaching from irrigation and/or rainfall.

Nontarget Effects

Although pesticides can effectively control pests, they can also be dangerous when misused. Fish kills, reproductive failure in birds, and acute illnesses in people have all been attributed to exposure to pesticides—usually as a result of misapplication, spray drift or the careless disposal of unused pesticides and containers. In addition to obvious nontarget organisms such as people, pets, birds, and wildlife, other important organisms that can be affected by pesticides include earthworms, honeybees and other beneficial arthropods, and fungi or other microorganisms that might degrade thatch or control pathogens, or are important to nutrient dynamics and overall soil health.

There are three principal ways in which pesticides can leave their application site: runoff, leaching, and spray drift during application. Runoff is the physical transport of pesticides over the surface of the ground with rainwater or irrigation water that does not penetrate the soil. Florida often experiences rainfall events with very high precipitation rates, resulting in significant amounts of runoff. Leaching is a process where pesticides are flushed through the soil by rain or irrigation water as it moves downward. Many of Florida's soils are sandy, making them more susceptible to leaching of dissolved nutrients and pesticides. Drift is the airborne movement of pesticide particles into nontarget areas during application. Droplet size, which is affected by nozzle type and spray pressure, wind speed, and application height are the most important factors influencing spray drift. Drift is one of the most likely causes of neighborhood complaints and may result in injury to greens or neighboring properties, pets, or people. It may also contaminate surface water if the pesticide settles on a waterbody. **Table 9.2** lists the potential drift for various droplet sizes under different wind conditions. In addition, secondary drift may occur when a pesticide volatilizes from the soil or leaf blade and moves with the air.

TABLE 9.2: Potential drift for various droplet sizes

DROPLET DIAMETER IN MICRONS	DROPLET TYPE	TIME REQUIRED TO FALL 10 FEET IN STILL AIR	DISTANCE COVERED FALLING 10 FEET IN A 3-MPH BREEZE
5	Fog	66 minutes	3 miles
100	Mist	10 seconds	409 feet
500	Light rain	1.5 seconds	7 feet
1,000	Moderate rain	1 second	4.7 feet

Due to Florida's soils and geology, there are also significant surface water—ground water interactions, which allow pollutants to move from one to the other. Sinkholes and springs are the most obvious, but equally important are the coarse soils, shallow water tables, and drainage ditches and canals.

Persistence and Sorption

The fate of a pesticide applied to soil depends largely on two of its properties: persistence and sorption. Persistence defines the stability of a pesticide. Most modern pesticides are designed to break down or "degrade" relatively rapid over time as a result of chemical and microbiological reactions in soils. Sunlight breaks down some pesticides, and soil microorganisms can break down others. Some pesticides are degraded or metabolized to intermediate substances, called degradates, as they break down. Degradation time is expressed as half-life ($T^1/_2$), the amount of time it takes for the concentration of a pesticide in soil to be reduced by one-half. For example, if the half-life of a pesticide is 10 days in the topsoil, then theoretically, the concentration would decrease from 100% to 50% over 10 days. It would take an additional 10 days for the concentration to be further reduced from 50% to 25%. In the soil, a pesticide's half-life may be affected by soil type, soil horizons, sediments, temperature, and pH.

Table 9.3 (next page) lists examples of pesticides used on Florida golf courses and their persistence based on their degradation in surface soils. Of the pesticides listed, atrazine takes the longest time to degrade, with a half-life of 60 days.

As a pesticide moves through soil, some of it binds to soil particles, particularly organic matter or clay particles, through a process called sorption, and some dissolves in soil water. As more water enters the soil through rain or irrigation, the sorbed pesticide molecules may be detached from soil particles through a process called desorption. The solubility of a pesticide and its sorption to soil are two critical factors affecting the fate of a pesticide.

A useful index for quantifying pesticide sorption on soils is the partition coefficient (Koc) which is defined as the ratio of pesticide concentration in the sorbed state (i.e., bound to soil particles) and the solution phase (i.e., dissolved in the soil water). Thus, for a given amount of pesticide applied, the smaller the Koc value, the greater the tendency to move into solution. Pesticides with small Koc values are more likely to leach, compared with those having large Koc values, which are more likely to bind with soil and organic matter. For example, in the table, glyphosate, which has a Koc value of 24,000, does not leach because it binds very tightly to soil. In contrast, dicamba, which has a Koc value of 2, can readily leach. This explains why dicamba should never be sprayed under the drip line of a tree, because it can readily move into the roots. Glyphosate, on the other hand, is frequently sprayed as an edging material around the trunk of a tree without causing damage. Dicamba is not bound to the soil, and glyphosate is strongly bound.

TABLE 9.3: Persistence and partition coefficients of pesticides used on Florida golf courses

COMMON NAME	TRADE NAME(S)	$T^1/_2$ (DAYS)	Koc (ML/G OC)
Dicamba	various	14	2
Metsulfuron-methyl	MSM, Manor, Blade	30	35
Iprodione	Chipco 26GT	14	700
Atrazine	various	60	100
Glyphosate	various	47	24,000

An added complexity in turf is thatch. When washed off turfgrass leaves, a pesticide encounters the thatch layer that accumulates on top of the soil. This layer of living and dead leaves, stems, and other organic matter provides sites for pesticides to attach and become immobilized. This process often explains the poor efficacy of certain pesticides on their target organisms (e.g., insecticides for controlling grubs).

Turf also supports an abundant population of microorganisms. Once in the soil, a pesticide may be metabolized and rendered ineffective by these microorganisms. The role and impact that thatch sorption and degradation have on pesticide mobility is an important area of ongoing research.

Estimating Pesticide Losses

When estimating pesticide losses from soils and their potential to contaminate ground water or surface water, it is essential to consider both persistence and sorption. In general, strongly sorbed pesticides (that is, compounds with large Koc and large $T^1/_2$) are likely to remain near the ground surface, reducing the likelihood of leaching but increasing the chances of being carried to surface water via runoff or erosion. In contrast, weakly sorbed pesticides are more likely to leach through the soil and reach ground water.

For nonpersistent pesticides with a short half-life, the possibility of surface water or ground water contamination depends primarily on whether heavy rains (or irrigation) occur soon after pesticide application. Without water for movement these pesticides are more likely to remain within the biologically active turf root zone where they may be degraded. In addition, the depth to the water table and the type of subsoil and surficial geology may also affect a pesticide's ability to reach ground water. Therefore, pesticides with intermediate Koc values and short $T^1/_2$ values may be considered lower risk with respect to water quality, because they are not readily leached and degrade fairly rapidly, reducing their potential impact on nearby waterbodies. Soils with hard pans (i.e., spodic horizons) or finer textured horizons in the subsoil may have a greater ability to adsorb a pesticide as it leaches through the surface horizons. The worst-case scenario with respect to ground water vulnerability is where sandy soil overlies porous limestone with a shallow water table.

Pesticide Selection and Use

The use of pesticides should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, referred to altogether as IPM. When a pesticide application is deemed necessary, its selection should be based on effectiveness, toxicity to nontarget species, cost, and site characteristics, as well as its solubility and persistence. Half-lives and partition coefficients are particularly important when the application site of a pesticide is near surface water or underlain with permeable subsoil and a shallow aquifer. Short half-lives and intermediate to large

Koc are best in this situation. Many areas of Florida have impermeable subsoils that impede the deep leaching of pesticides. On such land, pesticides with low Koc and moderate to long half-lives should be used cautiously to prevent rapid transport in drainage water to a nearby waterbody. Non-erosive soils are common to much of Florida, and pesticides with large Koc remain on the application site for a long time. However, the user should be cautious of pesticides with long half-lives, as they are more likely to build up in the soil.

