23RD ILLINOIS TURFGRASS CONFERENCE

North Central Turfgrass Exposition
November 10-12, 1982

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ILLINOIS TURFGRASS FOUNDATION
MIDWEST ASSOCIATION OF GOLF COURSE
SUPERINTENDENTS
UNITED STATES GOLF ASSOCIATION—
GREEN SECTION

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This publication was compiled and edited by Thomas W. Fermanian, Assistant Professor of Horticulture, University of Illinois at Urbana-Champaign. The manuscript was typed by Mrs. Jo Mahannah, secretary for the Illinois Turfgrass Foundation, and by Linda Randell. Anne Weeks prepared the manuscript for publication.

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FINDING AN ANSWER TO YOUR PROBLEM

Thomas W. Fermanian

When a problem comes up in your operation, finding a solution to it is not always easy. Too often the answer is not timely enough to be of any real value. Let us look at an example of this process. A golf course superintendent begins to notice a lack of vigor in a green or two. After a few days, this lack of vigor turns to wilt and the quality of these greens declines. The superintendent is quite concerned and seeks help from a consultant. The consulting turf expert suggests sending samples of the sick greens to a laboratory. Several days later, two greens are lost. Two weeks later, the superintendent receives a report from the laboratory stating that nematodes are infecting the turf and immediate treatment is necessary. A problem like this might have been avoided with a little previous planning. I want to take some time to outline some of the resources available to you in developing corrective measures for a problem.

First, let me show you a method for approaching potential problems and organizing the necessary corrective measures for the solutions.

Many of our troubles are just not recognized until they reach a critical state. Pythium blight, Fusarium blight, and several other diseases or insect problems too often fit this category.

Equipment breakdown, irrigation leaks, and employee absences also require immediate action. These problems often require background information, but the methods and materials required to correct the situation must be available immediately. The background information for these situations should be organized in a separate data base. A data base is a collection of bits of information organized in a manner that facilitates easy retrieval of the information. Other problems, such as poor drainage, localized dry spots, and thatch accumulation can be, and usually are, more persistent in nature. This persistence means a long-range plan must be developed to correct the situation. The background information for long-range planning can then be organized in a second data base. More important than simply categorizing problems, this division will allow you to organize defenses for both short-term and long-term needs for a single problem like the disease Fusarium blight.

It seems to me that the worst part of my high-school algebra course was trying to make sense of the word problems, not with solving the equations. The problem was deciding which equation needed solving. I think this problem can also exist in your own operation. It is usually easy to describe the damage or end results of a problem but often quite difficult to list the steps or occurrences that led to the end. This is why the method of problem solving is so important. Looking back at those algebra word problems, the first thing you were told to do was list all the facts stated in the problem. In analyz-

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ing your own problems, gather all the pertinent data first. Do not worry about how they relate to the problem at this point; that is the next step. Just assemble any facts that might possibly relate: weather, traffic patterns, fertilization, cultivation, or anything that could have an effect on the turf growth at that time. After all the facts are gathered, relationships can be determined and a step-by-step plan of recovery developed from this analysis. The final step is to implement your plan to test the validity of your analysis. I realize I grossly oversimplified this process for some problems, and for others it is probably too complex. The point I am trying to make is that problem solving requires some thought and organization and should not be just trial and error.

Let us look at those problem-solving steps a little more closely. Where do you begin collecting data? Probably most obvious is writing down your observations of the situation. What does the turf look like? What is the color? Are there signs of stress? Dig out a core of turf. What is the condition of the soil? Is thatch present? The key here is to record these observations, not so much for the immediate problem but for the future. When the same symptoms occur two years later, you can match it with a previous incident.

Some situations will require the testing of appropriate samples. Do not just test in a crisis situation; make a habit of testing samples from all areas on a regular basis--at least annually. Do not forget to record the results. There are no magic numbers with the test results. Your concern should be on the variation of the results from year to year.

There are many other sources of information. Many of these are obvious, but how many people record any of the information found in a magazine article? Again, my advice is to organize information in a form that is easily accessible. The best source of information is probably from your peers in local and national organizations. If you are not already a member of a local group, I highly recommend you to join one. It is for your benefit. Consultation help can be found at many different levels. There is always your friendly extension turfgrass specialist, but do not forget the county extension staff. They often have more experience with a local problem than the state staff and have access to a tremendous network of resources.

Nonprofit organizations like the USGA Green Section can provide a valuable service. Probably the greatest wealth of experience comes from professional consultants. Again, to gain the greatest benefit from these services the information has to be capsulized and recorded. The fourth category, educational conferences, will yield value over the next several days. There are many other continuing-education opportunities both in state and out of state.

Ever since my first year as a graduate student, I have heard how university research is of little use in predicting the value of a product or cultural procedure on professionally maintained turf. It might surprise you that most university researchers will agree with that statement. Field plot research is not meant to develop absolute cultural systems. Most of you cannot treat your own sites uniformly, so trying to relate a single experiment to all the turf in Illinois is impossible. The final step in research must be on-site evaluation. This does not mean just trying something one year and then something different the next year. It also does not mean doing replicated, statistically analyzed experiments. What I mean is side-by-side strip treatments applied to an area maintained in similar fashion to the rest of the site.

An ideal site for these trials is the practice green, nursery, practice fairway, the lawn of your headquarters, or any other similar turf. Consider establishing a nursery if you do not already have one. If you already have a bentgrass nursery, what about the other four or five grass species you maintain? I wonder how many *Poa annua* nurseries there are in the state. I know for a fact that at least one golf course in the state is growing *Poa annua*.

How about perennial ryegrass, Kentucky bluegrass, or the fescues? Just 1,000 square feet of each would be enough for product evaluation. Backpack sprayers are available for a relatively low price and do a good job for applying small amounts of materials. Granular materials can be applied with drop spreaders. Of course, utilizing small-plot application equipment will require some degree of calibration skill. This might be one area where the county extension staff can help. Again, these trials are of little value unless you record your observations or the results of the trial.

In addition to recording the results of these evaluations, here are a few other suggestions for information that should be stored in the long-range data base. All pesticides should be inventoried and their use documented. The process is simplified by combining both the inventory and final use on one record. Just as important as documenting the use of pesticides is recording the nature of the pest problem, which pest was treated, and the results of the application. If weather data are collected on site, they should also be recorded faithfully. Fertilizer use and soil or tissue test results can also be helpful in long-range planning. Timing of cultivation practices can also be planned more accurately when the results of other management practices are taken into consideration.

Up until now, I have left microcomputers out of this discussion. Accurate record keeping and utilization of the record information to assist in management decisions is independent of any tools used to achieve this end. Using advanced technology for data storage or retrieval will not make the information any more accurate or meaningful. Manual systems of record keeping can still provide accurate, useful information, just as they have throughout the history of turf management. Once you have designed and implemented a manual system, however, current computer technology can be added to provide faster, more versatile data retrieval. Predictive planning will take on a new importance in your total management program. One problem that can arise is overplanning, but with experience the computer data base can be an extremely productive tool.

I want to reemphasize the major points of the presentation. First, design and implement a paper-based filing system or data base to provide organization for record keeping. The data base will contain only the information you put into it. You can ignore portions of the data base but you cannot retrieve information that is not there. Finally, make the final evaluation of products or cultural methods at your own site. The time you spend on this activity might someday save your job--or better yet, provide the opportunity for a better one.

TURFGRASS PATHOLOGY: A NEW LOOK

Henry T. Wilkinson

In April 1982 a new program for the study of turfgrass diseases was started in the Department of Plant Pathology at the University of Illinois at Urbana-Champaign. This program was born out of a great need by members of the Illinois turfgrass community to advance their understanding of and ability to manage turfgrass diseases. The Illinois turfgrass community was instrumental in convincing the university of this need, and it will continue to play a vital role in the future of this program.

Turfgrass pathology is more complex than that of many other plants and for this reason is sometimes very frustrating to understand. This complexity stems from the fact that there are four basic subjects to consider in turfgrass pathology: (1) the perennial growth of the grass plant, (2) the cultivation and management practices applied to the grass plant ecosystem, (3) the numerous microorganisms that inhabit the turfgrass ecosystem, and (4) the environment. Most microorganisms that infect turfgrass are ever-present residents of the grass ecosystem, living in soil or thatch. These microorganisms attack when conditions permit. Each microorganism requires specific conditions to become a pathogen, and the appropriate conditions for one organism could be very similar to or very different from those of other microorganisms. For example, *Rhizoctonia solani* (brown patch) and *Sclerotinia homoeocarpa* (dollar spot) both infect grass during summer conditions of high temperature, high humidity, and low fertility, while *R. solani* and *R. cerealis* (yellow patch) infect grass at temperatures of 25° to 38° C and 15° to 25° C, respectively. It is imperative that research consider all facets of the turfgrass ecosystem if lasting disease-management systems are to be achieved.

The initial effort in development of the turfgrass pathology program was to establish which diseases were the most unmanageable and to define what type of research approach would advance our ability to manage them. Three major research subjects have been identified, and research on them has commenced. The subjects are: (1) diseases caused by *Rhizoctonia* species, (2) diseases caused by *Pythium* species, and (3) diseases of stressed turfgrass.

There are potentially three species of *Rhizoctonia* that can infect turfgrass: *R. solani* (brown patch), *R. cerealis* (yellow patch), and *R. zeae* (no disease named for the infection of grass). The research conducted on these fungi will determine where they exist in Illinois and will explore several management strategies for their control. *Rhizoctonia cerealis* (yellow patch) is presently unmanageable, owing to a lack of an effective fungicide or a thorough understanding of the disease etiology. Cooperative work with agricultural chemical companies and other universities will examine experimental chemicals and biocontrol strategies, respectively, as a means of managing this fungus.

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Species of *Pythium* cause foliar blights and crown rots of turfgrass. Protective fungicides are available but expensive. Research is being conducted to determine if microorganisms can be used as an alternative to or in combination with fungicides. The use of microorganisms could reduce the cost and quantity of fungicides required to control *Pythium* diseases. Specific bacteria have been identified and selected for their ability to antagonize *Pythium* species. Research will attempt to determine the most effective method of using these bacteria to control *Pythium* species in turfgrass. Initial results are promising, but development of this control program will require substantial research.

A very important and complex subject is diseases of stressed turfgrass. Stressed turfgrass is that in which the plant's resistance to attack by various facultative parasites has been reduced or lost. For example, *Fusarium* species will infect many grass species that are stressed by drought or temperature but will not often infect a vigorously growing, turgid plant. Fusarium blight of turfgrass appears to be a disease of stressed turfgrass. It can be observed on sodded and seeded lawns and limits the use of bluegrass on golf-course fairways. The new turfgrass research program will invest considerable time in the study of Fusarium blight. The research on this subject will be divided into two main sections: (1) to determine cultural methods that reduce stress on the turfgrass, and (2) to establish a method to effectively evaluate both fungicides and resistant grass selections for resistance to Fusarium blight. This research is in the preliminary stages of development; to ensure success, it must be very carefully designed due to the complexity of this disease.

In addition to the in-depth studies described above, part of the turfgrass program will address new and potentially destructive diseases of turfgrass. For example, a disease attacking bluegrass throughout the state was observed in 1982. The disease has no official name but is characterized by rings of yellowed grass plants. The rings range from several inches to several feet in diameter. Directly beneath the ring of yellowed plants is a dense white mycelium. The mycelium is the living fungus growing outside the plant. Preliminary observations reveal that this disease is associated with turfgrass having a thatch thickness of 2.0 to 3.5 centimeters. The cause and management of this disease are being intensely studied.

The new turfgrass program for research has started smoothly with the valuable help of the Illinois turfgrass community and will advance our understanding of turfgrass diseases. I welcome comments and ideas from each and every member of the turfgrass community.

TURFGRASS RESEARCH AT THE UNIVERSITY OF ILLINOIS

David J. Wehner

The turfgrass research program at the University of Illinois at Urbana-Champaign (UIUC) seeks to answer important questions regarding the successful management of turfgrasses in the state. Many different aspects of turfgrass management are being examined at the university. The purpose of this report is to list the research projects being conducted. Specific descriptions and the results of these projects are contained in the annual *Turfgrass Research Summary*, which is sent to all members of the Illinois Turfgrass Foundation (ITF). Nonmembers may obtain copies of this report from the ITF office. Any questions about specific experiments should be directed to the person responsible for conducting the research.

There are three full-time turfgrass researchers at the Urbana-Champaign campus. Dr. Tom Fermanian and I are in the Horticulture Department, and Dr. Hank Wilkinson is in the Plant Pathology Department. In addition, Dr. Mal Shurtleff in the Plant Pathology Department and Dr. Roscoe Randell in the Department of Agricultural Entomology have partial appointments in turfgrass extension. Dr. Wilkinson's research program is covered in another report in these proceedings; I will list the research projects being conducted in the Horticulture Department.

The following experiments are being conducted by Dr. Tom Fermanian:

1. Cultivar evaluation studies
    a. national Kentucky bluegrass evaluation
    b. national perennial ryegrass evaluation
    c. regional turfgrass species and cultivar evaluations
2. Pesticide evaluation studies
    a. preemergence crabgrass control studies
    b. growth retardant evaluations
3. General management studies
    a. sand topdressing of creeping bentgrass
4. Fertilizer evaluations
    a. comparison of liquid nitrogen fertilizers
5. Computer-assisted establishment of turfgrass stands

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I am conducting the following experiments:

1. Cultivar evaluation studies

   a. bentgrass blend evaluation

2. Herbicide evaluations

   a. broadleaf weed control in turf
   b. annual bluegrass control studies

3. Fertilizer evaluations

   a. fall fertilization of Kentucky bluegrass

4. General management studies

   a. tall fescue management study
   b. fairway bentgrass study
   c. effluent water irrigation project
   d. environmental fate of pesticides
   e. heat stress--fungicide interaction study

The turfgrass researchers at UIUC are open to suggestions regarding the direction of research and specific problems needing to be investigated. Members of the industry should feel free to contact Dr. Fermanian, Dr. Wilkinson, or me when serious problems occur.

In order to conduct the necessary research, the support of the industry is vital. We would like to thank the following companies and organizations for their support of our program in 1982 through contributions of funding or materials:

Allied Chemical Co.
E. F. Burlingham & Sons
Cantigny Gardens & Museum
Central Illinois Golf Course Superintendents Association
ChemLawn Corp.
Chicago District Golf Foundation
CIBA-GEIGY Corp.
W. A. Cleary
Deere & Co.
Diamond Shamrock Corp.
DuPage County Extension Office
E. I. Du Pont de Nemours & Co.
Elanco Products
Estech General Chemicals Corp.
BFC Chemicals, Inc.
Hawkeye Chemical Co.
Illinois Turfgrass Foundation, Inc.
International Seeds, Inc.
Jacklin Seed Co.

Lakeshore Equipment & Supply Co.
Lebanon Chemical Corp.
Lofts Pedigreed Seed Inc.
Mallinckrodt Inc.
Midwest Association of Golf Course Superintendents
Mobay Chemical Corp.
Monsanto Co.
Northrup King Co.
Pickseed West, Inc.
Pure Seed Testing, Inc.
Rhone-Poulenc, Inc.
Rock Island County Extension Office
O. M. Scott & Sons Co.
Silver Lake Country Club, Inc.
Stauffer Chemical Co.
University of Illinois Athletic Association
Benedict O. Warren
Warren's Turf Nursery, Inc.

CHALLENGES FOR THE TURF INDUSTRY IN THE 1980s

James B. Beard

It is appropriate at the start of a new decade to pause and reflect on our past before projecting into the future. In 1980, we celebrated the historic 150th anniversary of a major event in the evolution of turfgrass culture. Mr. Edwin Budding invented the first lawn mower in 1830. It was a reel design with catcher, which was built in a shed and tested on a nearby grassy area at night in order to maintain secrecy before patenting. The manufacturing rights were obtained by Ransomes Manufacturing, which sold 1,000 units by 1850. The next milestone was 50 years later in 1900 when the first powered mower was developed. It cut a very narrow swath and was steam-driven, but unfortunately it weighed 1-1/2 tons. Then, also in 1900, the internal combustion engine was introduced in a powered mower. The electric mower was introduced in 1925. During this period in the development of the turfgrass industry, most approaches to turfgrass culture evolved as an art through trial-and-error methods.

The year 1950 marked the start of our greatest advances in the science of turfgrass culture. Both land grant universities and private industry devoted major research efforts toward solving the problems of turfgrass culture and developing a set of scientifically based principles. As a result, the 1960s and 1970s have been a golden era in the use of quality turfs, the development of professional turf managers, and the generation of research information concerning the science of turfgrass culture. We can be proud of these accomplishments. However, many of these advances in turfgrass culture were based on cheap, abundant resources--a trend that cannot continue.

What can we anticipate in the 1980s? Projecting into the future is a risky occupation, but it can serve as a useful guide for preparing for the future--even if the projections are not entirely correct. The remainder of this paper will address the six major areas of concern for the 1980s: energy, water, pesticides, nutrients, equipment, and manpower.

ENERGY

The news media bombard us daily with the energy problems of our country. They are real, but I am confident that we have the capability, through the ingenuity of the human mind, to develop alternative energy sources that will replace oil in many roles. However, these future energy sources will be available at a higher cost. As a result, energy conservation will be a high priority for the turfgrass industry in the 1980s. What are the trends?

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1. Mowing -- increased use of reel mowers, as they are cheaper to power than rotary units; a trend toward larger, more mobile mowing equipment.

2. Fertilization -- lower rates of nitrogen application, coupled with the acceptance of a lighter green color.

3. Irrigation -- increased pumping costs that could lead to more efficient, lower-pressure heads.

4. Equipment -- the impact of higher energy costs on the basic purchase price of equipment, pesticides, and fertilizers, which is further amplified by our current high inflation rate. A partial solution is continuing emphasis on increasing efficiency, which translates to cost control.

WATER

I believe that water is the greatest problem facing the turfgrass industry. Energy will be available at a price. Water availability problems will not be limited to the more arid regions but will also be a problem facing the urban areas in the more humid, high-rainfall regions during periods of extended drought. There is also concern for water quality as well as actual availability. Salinity is an increasing problem where effluent water is used, in arid regions, and along coastal areas (such as Florida and Texas) where salt water is encroaching as groundwater supplies are pumped out.

Far too many intensively maintained, high-quality turfs are now overwatered. Studies have indicated that as much as a 50 percent saving in water use could be achieved simply by applying the cultural practices now known. Overwatering not only wastes water but also leads to increased disease, soil-compaction, weed, and nutrient-leaching problems. The good turf manager of the future will be capable of making the very difficult decisions involved in proper irrigation practices. The turf manager who maintains a green, high-quality turf by a philosophy of maintaining constant water supplies in the soil, through overwatering, will become obsolete.

In summary, the following trends may be anticipated:

1. Less water available for turf use

2. Higher costs both for water and for pumping

3. Increased use of effluent water

4. Declining water quality

5. Water allocation, as has already occurred in certain areas of California, even for landowners who possess private wells

Again, the solution is conservation. It involves better-designed and better-installed irrigation systems as well as the implementation of more efficient watering practices by the turfgrass manager. In the future, we hope that research will be able to develop improved turfgrass cultivars that will have lower water-use rates, improved drought tolerance, and a better ability to grow in saline soils.

PESTICIDES

Some individuals have been guilty of misuse of pesticides in the past. There was a need for use restrictions and educational programs to avoid potential problems in the future. This need resulted in formation of the Environmental Protection Agency (EPA), whose primary emphasis to date has been on environmental impacts. We have seen the elimination of many pesticides that are not rapidly biodegradable. The lack of persistent soil-active insecticides, such as the chlorinated hydrocarbons, has led to a substantial increase in white grub problems across the United States. Now, more costly control programs and diagnostic procedures must be developed through integrated pest-management programs to alleviate this and similar pest problems in the future.

Governmental controls have also greatly increased the cost of developing and registering a new pesticide. Knowledgeable specialists in this field indicate that there may be no new pesticides developed specifically for turf use in the future. Most pesticides that do become available for turf use will be spin-offs from the agricultural industries. Thus, during the 1980s, we may have only two to four prominent new turf pesticides developed. At the same time, the EPA may remove registration approval for more turf pesticides than that. There is also the problem of escalating costs for pesticides. The following are some of the trends in pesticide use:

1. Few pesticides available to the turf industry

2. Costs increasing substantially

3. Tighter controls on pesticide use

4. Emphasis on selective control rather than broad-spectrum applications

5. Increasing employee awareness (through training programs) regarding safe handling of pesticides

In summary, we will need increased efficiency when applying pesticides, yet we must retain adequate safety standards. Pesticide usage will be practiced only as needed to control a serious, threatening pest.

NUTRIENTS

For the most part, fertilizers will be subject to the same trends as pesticides. These trends include increased cost, more restrictions on use, and reduced application rates. Lower nitrogen levels will be used, along with increasing rates of iron and potassium application relative to the nitrogen application rate. This practice translates to a more controlled shoot-growth rate. Through research, there will be further improvements in the development of slow-release nutrient carriers to extend the longevity of release and thus reduce nutrient leaching losses. Emphasis on maximizing the efficiency of nutrient utilization will also be achieved through other techniques such as the use of mulching mowers for recycling of nutrients. Research will also emphasize the development of cultivars that have lower nutrient requirements but will retain their important functional characteristics.

EQUIPMENT

Information from leaders in the equipment field indicates that no major innovative breakthroughs in mowing equipment can be anticipated in the 1980s. Such statements may be dictated by the need to maintain secrecy, even if there were some innovative concepts in the formative stages. Trends that are indicated include increased use of mulching mowers, better equipment for improved efficiency in pesticide and nutrient application, and increased use of diesel engines. All turfgrass equipment will experience a substantial increase in cost throughout the 1980s. Thus, there will be even greater emphasis on extending the operating life of this equipment through good preventive maintenance. Such programs translate to the hiring of a well-trained mechanic and the development of training programs for employees to insure proper operating and maintenance procedures that will maximize the operating life of each unit.

MANPOWER

The previous five areas of concern have all focused on the need for better-trained professional turf managers. They must possess the needed formal knowledge, followed by adequate experience to implement the previously mentioned operating efficiencies and conservation of resources. The job opportunities and salaries for such individuals will be better in the 1980s than ever before. Prospective turf managers will also be better educated than before in terms of formal degree programs. Adult educational activities, such as state and regional turfgrass conferences, will also play an ever-increasing role. Finally, individual turf managers must increase their efforts in developing on-the-job training programs for their employees.

SUMMARY

The key theme throughout this paper is efficiency. This focuses on management, and more specifically on the turf manager. There must be a constant vigil to seek efficiencies in the use of energy, water, pesticides, and labor. Through these efforts, the turf manager will be able to exercise cost controls that will provide a functional, adequate-quality turf for the user at the most economical cost.

There is also a second major theme--research. Research will develop new cultivars that will possess a slow vertical shoot-growth rate, low water-use rate, minimum nutrient requirements, drought hardiness, wear tolerance, disease and insect resistance, and green color retention at low fertility levels. This research will be critically needed by the turfgrass industry during the 1980s and 1990s. All professional turf managers should do their part by articulating and working for the support of research programs around the country.

Some might interpret this paper as taking a doom-and-gloom position. It is not intended to be that at all. It is intended as a realistic assessment of the situation that will stimulate thought on what adjustments need to be made to meet the needs for our changing times. We cannot continue to do things the same way we have for the past 20 or 30 years. We can continue to provide functional, quality turfs, which contribute so much to our quality of life in the United States. Achieving this goal will require more well-trained, motivated turfgrass managers than ever before. Thus, from an employment perspective, the demand for good turf managers, rather than just grass cutters, will be greater than ever before. The challenge will be great, but achievable. The future offers excellent opportunities for the well-trained, conscientious turf manager.

CURRENT TURFGRASS DISEASE CONTROL RECOMMENDATIONS

Malcolm C. Shurtleff

As with diseases of other plants, control measures for turfgrasses should start with a correct diagnosis. A correct diagnosis begins with thorough knowledge of the turfgrass, its adaptation, growing requirements, and expected problems (such as insects, infectious diseases, and noninfectious disorders). When other possible causes are eliminated, a disease problem should be considered.

An infectious disease results from the right combination of a susceptible grass plant, a virulent pathogen, and an air-soil environment favorable for infection and spread of the pathogen, plus the time necessary for disease to develop and express itself.

Integrated disease control involves the use of all cultural and chemical management tools. These tools are outlined in two issues of *Report on Plant Diseases* (RPD): Number 400, "Recommendations for the Control of Diseases of Turfgrasses," and 402, "Turfgrass Disease Control." Both RPDs will be revised in 1983. Copies of these publications (and 11 others covering other turfgrass diseases) are available at 15 cents each from Extension Plant Pathology, N-533 Turner Hall, 1102 S. Goodwin Avenue, Urbana, Illinois 61801. Checks and money orders should be made out to the University of Illinois.

Cultural management practices that are useful in controlling a wide range of infectious and noninfectious turfgrass diseases include:

1. Provide for good surface and subsurface drainage, a soil pH between 6 and 7, and a uniform soil mix.

2. Grow only well-adapted, disease-resistant grasses, blends, or mixes.

3. Buy only top-quality, pathogen-free seed, sod, plugs, or sprigs. Plant in a well-prepared, fertile seedbed. Avoid overwatering before plant establishment.

4. Fertilize based on soil tests for the grasses grown and their use. Avoid overstimulation, especially with a water-soluble, high-nitrogen material, in hot weather. A high level of potash (K_2O) helps suppress disease development. Avoid fertilizing during the last six to eight weeks of the growing season.

5. Mow frequently at the height recommended for the area, season, and grasses grown. Remove *no more* than one-third of the leaf height at one cutting. Avoid scalping. Toronto (C-15) decline and wilt disease, caused by a rickettsialike bacterium, is serious where the

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grass is cut at 1/8 to 3/16 inch. Grass in the collar (cut at 1/4 to 1/2 inch) is usually free of infection. Golf greens cut at less than 1/4 inch are asking for trouble and generally experience more and serious disease problems. Is the craze for faster and faster greens worth the higher costs for management and disease control?

6. During droughts, water established turf at each irrigation so that the soil is moist six or more inches deep. Repeat at 7- to 10-day intervals if the weather stays dry. Where Fusarium blight and nematode decline are serious problems, however, daily watering may be needed to keep the grass alive. Avoid frequent light sprinklings, especially in late afternoon or evening.

7. When grass is in moderate to dense shade, bordering trees, shrubs, and hedges will need selective pruning or removal. Shade-tolerant grasses and ground covers are also available.

8. Do not allow thatch to build up over 1/2 inch in higher-cut grasses, 1/8 inch or less for fine turf. Remove excess thatch in early spring or autumn when temperatures are low and grass is growing vigorously.

9. Core compacted turfgrass areas one or more times per year; spring and autumn are the best times. Where possible, control compaction by strategic placing of walks, fences, shrubbery, and flower beds.

10. Follow suggested insect- and weed-control programs for the area and grasses grown. Chemical control recommendations for all types of pests are updated annually and published in Illinois Circular 1076 by the Cooperative Extension Service and College of Agriculture at the University of Illinois at Urbana-Champaign. The latest revision, *1983 Turfgrass Pest Control*, is available in every county extension office and from the College of Agriculture.

When the ten basic cultural control practices outlined above do not check development of disease, a preventive fungicide program (as outlined in Circular 1076) will be needed.

Before using any fungicide, you should know what infectious diseases are most likely to occur in your turf and when they are likely to develop. The fungicides to use will depend on the grass being grown, the disease problems expected, the acreage that needs application, the local distributor or dealer, the cost of chemicals, application time, your equipment, available manpower, and your past experiences.

The only change in fungicide recommendations for 1983 will be the addition of vinclozolin (sold as Vorlan by Mallinckrodt) for control of Sclerotinia dollar spot. It gave us month-long protection against this disease in our Urbana trial in 1982. We had a resistant strain of the dollar spot fungus that devastated (99 to 100 percent loss of turf) our check, Tersan 1991, and Fungo 50 plots. The two outstanding dollar spot fungicides, giving better than 99 percent control for three weeks or more were Bayleton and Vorlan.

We will probably be recommending Vorlan to control other diseases in 1984, after we have evaluated additional spray trials. This product has looked promising for control of Fusarium patch (pink snow mold), leaf spot diseases, Rhizoctonia brown patch, and the red thread and pink patch disease complex.

Another promising turfgrass fungicide is fenarimol (sold as Rubigan by Elanco). It is currently being evaluated under the Environmental Protection Agency's experimental use permit 1471-EUP-50 to control Sclerotinia dollar spot, Fusarium blight, snow molds (Fusarium patch and Typhula blight), Rhizoctonia brown patch, and stripe smut. Rubigan is a protective, curative, and locally systemic fungicide. It provides long-lasting control at low rates with a wide margin of safety to perennial grasses. Rubigan also has the unique property of gradually reducing an infestation of *Poa annua*. Dr. David Wehner is currently evaluating this product for that purpose.

When applying any fungicide, always follow the manufacturer's directions and precautions for rates of use, interval between applications, compatibility with other chemicals, grasses on which the product can be used, and safe use and handling. The method of application is also critical. Use two to three gallons of spray per 1,000 square feet of turfgrasses to control such leaf-infecting diseases as leaf spots, powdery mildew, rusts, red thread, and pink patch. Other diseases, such as Sclerotinia dollar spot, Rhizoctonia brown patch, anthracnose, Pythium blight, Helminthosporium melting-out, and snow molds attack the grass crown and roots and survive in the thatch. Here five to ten gallons of spray per 1,000 square feet are needed. For diseases like Rhizoctonia brown patch, where the pathogen survives in the top 1/4 inch of soil in a resistant stage (as sclerotia), 15 gallons will probably do a better job. To control Fusarium blight and leaf smuts (including stripe smut), a soil drench using at least 1/2 inch (300 gallons) of water per 1,000 square feet is needed to move the systemic fungicide down into the rootzone where it can be absorbed by the roots. We suggest that the turf be watered thoroughly the day before applying the fungicide soil drench. Use 1/2 to 3/4 inch of water (300 to 450 gallons per 1,000 square feet) to assure better penetration of the fungicide.

Cultural control measures are the heart of a sound disease management program. There is an old saying that all the fungicides in the world cannot replace a poor turf management program. When a fungicide "fails," resistance to a particular chemical may be involved. Too often, however, there is a weak link in the management program that lets a particular disease take over. In many cases, the best fungicide will not bring the turf back to good health until a certain cultural management practice is corrected.

TURFGRASS INSECTS AND THEIR CONTROL IN 1982

Roscoe Randell

Annual white grubs *(Cyclocephala immaculata)* were again a problem in turfgrass areas in 1982, including home lawns, golf courses, and other highly managed grass areas.

The various labeled soil insecticides performed well in controlling annual white grubs if the chemical was drenched into the soil beneath the crown area. Oftanol 5G, labeled for use in Illinois and a few other states, controlled annual white grubs when applied either in the spring and summer as a preventative or in late summer as a rescue treatment to prevent further damage. Diazinon 14G, 5G, 2EC, and 4EC all performed well if applied after egg hatch in late July and immediately drenched into the soil. Trichlorfon (Proxol, Dylox 80S) controlled grubs effectively if applied as a control and watered in immediately. The combination of Sevin SP and Dursban 4E at half rates of each gave effective control of annual white grubs. Turcam 76WP was also effective on white grubs.

Five different replicated plots were established to determine effectiveness of the various chemicals listed above. Only one plot contained more than the economic damage level of grubs (12 per square foot) by mid-September. Table 1 gives the results of comparing diazinon and two formulations of Oftanol granules.

Table 1. Annual White Grub Control Plots--1982*

Treatment	Pounds of Active Ingredient per Acre	Grubs per Square Foot	
		14 days after treatment	21 days after treatment
Diazinon 5G	6.0	3.3	2.0
Oftanol 5G	2.0	4.0	4.0
Oftanol 5G	1.5	4.7	3.3
Oftanol 2G	2.0	2.0	3.3
Oftanol 2G	1.5	8.0	4.0
Untreated	---	22.0	0.0

*The plot was treated on 23 September and evaluated on 6 and 13 October. Results are the average of three replicates of each treatment.

Other areas where damage was beginning to appear were treated with one of the labeled insecticides. All performed satisfactorily when the correct amount was used, the chemical was drenched into the soil, and results were evaluated after at least two (preferably three) weeks after treatment.

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In central Illinois, a few lawns were damaged in late June and July by the true white grub (*Phyllophaga* species). Oftanol and diazinon were used with good results.

Black turfgrass ataenius (*Ataenius spretulus*) grubs attacked golf-course fairways and collars of greens and tees in 1982. These first generation ataenius grubs usually appear the last two weeks in June, but in 1982 the life cycle was delayed two to three weeks due to below-average soil temperatures. Replicated plots were established on two golf courses with a past history of ataenius activity. The results are given in Tables 2 and 3.

Table 2. Black Turfgrass Ataenius Control in 1982--Plot A*

Treatment	Pounds of Active Ingredient per Acre	Grubs per Square Foot
Oftanol 5G	2.0	2.0
Oftanol 2E	2.0	0.0
CG-12223 1G	2.0	11.0
Diazinon 5G	5.5	15.3
Untreated	---	61.0

*Treatments were applied on 24 May and evaluated on 1 July. Grub counts are averages of three replicates.

Table 3. Black Turfgrass Ataenius Control in 1982--Plot B*

Treatment	Pounds of Active Ingredient per Acre	Grubs per Square Foot
Oftanol 5G	2.0	2.0
Oftanol 2E	2.0	0.0
Proxol 80S	8.0	12.0
Diazinon 5G	5.5	8.0
CG-12223 1G	2.0	18.0
Sevin 80S + Dursban 4E	4 + 2	0.0
Untreated	---	36.0

*Treatments were applied on 25 May and evaluated on 8 July. Grub counts are averages of three replicates.

Many golf courses in the northern third of the state were treated to prevent grub damage; some others were treated where the number of grubs exceeded 40 to 50 per square foot and damage appeared in mid-July. Oftanol, diazinon, and trichlorfon, when applied at the correct amount and watered in, were effective in reducing black turfgrass ataenius activity.

Oftanol 5G is labeled for use in Illinois in 1983 for grub and billbug control.

DIAGNOSING AND REPAIRING WINTERKILL

James B. Beard

Now is the time to start considering a strategy for turfgrass damage occurring during the winter. Winterkill encompasses all types of damage that turfgrasses incur during the winter period. It can occur on both warm-season and cool-season turfgrasses, primarily in the northern portions of the warm-season and cool-season climatic regions for each group of species, respectively. The four major types of winter injury are desiccation, direct low-temperature damage, low-temperature diseases, and traffic effects. Note that ice-sheet damage caused by the hypothetical oxygen suffocation or toxic gas accumulation underneath an ice sheet is not listed. Winter injury associated with an extended period of ice coverage more commonly occurs during the freezing or thawing period when standing water increases the crown tissue hydration level. Subsequent injury of the turfgrass plant results if temperatures drop rapidly to below 20° F.

Winter injury of turfs is difficult to interpret because it results from interaction of a number of different environmental, soil, and cultural factors. If winter injury is suspected, the turfgrass manager should first determine (1) that actual injury has occurred to the turf, (2) the specific cause of injury, and (3) the specific turfgrass species, soil condition, or cultural practices requiring adjustment to minimize the chance that injury will recur in the future. Guidelines for making these assessments are presented in Tables 1 and 2.

ASSESSING THE EXTENT OF WINTER INJURY

As more favorable temperature and moisture conditions occur, signaling the initiation of spring greenup, one needs to assess whether winter injury has occurred. This assessment is neccessary so that the appropriate renovation and replanting steps can be initiated as soon as possible. In this regard, lead time is required to plan and purchase the appropriate planting materials and to prepare the needed equipment. Two diagnostic approaches can be used.

One diagnostic technique can be done well in advance of greenup. It involves collecting five to eight turf plugs from areas where winter injury is suspected and placing them in a greenhouse or under similar conditions of favorable light, temperature, and moisture so that greenup of the surviving turf can be initiated artificially. This gives an indication of the potential turf survival of the area, assuming that a representative set of turf plugs has been collected. This approach is an ideal biological indicator, which the turf manager can utilize to obtain an early assessment of the degree of turfgrass injury.

A second approach is to collect individual plants from the turf being assessed for winter injury. The diagnostic procedure involves removing the

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Table 1. Types, Symptoms, and Causes of Winter Injury Commonly Occurring on Turfs

Type of Winter Injury	Symptoms	Cause of Injury: External	Cause of Injury: Internal
Desiccation			
Atmospheric	Leaves turn distinctly white but remain erect. Damage occurs most commonly on higher locations that are more exposed to drying winds; it can range from small irregular patches to extensive kill of large areas.	A drying atmospheric environment, including high winds and low humidity. Also, soil water absorption is reduced at low temperatures or may be inoperative because the soil is frozen.	Desiccation of the plant causes shrinkage and collapse of the protoplasm that results in mechanical damage and death.
Soil	Leaves turn distinctly white and are semierect; the tissues, including the crown, are very dry. Damage commonly occurs in a more extensive pattern over the turf than for atmospheric desiccation.	Extended periods of soil drought, due to a drying atmospheric environment and lack of precipitation or irrigation.	(Same as above)
Direct low-temperature kill	Leaves initially appear water-soaked, turning whitish brown and progressing to a dark brown; they are limp and tend to lie as a mat over the soil. A distinctly putrid odor is frequently evident. Damage occurs most commonly in poorly drained areas such as soil depressions; it frequently appears as large, irregular patches.	A rapid decrease in temperature, particularly the adjacent soil temperature. Kill most commonly occurs during late-winter freezing and thawing periods. It may be associated with thawing of an ice cover that occurs from underneath.	Large ice crystals form within the plant tissues, causing mechanical destruction of the frozen, brittle protoplasm. The higher the water content of the tissue, the larger the ice crystals and the more severe the kill.
Low-temperature diseases			
Fusarium patch (pink snow mold)	Pink mycelium appears on leaves; tan, circular patches (1 to 2 inches in diameter) occur in fall. Or, white mycelial mass appears on leaves and white to pink circular patches (up to 2 feet in diameter) occur in winter or spring.	*Fusarium nivale*; favored by turfgrass temperatures of 32° to 40°F. and moist conditions.	Parasitic action of fungus.
Spring dead spot	Damage appears in the spring as irregular, circular dead spots, up to 3 feet in diameter; roots within the spot will be killed. Affected spots commonly recur in the same location each year and may gradually enlarge.	Causal organisms have not been identified; favored by turfgrass temperatures below 50° F.	Unknown

Typhula blight (gray snow mold)	Light gray mycelium appears on leaves, especially at the margins of the advancing ring; whitish gray, slimy, circular patches (up to 2 feet in diameter) occur; brown sclerotia (up to 1/8 inch in diameter) are embedded in the leaves and crowns.	*Typhula itoana*, *T. idahoensis*, or *T. ishikariensis*; favored by turfgrass temperatures of 32° to 40° F., usually under a snow or ice cover, especially during thaws.	Parasitic action of fungus.
Winter crown rot (LTB)	Light gray, matted mycelial growth may be evident on the leaves; irregular-shaped patches initially appear yellow and gradually deteriorate to a straw color; individual patches (up to 1 foot in diameter) may coalesce, causing damage over a large area.	Unidentified low-temperature basidiomycete; favored by turfgrass temperatures of 28° to 32° F., especially under a snow cover.	Injury results from hydrogen cyanide gas produced by the saprophytic fungus; subsequently the fungus invades the host plant.
Traffic			
On frozen turfgrass leaves	Erect, white to light-tan dead leaves appear in the shape of the footprints or wheels where they have been impressed onto the turf.	Pressure of traffic (shoes or wheels) on the rigid, frozen tissues. The problem most commonly occurs during the early morning hours.	Disruption of the frozen, brittle protoplasm by ice crystals surrounding and extending into the plant cells.
On wet, slush-covered turf	Leaves initially appear water-soaked, turning whitish brown and progressing to a dark brown; the leaves are limp and tend to lie as a mat over the soil. Damage appears in irregular shapes associated with previous patterns of concentrated traffic; soil rutting may also be evident.	Snow cover thaws to slush, causing increased hydration of the turfgrass crowns; traffic, including snow-mobiles, forces the wet slush into intimate contact with the turfgrass crowns. Kill most commonly occurs if this event is followed by a decrease in temperature to below 20° F.	Not completely understood, but related to the direct low-temperature kill mechanism.