Environmental characteristics of a pesticide can often be ascertained (without any additional information on environmental fate and/or non-target effects) by the environmental hazards statement found on pesticide product labels. The environmental hazards statement (referred to as "Environmental Hazards" on the label and found under the general heading "Precautionary Statements") provides the precautionary language advising the user of the potential hazards to the environment from the use of the product.

The environmental hazards generally fall into three categories:

1) general environmental hazards
2) non-target toxicity
3) endangered species protection

Advisories specific to these general categories include:

General Environmental Hazards

- *Generic water advisory (for terrestrial pesticides) — "Do not apply directly to water"*
- *Ground water advisory — for pesticides (or major degradates) that are mobile and persistent in the environment*
- *Surface water advisory — for pesticides with the potential to contaminate surfaces water via spray drift and/or potential for runoff for several months after application (i.e., persistent in soil)*

Non-Target Toxicity

- *High toxicity to aquatic organisms (i.e., fish and/or aquatic invertebrates)*
- *High toxicity to wildlife (i.e., birds and mammals)*
- *High toxicity to beneficial insects (i.e., honey bees). A "bee hazard" warning may be required in the environmental hazard section of the product labels for pesticide active ingredients or formulations that are acutely toxic to honey bees*

Endangered Species Protection

- *Product may have effects on endangered species — instructions are provided to users on mitigating potential effects (i.e., on the label or Endangered Species Protection Bulletin)*

Several factors should be considered when applying pesticides with potential environmental impacts specified on the label (Environmental Hazards statement) including:

Groundwater Hazards

- *Proximity to sinkholes, wells, and other areas of direct access to ground water, such as karst topography*
- *Highly permeable soils*
- *Soils with poor adsorptive capacity*
- *Shallow aquifers*
- *Wellhead protection areas*

Surface Water Hazards

- *Proximity to surface water*
- *Runoff potential*
- *Rainfall forecast*
- *Prevailing wind direction and speed (drift)*
- *Wind erosion*

Non-Target Hazards

- *Proximity to surface water*
- *Proximity to wildlife*
- *Potential for the presence of foraging bees and beneficial insects*

Endangered Species Protection

- *Proximity to federally listed species and/or habitat*

More information can be found in the following publications:

Pesticides and Their Behavior in Soil and Water
(available: http://psep.cce.cornell.edu/facts-slides-self/facts/gen-pubre-soil-water.aspx).

Pesticide Characteristics
(available: https://edis.ifas.ufl.edu/publication/PI202).

Pesticide Management for Water Quality, Principles and Practices
(available: http://psep.cce.cornell.edu/facts-slides-self/facts/pestmgt-water-qual-90.aspx).

Managing Pesticide Drift
(Available: https://edis.ifas.ufl.edu/pi232)

Pesticide Formulations
(Available: https://edis.ifas.ufl.edu/pi231)

Sprayer Nozzles
(available: http://psep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-spray-nozz.aspx).

Agricultural Spray Adjuvants
(available: http://psep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-adjuvants.aspx).

Pesticide Selection Best Management Practices

Select pesticides that have a low runoff and leaching potential.

Before applying a pesticide, evaluate the impact of site-specific characteristics (for example, proximity to surface water, water table, and well-heads; soil type; prevailing wind; etc.) and pesticide-specific characteristics (for example, half-lives and Koc values).

Select pesticides with reduced impact on pollinators.

Select pesticides that, when applied according to the label, have no known effect on endangered species present on the facility.

Pesticide Risk and Applicator Safety

Pesticides belong to numerous chemical classes that vary greatly in their toxicity. The human health risk associated with pesticide use is related to both pesticide toxicity and the level of exposure. The risk of a very highly toxic pesticide may be very low if the exposure is sufficiently small. Conversely, pesticides having low toxicity may present a potential health risk if the exposure is sufficiently high. Toxicity is measured using an LD_{50} value, which is the dose that is lethal to 50% of the test animal population. Therefore, the lower the LD_{50} value, the more toxic the pesticide.

Pesticide exposures are classified as acute or chronic. Acute refers to a single exposure or repeated exposures over a short time, such as an accident during mixing or applying pesticides. Chronic effects are associated with long-term exposure to lower levels of a toxic substance, such as the ingestion of pesticides in the diet or ground water.

Additional information can be found in the publication, *Toxicity of Pesticides* (available: http://edis.ifas.ufl.edu/pdffiles/PI/PI00800.pdf). Specific information on using herbicides safely and herbicide toxicity can be found in the publication, *Herbicides: How Toxic are They?* (Available: https://edis.ifas.ufl.edu/pi170)

Pesticide labels contain signal words that are displayed in large letters on the front of the label to indicate approximately how acutely toxic the pesticide is to humans. The signal word is based on the entire contents of the product, not the active ingredient alone, and therefore reflects the acute toxicity of the inert ingredients. The signal word does not indicate the risk of chronic effects. Pesticide products having the greatest potential to cause acute effects through oral, dermal, or inhalation exposure have **DANGER** as their signal word, and their labels carry the word **POISON** printed in red with the skull-and-crossbones symbol. Products that have the **DANGER** signal word due to their potential for skin and eye irritation only do not carry the word **POISON** or the skull-and-crossbones symbol. Other signal words include **WARNING** for moderately toxic pesticides and **CAUTION** for slightly to relatively nontoxic pesticides.

Additional information on pesticide labels can be found in the following publications:

Interpreting Pesticide Label Wording
(available: https://edis.ifas.ufl.edu/publication/PI137)

National Pesticide Telecommunications Network fact sheet, Signal Words
(available: http://npic.orst.edu/factsheets/signalwords.pdf)

Other sources of information include the following publication:

Pesticide Safety
(available: http://edis.ifas.ufl.edu/pdffiles/CV/CV10800.pdf)

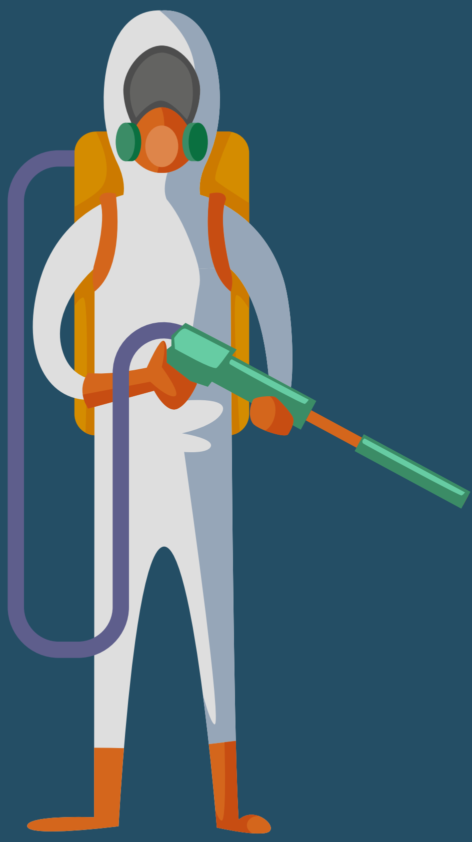
Pesticide Risk and Applicator Safety Best Management Practices

Select the least toxic pesticide with the lowest exposure potential.

Know the emergency response procedure in case excessive exposure occurs.

Pesticide Handling and Storage

The proper handling and storage of pesticides is important. Failure to do so correctly may lead to the serious injury or death of an operator or bystander, fires, environmental contamination that may result in large fines and cleanup costs, civil lawsuits, the destruction of the turf you are trying to protect, and wasted pesticide product.



Personal Protective Equipment (PPE)

Personal protective equipment (PPE) statements on pesticide labels provide the applicator with important information on protecting himself/herself. PPE provides a barrier between the applicator and a pesticide. PPE statements on pesticide labels dictate the minimum level of protection that an applicator must wear; additional protection is encouraged but is up to the discretion of the applicator. Some pesticides require additional garments during high-risk tasks such as mixing, loading, and cleaning. Note also that PPE may not provide adequate protection in an emergency situation.

Store PPE where it is easily accessible but not in the pesticide storage area (where it may become damaged or contaminated). Check the label and the Safety Data Sheet (SDS) for each pesticide for the safety equipment requirements.

Additional sources of information on PPE include the following:

Personal Protective Equipment for Handling Pesticides
(Available: http://edis.ifas.ufl.edu/pi061)

Laundering Pesticide-Contaminated Clothing
(Available: http://nasdonline.org/1912/d001868/laundering-pesticide-contaminated-clothing.html)

Personal Protective Equipment Best Management Practices

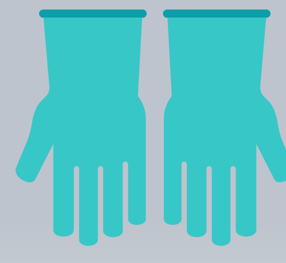
Provide adequate PPE for all employees who work with pesticides (including equipment technicians who service pesticide application equipment).

Ensure that PPE is sized appropriately for each person using it.

Make certain that PPE is appropriate for the chemicals used.

Ensure that PPE meets rigorous testing standards and is not just the least expensive.

Store PPE where it is easily accessible but not in the pesticide storage area.



Forbid employees who apply pesticides from wearing facility uniforms home where they may come into contact with children.

Provide laundering facilities or uniform service for employee uniforms.

The federal Occupational Safety and Health Administration (OSHA) requires employers to fit test workers who must wear tight-fitting respirators.

Meet requirements for OSHA 1910.134 Respiratory Protection Program.

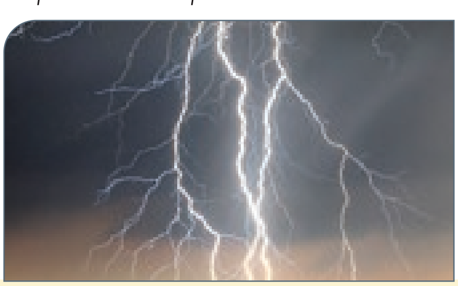
Pesticide Storage

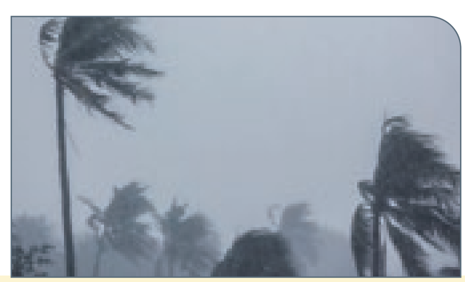
The storage and handling of pesticides and fertilizers in their concentrated forms pose the highest potential risk to ground water or surface water from agricultural chemicals. For this reason, it is essential that facilities for storing and handling these products be properly sited, designed, constructed, and operated.

Community Right-to-Know Laws

Florida law allows local governments to control the locations of pesticide storage facilities. Some of Florida's counties/cities choose to write such zoning ordinances, while others do not. Before you site a pesticide-storage facility, check to see if your local government has a zoning ordinance that influences the locations of these types of facilities. If so, it must be obeyed. Similarly, depending on the kinds of products stored and their quantity, you may need to register the facility with the Florida Department of Community Affairs (FDCA) and your local emergency response agency. Check with your dealer about community right-to-know laws for the materials that you purchase.

Every golf course management facility should have an emergency response plan in place, and course personnel should be familiar with the plan before an emergency occurs, such as a lightning strike, fire, or hurricane. Individuals conducting emergency pesticide cleanups should be properly trained under the requirements of the federal Occupational Safety and Health Administration (OSHA). For additional information on reporting chemical spills, see *Appendix B: Spill Reporting Requirements* and *Appendix C: Important Telephone Numbers*.





Chemical Storage

Storage Facilities

Pesticides should be stored in a lockable concrete or metal building. The secure storage of pesticides benefits everybody. It both helps to protect Florida's environment and reduces the risk of pesticide theft. It also reduces the chance of pesticides getting into the hands of vandals and terrorists. Secure storage is equally important for all pesticides—not just those that are highly toxic.

The pesticide storage area should be separate from other buildings, or at least separate from areas used to store other materials, especially fertilizers. These facilities should be located at least 50 feet from other types of structures to allow fire department access.

Floors should be impervious and sealed with a chemical-resistant paint. They should have a continuous sill to retain spilled materials and no drains, although a sump may be included. Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely. Shelving should be made of sturdy plastic or reinforced metal. Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides. Automatic exhaust fans and an emergency wash area should be provided. Explosion-proof lighting may be required. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building. PPE should be easily accessible and stored immediately outside the pesticide storage area. An inventory of the pesticides kept in the storage building and the SDSs for the chemicals used in the operation should be accessible on the premises but not kept in the pesticide storage room itself (since that would make them unavailable in an emergency).

Pesticide Storage Facilities Best Management Practices

Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.

Store pesticides in a lockable concrete or metal building that is separate from other buildings.

Locate pesticide storage facilities from other types of structures to allow fire department access.

Storage facility floors should be impervious and sealed with a chemical-resistant paint.

Floors should have a continuous sill to retain spilled materials and no drains, although a sump may be included.

Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.

Shelving should be made of sturdy plastic or reinforced metal.

Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides.

Automatic exhaust fans and an emergency wash area should be provided. Explosion-proof lighting may be required. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building.

Avoid temperature extremes inside the pesticide storage facility.

Personal protective equipment (PPE) should be easily accessible and stored immediately outside the pesticide storage area.

Do not transport pesticides in the passenger section of a vehicle.

Never leave pesticides unattended during transport.

Avoid purchasing large quantities of pesticides that require storage for greater than six months.

Adopt the "first in—first out" principle, using the oldest products first to ensure that the product shelf life does not expire.

Ensure labels are on every package and container.

Consult inventory when planning and before making purchases.

Ensure that labels remain properly affixed to their containers.

Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.

Maintaining a Pesticide Inventory

Do not store large quantities of pesticides for long periods. Adopt the "first in—first out" principle, using the oldest products first to ensure that the product shelf life does not expire.

Store pesticides in their original containers. Never put pesticides in containers that might cause children and others to mistake them for food or drink. Keep the containers securely closed and inspect them regularly for splits, tears, breaks, or leaks. All pesticide containers should retain their original labels. Arrange the containers so that the labels are clearly visible, and make sure the labels are legible. Refasten all loose labels, using nonwater-soluble glue or sturdy, transparent packaging tape. Do not refasten labels with rubber bands (these quickly rot and break) or nontransparent tape, such as duct tape or masking tape (these may obscure important product caution statements or label directions for product use). If a label is damaged, immediately request a replacement from the pesticide dealer or formulator. As a temporary substitute for disfigured or badly damaged labels, fasten a baggage tag to the container handle. On the tag write the product name, formulation, concentration of active ingredient(s), and date of purchase. If there is any question about the contents of a container, set it aside for proper disposal.

Flammable pesticides should be separated from those that are nonflammable. Dry bags should be raised on pallets to ensure that they do not get wet. Liquid materials should always be stored below dry materials, never above them. Labels should be clearly legible. Herbicides, insecticides, and fungicides should be separated to prevent cross-contamination and minimize the potential for misapplication.

Storage building plans are available from several sources, including the Midwest Plan Service, UF/IFAS Extension Bookstore, and the USDA–NRCS.