Table 2. Practices Available for Minimizing Winter Injury on Turfs

Type of Winter Injury	Cultural Practices that Minimize Injury		Specific Protectants	Turfgrass Species Most Commonly Affected
	Turfgrass	Soil		
Desiccation				
Atmospheric	Moderate nitrogen nutritional levels. Elimination of any thatch problem.	No coring in late fall	Conwed Winter Protection Blanket[R] Polyethylene (4 to 6 mil) Saran Shade Cloth[R] (94%) Topdressing (0.4 yd^3 per 1,000 sq ft) Windbreaks such as snow fence, brush, or ornamental tree and shrub plantings. Natural organic mulches.	All species
Soil	Moderate nitrogen nutritional levels. Irrigation or hauling of water to critical sites.	(Same as above)	(Same as above)	All species
Direct low-temperature kill	Moderate nitrogen nutritional levels. High potassium nutritional levels. Higher cutting heights. Elimination of any thatch problem. Avoidance of excessive irrigation.	Rapid surface drainage by proper contours, open catch basins, and ditches. Adequate subsurface drainage by drain lines, soil modification with coarse-textured materials, slit trenches, and dry wells.	Conwed Winter Protection Cover[R] Soil Retention Mat[R] Enhancing snow cover with snow fence or brush. Natural organic mulches such as straw. Soil warming by electricity.	Bermudagrass Annual bluegrass Fescues Ryegrass
Low-temperature diseases				
Fusarium patch	Moderate nitrogen nutritional levels. High potassium and iron nutritional levels. Moderate to low cutting height. Elimination of any thatch problem.	Avoiding neutral to alkaline soil pH.	Benomyl, Maneb + zinc, PCNB, and Thiophanate-methyl (Mercury chlorides are labeled for putting-green use only.)	Annual bluegrass Bentgrass Fescues Kentucky bluegrass Ryegrass

Spring dead spot	Avoidance of excessive winter irrigation. Moderate nitrogen nutritional levels. Elimination of any thatch problem.	Good surface and subsurface drainage. Cultivation when compaction is a problem.	None; very slow recovery.	Bermudagrass
Typhula blight	Moderate nitrogen nutritional levels. Moderate to low cutting height. Elimination of any thatch problem.	Good surface and subsurface drainage. Cultivation when compaction is a problem.	Anilazine, cadmium compounds, and Chloroneb. (For golf greens only: mercurous-mercuric chloride, PCNB, or PMA.)	Annual bluegrass Bentgrass
Winter crown rot	Elimination of any thatch problem. Moderate late-summer and fall nitrogen nutritional levels.	Good surface and subsurface drainage.	None in United States. Mercury chlorides and PCNB labeled for use in Canada.	Annual bluegrass Bentgrass Fine fescues Kentucky bluegrass
Traffic				
On frozen turfgrass leaves	Light application of water in early morning. This is most effective when the soil is not frozen and the air temperatures are above freezing.		Withhold or divert traffic from turf-grass areas during periods when the leaf and stem tissues are frozen.	All species
On wet, slush-covered turf			Withhold traffic on turfgrass areas during wet, slushy conditions, especially if a drastic freeze is anticipated.	All species in regions where freezing occurs

outer dead leaf sheaths surrounding the plant crown, cutting a longitudinal section or slice through the crown using a razor blade or sharp knife, and then examining the crown area under a magnifying lens. Firm white crown tissue with turgid cells indicates a healthy crown meristematic area that has survived the winter. Crowns that have turned brownish or dark colored with a mushy appearance (flaccid cells) have experienced extensive injury. The crown tissue is the critical area to examine for winter injury. A turf can lose all the leaves and roots from winter injury and still recover, as long as the meristematic areas in the basal crown of shoots and in the nodes of lateral stems (either rhizomes or stolons) survive the stress. These meristematic zones are capable of reinitiating both shoot and root growth once favorable spring growing conditions occur.

REPAIRING WINTER-DAMAGED TURFS

The first priority of a turfgrass manager is to provide the best possible conditions for reestablishment of the damaged turf area. For example, dry soils will warm up earlier in the spring than moist, perfectly drained soils. Thus, proper drainage is an important consideration. Further, the dead vegetative cover over the soil has an insulating effect that slows the rate of soil warming. Partial removal of the dead grass is desirable; a portion should be left on the surface, however, to act as a mulch. The mulch enhances seed germination and seedling growth of the area once it is overseeded.

Injured areas smaller than six inches in diameter will normally recover without reestablishment if the adjacent desirable turfgrass species possesses creeping lateral stems, such as rhizomes or stolons. Small areas on greens are best repaired by plugging with a cup cutter. On larger, more extensive areas of damage, reseeding, sprigging, or sodding is used to repair the area.

REESTABLISHMENT

Complete reestablishment of the area usually involves removal of the existing dead turf plus any allied thatch and soil layering problems. Deep cultivation and sometimes recontouring of larger areas are needed to correct drainage problems. The application of the appropriate material is made to adjust the pH into the desired range, followed by incorporation of a fertilizer at the proper rate and ratio based on a soil test. Subsequent planting may be done by sodding, vegetative sprigging, plugging, or seeding.

Small to intermediate-sized areas in high quality, intensively maintained turfs such as greens are usually reestablished by sodding. This involves removal of the dead turf and underlying soil to a sufficient depth so that the sod can be transplanted level with the existing area. It is important that the sod selected has a species composition and character similar to that of the area being resodded.

RENOVATION

In contrast to reestablishment, renovation of winter-damaged turfs involves reseeding or replanting into an existing area that has been only partially damaged. Renovation is appropriate when there is a sufficient stand of desirable turfgrass species remaining to make it feasible to salvage. The surviving plants help stabilize the soil against wind and water erosion.

The key steps in turfgrass renovation are as follows:

1. Eradication of undesirable weedy species. This usually will not be significant in the case of winter-injured turfs, except for winter annual weeds such as annual bluegrass in a dormant warm-season turfgrass.

2. Removal of any excessive thatch accumulation. Thatch removal can usually be accomplished by vertical cutting in two directions, followed by the use of a mechanical vacuum or sweeper for removal of the dead debris. When seeding, it is critical that the seed be brought into contact with the soil to ensure the most favorable conditions for seed germination and seedling establishment. The presence of an excessive thatch layer can interfere with this objective.

3. Turf cultivation by coring, grooving, or slicing. Turf cultivation usually requires two to five passes in opposite directions.

4. Correction of soil pH. Undesirable pH conditions can be adjusted with the appropriate lime or acidifying material.

5. Application of fertilizer at the proper rate and ratio based on soil test results.

6. Final coring or slicing to assist in incorporation of the fertilizer.

7. Planting by seeding with a renovation overseeder that inserts the seed into the soil, by mechanical sprigging, or by plugging.

8. Irrigation of the renovated area. The area should be irrigated deeply the first day and subsequently on a daily basis as needed to prevent visual water stress until the new planting becomes sufficiently established to stabilize the area.

In the case of small, intensively maintained areas such as greens, which need to be reestablished as rapidly as possible in the spring, a polyethylene cover can be used. The clear polyethylene cover functions similarly to a greenhouse in that it traps heat underneath, thereby accelerating warm-up of the soil, and thus stimulates earlier spring reestablishment.

MODERN IRRIGATION INSTALLATION PROCEDURES

James R. Burdett

In any rectangular golf course, the location of the source of water is a negligible factor. A pond is the most economical source of water, since it can be renewed by runoff water.

The cost of deep-well pumps for pressure is gigantic. Getting the water to the surface is only half the problem with deep-well pumps--delivering it to the irrigation system with sufficient force is the other half. Therefore, as a rule, it takes twice as much energy to have a deep well feeding directly into the system as it takes for a surface pump to develop the same gallonage and pressure. Also, the energy costs for a deep-well pump are continuous, whereas the pumping plant is a one-time cost.

WATER SOURCE

In showing diagrams of a typical pumping plant, we go through several steps. In the water source is a large screening area to prevent the whirlpooling of water into the wet well system. Whirlpooling action would tend to bring debris into the wet well. As a conduit for the water to enter the wet well, ductile iron is preferred for its long-lasting qualities, although corrugated steel is also used.

Depending on your particular situation, the wet well site is located 20 or more feet from the intake port. The wet well bottom is about 12 inches below the intake to allow for settlement of debris. The wet well bottom is concreted. The entrance to the wet well from the intake can be shut off with a sluice gate controlled from the top of the wet well. This gate allows you to cut off the supply of water in order to pump out and clean collected debris from the wet well.

Concrete rings are readily available in the Chicago area, as well as in many other areas, and thus are preferred for the wet well walls, although corrugated steel is usually used. To the side of the wet well is attached a ladder to facilitate access to the wet well. An access plate is, of course, on top next to the pumps.

Screens are attached at the foot of the pump-intake columns to keep out any debris. Debris is the bane of any irrigation system.

PUMPING PLANT

The pump house has several kinds of pumps. There is usually a jockey pump of around 25 horsepower that constantly develops as much pressure as the

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rest of the pumps in the system. The basic uses of the jockey pump are maintaining pressure in lines and supplying small amounts of water (for syringing, filling sprayers, and so forth).

Alongside the jockey pump are one or more main-line pumps of 50 or more horsepower that develop around 100 to 125 pounds per square inch. Downstream from the pumps come a wafer check valve and a shutoff valve (to allow removal of pumps without loss of water while the system is up) and a direct feed into the pressure tank (which also acts as a surge tank) rather than into a manifold.

Coming out of the tank we find a Wye strainer that collects any debris remaining. Please note that this is the third screen in the system. The first was in the source, the second at the entry to the pumps, and the third in the Wye strainer. Also, this Wye strainer has an automatic blow-off so that the debris that has reached this point is collected and will be flushed back into the wet well at the end of each watering cycle.

The next item in the pumping plant is the pressure-maintaining, pressure-sustaining valve with two-stage opening. This is sometimes called a delayed-opening valve. This valve is the heart of the system, as it senses the need for water downstream and oscillates to allow proper volume at a predetermined pressure.

Air-release valves are usually mounted on the tank (especially with turbine pumps) and also at high points of the system to eliminate air from the system. One of the major flaws in the polyvinyl chloride (PVC) system is the lack of air-release valves. Air in the lines, when hit by the force of pressurized water, can cause water hammer. Water hammer was not often a problem with mechanical joints in the old cast-iron or galvanized systems. With solvent-welded PVC joints, however, the constant hammer of water and air tends to loosen the joint; and, in about three to five years, repairs will have to be made to the connections (which are underground). Normally, at least three air-release valves are included in an 18-hole system.

Steel pipe is used outside of the pump house and at all bridge crossings (where the pipe is exposed). PVC is brittle when exposed to cold and can crack if hit when cold.

ISOLATION VALVES

Isolation valves are also important in modern irrigation systems. In the event of a break in the line, you can contain the break by isolation valves instead of turning off the entire system and waiting for it to drain. Usually not more than three holes will be in an isolation section, so the rest of the holes can be watered regularly while the break is being repaired. These valves are sized to the pipe and are iron bodied. At each tee and green, isolation valves are installed in valve boxes for individual isolation.

Valve boxes provide for a clean, orderly access to the underground system. On fairways, the boxes are located on the same side of the head for each valve, under a layer of sod. At the tees and greens, usually other valves are located in a valve box along with the isolation valve. Stone is used for each bottom area to facilitate drainage.

Weatherproof nema boxes are much more weather resistant and bug resistant than the tin boxes supplied for field controllers by the manufacturers of sprinkler equipment. Nema weatherproof boxes, used by telephone and power companies in their field locations, provide a measure of security from vandals. The field controller face packs placed horizontally in the nema provide a solid area for your field controller unit.

WIRE CONNECTIONS

Wire connections are extremely important in your system. It has been our experience that 99 percent of the problems with electrical irrigation systems are eliminated when the procedures outlined in our specifications and diagrammed on the typical page are followed using a PVC container and potting compound. These procedures are:

1. Strip ends of wires and push wires through the holes of the base socket.

2. Twist wires together and mechanically bond together using *solder*.

3. Pull wire connection back into base socket as far as possible.

4. Apply solvent cement to outside of sealing plug, then fill cavity of sealing plug completely with solvent cement.

5. Push sealing plug into base socket, using slight twisting motion, until it reaches bottom.

6. Push wires to unseat sealing plug to assure that cement completely seals the wire insulation and waterproofs the connection.

It is important that the joint be absolutely waterproof so that there is no chance for leakage of water and corrosion buildup on the joint.

PIPING AND HEADS

The architect's plans call for certain routing and head placement along with the isolation valves and other necessities of operation; now we depend on him to stake out the route. This route, of course, is approved by the golf course superintendent, who has to make the job work after the machines have pulled out. Following this approval, marking paint is applied to the routing.

Although some companies insist that they can pull in 3-inch pipe, it can be done only under ideal conditions (loose sand on new construction). We have found that the mounding of soil for 2-1/2-inch and smaller pipe is about as much as can profitably be restored. For 3-inch and larger pipe, sod is removed, trenching is done, pipe is put in with wires (which are taped together every 10 feet) laid in the same ditch, and the ditch is tamped and resodded.

Under the heads, a good, flat, interlocking stone (not pea gravel) is used for the dry well, then the soil is tamped to 90 percent of its original condition and sodded.

COST COMPARISON

We have slides of diagrams that we use to reinforce the written specifications for irrigation jobs. An important part of shopping is that comparisons of bids be made on an equal footing. Whether the plans and specifications have been drawn by an architect or by a supplier, all quotations should be on the same plans and specifications.

SUMMARY

When putting in an irrigation system for your golf course:

1. Get a good working design.

2. Write specifications fair to all (the course as well as the installer and supplier).

3. Have diagrams as well as written specifications (to prevent mistakes).

4. Have the designer on the job throughout installation.

If you remember these points, you will be able to live with your system for a long time.

SAND TOPDRESSING A HEAVILY THATCHED GREEN

Richard E. Burns

Turfgrass, being a perennial species, cannot be cultivated in the same manner as an annual crop. When we speak of cultivation in association with a turfgrass cultural system, we are referring to methods of selectively thinning an established turf without destroying it or altering it so severely that the surface would not recover rapidly enough to maintain playability or uniformity.

The necessity for cultivation is evident, however, when you realize that a golf course putting green is an intensely maintained turfgrass stand that is subject to severe wear and compaction, as well as to frequent application of fertilizer and pesticides. The golf course superintendent must maintain a high-quality turf under these conditions because it is demanded by a growing number of golfers.

A number of cultivation methods have been used on turfgrass over the years, including coring, grooving, slicing, forking, spiking, and topdressing.

BENEFITS OF TOPDRESSING

Topdressing is the application of a thin layer of soil or a soil mix to the surface of a turfgrass stand. The practice of topdressing, which has been used for over a century, was probably originally used to supply nutrients to the turfgrass plant as well as to smooth putting surfaces. It has since become a very popular and beneficial practice for the following reasons:

1. Smoother putting surface
2. Thatch control
3. Fewer disease and insect problems (because of the reduction in thatch)
4. Compaction control
5. Better shot-holding characteristics
6. Better movement of air, water, nutrients, and roots into the soil
7. Finer-textured turf

Actually, a good topdressing program is one of the most important management tools the golf course superintendent can use on established turf.

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Thatch Control

Thatch is a tightly intermingled layer of living and dead grass stems, leaves, and roots that develops between the zone of green vegetation and the soil surface. Thatch continues to be a turfgrass maintenance problem aggravating most growers even after years of practical experience and scientific study regarding its causes and control. Thatch removal remains a laborious and disruptive process and is usually possible only during certain times of the growing season.

A limited amount of thatch has some advantages. It provides resilience to the turf, moderates soil temperature extremes, and increases wear tolerance. Excessive accumulations, however, reduce drought tolerance, increase disease and insect problems, reduce infiltration rates, and cause shallow rooting. Excessive thatch also causes development of an uneven surface, which increases the opportunity for scalping and thus reduces the aesthetic value of the turf.

Thatch formation seems to occur because of an imbalance between plant growth and decomposition of organic residues. Thus, thatch accumulation is a direct result of management practices that produce abundant vegetative growth of grasses. A simple solution might be to reduce the growth rate of the grass, except that the problem of increased traffic and higher aesthetic standards demanded by the public requires the increased use of fertilizer and water to stimulate more growth--which results in more thatch. The need arises for cultural practices that would increase thatch decomposition without disrupting the turf surfaces. Practices that would slow thatch formation and increase the biological breakdown would be a welcome alternative to the damaging mechanical operations normally used to physically remove thatch.

The idea behind topdressing is to keep the thatch open and separated and to prevent dense, compacted mats from forming. Applying the topdressing materials at the proper rate and frequency will allow the topdressing to intermingle with the thatch as it develops, thus preventing the formation of layers. The intermingling of suitable materials also creates a better environment for organisms that normally decompose thatch. Topdressing blends the soil and thatch together, resulting in an integrated medium that incorporates the desirable features of each component while compensating for any undesirable features.

Use of Topdressing

Early topdressing materials used in the United States ranged from sand and organic-matter mixtures to topdressings prepared with one-third sand, one-third topsoil, and one-third peat or other available organic matter. These mixes were fine for the light traffic of the day; but, as play increased, problems of compacted soil, inadequate infiltration rates, and poor soil aeration arose. These problems led to an interest in using predominantly sand for topdressing putting-green turf. This program was developed by Dr. John Madison at the University of California.

A sand topdressing program is an attempt to build a better layer of sand on top of an existing heavier and finer-textured soil. The topdressing is applied at a rate that will allow it to intermingle well with thatch and avoid layering. Although pure sand topdressing has become very popular, some turf researchers hesitate to recommend this practice because of possible problems with excessive drainage and leaching, low microbial activity, insufficient water retention, and low organic-matter content.

Much confusion now exists as to what to use for a good topdressing program. Sometimes this confusion has led turf managers to adopt poor topdressing practices or avoid topdressing altogether.

FIELD STUDY

A study initiated at the University of Illinois at Urbana-Champaign was mainly concerned with the use of sand or modified high-sand mixes as topdressing media. The site of the study was an old, thatchy (one to two inches thick) bentgrass green where the major objective was to evaluate the effect of sand topdressing on the decomposition of the thatch.

Procedure

The experimental design for the field study is a split-plot design with three replications. The main plots received the following four treatments:

1. Biweekly application of each material at a rate equal to 2 cubic feet per 1,000 square feet; with no cultivation procedures

2. Monthly application at a rate equal to 4 cubic feet per 1,000 square feet; with vertical mowing in April, May, September, and October

3. Bimonthly applications at a rate equal to 4 cubic feet per 1,000 square feet; with vertical mowing in April and September

4. No topdressing; no cultivation (check plot)

Each main plot was divided into six subplots treated with different topdressing materials: fine sand; medium sand; a 9:1 sand-soil mix; an 8:1:1 sand-soil-peat mix; Milorganite; and a 9:1 sand-soil mix plus a wetting agent.

According to Madison, sand for topdressing and green construction should have a minimum of 75 percent of the particles in two adjacent size ranges. A wider range will result in a hard or compact mix because the spaces between the larger particles will be filled by the smaller ones. Using this information, a washed blend sand and a washed mason sand were chosen. The blend sand has the properties of a fine sand, while the mason sand has the properties of a medium sand. Medium sand was used in the sand, soil, or peat mixtures.

Results and Discussion

Quality ratings show the monthly treatments as highest, followed by biweekly and bimonthly. The check plots had the lowest ratings. The subplots had similar quality ratings except for the 9:1 sand mix plus wetting agent, which produced a slightly higher quality, and the Milorganite plots, which had the lowest quality.

Fall color showed the biweekly treatments to be best, then monthly; bimonthly treatments were far behind. The check plots again had the lowest ratings. The plots with 9:1 sand mix plus wetting agent showed the best fall color, and Milorganite plots showed the worst.

Dollar spot incidence showed the plots with biweekly treatments to have the most disease in 1982. The same results were also found in 1981.

Snow mold damage was least on plots with the monthly and biweekly treatments; however, the differences were slight. Results also showed that the medium sand, 8:1:1 sand mix, and the 9:1 mix plus wetting agent showed the least damage, with the Milorganite treatments showing the most.

Thatch thickness was originally measured with a millimeter scale on compressed and uncompressed cores. An additional method of measuring organic matter, the ashing technique, will also be used this year to evaluate the treatments further. Thatch decomposition will be evaluated over a period of several years.

EDAPHOLOGY OF THE GOLF GREEN*

Alfred J. Turgeon

Edaphology is the science that deals with the relationship between plant communities and the media supporting their growth. In golf greens, media can include native soils, modified soils, essentially pure sand media, and media with substantial accumulations of thatch and thatch-like derivatives. These media vary in the extent to which they satisfy the requirements of a turfgrass community as well as the requirements of play. In this paper, the desirable features of golf-green media will be explored, and the cultural strategies for maintaining these features will be discussed.