Operation Cleansweep is a mobile collection program that provides agricultural producers, nursery and golf course operators, and pest control services a safe and economical method of disposing of cancelled, suspended and unusable pesticides. Contact FDEP at https://floridadep.gov/waste/permitting-compliance-assistance/content/operation-cleansweep-pesticides.

Additional sources of information on Operation Cleansweep include the following:

Operation Cleansweep for Pesticides (Available: https://edis.ifas.ufl.edu/pi085)

Additional sources of information on maintaining a pesticide inventory include the following:

Secure Pesticide Storage: General Features (Available: http://edis.ifas.ufl.edu/pi068)

Pesticide Storage: Keep it in the Container (Available: http://edis.ifas.ufl.edu/pi255)

Pesticide Labeling: Storage and Disposal (Available: https://edis.ifas.ufl.edu/pi143)

Chemical Mixing and Loading

Pesticide leaks or spills, if contained, will not percolate down through the soil into ground water or run off the surface to contaminate streams, ditches, ponds, and other waterbodies. One of the best containment methods is the use of a properly designed and constructed chemical mixing center (CMC). The Midwest

Pesticide Inventory Best Management Practices

An inventory of the pesticides kept in the storage building and the Safety Data Sheets (SDS) for the chemicals used in the operation should be accessible on the premises, but not kept in the pesticide storage room itself.

Adopt the "first in—first out" principle, using the oldest products first to ensure that the product shelf life does not expire.

Florida offers "Operation Cleansweep" to assist with free disposal of cancelled, suspended, and unusable pesticides that are being stored.

Plan Service book, *Designing Facilities for Pesticide and Fertilizer Containment* (revised 1995), the Tennessee Valley Authority (TVA) publication, *Coating Concrete Secondary Containment Structures Exposed to Agrichemicals* (Broder and Nguyen, 1995), and USDA–NRCS Code 703 contain valuable information about constructing CMC facilities. One point to remember is that the sump is only a point of collection and pump suction; the containment volume is the entire volume of the bermed and sealed pad. The sump should be small enough to provide for rapid and easy cleaning.

Although the use of a CMC is not mandatory, adherence to the practices in the publications listed above is strongly encouraged. A CMC provides a place for performing all operations where pesticides are likely to be spilled in concentrated form—or where even dilute formulations may be repeatedly spilled in the same area—over an impermeable surface.

Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed. This surface should provide for easy cleaning and the recovery of spilled materials. In its most basic form, a CMC is merely a concrete pad treated with a sealant and sloped to a liquid-tight sump where all of the spilled liquids can be recovered. Pump the sump dry and clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (i.e., one that cannot be legally applied to the same site). Liquids and sediments can then be applied as a pesticide, provided the label instructions are followed, instead of requiring disposal as a (possibly hazardous) waste.

Absorbents such as cat litter or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates, or disposed of as a waste. Solid materials, of course, can be swept up and reused.

Wastewater from pesticide application equipment must be managed properly, since it contains pesticide residues. The BMP for this material is to collect it and use it as a pesticide in accordance with the label instructions. This applies to wastewater from both inside and outside the application equipment. The rinsate may be applied as a pesticide (preferred) or stored for use as makeup water for the next compatible application. Otherwise, it must be treated as a (potentially hazardous) waste. After the equipment is washed and before an incompatible product is handled, the sump should be cleaned of any liquid and sediment.

Additional information on handling pesticide wastewater can be found in the publication, *Proper Disposal of Pesticide Waste* (available: http://edis.ifas.ufl.edu/PI010).

Chemical Mixing and Loading Best Management Practices

Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed.

Mixing station surface should provide for easy cleaning and the recovery of spilled materials.

Pump the sump dry and clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (that is, one that cannot be legally applied to the same site).

Apply liquids and sediments as you would a pesticide, strictly following label instructions.

Pesticide Container Management

The containers of some commonly used pesticides are classified as hazardous wastes if not properly rinsed, and as such, are subject to the many rules and regulations governing hazardous waste. The improper disposal of a hazardous waste can result in very high fines and/or criminal penalties. However, pesticide containers that have been properly rinsed can be handled and disposed of as nonhazardous solid waste. Both federal law (FIFRA) and the Florida Pesticide Law (Chapter 487, F.S.) require pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. Under federal law (the Resource Conservation and Recovery Act, or RCRA), A PESTICIDE CONTAINER IS NOT EMPTY UNTIL IT HAS BEEN PROPERLY RINSED. Additional information on pesticide container management can be found in the publication, *Florida Solid and Hazardous Waste Regulation Handbook* (available: https://edis.ifas.ufl.edu/publication/FE612) and from the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392–4721 (available: https://pested.ifas.ufl.edu/).

Immediate and proper rinsing removes more than 99% of the container residues typically left by most liquid pesticide formulations. Properly rinsed pesticide containers pose a minimal risk for the contamination of soil and water resources, and preventing contamination is an important part of pesticide management. Containers holding liquid pesticides should be rinsed as soon as they are empty; thus, the time to rinse is during the mixing and loading process. Immediate rinsing has several advantages. A freshly emptied container is easier to clean, because the formulation residues have not had time to dry and cake on the inside of the container. Also, rinsing containers during the mixing and loading process solves the problem of what to do with the container rinse water, as it is added to the water used to prepare the finished spray mix. Newly emptied pesticide containers can be properly rinsed by either triple rinsing or pressure rinsing—both methods work. The steps for triple rinsing and pressure rinsing a container are as follows:

Triple Rinsing a Container

1. **Put on the PPE listed on the product's label.**
2. **Allow the formulation to drip drain from its container into the sprayer tank for at least 30 seconds.**
3. **Partially fill the container with clean diluent, usually water (about 20% of its capacity).**
4. **With the container cap placed back on, swirl the water so that all sides are rinsed.**
5. **Pour the rinse water back into the sprayer tank and allow the container to drip drain for at least 30 seconds.**
6. **Steps 2 through 5 twice more.**

Pressure Rinsing a Container

1. **Put on the PPE listed on the product's label.**
2. **Install a pressure-rinse nozzle on a hose connected to a water supply capable of delivering 35 to 60 pounds per square inch (psi) of water pressure.**
3. **Allow the formulation to drip drain from its container into the sprayer tank for at least 30 seconds.**
4. **Firmly press the pressure-rinse nozzle tip into the side of the pesticide container until the probe is inserted and seated, and then turn on and rinse the container for at least 30 seconds with it draining into the sprayer tank (Figure 32). For containers that are larger than 5 gallons, insert the pressure-rinse nozzle into the tank's bottom.**
5. **Allow the container to drip drain for at least 30 seconds.**

Pressure rinsing

Additional information can be found in the publication, *Pesticide Container Rinsing* (available: https://edis.ifas.ufl.edu/publication/PI003).

Recycle rinsed containers in counties where a program is available. For information about pesticide container recycling programs in your area, contact the Pesticide Information Office at the University of Florida, Gainesville, at (352) 392-4721.

Pesticide Container Management Best Management Practices

Rinse pesticide containers immediately in order to remove the most residue.

Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.

Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.

Puncture empty and rinsed pesticide containers and dispose of according to the label.

Pesticide Spill Management and Emergency Preparedness

Accidents happen. Advance preparation on what to do when an accident occurs is essential to mitigate the human health effects and the impact on the environment. The size and scope of the accident dictates the necessary response.

Golf course superintendents and landowners must comply with all applicable federal, state, and local regulations on spill response training for employees, spill-reporting requirements, spill containment, and cleanup. Keep spill cleanup equipment available when handling pesticides or their containers. If a spill occurs of a pesticide covered by certain state and federal laws, you may need to report any accidental release if the spill quantity exceeds the "reportable quantity" of active ingredient specified in the law. Small liquid spills may be cleaned up by using an absorbent such as cat litter, diluting with soil, and then applying the absorbent to the crop as a pesticide in accordance with the label instructions. Large spills or uncontained spills involving hazardous materials may best be remediated by hazardous material cleanup professionals. For additional information on reporting spills, see *Appendix B: Spill Reporting Requirements* and *Appendix C: Important Telephone Numbers*.

Clean up spills as soon as possible. The sooner you can contain, absorb, and dispose of a spill, the less chance there is that it will cause harm. Always use the appropriate PPE as indicated on the SDS and the label.

In addition, follow the following four steps:

1. **CONTROL actively spilling or leaking materials by setting the container upright, plugging leak(s), or shutting the valve**
2. **CONTAIN the spilled material using barriers and absorbent material**
3. **COLLECT spilled material, absorbents, and leaking containers and place them in a secure and properly labeled container**
4. **STORE the containers of spilled material until they can be applied as a pesticide or appropriately disposed of.**

For emergency (only) information on hazards or actions to take in the event of a spill, call CHEMTREC, at (800) 424–9300. CHEMTREC is a service of the Chemical Manufacturers Association. For information on whether a spilled chemical requires reporting, call the CERCLA/RCRA help line at (800) 424–9346.

Pesticide Spill Management and Emergency Response Best Management Practices

Develop a golf course facility emergency response plan which includes procedures to control, contain, collect, and store spilled materials.

Prominently post "Important Telephone Numbers" including CHEMTREC, for emergency information on hazards or actions to take in the event of a spill.

Ensure an adequately sized spill containment kit is readily available.

Designate a spokesperson who will speak on behalf of the facility should an emergency occur.

Host a tour for local emergency response teams (for example, fire fighters, etc.) to show them the facilities and to discuss the emergency response plan. Seek advice on ways to improve the plan.

Absorbents such as cat litter or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates or disposed of as a waste.

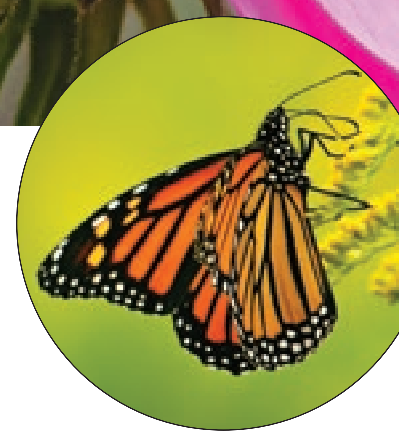
Sweep up solid materials and use as intended.

Applying pesticide to prevent mole cricket infestation —with no spills!

SECTION 10

POLLINATOR PROTECTION

Most flowering plants need pollination to reproduce and grow fruit. While some plants are pollinated by wind, many require assistance from insects and other animals. In the absence of pollinators, many plant species, including the fruits and vegetables we eat, would fail to survive.



The western honey bee (*Apis mellifera*) is one of the most important pollinators in the United States. In addition, thousands of native bee species, including bumble bees (*Bombus* spp.) serve as important pollinators. In Florida, there are over 300 native bee species and many flies, butterflies, moths, and beetles that provide valuable pollination service for native plants and agricultural crops. Many pollinating insects also feed on and control turfgrass insect pests. Therefore, protecting insect pollinators is important for the sustainability of agriculture and natural habitats, but also for golf course pest management programs. Pollinator protection occurs through responsible pesticide stewardship and providing habitats that attract and support pollinators.

Pesticides are products designed to reduce pests (for example, insecticides control insects, fungicides control fungal diseases, and herbicides control weeds) and facilitate healthy, functional plants. Pesticides and other plant growth-altering products are commonly used in golf course management. The non-target effects of such products on insect pollinators are of increasing concern around the world. Therefore, pesticide applicators, including those on golf courses, need to be mindful of the impact that pesticides can have on pollinators and their habitats.

Regulatory Considerations

Principles

Most pesticide labels contain pollinator-protection language outlining the required best practices of that product to reduce risks to pollinators from its application. Follow the label, it is the law.

Pesticide applicators must be aware of honey bee toxicity groups and able to understand precautionary statements. For example, many insecticide labels specifically state, "Do not apply this product to blooming, pollen-shedding or nectar-producing parts of plants if bees may forage on the plants during this time period." and "Do not apply to plants that are flowering."

Recordkeeping is a best practice and may be required by law in order to use some products. IPM principles suggest that you keep records of all pest control activity so that you may refer to information on past infestations or other problems to select the best course of action in the future. Recordkeeping can also provide assurance of proper product selection and application related to pollinator protection.

Best Management Practices:

Proper records of all pesticide applications should be kept according to local, state, and federal requirements.

Use records to establish proof of use and follow-up investigation of standard protocols regarding:

- *Date and time of application*
- *Name of applicator*
- *Person directing or authorizing the application*
- *Weather conditions at the time of application*
- *Target pest*
- *Pesticide used (trade name, active ingredient, application rate, formulation, amount of water)*
- *Adjuvant/surfactant and amount applied, if used*
- *Area treated (acres or square feet) and location*
- *Total amount of pesticide used*
- *Application equipment*
- *Additional remarks, such as the severity of the infestation or life stage of the pest*
- *Follow-up to check the effectiveness of the application*

Those applying pesticides, and who make decisions regarding their applications, should be able to interpret pollinator protection label statements.

Those applying pesticides should be aware of honey bee and native bee biology.

Those applying pesticides should understand the various routes of exposure to pesticides (outside the hive and inside the hive).

Those applying pesticides should understand the effects of different pesticide classes on bees.

Pollinator Habitat Protection

Principles

It is important to minimize the impacts of pesticides on bees and other beneficial arthropods. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans.

Be mindful of pollinator activity and presence. When applying pesticides, prevent pesticide exposure to pollinators in play and non-play course areas.

Pollinators require a diversity of flowering species to complete their life cycle. Pollinator habitats should contain several wildflower species of different colors and heights, with blossoms throughout the entire growing season.

A bee colony provides encouragement to honeybees to maintain a pollinator home at World Golf Village Resort in St. Augustine.

Best Management Practices:

- Follow label instructions directing the application of pesticide when the plant may be in bloom.
- Do not apply pesticides to plants that are in bloom.
- Stay on target by using coarse-droplet nozzles, low application heights, and monitoring wind to reduce drift.
- Do not apply pesticides when and where pollinators are active.
- Before applying a pesticide, scout/inspect the area for both harmful and beneficial insect populations and use pesticides only when pests exceed a threshold of density or damage.
- Mow flowering plants (weeds) before an insecticide application.
- If flowering weeds are prevalent, control them before applying insecticides.
- Use insecticides that have less impact on pollinators (e.g., avoid neonicotinoid applications near flowering plants).
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site (target) movement of pesticide.
- Avoid applications during unusually low temperatures or when dew is forecast.
- Use granular formulations of pesticides that are known to be less hazardous to bees.
- Consider lures, baits, and pheromones as alternatives to insecticides for pest management.
- Develop new pollinator habitat and/or enhance existing habitat in out-of-play areas where risk of insecticide exposure is low.
- Create pollinator habitats composed of several plant species to maximize their value to pollinators.

SECTION 11

MAINTENANCE OPERATIONS

Good Housekeeping

Good housekeeping within and outside the maintenance facility is critical to protecting Florida's natural resources. Managers responsible for the operation, training and supervising of employees should audit routinely to measure BMP effectiveness, repair needs, and future improvements.