A turfgrass growth medium should provide adequate water-holding and cation-exchange capacities to support the moisture and nutritional requirements of the plant community. In addition, it should have a sufficient concentration of oxygen to support respiratory and other physiological processes occurring both in turfgrass roots and in beneficial soil organisms in the turfgrass rootzone. Because of the soil-compacting effect of traffic on golf greens, retention of soil aeration capacity to provide sufficient concentrations of soil oxygen is difficult, especially where traffic intensity is high. Therefore, with increasing traffic, the trend has been toward compaction-resistant (e.g., high sand) media to ensure adequate soil aeration, usually at the expense of moisture- and nutrient-retention capacities.

The provision of high-sand media for golf greens can occur in one of two ways: at construction or subsequently through topdressing. In constructing a new green, combinations of medium-textured sand, organic materials (usually fibrous peat moss), and perhaps small quantities of loam soil are used for the rootzone mix. This may be underlain with a coarser-textured medium (USGA Green Section system) or plastic sheets (Purr-Wick system) to hold water and dissolved nutrients in the lower portion of the mix. With drying at the surface from evapotranspiration and moisture uptake by plants, upward capillary flow from the moisture reservoir to the surface serves to replenish surface moisture and nutrients. This mechanism compensates in part for the relatively poor moisture- and nutrient-retention capacities of the sandy medium.

Newly established, high-sand greens are usually firmer than many golfers prefer because of the rigidity of the sand and the lack of sufficient concentrations of organic residues at or near the surface. With proper management, a high-sand green usually becomes more resilient in time, thus providing a more satisfactory surface for play.

Sand topdressing has become a popular method for converting existing greens to ones with high-sand composition. This method has been employed as a faster and less expensive alternative to rebuilding. Many regard this as a

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*This paper was not presented at the Illinois Turfgrass Conference.

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less effective alternative as well; however, its widespread popularity demands that it receive a thorough review and analysis.

Many observers have reported an almost immediate improvement in turf quality following sand topdressing. Presumably, this is the result of the alteration in the surface microenvironment where rooting is initiated and shoot growth occurs. With subsequent topdressings, the surface layer of sand increases in thickness and becomes a more significant component of the media profile supporting turfgrass growth.

A surface layer of sand usually has properties that differ substantially from those of the underlying soil. Typically, cation-exchange capacity, water retention, and biological activity are lower in sand, while water movement and aeration capacity are higher. However, the properties of a growth medium are not only influenced by the characteristics of each layer considered independently but also by the influence of one layer upon another in the profile. For example, the rate of water movement into a turf (i.e., infiltration rate) with a surface sand layer is often limited by the properties of the soil layer immediately below the sand. Following irrigation or rainfall, water may actually accumulate and persist in the sand layer, not because of the water-retention properties of the sand but due to the slower rate of water movement into the underlying soil.

If the reverse situation existed (i.e., finer-textured soil layer situated atop a coarser-textured sand layer), water from irrigation or rainfall would tend to accumulate in the upper layer of finer-textured soil in a perched water table. This is due to the disruption in the continuity of water films that occurs at the interface between the two media. Water will not move across this interface until the water potential in the upper soil layer builds to a level sufficient to overcome the attraction between the water and the finer-textured soil. With the accumulation of a sufficient "water column" in this layer, water will enter the coarser-textured soil and be conducted rapidly away.

These principles can be applied to turfgrass media in which layers exist either by design or by error. In the USGA Green Section design for greens construction, a perched water table is intended to compensate for the otherwise poor water- and nutrient-retention properties of the rootzone mix. In many other greens, however, different textural layers in the profile reflect inadequate mixing of soil constituents prior to planting or topdressing of established greens with different materials. In either case, these layers cause serious disruptions in the movement of water, nutrients, and oxygen and result in adverse effects on turfgrass growth and quality.

Where a substantial thatch layer develops, it also constitutes an important component of the media profile influencing turfgrass growth. The extent to which the turfgrass root system occurs within the thatch layer determines the relative importance of the thatch as a growth medium. In any case, thatch is physically analogous to coarse sand in that aeration porosity is high and retention of plant-available moisture is low. Nutrient retention in undecomposed thatch is also quite low. As water does not move from a finer-textured medium to a coarser-textured medium until a sufficient water potential develops, it will not move upward from a fine-textured soil to a coarse-textured thatch following evapotranspirational water loss from the thatch, even though the moisture content of the underlying soil may approach saturation. Thus, the textural difference between thatch and an underlying soil of finer texture can result in a highly wilt-prone turf.

Topdressing, or the inclusion of soil particles or aggregates into a thatch layer, is performed ostensibly to promote the decomposition of the organic residue and, with respect to greens, to true the surface. Where a loam soil is used for topdressing, the effects include improved water and nutrient retention in thatch, which actually becomes a thatch-like derivative (often called mat) following soil inclusion. Presumably, upward water movement from the underlying soil to the thatch-like derivative (in response to evapotranspirational water loss) is also improved.

If sand is used as the topdressing material, the following question arises: would the inclusion of sand in a thatch layer significantly influence the physical, chemical, and biological properties of the medium? As this research has not been done, one can only speculate as to specific effects achieved. Consider the likely effect on physical properties: if thatch and sand are both coarse-textured media, would not the product of inclusion of one (sand) into the other (thatch) also be coarse textured? Without the benefit of experimental data, it is still reasonable to speculate that the resulting mixture would no longer behave like a coarse-textured medium because of the overall reduction in aeration porosity. This reduction is due to the insertion of sand particles into the aeration (large) pores in the thatch or the permeation of the sand medium with organic materials from the thatch, depending upon the relative amounts of each. The resulting thatch-like derivative would probably retain more moisture than either component would independently.

The cation-exchange capacity of the thatch-like derivatives, measured in the conventional fashion and expressed as milliequivalents per 100 grams, would be substantially less than for the original thatch. This is due to the addition of the substantial weight of the sand with essentially no increase in nutrient-absorbing sites. The actual nutrient-retention capacity of the resulting medium, however, would probably increase. This increase is explained by the fact that the inclusion of sand in the thatch layer would have little effect upon the total volume of this medium; thus, cation-exchange capacity expressed on a volume (rather than weight) basis would not change, but the percolation of water through the medium would be slowed due to reduced aeration porosity. This, in turn, would result in less leaching of fertilizer nutrients and in effect in improved nutrient retention. Also, because of a more favorable moisture level sustained in the thatch-like derivative, the turf would be less susceptible to volatilization loss of nitrogen as ammonia.

The biological properties of the thatch-like derivative would probably be different from those of thatch, due principally to enhanced moisture retention. Microbial populations would probably be sustained at more stable levels than where wide moisture fluctuations induce rapidly increasing and decreasing population growth. Also, the physical abrasion resulting from the addition and movement of sand would tend to break up the organic constituents of the thatch-like derivative and thus accelerate decomposition, especially under heavy traffic.

The objective of a sand topdressing program is to achieve and sustain a proper balance between sand and organic matter. With sand providing a structural matrix, and with organic matter having mitigating influences upon the physical, chemical, and biological properties of the medium, the real challenge in implementing the program (whether on a sand-based green or one that is being converted to sand through topdressing alone) is to conduct it at the most favorable frequency and intensity. If performed too often or with too much sand per application, the organic matter (thatch) would become so diluted that its desirable impact would be seriously reduced. If performed too infrequently or with insufficient quantities of sand, the medium would behave too much like thatch.

With continuing research directed at the development of techniques for optimizing the results of sand topdressing, many of the questions raised in this paper should be answered and many of the assumptions adequately tested. Turfgrass managers and numerous others who enjoy the benefits of high-quality turf should be better served as a result.

SELECTION AND ESTABLISHMENT OF ROADSIDE TURF

Merle Krause

Since the start of major highway construction 40 to 50 years ago, the Illinois Department of Transportation (IDOT) has had to establish turfgrass cover for thousands of acres of highway right-of-way. Construction then and now has caused many problems in the establishment of a good ground cover. Soil compaction, poor soils, steep slopes, and erosion have added greatly to the problem. Even after the highway is constructed, winter salting hampers good turfgrass establishment.

During the history of highway construction in Illinois, two basic seed mixes have been used as a standard, one with a majority of Kentucky bluegrass and one with a majority of tall fescue. Both are cool-season, nonnative grasses that require a large amount of maintenance. During the past 15 years, a crown vetch mixture has been used on slopes for erosion control. Most highway districts throughout the state, however, have discontinued the use of crown vetch for the following reasons:

1. Disease and insects are problems.

2. Crown vetch hides erosion.

3. After a few years of lush growth, the stand seems to degrade and open up areas for weed growth, especially noxious weeds.

4. Spraying weeds also kills the vetch.

Until four or five years ago, any changes that were made were in the techniques of seeding; we stayed with the basic bluegrass or tall fescue mixtures. The following is a short list of some of the techniques and products that were used:

1. A bulldozer with a three-foot tooth welded to the blade was used to deep rip hard, compacted slopes before seeding.

2. An excelsior blanket was very good for erosion control on slopes.

3. Excelsior mulch blown through a straw blower was effective for seeding around buildings and cars because asphalt is not needed for tacking material.

4. Hold-grow is a paper blanket that has worked well for erosion control.

5. Fiberglass roving with an asphalt cover has worked well in areas of heavy erosion.

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6. Shredded bark as a seeding mulch has worked well in areas where straw and asphalt cannot be used.

7. Aquatain is a liquid product that seals the moisture in the soil. IDOT has used this on an experimental basis only.

8. Some of the equipment used was:

   a. hydroseeders--good for slope seeding

   b. heavy construction tillers--to work up hard, compacted soils

   c. mulch blowers--to mulch all seeded areas

   d. seeders (almost every type and kind are used for highway seeding)

The Illinois Department of Transportation has stayed with the two basic seed mixes because maintenance funding has always been available for mowing and spraying. In 1975, IDOT spent 6.5 million dollars to mow approximately 133,000 acres of turf; about 160,000 gallons of fuel were used--while the traveling public was waiting in line to purchase fuel. We began to realize that fuel needed to be conserved. At the same time, rising labor and equipment costs and increasing numbers of acres to maintain (because of new construction) took their bite out of the state budget. Highway planners and architects knew that changes had to be made. As land managers of the largest single land holder in the state, they have a responsibility to the people of the state and to the environment to manage the land in a responsible manner. Although cost saving was the main reason for the changes, many new and innovative ideas have emerged and are being tested. For the first time, we are working on changing the basic seed mixes to ground covers that are geared to a particular highway condition.

Reduced or limited mowing became a policy, with definite cost saving to the state. However, after two to three years of no maintenance, the bluegrass and the tall fescue areas started to get weedy and unsightly. Noxious weeds especially became a problem. The planners noticed that some of the native grasses and wild flowers were becoming established in the unmowed turf and seemed to do quite well. Presently, there are many experiments throughout the state using native grasses and wild flowers. The following is a list of advantages for native cover:

1. They are better adapted to the climate and soil conditions.

2. They are warm-season grasses and grow vigorously during the hot summer.

3. They grow well in poor soil conditions.

4. Fertilization is not needed.

5. They are very deep rooted, 8 to 15 feet deep as compared to 6 to 8 inches for cool-season grasses, so they are very good for erosion control.

6. They provide good wildlife habitat.

7. They form diverse natural prairie communities that do not allow the invasion of weeds.

8. They provide beauty. There are over 300 flowering plants that are native to the midwest prairie. The grasses themselves add color and texture to the landscape throughout the four seasons.

9. There are native grasses and wild flowers that grow anywhere. Different mixes can be established for soil conditions from dry and sandy to wet and marshy.

10. After they are established, prairie plants require no mowing or spraying, allowing a definite cost saving.

11. They are a natural resource that was almost eliminated from the midwest landscape; they are now being saved.

The prairie-establishment projects throughout the state are still in the experimental stage, and it will be a few years before definite results can be published. The preliminary results, however, are very promising.

Other turf-establishment projects that have been started over the past few years include:

1. The planting of bromegrass-alfalfa mix along roadsides where wildlife need cover and food.

2. The use of Fult's *Puccinellia distans* and Dawson's red fescue in areas of high salt concentration, mainly in towns along the shoulder and in boulevard plantings where winter salting kills other grass species.

3. The use of buffalo grass (a native grass that grows to only 6 inches in height) along shoulders to reduce the number of mowings needed.

4. The use of zoysiagrass as a highway turf cover (a new project in southern Illinois).

The past five years have been exciting to most of the highway planners and architects because of the opportunity to try new ideas. The really exciting part is that most of the changes are working to benefit the state and the environment. The next five years, I am sure, will prove to be just as fruitful, as results of present experimentation are evaluated and new ideas are initiated.

USING PLANT GROWTH REGULATORS TO DEVELOP AN EFFICIENT MANAGEMENT SYSTEM FOR ROADSIDE VEGETATION

Michael T. McElroy , Paul E. Rieke, and Shawn L. McBurney

Plant growth regulators (PGRs) for use on turfgrasses have been under investigation for more than 25 years. There have been many important improvements since those first compounds were tested. Today, PGRs offer greatly improved reliability in their response, although there is still much to learn about their use. New products are being developed and tested by several agricultural chemical manufacturers. Companies have spent millions of dollars on the research and development of several PGR compounds. Researchers are working to develop compounds that have a wider window of activity (the time span in calendar weeks during which any particular PGR compound must be applied for maximum effectiveness). A wider window of activity, such as five weeks versus ten days, would clearly be an advantage for the persons in charge of PGR application.

There are several PGR compounds, some of which are experimental, that are suited for low-management utility turfs. Scientists are also beginning to apply their knowledge of PGRs to the more highly maintained turfs such as home lawns, some industrial grounds, and golf courses. Utility grasses are defined as those needing low maintenance and having low traffic with little subsequent wear. Examples of utility turfs would be (1) highway roadsides, (2), utility park areas, (3) industrial grounds, (4) airport grounds, (5) cemeteries, and (6) golf course roughs. PGRs are also useful around trees and in fence rows.

RESEARCH IN MICHIGAN

For safety and aesthetic reasons, Michigan and most other states must manage their roadsides. The most common and most costly maintenance practice is mowing with power take-off (PTO)-driven mowers. Higher fuel and labor costs are resulting in a reevaluation of mowing as a management practice. Many Michigan roadsides are mowed twice each year at a cost of approximately $18 per acre on flat ground, rising dramatically to $200 per acre and higher on severe slopes. Mowing costs are becoming prohibitive to highway departments. Rising costs, along with improved reliability of PGRs, have given rise to investigations aimed at development of practical and economical roadside PGR management systems.

Michigan roadside managers have some unique problems when considering a PGR management system:

1. The law requires that vegetative cover be established on slopes of all construction sites prior to each winter season for erosion control. Roadside managers are inadvertently forced to use quick-germinating grass species, which are usually much less suited

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to an integrated PGR management system. We should develop seeding mixes for a plant community that has predictable PGR responses.

2. The areas to be treated are too large for the critical time of application (the window of activity). Treatment of the thousands of miles of roadsides would only be possible if the window of activity were three to four weeks in duration or longer, meaning that areas sprayed 15 April react similarly to those treated 15 May.

3. Even with the most carefully conceived PGR management systems, roadside managers will always have to contend with volunteer grass and weed species. Volunteer vegetation generally offers less predictable PGR responses and therefore must be considered another problem to be solved as we work toward creating these systems.

Michigan roadsides also have advantages when considering PGR application:

1. Roadsides receive very little traffic or wear, which at this time is a necessary precondition for PGR management systems.

2. Aesthetic quality of a roadside is generally lower than that of many other sites. For this reason, the inevitable variation in the responses of different species to the PGR is more tolerable.

The Michigan Department of Transportation, with matching funds from the federal Department of Transportation, has contracted with Michigan State University to evaluate the feasibility of PGR application to highway roadsides. Our research efforts will be concentrated into six studies; four will be located at highway roadside sites, and two will be at university research facilities on campus.

Through these studies, we are seeking answers to some important questions associated with the use of PGRs. For specific PGRs, we will be determining: (1) effective and economical rates of application, (2) the window of activity with regard to the critical timing of application for each compound, and (3) programs to reduce the mowing energy input. We will be looking at the differential response found among plant species with each PGR compound and evaluating PGR mixtures to solve this problem. We are considering seeding strategies to provide the necessary rapid establishment and still yield a plant community suited to incorporation within integrated PGR management programs.

Our ultimate goal is to be able to make practical recommendations and give sound counsel to those interested in PGR application, regardless of their management emphasis. In addition to uses on roadside and utility turfs, there is potential for effective application on higher-quality turfs.

RESEARCH RESULTS TO DATE

DOT 1 - PGR Application Timing Study SP82

Embark was applied at 0.193 kilogram of active ingredient per hectare (kg a.i./ha) on four dates (27 April 1982, 10 May 1982, 25 May 1982, and 17 June 1982). This study is located at Highway Site 1, which is predominantly Kentucky bluegrass and fine fescue.

Vertical vegetative growth was measured on several dates. The 25 May 1982 application gave the best overall control. It should be noted that a growth reduction of approximately three centimeters (1-1/4 inches) was statistically significant by our tests. Realizing that the vegetative parts of the grass plants typically fall horizontally once they grow taller than four to five inches, it can be seen that this parameter is meaningless in a roadside situation.

Seedhead height and density become a major concern for roadside managers due to their more upright growth habit. We found fewer and shorter seedheads on the plots treated on 27 April 1982 and 10 May 1982. This is a very noteworthy response, particularly with the finer grass species, whose seedheads and stalks give the area an unkempt appearance.

Grass color was enhanced by the 27 April 1982 and 10 May 1982 treatments. The mechanism of this response is unknown and will be discussed further in another section of this paper. We consider this a positive response because, from a manager's perspective, greener grass is desirable in most situations.

DOT 2 - Roadside PGR Compound Evaluation Study SP82

Chemicals applied were: Embark (0.140 kg a.i./ha), Eptam (6.7 kg a.i./ha), PP-333 (1.7 kg a.i./ha), EL-500 (1.7 kg/ha), Glean (0.14 kg a.i./ha), and Experimental 1. All compounds were applied on 8 May 1982. This study is located at Highway Site 2, which is primarily Kentucky bluegrass and fine fescue with some coarser grasses (e.g., orchardgrass, redtop, tall fescue, and quackgrass) sporadically mixed throughout.

Vertical vegetative growth reduction was observed on several evaluation dates. Nearly all compounds showed statistically significant growth inhibition with 5 to 10 centimeters (2 to 4 inches) less growth than the control. However, a growth reduction of this magnitude in a roadside situation would not be practical.

As in DOT Study 1, seedhead height and density are the most important factors to be considered. Embark application reduced seedhead density by 33 percent; Eptam resulted in a 75 percent density reduction. PP-333 actually increased seedhead density. Fine grass (e.g., bluegrasses and fescues) seedhead height reduction ranged from 10 to 26 centimeters (4 to 10 inches) with Embark, Eptam, PP-333, and EL-500. The responses of the coarser grasses were much more varied and were therefore statistically insignificant. Because of the typically upright growth and visibility of seedheads, the seedhead repression response is a strong point in favor of chemical regulation.

Vegetative color enhancement was also seen in this study. Embark, Eptam, and Experimental 1 gave improved green color.

IDW - Supplementary Bluegrass PGR Study SU82

Embark, El-500, and PP-333 were each applied at two rates; combinations of EL-500 with Embark and PP-333 with Embark were also evaluated. All treatments were applied on 15 July 1982. This study was located at the Hancock Turfgrass Research Center on 'Enmundi' Kentucky bluegrass with regular automatic irrigation.

Clippings were collected and weighed on 12 August 1982, 28 days after treatment. All compounds, rates, and mixtures gave statistically significant responses with 40 to 70 percent less yield by clipping weight. Relative regrowth ratings, 12 days after mowing, showed that all compounds and mixtures were still actively inhibiting plant growth. The PP-333 with Embark combination showed the least regrowth on this date.

On 16 September 1982, 36 days after the first mowing and two months after treatment, final clipping weights were taken from both uncut and previously cut plot areas. Total growth inhibition and regrowth inhibition were evaluated by this method. All but one of the previously uncut plots exhibited statistically significant growth reduction. Clipping weights from the PP-333 with Embark plots showed very significant growth reduction on uncut plot areas for both dates. The final clipping weights taken from the previously cut plots showed that several PGR compounds had affected regrowth but that only the two rates of PP-333 had given statistically significant growth inhibition. The PP-333 with Embark treatments were not significantly different from our check.