Routine inspections should evaluate employee performance towards properly maintaining and applying the necessary BMPs. Timely inspection meetings allow for questions and follow-up, which supports positive morale, accident prevention and identifying inappropriate practices that may negatively impact the environment.

There are five important areas of concern that requires constant attention: Fueling Areas, Equipment Washing Facilities, Chemical Mixing Centers (see Section 9), Equipment Storage Areas, and Waste Handling Sites. Each area requires a separate BMP checklist to ensure employee safety, to minimize environmental risks and support reliable equipment operation and longevity.

Last, recordkeeping is essential for reporting incidences, supporting renovation needs and meeting federal, state and local government compliance requirements.

Fueling Areas

Storage Tank Compliance is part of the Permitting and Compliance Assistance Program in the Florida Department of Environmental Protection's Division of Waste Management: (https://floridadep.gov/waste/storage-tank-compliance). In 1983, Florida was one of the first states to pass legislation and adopt rules for underground and aboveground storage tank systems (USTs and ASTs). Florida relies on groundwater for about 92% of its drinking water needs and has some of the most stringent rules in the country. Stationary aboveground tanks with a capacity greater than 550 gallons and underground storage tanks with a capacity greater than 110 gallons are regulated by FDEP. This guide provides helpful information when considering storage tanks:
https://floridadep.gov/sites/default/files/GettingStarted-New_Storage_Tank_Owner-Guidance2019.pdf

The first line of managing the maintenance of fueling areas is to minimize the possibility of discharge and the need for disposal. With rainfall, if the containment volume is adequate, the evaporation of accumulated rainfall is often sufficient. Critical levels at which discharge is considered should be established for each facility and the levels marked on the containment wall. This prevents the frequent and unnecessary discharge of small volumes.

The water to be discharged must always be checked for contamination, by looking for an oil sheen, observing any smell of fuel or oil, or by using commercially available test kits. Never allow any water that is contaminated to be discharged to the environment.

Treat contaminated water on-site by using commercially available treatment systems, discharging it to an FDEP-permitted off-site industrial wastewater treatment system, or transporting it by tanker truck to a treatment facility. Never discharge contaminated water to a sanitary sewer system without written permission from the utility. Never discharge to a septic tank. For more information on disposal options, contact the appropriate FDEP district office.

If the water is not contaminated, it can be reused or discharged to a permitted stormwater treatment system, such as a retention area, grassed swale, or wet detention pond, although this practice is not encouraged. Do not discharge it during or immediately after a rainstorm, since the added flow may cause the permitted storage volume of the stormwater system to be exceeded.

Fueling Area Best Management Practices

Above-ground storage tanks (ASTs) are preferred as they are more easily monitored for leaks.

Fueling stations should be located under roofed areas with concrete pavement, not asphalt.

Fueling areas should also have spill containment and recovery facilities located nearby.

Develop a record-keeping process to monitor and detect leakage from storage tanks.

Visually inspect any AST for leakage and structural integrity.

Secure fuel storage facilities and allow access only to authorized and properly trained staff.

Equipment Washing Facility

General

An equipment-washing facility can be a source of both surface and ground water pollution, if the wastewater generated is not properly handled. All equipment used in the maintenance of golf courses and associated developments should be designed, used, maintained, and stored in a way that eliminates or minimizes the potential for pollution. Wastewater generated from the general washing of equipment, other than pesticide application equipment, may not have to be collected. Always check with local authorities to determine which BMPs are accepted in your jurisdiction.

BMPs for the disposal of wastewater (from other than pesticide application equipment, and with no degreasers or solvents) depend on several factors, such as the volume of washwater generated, the

nature of the surrounding area, and the frequency of the operations. For limited washdown of ordinary field equipment, it may be legal to allow the wastewater to flow to a grassed retention area or swale. Do not allow any wastewater to flow directly into surface waters. Always check with local authorities to determine whether other requirements may apply. Discharge to a septic system is illegal.

Grass clippings-covered equipment should be brushed or blown with compressed air before being washed. Dry material is much easier to handle and store or dispose of than wet clippings. It is best to wash equipment with a bucket of water and a rag, using only a minimal amount of water to rinse the machine. Spring-operated shutoff nozzles should be used. Freely running hoses waste vast amounts of water, and water can harm the hydraulic seals on many machines. Where formal washing areas are not available, a "dog leash" system using a short, portable hose to wash off the grass at random locations with syringing valves may be an option. Do not allow any wastewater to flow directly into surface waters or storm drains.

While there are no state requirements to have a closed recycling system for wastewater, the use of a well-designed system is considered one of the available BMPs to deal with this

issue. Some local governments require such a system. The FDEP publication, *Guide to Best Management Practices for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment Wash Facilities* (available: https://floridadep.gov/sites/default/files/GuideBMPClosed-LoopRecycleSystems.pdf), provides additional information on the design and operation of these facilities, and the BMPs that may help you avoid the need for a permit. Be cautious in operating a system where maintenance activities are involved, because the filters can concentrate traces of oils and metals that are washed off the engines and worn moving parts. In some cases, the concentrations of these substances can become high enough that the filters must be treated and disposed of as hazardous waste. Ask the recycling systems manufacturer or sales representative, or your FDEP district office, for information on filter disposal. The contractor who handles oil filters, waste oil, and solvents can probably handle these filters, too.

Oil/water separators can be used but must be managed properly to avoid problems. Do not wash equipment used to apply pesticides on pads with oil/water separators, since the pesticide residues will contaminate the oil that is salvaged. Be aware that the oil collected in these systems may be classified as a hazardous waste (due to the high concentrations of heavy metals from engine wear), making disposal expensive. Usually, filters from these systems may be disposed of at an approved landfill. Keep all records on the disposal of these materials to prove that you disposed of them properly.

Oil/water separators are generally not necessary, unless the water from the system is to be reclaimed for some particular end use, or large volumes of water are generated and the industrial wastewater permit, local government, or receiving utility requires such a system.

Pesticide Application Equipment

Wastewater from pesticide application equipment must be managed properly, since it contains pesticide residues. The BMP for this material is to collect it and use it as a pesticide in accordance with the label instructions for that pesticide. This applies to wastewater from both the inside and the outside of the application equipment. Often, the easiest way to do this is to wash the equipment in the chemical mixing center (CMC). The pad should be flushed with clean water after the equipment is washed, and the captured wastewater should be applied to the labeled site as a dilute pesticide, or it may be pumped into a rinsate storage tank for use in the next application. FIFRA, Section 2(ee), allows the applicator to apply a pesticide at less than the labeled rate. The sump should then be cleaned of any sediment before another type of pesticide is handled.

Clean the tires and particularly dirty areas of the equipment's exterior with plain water before bringing it into the pad area. This practice prevents unwanted dirt from getting on the mix/load pad and sump, or from being recycled into the sprayer. Avoid conducting such washing in the vicinity of wells or surface waterbodies. It may be necessary to discharge the washwater to an FDEP-permitted treatment facility.

Equipment Washing Best Management Practices

Use compressed air to blow off equipment. This is less harmful to the equipment's hydraulic seals, eliminates wastewater, and produces dry material that is easier to handle.

Wash equipment over a concrete or asphalt pad that allows the water to be collected, or for some limited operations, to run off onto a grassed area to soak into the ground, but never into a surface waterbody or canal. After the residue dries on the pad, it can be collected and composted or spread in the field.

Handle clippings and dust separately. After the residue dries on the pad, it can be collected and composted or spread in the field.

Minimize the use of detergents. Use only biodegradable non-phosphate detergents.

Solvents and degreasers should be used over a collection basin or pad that collects all used material.

Minimize the amount of water used to clean equipment. This can be done by using spray nozzles that generate high-pressure streams of water at low volumes.