Color response was observed but was not significant for all compounds when compared with the control. The PP-333 with Embark combination gave the highest and most consistent color enhancement.

Data analysis from the Kentucky bluegrass study (IDW) has led us to propose one theory to explain this phenomenon. Briefly stated, the theory proposes that the observed response is the result of continued production and storage of phytosynthates in the artificially regulated plant. It is thought that these PGRs work in a way that inhibits cell elongation and/or meristematic activity (growth). However, these chemicals do not appear to affect the photosynthetic process; we therefore surmise that the photosynthetic products are stored by the turfgrass plant, thus giving the color enhancement response. It appears that, as the result of the first mowing, the plant was taken out of its chemically dormant state and resumed active growth. Upon resumption of growth, a rate increase was observed, theoretically resulting from the use of the stored photosynthates. This response is very interesting and will be further investigated next season.

SUMMARY

In summary, here are some factors to consider when initiating a PGR management program for turfgrasses:

1. Soil-active PGRs have a broader window of activity for plant uptake and more predictable responses. Soil variability may alter efficacy.

2. Foliarly active PGRs give less consistent response. Varying weather conditions will alter efficacy.

3. The site must be an area where traffic and wear are minimal.

4. Is control of vegetative growth or seedhead development more important in the management program?

5. Continued PGR application may result in an accumulation of senescent plant tissue, reduced turf density, discoloration, weed encroachment, and increased disease susceptibility. These parameters are affected by the timing of PGR application, the initial vigor of the grass plants themselves, and a variety of soil and moisture factors under which the grasses are surviving. Damage symptoms will not be masked by continued plant growth.

6. If increased weed or disease problems result, will additional chemical controls be acceptable? Will the efficacy of pest control chemicals be changed when PGRs are used?

7. Will a PGR program be cost effective (see Table 1)? How could this affect management options?

8. What grass species should be controlled through the use of PGRs?

9. Is the critical timing of application feasible in the situation?

Table 1. Cost per Hectare of PGR Applications

PGR	Formulation	Rate of Application (kilograms of active ingredient per hectare)	Cost per Hectare as Applied
Embark	2 lb a.i./gal*	0.140	$9.26
Eptam	10G	6.7	$59.28
EL-500	50WP	1.7	not available
PP-333	50WP	1.7	not available
Glean	75DF	0.14	$76.57

*a.i./gal: active ingredient per gallon

TURFGRASS PLANT GROWTH REGULATORS: THEIR BENEFITS, APPLICATION, AND ECONOMICS OF USE IN ROADSIDE MAINTENANCE OPERATIONS

Jeffrey L. Hagman

With the cost of labor, equipment, and fuel continuing to rise, many grounds maintenance budgets have come under close scrutiny. Federal, state, and local government agencies are requesting their roadside and grounds maintenance managers to provide the same overall maintenance with less money, fewer people, or both. The challenge is to reduce current operating costs with minimal adverse effects on the long-term quality and appearance of the roadsides. Contract maintenance and contract mowing have been used in many cases to control rising operating costs, but they require additional people to set up, coordinate, and supervise the contracts.

USE OF PLANT GROWTH REGULATORS

Recently, plant growth regulators (PGRs) have been incorporated into many vegetation maintenance programs. A plant growth regulator is a chemical that modifies plant growth processes without appreciable phytotoxic effects. A PGR will not kill a plant as an herbicide will, but it changes the normal physiological or morphological plant processes and growth. PGRs that are beneficial to some aspect of plant growth have been selected and improved to provide economic benefits.

Grounds maintenance personnel are using PGRs to save mowing dollars so that the money can be reallocated to other vital maintenance activities. In addition, they are finding that overall grounds maintenance productivity can be increased and costs reduced by the proper use of a PGR.

Many more chemical companies are devoting a large portion of their research efforts toward developing plant growth regulators, believing that PGRs represent the future in vegetation management.

The application and use of a PGR is fairly straightforward. Plant growth regulators for turfgrass are ideally suited to areas that are classified as low-maintenance and hard to mow or trim. These areas are typically the most labor intensive, requiring specialized mowing and trimming equipment, and consequently more dangerous for mowing personnel. Included in these areas are highway and utility rights-of-way, roadsides, parks, schools, airports, industrial parks, cemeteries, and golf course roughs.

Some new PGRs are finding additional acceptance for use in reducing the growth rate of woody ornamental species. The repeated pruning and trimming requirements for hedges, ground covers, and some ornamental shrubs can be substantially reduced by spraying a growth regulator. PGRs currently available for commercial use on turfgrass and woody ornamentals are listed in Table 1.

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Table 1. Plant Growth Regulators for Commercial Use on Turfgrass and Woody Ornamental Plants

Product	Manufacturer	Registered Uses	
		Turf	Woody Ornamentals
Atrinal	Hoffman-LaRoche, Inc.		X
Embark	3M	X	X
Maintain	Uniroyal, Inc.	X	X
Royal MH	Uniroyal, Inc.	X	X

A PGR may be applied any time the grass is green and actively growing. The ideal times to apply a PGR are in the early spring or late summer, as these are typically periods of lush vegetative growth. Any pressure spray equipment suitable for spraying herbicides will generally do a good job in applying a PGR. Anyone who can do an acceptable job of spraying herbicides can satisfactorily apply a PGR. Thorough coverage of the plants is important, as the PGR will affect the growth of only those plants whose leaves it touches.

In this day and age, every person must be more concerned and knowledgeable about chemicals and their effects on the environment. Plant growth regulators are registered for use by the Environmental Protection Agency. Prior to being registered and sold, PGRs must undergo extensive toxicological, environmental, and efficacy studies. When used according to their labels, PGRs represent an environmentally acceptable management tool.

DETERMINING COST BENEFITS

In order to determine how a plant growth regulator can be an economic benefit in a grounds maintenance operation, it is essential to know the costs associated with existing grounds maintenance operations, particularly mowing. In a recent survey of 600 grounds maintenance managers and engineers across the country, 63 percent of the respondents agreed that it is very important to know how much it costs to mow per acre. Yet, only 24 percent could actually provide a per-acre mowing cost. This situation is to be expected because, until quite recently, alternatives to mowing roadsides were not available. According to the survey, the average cost to mow was $32.55 per acre on flat, easy-to-mow areas and $55.63 per acre for difficult-to-mow areas.

In addition, the survey showed that there is an opportunity and need to educate grounds maintenance professionals on mowing costs, so they can make a valid comparison on using a PGR to eliminate some of their mowing. Knowledge of existing mowing and other maintenance practices is essential to make a valid comparison with alternative means of controlling plant growth.

A cost-comparison analysis can be made between mechanical mowing versus spraying a plant growth regulator. The factors that should be included in calculating an accurate per-acre mowing cost are:

1. Labor--the hourly wage of the person assigned to do the job

2. Labor burden costs--other labor costs (e.g., employer social security, workmen's compensation, insurance)

3. Travel time--to and from the job site

4. Equipment fixed costs--the purchase price for the mowing and trimming equipment spread over a number of years, operating at a number of hours per year (this will provide an equipment depreciation cost)

5. Equipment operating cost--fuel consumed per hour

6. Equipment maintenance cost--the cost for labor to change oil, grease, and sharpen blades

7. Fuel and vehicle expense--per-mile cost of transporting mowing equipment and personnel to and from job site

8. Parts and supplies--replacement blades, oil, grease, filters

9. Indirect costs--equipment storage, taxes, insurance

Spraying is usually faster, easier, and less expensive than mowing, and it uses less fuel. The costs associated with spraying an acre with a plant growth regulator are:

1. Chemical costs--divide the PGR cost per gallon by the number of acres the gallon will cover.

2. Application cost--if the cost of spraying an acre is not known, assume it is the same as for mowing one acre.

To complete the cost comparison analysis between mowing and spraying a PGR, multiply the cost per acre to mow by the number of times mowed in a typical eight-week period. Compare this figure with the chemical cost of a PGR plus its application cost. In general, a PGR will more than pay for itself by the time it has eliminated the second scheduled mowing. The savings come from the many mowings that are not needed during the eight weeks the PGR is doing its job.

CONCLUSION

By incorporating a growth regulator into roadside maintenance programs, highway maintenance supervisors and managers have been able to upgrade overall maintenance operations by allocating more time and money to other grounds improvements. Use of a PGR breaks down the boredom of routine mowings, and mowing crews are exposed less often to the hazards associated with mowing and trimming. It also gives crews an opportunity to become more valuable in other ways. Plant growth regulators are a new management tool. A highway- or grounds-maintenance professional who can show how to do as good a job on a lower budget is one of the most valuable assets any management can ask for these days. If you have areas that are real problems to mow or if the grass is growing faster than your budget, a plant growth regulator just might be the answer.

BETTER CEMETERY TURF

Thomas W. Fermanian

Many problems in turf management are due simply to poor planning. The lack of preventive disease control in critical areas is a good example. The damage done to a turf site where preventive disease control was not practiced might not be so severe if corrective measures were planned in previous seasons. I want to discuss, in chronological order, some management tools that can help prevent these types of problems; this information is outlined in Table 1. I will begin the season in April, although the absolute timing for any management practice will differ throughout the state of Illinois. The order, however, should remain the same.

Table 1. Turfgrass Management Calendar for Cemetery Turf

Month	Treatment
April	Debris removal, vertical mowing, aerification, and soil testing
May	Preemergence weed control, mowing, application of plant growth regulator, fertilization, irrigation, and cultivation
June	Broadleaf weed control, monitoring for pests, mowing, and fertilization
July/August	Irrigation, mowing, and emergency pest control
September	Overseeding, establishment, cultivation, fertilization, mowing, and irrigation
October	Broadleaf weed control, mowing, and fertilization
November-February	Equipment maintenance; inventory, budgets, and planning for the next season

APRIL

Spring cultivation of compacted soils or thatched areas is most effective when conducted just after the resumption of growth in spring or after the first mowing. Vertical mowing can be utilized in areas of light thatch accumulation or light compaction. The deeper the vertical mowing, the greater the

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need for pest control and irrigation for recovery of the turf. In areas of heavy thatch accumulation or compaction, core aerification is much more effective.

MAY

By mid-May, the turf in most areas of the state has resumed full growth. At this time, a decision needs to be made on where preemergence herbicides and growth regulators will be applied.

Mowing should be started at the normal maintenance height for high-cut, cool-season turfs (1.5 to 2.5 inches). For warm-season or high-maintenance turfs, it would be considerably shorter, generally around 0.5 inch. Cultivation must precede any other practice.

Crabgrass and *Poa annua* are of primary concern in weed control. Both weed species are controlled with the use of a preemergence herbicide. Table 2 lists the life length and the herbicides recommended for the control of these two pests and other common weeds in turf.

After the second mowing of turf in the spring, the first application of fertilizer should be made. While there are 16 or more essential elements for proper nutrition of turfgrasses, there are three major elements of concern in fertilization programs: nitrogen, phosphorus, and potassium. The latter two, phosphorus and potassium, should be applied according to the results of a representative soil test. Samples for this test can be obtained anytime in the spring after the resumption of turf growth. Nitrogen, however, should be applied on a scheduled basis. Table 3 lists the annual nitrogen requirements for Illinois turfgrasses.

Table 3. Annual Nitrogen Requirements for Illinois Turfgrasses

Species	Pounds of Nitrogen per 1,000 Square Feet
Kentucky bluegrasses	
Improved varieties*	4 to 6
Common-type varieties**	2 to 4
Creeping bentgrasses	3 to 6
Fine fescues	1 to 3
Tall fescue	3 to 5
Ryegrass	3 to 4
Zoysiagrass	2 to 4
Bermudagrass	4 to 8

*Includes A-20, A-34, Adelphi, Baron, Bonnieblue, Cheri, Glade, Majestic, Sydsport, Touchdown, and Victa.

**Includes Delta, Kenblue, Park, and Newport.

For optimum results, these totals should be divided into three to four applications. The spring application should generally be no more than 1 to 1.5 pounds of actual nitrogen per 1,000 square feet, and the source should

Table 2. Chemical Control of Weed Grasses in Turf

Weeds	Life Length	Herbicide	Rate (lb. a.i. per acre)	Remarks
Annual bluegrass	annual or perennial	benefin (Balan)	3	Apply in early spring and late summer. Do not use on bentgrass putting greens.
		bensulide (Betasan)	10	Apply in late summer before the return of cool weather to prevent development of new plants. Fairly safe for use on bentgrass putting greens.
		DCPA (Dacthal)	12	Apply in early spring and late summer. Do not use on Cohansey or Toronto bentgrass putting greens.
		endothall (Endothal)	3/4	Apply during warm weather in late summer to Kentucky bluegrass turf. Repeat in two weeks if necessary. After last application, as annual bluegrass turns brown, overseed with desirable grasses or insert plugs of sod into large bare areas to promote rapid healing. Has little or no preemergence activity.
Crabgrass Foxtails	annual	benefin (Balan)	2	Apply before emergence of crabgrass in early spring. Not recommended for use on bentgrass turf.
Barnyardgrass		bensulide (Betasan)	7.5	Apply before emergence of crabgrass in early spring.
		DCPA (Dacthal)	10	Apply before emergence of crabgrass in early spring. May injure bentgrasses and fine-leaf fescues.
		siduron (Tupersan)	12	Apply before emergence of crabgrass in early spring. Use at half the recommended rate in conjunction with seeding Kentucky bluegrass. May injure some bentgrasses and fine-leaf fescues. Do not use on bermudagrass.
		organic arsenicals (DSMA, MSMA, etc.)	follow labels	Apply soon after emergence of crabgrass. Three applications at 7- to 10-day intervals are usually required. May cause some discoloration of the turf.
Goosegrass	annual	DCPA (Dacthal)	15	Goosegrass is harder to control than crabgrass; complete control is rarely achieved. Better control may result if a second application is made at half rate in early June.
		oxadiazon (Ronstar)	3	Apply before emergence of crabgrass in early spring. Do not use on red fescue or bentgrass. Do not apply to wet turf.
		organic arsenicals (DSMA, MSMA, etc.)	follow labels	Apply soon after emergence. Three or more applications at 7- to 10-day intervals may be required for control. May cause some discoloration of the turf.
Bentgrass Nimblewill Tall fescue Quackgrass Bermudagrass	perennial	amitrole dalapon amitrole + dalapon glyphosate	4 10 2 + 5 2	These give nonselective control. Amitrole and dalapon may persist in the soil for up to 4 and 6 weeks, respectively. Overseeding should be delayed until chemical residues have dissipated. Glyphosate has no residual activity in the soil; repeated treatments may be necessary for complete control.
Nutsedge	perennial	bentazon	1	Treat soon after emergence before new nutlets form. Repeat application as necessary for control, up to a total of 3 lb. a.i.per acre per season.

contain at least 50 percent water-insoluble nitrogen. This water-insoluble portion of the fertilizer will help to extend the period of nitrogen release, thus helping extend turf growth farther into the season. A secondary advantage in using slow-release nitrogen sources is that they minimize the accumulation of thatch.

For a quick, short-lived color enhancement, chelated iron or iron sulfate (0.75 to 1 ounce of iron per 1,000 square feet) can be used. The iron in these applications is absorbed through the foliage and is not translocated throughout the plant; the effect is therefore lost after several mowings. So, this color enhancement should only be planned for a short-term, special use of the turf.

This is also the optimum time for the application of a plant growth retardant. I wish to emphasize that turf managers should wait until the turf to which the plant growth regulator is to be applied is at the full green-up state and until they are fully satisfied with the look of the turfgrass stand. There is also a need for both weed and disease control in the areas where plant growth retardants are applied.

JUNE

While mowing and watering should continue, June marks the beginning of strong pest pressures. One important pest or group of pests to be controlled in June is the broadleaf weeds. Optimum weed control will occur in late fall, but a secondary choice is in June or after the first application of fertilizer. Table 4 includes a partial list of weeds found in most turfgrass areas and lists their relative susceptibility to the three broadleaf weed controls commonly used. Both disease and insect pressure will be moderate to high at this time, and daily observation of the entire turfgrass site will be required for discovering any activity from these pests.

JULY AND AUGUST

July and August are probably the hardest months on cool-season turfs, and the major objective of your management program should simply be to carry the stand at its present state through these two months until the resumption of the growing period in the fall. Do not push the turf; just keep it alive and growing at at a reasonable pace. The only practices that should occur in July through August would be emergency pest control, irrigation, and mowing. Be careful in your irrigation practices to encourage deep root systems. For high-cut, full-season turf, such as Kentucky bluegrass, water deeply but infrequently.

SEPTEMBER

September is the best time for overseeding thin turfgrass areas or establishing new areas. Cultivation should precede the overseeding step.

Information on current varieties and species recommendations can be found in the Horticulture Fact Sheet, "Turfgrass Selection for Illinois."

Table 4. Chemical Control of Broadleaf Weeds in Turf

	2,4-D[1]	MCPP[2]	Dicamba[3]	Combination of the three[4]
(S = susceptible; I = intermediate control; R = resistant)				
Black medic	R	I	S	S
Carpetweed	S	I	S	S
Chickweed				
common	R	S-I	S	S
mouse-ear	R	S-I	S	S
Chicory	S	S	S	S
Daisy, oxeye	I	I	I	I
Dandelion	S	S-I	S	S
Dock, curly	I	I-R	S	S
Ground ivy	I-R	I	S-I	S
Hawkweed	S-I	R	S-I	S
Henbit	I	I	S	S
Knotweed	R	I	S	S
Lambsquarters	S	S	S	S
Mallow, roundleaf	I-R	I	S-I	S
Plantain				
broadleaf	S	I-R	R	S
buckhorn	S	I-R	R	S
Purslane	I	R	S	S
Red sorrel	R	R	S	S
Speedwell				
creeping	R	R	R	I
purslane	I	I	I	S
Spurge, prostrate	I-R	I	S-I	S
Thistles	S-I	I	S	I
White clover	I	S	S	S
Wild carrot	S	S-I	S	S
Wild onion	I	R	S-I	S
Woodsorrel, yellow	I	I	I	S
Yarrow	I	I-R	S	S

[1] A basic herbicide for use in combination with one or more of the others for broad-spectrum postemergence control of broadleaf weeds. Standard rate of application is 1 lb./A. Not recommended for use on bentgrass putting greens.

[2] Safe for use on bentgrass putting greens at 1/2 to 1 lb./A. during cool weather periods. Can apply to general turf at 1 lb./A. with 2,4-D.

[3] A very effective herbicide for broadleaf weed control when combined with 2,4-D or as a 3-way combination. Use at 1/4 lb./A. with 2,4-D; use at 1/8 lb./A. with 2,4-D + mecoprop. Do not apply above roots of trees and shrubs.

[4] Premixed combinations of 2,4-D, MCPP, and Dicamba (for example, Trimec and Trexsan) are commercially available.

This fact sheet is available in all extension offices throughout the state or from the author (T. W. Fermanian) at the University of Illinois. Early fall or September is also an excellent time for cultivation of compacted soils or impervious layers; it can be accomplished with a vertical mower or a core aerifier as in the spring. Make sure to precede any pesticide applications with these cultural practices.

Early fall is also the best time for fertilization because a second growth period is beginning. This fertilization can be the heaviest of the year (generally one to two pounds of nitrogen per 1,000 square feet) because of the optimum growth rate of the turf.

OCTOBER

In October or late fall, a final fertilizer application can be made. This late fall fertilization should be applied only to cool-season turfs and in the general amount of one pound of nitrogen per 1,000 square feet. This application should be made just as mowing requirements begin to reduce due to the cooling of air temperatures in the fall. This time is also the best time for application of broadleaf weed controls, as outlined earlier in this paper.

NOVEMBER THROUGH FEBRUARY

The turf season does not end after October, however. November through February are also extremely important months for any turfgrass manager. Equipment maintenance is necessary for any efficient turfgrass facility, so all equipment should be checked and repaired during the off-season. It is also a good time to prepare budgets for the next season and to plan on building inventories necessary for maintaining the turf areas the following year. But probably most important are the plans you make for the next season. It is never too early to begin to plan a strategy for maintaining good turf at your site.

Last, but not least, do not forget the numerous educational opportunities that are provided in the winter months both by the University of Illinois and the Cooperative Extension Service and by many other commercial and educational institutions. Take advantage of this training--it might help you plan for a better season.

MOISTURE MANAGEMENT FOR TURF

William H. Daniel

Proper soil moisture management is necessary for production of good turf. Some questions basic to understanding soil moisture are:

1. What is the use of the turf?

2. What does the grass need?

3. What do roots need?

4. What does soil provide?

5. What does weather provide?

6. What can irrigation accomplish?

7. Why sense soil moisture?

The user needs an accessible area that provides firm, moist, uniform playing conditions. Wet spots, dormant turf, hard ground, or closed courses create problems for management as well as players.

The normal green tissue of grass contains 80 to 88 percent water. Turgid, healthy grass with adequate nutrition and proper care provides good turf ready for use.

Air or oxygen, water, and nutrients are essential to root nurture. Those who have observed the rapid damage created by wet wilt appreciate the necessity of the presence of oxygen for a root to absorb moisture and nutrients. Adequate drainage is vital to root development; however, the lack of available water at the tip of the root causes wilting and death of leaf tissue. Turf managers cringe at the thought of a water shortage. The blessings of irrigation are mixed, but irrigation is vital to maintain today's turf production standards. Maintaining the proper balance of moisture in the soil is a major key to good turf.

Soils provide anchorage for the plants. For athletic turf this becomes a challenge. The extensive use of aerification illustrates the need for air-water exchange; it is a primary method of relieving compaction. The soil in all its variations must provide nutrients for absorption by the roots. The soil must also store and release moisture to roots.

What does climate provide? Large areas of the country share a common experience of extremes in cold and hot temperatures, wind movement, and cloud cover or sunshine. Rainfall can be devastating, especially with the thunderstorm delivery characteristic of the Midwest. Compensating for weather

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extremes presents a challenge. Most turfed areas are equipped with an irrigation system to supplement water as needed.

Although the problems with turfgrass irrigation are legion, much progress has been made. Our irrigation water is available in variable patterns and is controlled by time clocks, by hand, and by guess. We are fortunate that major turf irrigation companies have provided great modern systems.

SOIL SENSING

We know that proper soil moisture is an important factor in producing a consistently good turf cover. The use of soil moisture sensors aids the natural process of plant growth. The soil serves as a reservoir for water storage; the roots have the potential for feeding the plant. Eliminating excess applications of water improves the desired water-air balance.

Soil moisture-sensing technology has made great strides. You can now determine the moisture needs of any given turf area with simple-to-use sensors. The equipment required includes a meter connected to probes placed in desired locations.

The use of the sensor provides the turf manager with confidence; it eliminates the guesswork of when to irrigate. The use of the sensor saves man-hours and eliminates wasted water (which is becoming a valued resource).

My message today is to try a sample installation. Begin on a small scale. Prove that you can maintain desired soil moisture levels. Eventually the individual time clocks may be modified or eliminated. Finally, the wisdom and experience of each of you can be extended by the use of moisture-controlling machines.

AVAILABLE SYSTEMS

One soil moisture-controlling unit is designed with a simple printed circuit with a 24-volt electric supply and a single on-off resistance point, which is set near wilting point. Other printed-circuit controllers are being developed by Water Sentry, Boregman Corporation, 129 Industrial Avenue, Coldwater, Michigan, 49036.

The Irrometer measures soil moisture by the use of porous ceramic cups attached to tubes filled with water. The moisture tension is indicated on a 0-to-100 dial. More than 300,000 have been sold by Irrometer Company, Incorporated, P. O. Box 2424, Riverside, California, 92516.

An electrical conductivity system for soil moisture sensing uses pairs of stainless steel probes spaced in the rootzone 20 inches apart. Multiple pairs are placed vertically 1 to 2 inches and 3 to 4 inches below the surface in the area of active roots. An individual wire connects one probe of each pair to the controller, and a common wire connects the remaining probes to the controller. A protective housing is provided for the 110-volt electric controller. When the soil is wet, the conductivity reading on the dial is adjusted to read 100. A second dial is adjusted for desired dryness before irrigation is automatically activated. Probes and controller are available through Turfgrass Services, Incorporated, 643 N. Sharon Chapel Road, West Lafayette, Indiana, 47906.

THE TEN BASIC ANNUAL FLOWERING PLANTS: THEIR USE AND MAINTENANCE

Barry A. Eisenberg

Annual flowering plants can offer interest and color in large turf areas. The plants are generally easy to install and maintain if some simple procedures are followed. Many problems encountered with annual plants can be avoided by selecting the proper kind of annuals. In this paper, annual plant handling will be discussed and some of the hardier annual plants will be identified.

PLANTING AND MAINTENANCE PROCEDURES

Before you place any annual plant in the soil, you must prepare the planting bed. In order to have adequate moisture-holding capacity, you often need to incorporate organic matter in the soil, such as peat moss, leaf mold, or aged compost. At this time it is a good idea to include a preplant fertilizer at a rate of one pound of actual nitrogen per 1,000 square feet. Plastic mulches can be used to retain moisture, add heat at the beginning of the season, and control weeds. These plastic mulches can be unsightly and must be removed at the end of the season.

Weed control in annual beds can be a problem. Many gardeners do not use herbicides because of the belief that they stunt, discolor, and reduce the vigor of annuals. But, as long as herbicides are used properly and labeled instructions are followed, there should not be a problem. Labeled herbicides for annual beds include Enide, Dacthal, Treflan, Surflan, and Furloe. Again, be sure to follow all labeled instructions.

When you first receive your plants, the following points should be considered. First, most annuals are produced with high nitrogen fertilization, which can make the growth soft and overly succulent. This condition can reduce plant survival. We therefore recommend that you harden off your plants for 7 to 10 days at your location before planting. This time period allows you to leach the soil in addition to acclimating the annuals to your specific environment. Be sure to keep your plants well watered, because most are planted in mixtures of peat moss and soil. Once peat moss dries out, it is extremely difficult to rewet.

When placing plants in flower beds, you should pay close attention to the weather. If it is hot, you should consider planting either in the early morning or the evening when it is cooler. In addition, be sure that the plants are watered as you plant. *Do not* plant a large bed to completion and then water, because the plants you put in the ground first will probably have already wilted. This wilting can reduce plant growth. It is also a good idea to pinch flower buds at this time. A plant has a limited nutrient resource, and these nutrients will go preferentially to the flowers instead of the vegetative growth at this time in the annual's life.

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It is best to plant in mid-May. There is a chance that frost will still occur, but you should not be afraid to take a chance. The earlier plants are planted, generally the better they will do. Of course, plant availability will dictate planting times in several areas.

The first two weeks your plants are in the soil can be critical. For the first 7 to 10 days it may be necessary to mist the foliage several times a day, in addition to thoroughly wetting the soil if it is hot. After that time period, you may stop misting and water as needed. After six weeks, and every six weeks that follow, we recommend applying 0.5 pounds of actual nitrogen per 1,000 square feet, either as a dry or liquid fertilizer. Remember, annual plants should be kept growing at all times in order to achieve the highest quality. Some plants will also need to be pinched in order to achieve adequate lateral branching. Any weeds present should be pulled. Watch out for slugs; they can destroy a crop in days. We recommend using commercial slug baits for their control.

PLANT SELECTION

The selection of your plants can be critical. Everyone wants plants that flower early in the season, but unfortunately there are few annuals that flower early. Pansy and viola plants are probably your best bet, but we recommend bulbs for several reasons. First, their maintenance is minimal, and second, their total effect is outstanding. Bulbs can be used for up to three years. If bulbs are potted into containers, they can be removed easily after flowering when the foliage begins to yellow. Bulbs as well as perennials need to be used to a much greater extent. Bulbs such as daffodils, tulips, and hyacinths should be considered. Bulbs should be planted in large masses for the best effect.

Unfortunately (or fortunately, depending on your point of view), most annuals flower between July and September. Late-flowering annuals include geraniums and marigolds, as well as several others. But for a spectacular display of fall color you should use chrysanthemums. These plants will flower until you get a hard frost. Chrysanthemums are low-maintenance and relatively problem-free plants. The color selection and plant growth habit are extensive.

The following paragraphs will highlight some of the superior annual plants for the Illinois area. This is by no means a complete list, nor do I mean to imply that you should not attempt to use other annuals. Annuals can be grouped into those that will grow and flower in the shade and sun. There are many more annuals tolerant of sun than shade.

Petunias and marigolds are always good sun annuals. They are easy to grow, flower readily, have a wide assortment of colors and forms, as well as being readily available in the industry. Marigolds come in yellows or oranges and can vary in size from six inches to three feet. Petunias normally reach a height of 15 inches and vary in flower form and color.

Salvia and geraniums are two other popular sun annuals. Salvia comes in the familiar red flower color, but there are also blues and whites. They are generally 30 inches tall or shorter. The use of a contrast color plant such as dusty miller, which has gray foliage, will help highlight flower colors. Geraniums can be grown from seeds and cuttings. Seedling geranium flowers are not normally as showy as flowers from cutting varieties, even though they can be more numerous. Seedling geraniums also have a problem with flower shatter, but geranium breeding programs are trying to solve it. The spraying of silver nitrate or other silver compounds on the geranium flowers can help alleviate the shatter problem.

Sun annuals such as snapdragons, phlox, and portulaca are also good selections in some areas. Portulaca flowers readily and is succulent in nature. The flowers do not remain open all day, which could reduce their use. Snapdragons vary in size from ten inches to four feet and come in a wide assortment of colors.

Two sun annuals that should be used more often are tobacco and vinca. The flowering tobacco plant flowers all spring and summer and comes in a variety of colors. The plants are 18 inches tall and are compact growers. Vinca flowers are pink or white; the foliage is extremely glossy. The plants will grow to about 18 inches, and there are new selections whose growth habit is more like a ground cover.

The shade annuals include coleus, impatiens, pansy, and begonia. The wax begonia can be grown in sun or shade, but in hot, windy areas it does better with some shade. Flowers range from white to red. The foliage is glossy and can be light green or reddish depending on the cultivar. Plants will grow about 15 inches tall.

Coleus plants are not grown for their flower but rather for their foliage. The leaf coloration includes greens, yellows, and reds. These plants should be pinched when young to encourage branching. Impatiens, unlike coleus, is grown for flower. The flowers cover the entire plant and are highlighted against their glossy green foliage. Impatiens should not be overfertilized, since they can become overly succulent.

An early-flowering, shade-tolerant annual is the pansy. It is a popular plant because of its flower habit and because it flowers early in the spring. Plants are generally 10 inches tall and can be covered with flowers if proper care is taken.

Regardless of your flower selections, you should practice annual plant rotation. Do not plant the same plants year after year in the same area, because diseases can cause problems. In addition, keep records; they will help you in the future. And by all means, visit annual trial gardens such as the one organized by Mr. Gail Fosler at the University of Illinois in Urbana. At sites like these, you can evaluate hundreds of annual varieties. Contact local greenhouses to see if there are trial gardens around your area.

CONCLUSION

The use of annual plants can add interest and color to an otherwise green landscape. Annuals do create more work, but the benefits vastly outweigh the time they require. Try annuals in one area to begin with and determine if they will work for you.

TREE MAINTENANCE IN DIFFICULT SITES

Gary J. Kling

We depend upon trees in all aspects of our lives. Trees not only provide us with a source of food, fiber, and shelter, but they also are an important source of enrichment and beauty essential to the enjoyment of our lives. We look at trees for their displays of flowers and fruits, their interesting leaf shapes and sometimes spectacular color, and even the texture and boldness of their bark and stems. Golf courses, cemeteries, and parks would be much less interesting without trees.

Although most people live in urban areas, cities contain only a small number of trees in relation to population size. The reason we do not see more trees in urban areas is that cities are difficult places for trees to grow. Heavily trafficked downtown areas do not stand alone in their problems of tree culture. Every golf course, park, and cemetery also has some unfavorable sites for tree growth. Several major causes of tree problems in these high-use areas include: soil compaction, restricted growing area (for both shoot and root), poor water drainage, physical damage to roots from construction, deicing salt, and improper planting techniques.

SOIL COMPACTION

Soil compaction is the greatest enemy of urban trees. Tree roots require a loose, well-aerated soil to allow for root growth and proper gas exchange. Compacted soils do not allow for adequate root growth to support the above-ground portions of the tree. In addition, the reduced aeration of compacted soils restricts the normal functioning of roots for water and mineral uptake. Soil compaction can be caused by large amounts of pedestrian or vehicular traffic over the root system. This problem is common around tee and green areas of golf courses. The problem is intensified during or following a rain or irrigation when the soil is saturated.

How can you tell if your trees are suffering from soil compaction? The condition of the turf beneath the tree is often an indicator of the soil condition. A healthy, dense turf is a good indication that the soil is in reasonably good condition, although poor grass growth may result from shade. The soil under the tree should feel slightly springy as you walk over it. If it feels hard, as if it were paved, the soil is extremely compacted. Soil compaction will slow the growth of these trees, and extended exposure to these conditions will result in branch dieback, thinning of the crown, and increased susceptibility to diseases and insects.

Soil compaction can be measured in the laboratory by determining the bulk density of the soil. Bulk density is expressed in units of grams per cubic centimeter (g/cm^3). The recommended bulk density for fine- and medium-

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textured soils (clays, silts, loams) should have a bulk density of 1.0 to 1.6 g/cm^3. Sandy or coarse-textured soils should have a bulk density of 1.3 to 1.8 g/cm^3.

The best way to handle potential soil compaction problems is to prevent or avoid them. Proper design of facilities should route pedestrian and vehicular traffic to their destinations without endangering the plant material. An occasional fence or plant barrier may be required to direct or reroute traffic in order to distribute the wear. Avoid traffic around the plants when the soil is wet. The use of mulches, especially around new plantings, will allow the root systems of trees and shrubs to become established and grow with a minimum of interference. Careful consideration should be given to selection of plant material for high-use areas. Trees are usually selected for their size, habit, texture, and color; however, it is imperative that consideration be given to site tolerance when selecting trees for high-use areas. This includes their pH and moisture requirements, transplantability, and tolerance of soil compaction. Trees such as *Acer ginnala* (Amur maple), *Acer platanoides* (Norway maple), *Ailanthus altissima* (tree of heaven), *Fraxinus pennsylvanica* (green ash), *Ginkgo biloba* (maidenhair tree), *Gleditsia triacanthos* (honey locust), *Malus* species (flowering crab apples), *Platanus occidentalis* (sycamore), *Populus* species (poplars), *Quercus palustris* (pin oak), *Quercus rubra* (red oak), *Salix* species (willows), *Tilia cordata* (little-leaf linden) and *Ulmus* species (elms) are recommended for sites where soil compaction may be a problem. Not all of these trees may be desirable for your particular site. Some of these trees have other problems such as weak wood, lack of ornamental characteristics, and susceptibility to diseases, which would eliminate them from further consideration. Keep in mind that not one of these species is a "supertree" capable of growing on any site. Proper horticultural practices must be followed if even these trees are to survive.

Correction of existing compaction damage is very difficult. By the time symptoms are noticed on the plant, it is often too late. If the problem is diagnosed in time, several measures can help alleviate the problem. Water and fertilize the plant as required. Aerate the soil around the tree or shrub if possible. Pruning may be required to thin the crown in order to reduce the demand on the root system. Soil additives, such as gypsum and many others advertised as miracle cures, usually do little to correct soil compaction. If all efforts to revitalize the tree fail, it is probably best to remove the tree, correct the problem, and replant.

RESTRICTED GROWING AREA

Restricted growing area is a particularly acute problem in urban areas. As population pressures swell our cities, less space is available for plants. City planning, or the lack of it, has restricted the growing space for both roots and shoots. Adequate growing area is essential to the long-term survival of trees in urban areas. The combination of compacted soils and limited growing areas is a major cause of tree death in our cities. It is not uncommon to see trees that have potential for large size given an open soil space that is less than five feet on a side, with the surrounding area entirely paved. Not even the toughest of trees can survive this kind of treatment. Trees require large amounts of space for water and mineral uptake and proper anchorage. Roots usually do not grow for any great distance under pavement because of poor aeration, compaction, and lack of adequate moisture. Trees should be given an absolute minimum of 25 square feet of open soil surface area. Any increases in the allotted area will help greatly. Doubling the diameter of the soil area increases the available growing space fourfold.

Allowance of insufficient space for the ultimate size of a tree's crown can lead to a number of problems. As the tree crown develops, lack of growing space may result in misshapen forms and an overgrown appearance. The additional pruning required to maintain such trees becomes an increasing problem with corresponding expense. Inadequate space caused by the close proximity of large buildings can result in excessive shading of the crown, resulting in weak, spindly trees. Areas surrounding large buildings also have much higher wind velocities, placing additional stress on trees and shrubs at all times of the year. Allowance of adequate space or the selection of species with medium to small sizes will help a great deal in reducing tree failure and maintenance costs.

WATER DRAINAGE

Problems with water drainage can be caused by a high water table or inadequate provisions for handling surface runoff. Plant roots must have good aeration to allow for uptake of water and minerals and for normal functioning. The low oxygen, high carbon dioxide environment created by flooding can prevent uptake of water. Some tree species will tolerate only one or two weeks of flooding, while other species can survive for several months. Lists of plants that tolerate wet conditions can be obtained from tree maintenance books, nursery personnel, and the University of Illinois Cooperative Extension Service. Installation of drain tile or gravel drains below the planting hole may be beneficial. These drains must extend downslope to an open area to allow for adequate drainage. A few shovels of gravel thrown into the bottom of the planting hole as the only source of "drainage" may actually be worse than no treatment at all. These undrained gravel beds impede the flow of water down through the soil profile; thus the soil above a gravel bed may be wetter than the adjacent soil. All the answers are not known about the best ways to provide planting-hole drainage, and care should be exercised in their usage.

CONSTRUCTION DAMAGE

Construction damage to trees is a common occurrence. Direct injury to the tree can occur when large roots are severed during digging operations. The hole should be closed as soon as possible to prevent drying of the root system. If the hole is left open or if roots must be exposed for more than a few minutes, frequent syringing of the roots with water or covering them with a moist cloth or mulch will help reduce further injury. The loss of roots can be compensated for by a proportional pruning of the crown and watering.

A frequent and often more serious injury resulting from construction is soil compaction. Areas under trees become parking places for heavy construction equipment and piles of building materials. Well-meaning persons often place a barricade around the trunk to prevent injury to the bark but fail to recognize that the entire root system of the tree also requires protection. A barricade surrounding as much of the root system of the tree as possible is desirable. Remember that a large proportion of a tree's roots is in the area of the drip line, but roots may also extend several feet beyond.

DEICING SALT

Urban and roadside trees can be severely damaged by exposure to deicing salt. Although the salt is applied to roadways and sidewalks, most of it eventually ends up in the soil or on plants. High concentrations of salt are toxic to plants; they also break down soil structure, resulting in tight, poorly drained soils. Calcium chloride, often sold as sidewalk deicer, is toxic to plants but is less damaging than the ordinary sodium chloride that is commonly spread on roads. Salt accumulation in the soil causes a slowing of plant growth that often goes unnoticed. Reduced growth is usually accompanied by early fall color and leaf drop. High concentrations of salt or repeated exposures can result in plant death. Runoff salt damage can be avoided by the use of raised planters or barriers around planting holes. Raised planters should be lined with two inches of Styrofoam to prevent cold injury to roots. Salt accumulations in the soil should be flushed out with as much water as possible without flooding the plant.

Salt-spray injury that occurs near roadways can be even more damaging than salt runoff. Exposure to salt sprays can reduce growth or even kill the buds of trees. Death of terminal buds results in excessive branching of deciduous trees, producing a witch's-broom effect. On conifers, the injury appears as a browning of the needle tips that progresses toward the base. Plants exposed to salt sprays should be syringed to remove salt deposits as often as possible. Selection of salt-resistant plants may be required in high-exposure areas.

PLANTING TECHNIQUES

Trees grown in high-use or difficult sites can be given a head start by the use of proper planting techniques. The most important advantage you can give a tree or shrub is to plant it properly. Handle trees and shrubs gently, taking care not to break the soil ball or allow the roots to dry out. The circling roots of container-grown plants should be straightened or cut to encourage growth into the surrounding soil. Failure to do so could result in the death of the tree from girdling roots 10 to 20 years later. A common mistake is to plant a tree too deep. While this may improve the tree anchorage slightly, the long-term damage greatly outweighs the benefits. Trees should be planted at the same depth as in the nursery. Remember that they will settle slightly after planting. Remove all twine from around the trunk, and remove as much burlap as possible without disturbing the soil ball. Papier-mâché pots may take several months to decompose and therefore should be removed. You want to do everything you can to encourage new root growth into the surrounding soil. Any barrier to root growth must be removed for fast establishment. Newly transplanted trees should be mulched, watered, and staked as necessary. The use of a tree wrap or tree guard is also recommended.