Do not discharge wastewater to surface water or ground water either directly or indirectly through ditches, storm drains, or canals.

Do not conduct equipment wash operations on a pesticide mixing and loading pad. This keeps grass clippings and other debris from becoming contaminated with pesticide.

Never discharge to a sanitary sewer system without written approval from the proper entity.

Never discharge to a septic tank.

Other options include the following:

Use a closed-loop wastewater recycling system and follow FDEP BMPs.

Discharge to a treatment system that is permitted under FDEP industrial wastewater rules.

Use the wastewater for field irrigation.

Equipment Storage and Maintenance

Equipment used to apply pesticides and fertilizers should be stored in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment, and these residues can contaminate soil or water. Pesticide application equipment can be stored in the CMC, but fertilizer application equipment should be stored separately. Blow or wash loose debris off the equipment to prevent dirt from getting on the CMC pad, where it could become contaminated with pesticides.

Other equipment should be stored in a clean, safe and protected area when not in use. One BMP is to use paint to delineate parking areas for each piece of equipment. This makes it easy to notice fluid leaks and take corrective action.

Equipment Storage and Maintenance Best Management Practices

Store and maintain equipment in a covered area complete with a sealed impervious surface to limit risk of fluid leaks contaminating the environment and to facilitate the early detection of small leaks that may require repair before causing significant damage to the turf or the environment.

Seal floor drains unless they are connected to a holding tank or sanitary sewer with permission from the local wastewater treatment plant.

Store pesticide and fertilizer application equipment in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment and possibly contaminate soil or water.

Store solvents and degreasers in lockable metal cabinets away from ignition sources in a well-ventilated area. These products are generally toxic and highly flammable. Never store them with fertilizers or in areas where smoking is permitted.

Keep an inventory of solvents and SDS for those materials on-site but in a different location where they will be easily accessible in case of an emergency.

Keep basins of solvent baths covered to reduce emissions of volatile organic compounds (VOC).

When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.

Always use appropriate PPE when working with solvents.

Never allow solvents or degreasers to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.

Collect used solvents and degreasers in containers clearly marked with contents and date; schedule collection by a commercial service.

Blow off all equipment with compressed air to reduce damage to hydraulic seals.

Waste Handling

Hazardous Materials

Ensure that all containers are sealed, secured, and properly labeled. Use only FDEP-approved, licensed contractors for disposal.

Pesticides

Remember, pesticides that have been mixed so they cannot be legally applied to a site in accordance with the label must be disposed of as a waste. Depending on the materials involved, they may be classified as hazardous waste. Operation Cleansweep staff may be able to provide additional information (available: http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides/pages/contacts.htm).

Pesticide Containers

Rinse pesticide containers as soon as they are empty. Pressure rinse or triple rinse containers and add the rinse water to the sprayer. Shake or tap non-rinseable containers, such as bags or boxes, so that all dust and material fall into the application equipment. Always wear the proper PPE when conducting rinse operations. See the section on pesticide container management in Chapter 9 for more details.

After cleaning them, puncture all pesticide containers to prevent reuse (except glass and refillable minibulk containers). Keep the rinsed containers in a clean area, out of the weather, for disposal or recycling. Storing the containers in large plastic bags is one popular option to protect the containers from collecting rainwater. Recycle rinsed containers in counties where an applicable program is available or take them to a landfill for disposal. Check with your local landfill before taking containers for disposal, as not all landfills will accept them.

Used Oil, Antifreeze, and Lead-acid Batteries

Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them. In Florida, recycling is the only legal option for handling used oil. Oil filters should be drained (puncturing and crushing helps) and taken to the place that recycles your used oil, or to a hazardous waste collection site. Many gas stations or auto lube shops accept small quantities (including oil filters) from individuals.

Antifreeze must be recycled or disposed of as a hazardous waste. Commercial services are available to collect this material.

Lead-acid storage batteries are classified as hazardous wastes unless they are recycled. All lead-acid battery retailers in Florida are required by law to accept returned batteries for recycling. Used acid from these batteries contains high levels of lead and must be disposed of as a hazardous waste, unless the acid is contained within a battery being recycled. Make sure that all caps are in place to contain the acid. Store batteries on an impervious surface and preferably under roof. Remember, spent lead-acid batteries must be recycled if they are to be exempt from strict hazardous waste regulations.

Do not mix used oil with used antifreeze or sludge from used solvents.

Solvents and Degreasers

One of the key principles of pollution prevention is to reduce the unnecessary use of potential pollutants. Over time, the routine discharge of even small amounts of solvents can result in serious environmental and liability consequences, due to the accumulation of contaminants in soil or ground water. As little as 25 gallons per month of used solvents to be disposed of can qualify you as a "small quantity generator" of hazardous waste, triggering EPA and FDEP reporting requirements.

Whenever practical, replace solvent baths with recirculating aqueous washing units (which resemble heavy-duty dishwashers). Soap and water or other aqueous cleaners are often as effective as solvent-based products. Blowing off equipment with compressed air instead of washing with water is often easier on hydraulic seals and can lead to fewer oil leaks.

Storage

Store solvents and degreasers in lockable metal cabinets in an area away from ignition sources (e.g., welding areas or grinders), and provide adequate ventilation. They are generally toxic and highly flammable. Never store them with pesticides or fertilizers, or in areas where smoking is allowed. Keep basins or cans of solvent covered to reduce the emissions of volatile organic compounds (VOCs) and fire hazards. Keep an inventory of the solvents stored and the SDSs for these materials on the premises, but not in the solvent storage area. Keep any emergency response equipment recommended by the manufacturer of the solvent in a place that is easily accessible and near the storage area, but not inside the area itself. Follow OSHA signage requirements.

Use

Always wear the appropriate PPE, especially eye protection, when working with solvents. Never allow solvents to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems, even in small amounts. Solvents and degreasers should be used over a collection basin or pad that collects all used material. Most solvents can be filtered and reused many times. Store the collected material in marked containers until it can be recycled or legally disposed of.

Solvent disposal

Private firms provide solvent washbasins that drain into recovery drums and a pickup service to recycle or properly dispose of the drum contents. Collect used solvents and degreasers, place them into containers marked with the contents and the date, and then have them picked up by a service that properly recycles or disposes of them. Never mix used oil or other liquid material with the used solvents. Use only FDEP-approved, licensed contractors.

Composting

Ideally, composting sites should be located on a contained impervious surface pad to prevent translocation of nutrient-enriched leachate to runoff or leaching and allow the periodic turning of materials. Grass clippings and routine, healthy landscape trimmings should be composted and used to improve the soil. Do not compost diseased material, as this may spread disease.

Paper, Plastic, Glass, and Aluminum Recycling

Office paper, recyclable plastics, glass, and aluminum should be recycled in accordance with local recycling ordinances. Place containers for recycling aluminum cans and glass or plastic soft drink bottles at convenient locations on the golf course. Check with your local collection provider to ensure proper collection and disposal of other recyclable materials. This can include electronics, computer equipment, light bulbs, and used tires.

Waste Handling Best Management Practices

Pesticides that have been mixed for application must be disposed of as waste and may be classified as hazardous waste depending on the materials involved. Contact local authorities for guidance regarding proper disposal.

Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them as directed by local and state authorities.

Antifreeze may be considered hazardous waste by state or local laws and should be handled accordingly. Commercial services are available to collect and recycle antifreeze.

Lead-acid batteries are classified as hazardous waste unless they are properly recycled.

Store old batteries on impervious surfaces where they are protected from rainfall and recycle as soon as possible.

Recycle used tires.

Recycle or dispose of fluorescent tubes and other lights according to state requirements.

SECTION 12

ENERGY

According to the GCSAA Golf Course Environmental Profile, Vol. IV (GCSAA 2012), six major energy sources were identified for golf course use: electricity, gasoline, diesel, natural gas, propane and heating oil. In addition, operational uses were segmented to meet irrigation, turf maintenance, buildings, clubhouse operations, swimming pools and various amenity needs. The overall conclusion of the study suggests that golf facility managers must take steps toward identifying options for conservation, efficiency, and cost savings.

To address current needs and future energy reduction opportunities, managers should evaluate current energy conservation performance practices based on the following categories:

General energy conservation position statements on policy and planning

Buildings and amenities statements —buildings, infrastructure and facility amenities such as the clubhouse, swimming pool, restaurant, parking lot, kitchen, offices, maintenance building(s), tennis courts, etc.

Golf course statements — the golf course and surrounding landscapes, pump station, irrigation system and related agronomic operations (playing surfaces, equipment, turfgrass maintenance, etc.)

When incorporating new energy efficient pieces, apply the 93% rule suggested by Dr. Pierce Jones from the University of Florida. The 93% rule = Instead of investing money to be 100% compliant with every possible scenario relating to energy efficiency, do 93%, which will get you at 99% efficiency. The other 7% is not worth the investment, long or short term, for the remaining 1%.

The first step is to perform a thorough energy audit on the entire Golf Course Maintenance Operation. Energy audits are typically performed by the energy supplier and are offered at little to no expense.

Each of the following areas on the golf course should be evaluated using the following Best Management Practices:

IRRIGATION

Understand that the irrigation pump system is the largest user of energy. A well-engineered pump station is critical to reducing energy consumption.

Establish a baseline for performance parameters to optimize irrigation pumps. It may be necessary to bring in an electrical engineer to assist with developing these parameters.

Consider benchmarking performance against similar-sized facilities.

Ensure efficient design, selection, operation, and maintenance of irrigation pumps, irrigation controls, and other irrigation components. A poorly maintained system will result in low efficiency leading to longer run times and excessive energy utilized. Additionally, repairing of leaks in a timely manner will reduce pump cycling further limiting energy usage.

Conduct an irrigation audit to determine system efficiency. Efficiency can often be improved with very little cost.

Consider reducing pump station pressures to maximize efficiency and reduce vaporization of water due to excessively high pressures.

Assess irrigation pump efficiency; consider alternative equipment, products, and practices; use energy efficiently to maximize the output of the pump station. Consider switching from pressure valve-controlled systems to variable frequency drives.

Add a low horsepower "jockey" pump to the pump station so if irrigation (syringing) is necessary during peak energy demand times, the cost to run that smaller pump will be less and the demand charge will be less.

Install adequate meters, gauges, etc. Inspect meters on a regular basis to identify abnormal watering usage or leaks in the field. Ensure accuracy of all meters by having them checked once every five years, or more frequently as required.

Identify the lowest cost time to operate the pump station and use that window to irrigate when possible. Install lock-out devices on pump stations to avoid peak demand charges or time of use charges.

Reduce the amount of irrigated turf (without slowing the pace of play) and replace with native plants (right plant, right location, right size, right time of year, right density, and maintain until fully established) to increase habitat and reduce water usage. If irrigation usage is not reduced, then the native plant installation may not be worth the effort.

Maintain a proper balance of nutrients in the soil. Using moisture controlling amendments, such as wetting agents, or incorporating organic materials, may help reduce water and fertilizer use.

BUILDINGS

Establish an energy management plan for the facility based on current energy use baselines to optimize efficiency.

Continually track and measure energy use at the facility based on energy assessment units, for example, kilowatt hour. Evaluate billing meters.

Invite your energy supplier to provide an energy audit for your building.

Monitor temperature/environmental settings (heat loss, etc.)

Implement schedules/controlled use. For instance, ensure that large energy using items are powered only when needed.

Consider the materials: use insulation and color selection. A lighter colored building and roof will reduce demand for air conditioners and fans.

Ensure efficient lighting in both interior and exterior areas. Tubular L.E.D. lights provide more light (brightness) than t-5 or t-8 electronic ballast fluorescent lights. In many cases, the cost of switching to L.E.D. is comparable to the replacement of existing fixtures and bulbs.

Consider motion sensors, light sensors (photocells), temperature sensors, and timers to turn off lights, fans, motors, etc., when not needed.

Adding timers on washwater recycling system pumps and motors will reduce electrical usage during non-use hours.

Consider installing air locks on doors to all temperature-controlled rooms where practical, especially in high traffic areas like break rooms. These will reduce energy loss.

Evaluate needs on soda machines to determine if the benefit outweighs the energy use. Consider installing energy miser devices on soda machines. Energy mizer devices can actually reduce electricity use on soda vending machines by running the compressor or cooler only when the temperature rises to a certain level.

Consider replacing low efficiency "window unit" type air conditioners with more efficient mini-split units. Sometimes energy suppliers will offer a rebate for this upgrade.

A/C units should have a SEER rating of at least 18 with variable speed air handlers

A/C units should be serviced by professionals every six months and the air filters changed or cleaned every month.

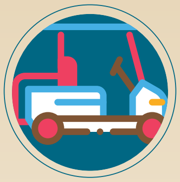
The proper use of ceiling fans in rooms with A/C can allow the thermostat to be raised 2-3 degrees higher and maintain the same comfort level.

Thermostats should be under lock so employees cannot manipulate the temperature controls. Additionally, using a programmable thermostat to adjust temperature controls when the room is not being used/occupied can further offset energy consumption.

Train staff to buy-in to the program. Turning off fans and lights, planning your trips out onto the course, etc. can result in significant savings over the long run.

Use sleep mode on computers when not in use, or turn them off at the end of each work day.

Consider adding a photovoltaic solar energy system to offset, meet or exceed your energy usage. Golf course maintenance facilities are ideal for these systems because they are often hidden from view, provide a roof free of obstructions and often have a roof that is at the ideal pitch for installation. These systems can offer a short return on investment that will continue to pay off for the life of the system.



EQUIPMENT

Consider alternative equipment, products, and practices.

Evaluate golf car equipment/operations and ensure proper selection, operation, charging, and maintenance. Maintain proper tire pressure to improve fuel efficiency. Check battery water in electric carts monthly to maximize charge cycles.

Optimize equipment use data including hours operated, use patterns, etc. Monitoring equipment use and flow patterns on the course can reduce fuel consumption, equipment repair, as well as labor costs.

Ensure proper selection (type, size, etc.), operation, and equipment maintenance. Consider using larger mowers to reduce fuel usage and labor needs.

Evaluate use of alternative energy/fuels.

Evaluate cleaning practices (dry vs. wet). Using a broom to clean equipment before washing can reduce water usage and energy to recycle washwater.

Evaluate alternative transportation. Combine tasks to reduce trips onto the course and the additional labor needed.

Identify the lowest cost time to operate the charging systems and use that window to re-charge when possible.

Consider using solar-powered pond fountains and aerators to eliminate energy usage.

EVALUATE ALL ENERGY PROVIDERS: Evaluate all energy providers (electricity, natural gas, solar and liquid petroleum fuels) for costs, efficiency/assistance programs, and incentives.

Work with energy providers and evaluate existing programs, resources, etc.

Identify incentives and programs from energy providers.

Consider U.S. Green Building Council's LEED program.

Consider EPA's EnergyStar, Portfolio Manager, etc.

Consider energy management software, services, etc.

GCSAA
Golf Course Superintendents Association of America

Florida Chapter
GCSAA
Golf Course Superintendents Association of America

Florida Department of Environmental Protection