PREVENTIVE MAINTENANCE

All landscape plants, regardless of age, should receive periodic inspections to be sure that they are healthy. A walking inspection is probably the best method for spotting problems that may not be evident if your daily movements around the grounds are made in a motorized vehicle. Examine leaves for obvious signs of stress, insect injury, or nutritional deficiencies. Stems should be inspected for signs of insects or diseases. A walk around the tree should reveal if soil compaction is a problem. Measure the shoot growth of your trees to be sure it is normal for that species. Reduced shoot growth can be an early warning signal of developing problems. Check the crown density for signs of crown thinning. Look for a flare at the base of the trunk where it enters the soil. The lack of a flare indicates the presence of girdling roots or a fill made over the root system. Dig down to find the cause. These occasional inspections will keep you on top of developing problems and enable you to take corrective measures before major problems arise. The use of proper selection and planting techniques, combined with preventive maintenance, will allow trees, shrubs, turf, and people to live in harmony.

COMPACTION AND WEAR ON ATHLETIC FIELDS

David J. Wehner

All turfgrass areas receive traffic, but at differing levels of intensity. A home lawn may receive only occasional use by the homeowner, while an athletic field, especially at the high-school level, may be used by several schools for both games and band practice. The heavy use that some fields receive makes it difficult to maintain adequate turf cover.

There are two components of traffic, turfgrass wear and soil compaction. An understanding of the effects of traffic on the turf and underlying soil will help in making the correct decisions regarding the successful management of these fields.

TURFGRASS WEAR

Turfgrass wear can be defined as the direct pressure on the plant that tends to crush the leaves, stems, and crowns. The effect of wear is accentuated by the scuffing or tearing action resulting when an athlete makes cuts or turns while running.

The easiest solution to the wear problem is to use species that are resistant to wear. Research conducted in the 1960s indicated that tall fescue was more wear tolerant than Kentucky bluegrass and perennial ryegrass. Research conducted more recently has tended to contradict these earlier findings. At Michigan State University, a special apparatus was built to study the effects of wear on turfgrass stands. This apparatus consisted of a wheel that revolved around a stationary point such that the wheel followed the same track on the turf. The wheel apparatus was constructed so that only wear and not compaction was applied to the plots. The results of this research indicated that perennial ryegrass was more wear tolerant than tall fescue and Kentucky bluegrass, while the wear tolerance of the latter two species was approximately equal. The investigators felt that the reason tall fescue was more wear tolerant in the earlier studies was that there was an effect due to the environment; that is, the earlier tests were conducted in an area where environmental stress was a problem. Tall fescue, weakened less than Kentucky bluegrass and perennial ryegrass by environmental stress, was more resistant to traffic.

In another study conducted at Michigan State University, researchers looked at the chemical composition of the plants for clues as to why one turfgrass species was more wear resistant than another species. They found that the amount of fiber and cell-wall components in the plant, when expressed on an area basis, showed good correlation with the wear tolerance of the turfgrass species.

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There are several factors that affect the amount of wear that a turfgrass plant can tolerate. The general concept that applies is that the healthier a plant is, the more it can withstand. Specific factors that can reduce wear tolerance are short mowing heights, a nutrient deficiency, shading of the plants, soil moisture stress, and the presence of frost with excessive tissue hydration. The closer a turf is mowed, the less traffic it can withstand, because there is not enough tissue above ground to support weight. When nutrients are deficient, the plant is unable to recover from the impact of the traffic. In a shaded situation, the plant is already weak because there is not enough light for normal growth and the leaves are soft. A deficiency in soil moisture reduces leaf turgidity, which is necessary for a plant to bear weight.

Much damage can be done to turf if it receives traffic before a frost has dissipated. In cold weather, traffic should not be allowed over areas without adequate snow cover or where the ground is not thoroughly frozen.

SOIL COMPACTION

The other component of traffic is soil compaction, which can be defined as the pressing together of soil particles to form a dense mass. An ideal soil contains about 50 percent of its volume as pore space, with half of the pore space holding water. When a soil is compacted, the particles are pushed closer together so that the pore space is eliminated. When the pore space is reduced, there is less volume for water, air, and root growth. A compacted soil also undergoes extremes in temperature variation because heat is conducted more readily. These conditions result in a weaker plant that is more susceptible to environmental stresses as well as diseases and insects. Thatch tends to accumulate faster on compacted soils.

Research conducted at Kansas State University determined the relative tolerance of tall fescue, Kentucky bluegrass, and perennial ryegrass to compaction applied with a smooth roller. The compaction treatments were such that the wear component was minimal. The results of the research indicated that perennial ryegrass and Kentucky bluegrass were more tolerant of compaction than tall fescue. The effect of the compaction treatments was determined by visual evaluation of stand quality and percent cover after treatment application.

The ability of a soil to withstand compaction is influenced by its moisture content. A wet soil is resistant to compaction because the water in the soil pores cannot be compressed. Dry soil is resistant to compaction because the soil particles cannot slide across each other to fill the pore spaces. However, when the soil is at field capacity, it is most susceptible to compaction. At field capacity, there is just enough water present to allow the soil particles to slide together and fill the pore space between them. The presence of a thatch layer can help reduce the susceptibility of the turf to compaction. Of course, the trick is to have just enough thatch to make the turf resilient but not enough thatch to cause other problems.

Once a turfgrass area becomes compacted, steps must be taken to allow the turfgrass growth rate to return to its normal level. The most common way to alleviate compaction is to core aerify the area. Core aerification consists of removing a plug of soil so that new pores are created. On most turfgrass areas, the soil should be separated from the plugs by vertical mowing or dragging and then the debris picked up. On putting greens, where the existing soil may be poor, the plugs can be removed and a high-quality topdressing worked into the holes. The effects of aerification can be quite striking, especially when the turf comes under drought stress. Evidence of this was demonstrated on soil modification plots at Pennsylvania State University. The plot area that had been aerified remained greener for a longer period after irrigation was discontinued.

The other approach in dealing with soil compaction is to design a system that will help prevent the problem, which can be done through soil modification. Soil modification is the addition of a coarse-textured soil amendment, usually sand, into a soil to help resist compaction. This subject is covered by W. H. Daniel in "Rootzone Systems for Natural Turf" in these proceedings.

CONCLUSION

The astute turfgrass manager should understand the factors affecting the amount of traffic a turf can withstand. By designing his maintenance program to produce a healthy stand and avoiding some of the conditions promoting traffic injury, the manager can provide a high-quality athletic field.

ROOTZONE SYSTEMS FOR NATURAL TURF

William H. Daniel and Raymond P. Freeborg

Everyone agrees that a good natural turf is the ideal playing surface, but how can it be achieved? How can mud and the ensuing maintenance problems be eliminated? How can the precise turf conditions of proper moisture content and desired temperature be maintained?

Four options for rootzone construction are described in this paper. The choice will depend on a variety of factors: intended use, extent of use, existing facilities, and budget, for example.

OPTION 1 - PRESCRIPTION ATHLETIC TURF (PAT)

The Prescription Athletic Turf (PAT) system provides a flat, natural surface that offers maximum control of soil moisture, allowing for removal, conservation, and addition of water. The PAT-system field is engineered to offer the manager options for counteracting the extremes of wear and weather.

The removal of excess water is simple. Should it rain, turn on the suction pump, before or during a game, to pull the surplus rain away from the surface to avoid mud and to maintain firm, playable turf. The system is designed with a uniform pattern of slitted drains attached to collectors that extend to the pump in the control center. This design provides a stable playing surface and favors increased use. The chances of having a wet, torn turf surface are minimized.

For maximum water conservation, a continuous plastic barrier is placed over the smooth, flat subgrade and up the outer edge. This prevents loss of moisture to the subgrade, thus conserving maximum rainfall and nutrients. Only excess rainfall is eliminated through the adjustable outflow control. The need for irrigation is minimized.

The addition of required irrigation is achieved automatically. Pairs of soil moisture sensors implanted near the turf roots and connected to an adjustable controller indicate soil moisture content and needs. An electrically controlled valve permits subirrigation by watering back through the drain tubes, regardless of prevailing wind or use of the field. Surface irrigation can also be automatically controlled, provided the common wire for the valves is connected to the controller. The end result is simplified management, minimum labor, and healthier turf with deep roots.

Between the turf and the plastic barrier is a bed of compacted sand, which holds moisture at low tension and diffuses the applied suction uniformly. The flat turf surface provides coaches, players, and spectators the best possible view of all the action of football, soccer, or other sport.

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Baseball infields can be constructed to include concentrated suction to improve drainage. Then, when it rains, covers will be necessary only for the dense clay areas of pitching mound and home plate. The center field for professional football (where most play occurs) can be provided increased suction for maximum effectiveness.

Experience in building PAT fields indicates that installation requires approximately one month. A seeded field requires an additional two months for development, and an additional month's establishment of roots is desirable for sodded fields.

The PAT system is most beneficial in climates with heavy or extended rain during portions of the playing season. In drier climates, however, fields need the water conservation features most. The need for wise use of water resources continues to grow.

Three professional stadiums operating PAT systems are Kennedy Stadium in Washington, D.C.; Mile High Stadium in Denver, Colorado; and the Orange Bowl in Miami, Florida. Five universities and four high schools now use the PAT system.

The system is patented to assure that its identity and quality are maintained (USA 3908, 385 30 SE 75, and Canadian 985, 516 16 MR 76). Licensees for planning and installing the PAT system are located across the United States. Turfgrass Services, Incorporated, 643 N. Sharon Chapel Road, West Lafayette, Indiana 47906, provides the franchises and selected licensees. A two-year advisory service is provided following installation to assure maximum use of facilities and the best turf possible.

OPTION 2 - THE SAND-BED METHOD

The sand-bed method uses dune, river bed, or pit sands. The use of sand provides for faster water penetration; avoid silt and clay.

Procedures for building a sand-bed field are:

1. Shape subgrade (soil) to a one percent slope at a depth of four to six inches below final grade.

2. Cut trenches three inches wide, 10 to 20 feet apart, and 4 to 12 inches deep into the subgrade.

3. Place narrow, slitted drains (two-inch-diameter Turfflow drain tubes or equivalent in trenches).

4. Install an automatic irrigation system throughout the field (use some of same trenches).

5. Spread a blanket of sand four to six inches thick, filling the drain trenches.

6. Spread one to two inches of peat, bark, sawdust, manures, etc.

7. Spread fertilizer containing a slow-release nitrogen.

8. Mix peat and fertilizer from steps six and seven into the upper half of the sand (to hold nutrients and moisture at the surface).

9. Grade to a final contour, roll to compact.

10. Seed the field or lay sod grown on sandy soil.

The system is designed to assure fast water penetration even with compaction. The crown of the field may be only 6 to 10 inches high, and excess rainwater can more easily move into the sand mix and subdrains. Irrigation should be automatic, for sands tend to be droughty.

Research of sand rootzones by Bjorne Langvad of Sweden during the 1960s; by D. Bingaman, D. Ralson, and W. H. Daniel from 1966 to 1971; and by W. B. Davis and others in California during the 1970s shows that good turf, when properly maintained, provides good wear.

Many Scandinavian soccer fields have been built using these principles. In Oregon, California, and New Jersey, a 12-inch-deep sand bed has been used with the addition of no soil.

The Purr-Wick system (Plastic Under Reservoir Rootzone with Wick Action) involves a moisture barrier under a deep sand bed that provides a system of water conservation, a flat playing surface, and increased wear tolerance.

OPTION 3 - ADDING SAND TO SOIL

Improvement of many older athletic fields has been achieved by mixing sand, one to six inches, and peat into the surface. Improvement can be significant only when the sand predominates (usually above 80 percent). Ample sand, uniform mixing, and aerifying annually will improve playability.

Limitations of the system are evident when it rains; mud can still be a problem. Under some circumstances, such a mixture may loosen, provide less traction, and create an uneven surface as the turf wears.

OPTION 4 - NATURAL EXISTING SOIL

In previous times, a good topsoil managed as farmland was the practical approach to building athletic surfaces. Simplicity was the rationale, and economical construction was the objective. Schools tended to choose a natural local soil, generally a mixture of clay, silt, and sands. After the track, stands, and other features were completed, the field was crowned, tilled, fertilized, and seeded. Such fields may look good before the season, but a rainy season can be disastrous!

Agricultural tile drainage backfilled with soil is obsolete. Avoid architectural specifications that call for conventional tile. Standard drainage is ineffective for the quick removal of water necessary for athletic playing surfaces.

Vertical trenching can provide faster drainage and is a low-cost way to remove excess surface water; it has been used to improve wet areas in fairways and playgrounds. Procedures for vertical trenching are:

1. Shape new area to final grade.

2. Cut vertical trenches approximately 15 feet apart and no more than three inches wide. Trenches can be long parallel runs. Each trench should be level or slightly sloped.

3. Place narrow slitted drain tubes in bottoms of trenches (Turfflow drain tubes or equivalent).

4. Backfill with washed sand until it overflows; the sand must extend to the final surface.

5. Remove or use the soil from the trenches to level nearby areas.

6. Keep sand free of any soil cover during planting.

Continue to add trenches until the drainage is adequate for the area. If the surfaces of the vertical trenches become covered, reestablish vertical drainage by slitting the surface of the trench and adding sand as needed.

ADDITIONAL CONSIDERATIONS

Points to consider in the selection or construction of athletic turf rootzones:

1. *Compaction.* Athletic use of an area and the use of maintenance equipment cause compaction of rootzones in which soil predominates. The finer particles of clay and silt are pushed and bound together. When dry, the soil becomes excessively hard, causing injuries to players. Repeated aerification or cultivation will be needed to counteract compaction.

2. *Mud.* The closely packed clay and silt restrict air movement and water penetration. The water remains on the surface, creating mud. The field is damaged for the season following a muddy game. Reworking, reseeding, and repair are required to produce desirable playing conditions.

3. *Purpose.* Natural (muddy) soil is difficult to use for physical education activity. Damage to equipment, uniforms, and buildings is an added burden. Because of such problems, many fields are reserved for prime events and are not used to the maximum extent.

SUMMARY

A football player runs, turns, stops, twists, pushes, slips, falls, slides, and rolls. It is estimated that half the players fall to the ground during an average play (approximately 1,600 falls per game). The surface should be firm for running, but it should provide give for falling.

Equally important is the proper traction needed for desired muscle response. It has been determined that the turf should provide enough support to restrict the foot movement to less than a half-inch downward and a half-inch sideways in any normal action.

Trainers are keenly concerned about ankle and knee injuries. Shorter cleats on the athlete's shoe are recommended for natural turf and tend to reduce such injuries. Player safety is all-important. A good turf surface provides a prime safety factor.

MAINTENANCE OF ARTIFICIAL AND NATURAL PLAYING FIELDS

George P. Toma

Whenever I have the opportunity to speak to a group of athletic field turf managers, I look across the room and wish there could be two or three times the number of people here. For this reason, it would be nice if two or more members of your organizations came along. I would like to see our stadium managers, the heads of parks and recreations departments, and even the owners of amateur and professional teams at all of these turf meetings. If we could get these people to come along for a day, it would be worthwhile for all of us concerned with the care and management of athletic fields. Many times our turf programs have to start with these people.

I believe that there is often a communication gap among all of us in our organizations when we propose to improve our playing fields. Those higher up in command would get a better idea of the problems involved in improving our playing conditions if they attended these meetings. We could show them ways of saving money and demonstrate that a few more dollars could sometimes give them a playing field that is superior to artificial turf.

The only time many of our supervisors become concerned about our playing fields is when it rains or when the grass does not look good. They become really concerned when it is raining, especially when a double header is scheduled with a near sell-out. The field is saturated and they become very jumpy. They wish to do everything possible then--even bring in helicopters at $100 or more per hour to dry the field. The next day the sun comes out, and everything is forgotten until it rains again for a big game. We can never get them down to brass tacks to remedy the situation. Bringing in helicopters at a vast expense is not the answer; the answer is to get them thinking. If we could get them to understand our soil, turf, and equipment problems, then we could start on our maintenance programs.

Money may be available for a helicopter but not for some type of drainage or the purchase of an aerifier to eliminate the problems of a wet, compacted playing field. I know what some of you go through, because groundskeepers are dedicated professionals. Without the proper equipment, our job is really tough; but you can still have a respectable field on a very low budget.

In Kansas City, our former playing field of natural grass was the envy of every baseball, football, and soccer team. We operated on a limited budget with poor soil conditions; there was no tile drainage except for the natural sloping surface drainage; we lacked the necessary turf maintenance equipment; and we had no automatic irrigation system. Working under these conditions, we still maintained a field that was used by baseball, soccer, football, and other events--and the thrill of all of this was that we had no complaints from the players. We had only one knee injury in nine years, and it was a nonsurgical one. Foreign soccer players stated that we had the second-best

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soccer field in the world--only one in England was better. Despite these all-around poor conditions and having three sports played on one field, the natural grass survived, giving the athletes a field they enjoyed playing on and the fans a beautiful sight.

In August of 1972 we opened our new Arrowhead Stadium, home of the Kansas City Chiefs, with an artificial surface of 3M Tartan Turf. In April of 1973 we opened our new Royals' Stadium, home of the Kansas City Royals, with the same Tartan Turf. I have worked with artificial turf since 1967 on a limited basis, so working our two new stadiums with artificial turf did not hit me all at once. I have worked on three artificial turfs: Poly Turf by U. S. Biltrite, Astroturf by Monsanto, and Tartan Turf by 3M. The only one of those still available is Astroturf, and there are new ones called Super Turf and All Pro Turf.

The transition from natural to artificial turf for my employees was minor; maintaining natural grass has taught us how to maintain artificial turf. I have found in my travels that if you have a good natural grass field and switch to artificial turf, you will have a good artificial turf field--if the installation is good. If you have a poor natural grass field, you can bet that you will find that the artificial turf will also be poor. I do not see a vast difference in maintaining both types of fields. They are about even in advantages and disadvantages, but natural grass that is well maintained provides a much better playing surface for the players, with fewer complaints and injuries.

In Kansas City, our old natural grass field cost between $15,000 and $20,000. In comparison, our new Tartan Turf fields cost around $1,200,000. Our field at Arrowhead Stadium is now eleven years old and still looks good on top; but the padding is coming loose from the asphalt base, and we are due for a change.

Our baseball field was replaced two years ago, after two years' use, because of poor installation and inferior turf. 3M dropped Tartan Turf in 1974. Our warranty was for five years, so they replaced the surface of the entire field at their cost. This time, their turf and workmanship were much better. The padding, however, was not replaced--the situation may be compared to putting shingles over a rotted two-by-four. The field will probably last only two more years.

It takes the same number of people to maintain artificial turf as to maintain natural grass. In maintaining our natural grass field, we had equipment worth $3,000, as compared to nearly $40,000 for artificial turf. We had one Toro professional mower, one Jacobsen Estate mower, and one three-gang roller and pin spiker. For maintaining artificial turf, we use two $4,000 vacuums; if we do not vacuum, we lose our warranty. It costs us $2,000 a year for vacuum brushes and bags. We use a $5,000 tractor to pull the vacuum sweeper and a $10,000 35-horsepower tractor to pull a $12,500 water removal machine (of which we have three). The self-propelled water removal machine costs $37,000. We have a $3,000 air compressor to blow the dirt out of the turf around the bases, plus hand and wet vacuum machines. One can see that it takes some equipment to maintain artificial turf at professional standards.

One advantage of artificial turf is that it gives the employees a little more sleep. Work begins at 10:30 AM; with natural grass, we had to start at 7:00 AM to remove the tarp so that it would not burn the grass when the sun came out. At 10:30 AM, we remove the vinyl-coated nylon field cover, which is 160 feet square. The cover is placed on the infield each and every night after the game. This is a little more difficult than with natural grass, since we cannot drive large bridge spikes into the turf to prevent the winds from blowing the cover away. Instead, we use a vast number of sandbags. The field cover is used to keep the sliding pits (dirt around the bases) from becoming mud and to keep the artificial turf dry so that the balls will not skip. Ground balls on wet artificial turf have the tendency to skip rather than bounce.

Instead of mowing the turf, the field is now vacuumed. The amount of time required for vacuuming is double or even triple that for mowing, as one must creep along to get the dirt out of the turf. Daily the men walk the entire field with a special ammonia solution to wash out tobacco juice stains. With a special paintbrush comb, they comb out burns (fused turf blades caused by players' shoes when they stop and start suddenly). They also carry a special aerosol can of gum freeze with which they freeze gum melted into the turf; then they comb out the gum with special combs. Daily, or as needed, a special pipe hose connection on an air compressor is used to blow the dirt out of a 12-inch band of turf around the sliding pits; the dirt is then hand vacuumed.

There is no drainage system on artificial turf, except for the drains along the playing field walls. After a rain, we must take the water-removal machine and remove the excess water. The roller-squeegee machine takes around one hour, but this type of machine is very harmful to the padded base. The water-vacuum machine takes four to eight hours. After the excess water is removed, plenty of sun and wind are needed to dry the artificial fibers.

Before a game, it takes a few more workers to get the field ready after the allotted practice time of 15 minutes. They vacuum the infield sideline area, use push brooms to sweep the dirt off the turf around the sliding pit areas, and remove gum.

Our men's daily bonus for working on artificial turf is working both bull-pen areas, which are 24 feet by 80 feet of zoysiagrass on a Purr-Wick System sand base laid over $65,000 worth of artificial turf. Here, they can breathe again on a hot day, when turf temperature can range between 120° and 140° F.

To maintain a good artificial turf field, one must have a good maintenance program. A very, very important factor is that one must not wear out the turf through too much maintenance.

An advantage of artificial turf is that it can withstand more extra events than can natural grass. But, as playing conditions go, a well-maintained natural grass field is much better than artificial turf. Ninety-nine percent of the players dislike artificial turf, especially on hot days when the surface temperature can hover around 130° to 140° F. Players playing on artificial turf all year complain that their legs get tired in late August.

During hot day games in Kansas City, players place their feet in ice-filled boxes when they come into the dugout between innings.

Multipurpose stadiums have a conversion system to cover up the dirt area for football. This is time-consuming, and it is a tough job to get everything to line up. There are often humps that cause players to slip and fall. In the past, we would have to convert the dirt areas on our natural grass field to grass for football. We had good results with two methods: the seeding method and the sodding method. Dick Erickson, groundskeeper for the Minnesota Vikings and Twins, used these methods with great success with the help of Dr. James Watson of Toro.

With the seeding method, we would pregerminate ryegrass by placing the seed in 55-gallon barrels. The barrels had nail holes on the bottoms with wooden pegs for letting the water out. The seed would soak for 72 hours, and water was replaced twice daily. On the Friday before the last Sunday baseball game, the seed would be dumped on a concrete floor to dry. On Saturday we would mix the seed with Milorganite or perlite to facilitate the handling, and it would be ready to seed on Sunday. To prepare the soil of the dirt infield, baselines, mound, and home plate, we would scarify lightly with a homemade nail drag in order to retain the firmness and even footing from the baseball infield. One must seed between 40 and 60 pounds per 1,000 square feet. The seed would be put down after the game on Sunday, using a nail drag or a rake to rake it in lightly, followed by a light rolling and a good soaking. It would then be kept moist, not saturated. On Tuesday, we would top-dress the area lightly if needed. To hasten the germination and growth, one can cover the area with polyethylene; this proved worthwhile for the 1973 Super Bowl Game in the Los Angeles Coliseum when the field was moved 20 yards to an area without grass. On Friday or Saturday, we would use a full-roller greens mower and mow at one inch. Results were always great. We had the green color that we needed and the footing that came from the firmness left over from the dirt playing surface for baseball.

If you sod an area like this or any part of a football field during the season, it is ready for use as soon as you remove your equipment. Usually sod growers cut their sod for delivery 18 inches by 72 inches, with a half-inch of soil, which is fine when you have a month to go and the grass has a chance to knit. But when you have an hour or a day, it will not work. It will work if you have the sod grower cut the sod 18 inches by 36 inches with 1-1/2 to 2 inches of soil. I have sodded in this manner and never had a piece come up. A number of years ago, in the Orange Bowl, we sodded areas of the center of the field on Thursday and Friday and played the Super Bowl Game on Sunday with no problems. Last year, at Candlestick Park in San Francisco, this method was used for the N.F.L.-N.F.C.D.N. play-off games.

At Arrowhead Stadium, home of the Kansas City Chiefs, we have had our Tartan Turf field for eleven years. The team practiced daily on Tartan Turf and ran their tackling sleds over it for three years. There seemed to be many leg injuries, and they healed slowly. Three years ago, we built a natural grass practice field, and they now do all their practicing on that field. At times, I wish they would do some practicing on the artificial turf and give the natural grass a rest, but they prefer the natural grass.

On an artificial turf field, one does not replace divots after a game. Instead of walking every five-yard lane with pregerminated seed and soil mix, the workers carry a bucket with ammonia solution, a paintbrush comb, and an aerosol can of gum freeze. They remove shoe polish, turf burns, and gum. Some of the turf burns can be as much as six feet long. Depending on how hard the game was played, it could take four people eight hours to get the burns, stains, gum, and shoe polish off the field after an average game.

Cigarette burns are a major problem. There should be no smoking on artificial turf, because the hot ashes and butts will melt an area about the size of a dime. A year ago, we had a visiting coach and team doctor who both smoked. Between them, they put 28 burns on the sidelines.

The cost of decorating a football field of artificial surface is 75 percent more than for natural grass. It costs an average of $500 for paint alone to paint the six-foot white border. Sometimes it must be done for each game.

One square yard of natural turf resodding may take only minutes, but one square yard of artificial turf replacement may take a day.

An advantage of artificial turf is that it can be used for rock concerts. Rock concerts bring in big paychecks to the stadiums, but they are big headaches for the groundskeepers. A lot of hard work goes into preparing a field for rock concerts. We use two different methods.

In Royals' Stadium, we first cover the artificial turf with polyethylene, then lay 1300 to 3000 sheets of Homasote board (4 feet by 8 feet by 1/2 inch). We then cover the board with polyethylene and finally a heavy 18-ounce nylon cover. Around the stage area, we use 800 sheets of plywood (4 feet by 8 feet by 3/4 inch) for forklift traffic. One can see the work and the expense involved to protect the turf from fires, soft drinks, alcoholic drinks, knife cuts, and many other things.

In Arrowhead Stadium, we use a nylon tarp cover followed by 1000 to 2100 sheets of plywood (4 feet by 8 feet by 3/4 inch) for a roadway and stage area. We cover the field with a special aluminum-fiber glass-vinyl canvas cover. A cover for a football field for rock concert protection costs between $40,000 and $60,000. After six uses, it must be replaced. The filth left on a field after a rock concert is unbelievable!

Our crew, whose ages are between 16 and 22 years, works on many grasses. They work on artificial grass, the zoysiagrass bull pens, and our landscaped islands, which are a blend of 'Merion', 'Windsor', and 'Fylking'. Our practice field is a mix of Kentucky bluegrass cultivars 'A-34', 'Baron', 'Ram', 'Merit', 'Vantage', plus ryegrass cultivars of 'Pennfine', 'Yorktown', 'Elka', 'Regal', and 'Derby'. Our summer practice field, which is used by 100 players for four hours daily, is 'Midiron'.

Professional sports, such as baseball, football, and soccer, and a variety of other events are held today in what we call multipurpose stadiums, which were built to house all these events for the sports fans of America. The primary users of these stadiums are usually professional teams. The players are the best men available. These men are professionals. Their employers have invested millions of dollars in them. These athletes have the best doctors, coaches, and equipment. Stadium playing-field walls are padded for their protection. Usually, everything is done to prevent injury to these valuable players in order to protect the clubs' investments and to have a first-class performance.

The playing field sometimes gives us a different picture. Home and visiting players become aware of a poor playing field, and they become wary. When players make such remarks as "what a rock pile (or sand pit, or pavement)...an obstacle course," it is a safe bet that the playing of the game will be second-rate. Good natural or artificial turf is necessary to give these athletes the best possible conditions on which to perform and to help protect them from injury. This is where we, the groundskeepers, come in. Are we professionals in our field as are the athletes in theirs? Are we trying to give the players the best playing field on which to perform, the fans a field of beauty, and the management a sound and reasonable operation?

These questions should be answered by the condition of the playing field. It is our job to grow good turf or to maintain a good artificial turf.

LOW-VOLUME LAWN SPRAYING

Thomas F. Jessen

If you subscribe to *Lawn Care Industry* magazine, you have read the many articles concerning fuel costs. There have been at least five or six within the last year, with various suggestions: keep your tires properly inflated, schedule your routes to minimize extra miles, switch to propane, or switch to diesel. It seems that everyone in the lawn-care industry has been trying for years to come up with a method that will enable them to economically haul around tons and tons--of what? Not fertilizer certainly! Tons and tons of water. They have all been starting the search for lower costs beginning with the false assumption that the only way to spray lawns is to dilute the fertilizer with four to five or more parts of water. It has been a fruitless search--indeed, an impossible search--because, no matter from what source of energy (gas, diesel, or propane) or how efficient an engine is, its mileage is inversely related to the weight carried. The more weight an engine carries, the less its mileage. But the reverse is also true--the less weight carried, the greater the mileage. That is why using less water is the only way to a significant reduction in high fuel costs; and, as we will see, low-volume spraying is also the answer to high capital equipment costs as well.

Low-volume spraying (LV) is a technique of applying lawn fertilizer and pesticides using less water in the spray solution. While most companies spray three to five or more gallons of solution per 1,000 square feet, LV spraying uses a rate of one gallon or less per 1,000 square feet. The first thought that comes to mind is that it will burn the lawn. When I first heard about LV, I thought the same. But at least one company has been spraying with *less* than one gallon per 1,000 square feet for about 15 years. The obvious success of that company convinced me to try LV.

RATES AND TYPES OF FERTILIZER

When our first trucks rolled last spring with a 10-2-4 LV solution, spraying one pound of urea nitrogen along with phosphorus, muriate potash, and Presan per gallon, I confess I was nervous. I sat by the phone waiting for all the burn complaints to flood the switchboard. Days passed, then weeks, and there were no complaints. During Round 2 the temperatures were on the rise, and I was spraying a 7.5-1.5-2 solution with 3/4 pound urea nitrogen, potassium sulfate, 2,4-D, and MCPP. During Round 3 the temperatures were consistently in the 80° to 90° F. range, and we were in the middle of a drought stress period. I began including Formolene to supply half of the nitrogen in the spray solution to formulate an analysis of 5-1-1. Still we received no burn complaints.

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RELIABILITY AND SAFETY

After 8,000 applications and no serious problems arising from LV, I was more than confident--I was convinced. LV is just as reliable and safe as the three-gallon-per-1,000-square-foot technique that I had used for the last eight years. Certainly, I am not going to claim that my company never burned a lawn this season. I expect that few, if any, of us in lawn spraying could make that statement. I do claim that, in comparison with the previous eight years of high-volume (HV) spraying, there was no increase in the number of burned lawns. In fact, I believe there were actually fewer cases of burn than in the season before. Of the small number of burns, most were very minor tip burn resulting from applicator error in trimming too heavily, or occurring when we used the muriate potash. As well as being safe, LV offers the advantage of superior weed control. I have been getting great results using only 2,4-D and MCPP; I have even twisted violets.

Why has there been no increase in burning? Maybe the answer lies somewhere in the fact that, in an application to 1,000 square feet, both HV and LV solutions contain the same amount of active ingredients. The only difference is that HV has more water. If we look at what happens to both HV and LV solutions after an application, we realize that in about 15 minutes (depending on the temperature and humidity) all the water has evaporated, leaving only the concentrated material behind. This residue, whether from HV or LV, will contain the same ratios of nitrogen, phosphorus, and potassium once the water is gone. Most important, the molecules of residue left from LV will be in contact with less leaf area, because with LV we do not saturate the lawn. Also, LV dries more quickly because there is less water. In both methods a percentage of the material drips off the leaves.

The reason why LV does not burn is not as important as the fact that LV has been shown to be as safe as HV in thousands of actual production applications.

I appreciate your skepticism. But, if we keep open minds and explore this new world of LV, we will discover some of LV's truly fantastic benefits for your company.

LV SPRAY EQUIPMENT

The LV concept allows the redesign of spray equipment. In LV spraying, the spray pattern stays virtually the same as for HV, so our applicators and customers can easily accept the change. Modified ChemLawn nozzles, smaller tee jets, or flood jets can be used. Rapid production rates of 1,500 square feet per minute are possible. In LV terms, that is only 1.5 gallons per minute (gpm). It requires less than 20 pounds of pressure to deliver 1.5 gpm through 300 feet of half-inch inside-diameter hose. With such low volume and pressure, a 12-volt electric pump can be used. It operates on the truck battery. A pressure-limit switch shuts the pump off when the gun is shut off and on when the trigger is pulled, so the battery will not wear down. Since the truck is not running while spraying, it takes no fossil fuel to deliver the spray, and there is virtually no noise. Twelve-volt mechanical agitation is needed. Any spray truck has to have the capacity to do a good day's work--a minimum of 150,000 to 200,000 square feet per fill-up. With LV, that is only 150 to 200 gallons.

The LV system is so lightweight and compact that it can mount on a minipickup truck that gets 18 to 24 miles per gallon. Minitrucks are economical to operate, and they easily service distant accounts. Minitrucks maneuver like cats through the most congested city streets and traffic. Applicators practically never have to search for parking places. The smaller trucks take up less room, so more spray units can fit into existing warehouse space. A minipickup does the work of a two-ton truck, and a 3/4-ton pickup becomes a two-man rig.

OPERATING COSTS OF LV VERSUS HV

Table 1 compares estimated operating costs based on 10,000 miles of driving per season, power takeoff (PTO) fuel consumption for 900 hours of pump time, maintenance, and fertilizer and gasoline fill-up time. I used International Harvester's mileage estimates of 4.78 and 8.47 miles per gallon for two-ton gas and diesel trucks, respectively. The estimates for mileage, maintenance, and fuel fill-up time appeared in an article in the September 1981 issue of *Lawn Care Industry*. The estimates for the minipickup are based on my own experience. The other component of fuel cost is the fuel needed to drive the pump. I used ChemLawn's estimate of 1.4 gallons per hour of PTO operation as given in another article in *Lawn Care Industry*. The operating cost per season for a 2-ton pickup is $5243.00 (with about $1500 just to run the PTO). The 2-ton diesel operating cost is $2877.25. The operating expenses for the minipickup, which has zero hours of PTO time (remember the battery-operated pump), are merely $1410.50.

VEHICLE AND EQUIPMENT PURCHASE COSTS FOR LV AND HV

Table 2 contains a comparison of the purchase costs for vehicle and equipment for HV and LV spraying. The HV spray equipment estimate is from a well-known manufacturer and includes a 1,250-gallon, split-compartment, mild-steel tank. The truck prices are from local dealers. These figures were determined by asking each vendor to give me their best estimate for price, terms, and interest rates.

The 2-ton diesel truck sold for $21,238.74, equipment listed for $7,920.00, totalling $29,158.74. The 2-ton gas truck and equipment cost $22,923.04. The LV truck and equipment sold for $11,377.92. It costs $11,000 to $18,000 less to field the LV rig.

TOTAL FIRST-YEAR COST COMPARISON

First-year costs include down payments, 12 monthly payments for truck and equipment, and operating costs for one year.

Table 1. Estimated Operating Expense Comparison

	Minipickup (Datsun)	2-Ton Gas Pickup (International Harvester 1724)	2-Ton Diesel Pickup (International Harvester 1754)
Miles/Year	10,000	10,000	10,000
÷ Miles/Gallon	18	4.78	8.47
= Gallons/Year	556	2,092	1,181
x Cost/Gallon	$1.25	$1.25	$1.25
= Fuel Cost per Year	$695.00	$2,615.00	$1,476.15
Production Days	150	150	150
x Hours/Day	6	6	6
= Hours/Year	900	900	900
x Gallons/Hour	0	1.4	0.7
= Gallons/Year	0	1260	630
x Cost/Gallon	$1.25	$1.25	$1.25
= PTO Time (1300 RPM) Cost/Year	$0.00	$1,575.00	$787.50
Miles/Year	10,000	10,000	10,000
x Cost/Mile	$.0528	$.0528	$.0201
= Maintenance/Year	$528.00	$528.00	$201.00
Gallons	200	1200	1200
÷ Gallons/Minute	60	60	60
= Hours/Fill	1/12	1/3	1/3
x Fills/Year	150	150	150
= Hours/Year	12.5	50	50
x Cost/Hour	$6.00	$6.00	$6.00
= Fertilizer Fill Cost	$75.00	$300.00	$300.00
Production Days/Year	150	150	150
÷ Days Between Fills	2	1	2
= Fills/Year	75	150	75
x Hours/Fill	1/4	1/4	1/4
= Hours/Year	18.75	37.5	18.75
x Cost/Hour	$6.00	$6.00	$6.00
= Gas Fill Cost/Year	$112.50	$225.00	$112.50
Total Operating Costs/Year	$1,410.50	$5,243.00	$2,877.25

Table 2. Comparison of Equipment Costs for Low-Volume and High-Volume Spraying

A. Vehicle Purchase	Datsun (Short Bed)	GMC 6000 Gas	GMC 6000 Diesel
Sales Price	$6,377.92	$15,000.04	$21,238.74
- Down Payment	$900.00	$3,000.61	$4,247.75
= Amount Financed	$5,477.92	$12,002.43	$16,600.64
Monthly Payment	$176.00	$428.42	$592.55
x Number of Months	36	36	36
= Monthly Payment Total	$6,361.56	$15,423.12	$21,331.80
+ Down Payment	$900.00	$3,000.61	$4,247.75
= Total Cost	$7,261.56	$18,423.73	$25,579.55

B. Spray Equipment Cost	LV2000	Brand X (1250 gallon)
List Price	$5,000.00	$7,920.00
- Down Payment	$1,000.00	$1,584.00
= Amount Financed	$4,000.00	$6,336.00
Monthly Payments	$141.39	$226.21
x Number of Months	36	36
= Monthly Payment Total	$5,090.04	$8,143.56
+ Down Payments	$1,000.00	$1,584.00
= Total Cost	$6,090.04	$9,727.56

C. Total Equipment Cost (Truck and Spray)	Datsun	GMC	GMC diesel
	$13,351.60	$28,151.29	$35,307.11

Table 3. Comparison of First-Year and Three-Year Costs for Low-Volume and High-Volume Spray Equipment

	Datsun (Short Bed)	GMC 6000 Gas	GMC 6000 Diesel
Down Payment	$1,900.00	$4,584.61	$5,795.75
12 Monthly Payments (Truck)	$2,112.00	$5,141.04	$7,110.60
Operating Cost	$1,410.00	$5,243.00	$2,877.25
12 Monthly Payments (Equipment)	$1,696.68	$2,714.52	$2,714.52
Total First-Year Costs	$7,118.68	$17,683.17	$18,498.12
Total Cost for Three Years	$17,581.60	$42,296.29	$42,354.86

The 2-ton diesel's first-year estimated cost is $18,498.12; the 2-ton gas truck will cost $17,683.17 (see Table 3). But the LV rig will cost only $7,118.68 the first year. The LV system can save $10,000 to $11,000 the first year. If we remember that the total LV system cost only $11,500, we realize that the LV system will almost pay for itself the very first year.

If we extend these estimates for three years, it will cost over $42,000 to field the HV rigs and only $17,500 for the LV. That is a difference of $24,500. If we look at it in terms of cost per application (estimating 700 applications per round for three years), the HV rig costs over $5.00 for each and every application it makes, and the LV costs less than $2.00.

CONVERTING HV EQUIPMENT TO LV

When I switched to LV this year, I had a couple of dinosaurs under contract. (I call my 2-ton trucks dinosaurs because I believe they are on the verge of extinction.) Since the existing trucks are used with the new electric pumps and agitators, they now haul only one-third the weight--and their mileage has improved by about one-third. PTO time is eliminated by installing the electric pumps. It now takes less time to fill up with fertilizer and gas. Savings of $2,700 per rig are possible by converting HV to LV.

IMPLEMENTING LV

The proper strategy to introduce LV is important. For the first year, continue using the large trucks (after they have been converted to LV, of course). The customer does not know how much material is in the tank, and you can enjoy the immediate saving that LV conversion offers. Add a mini-truck to the fleet, giving everyone a chance to see it. Then, as the larger trucks need replacing, buy smaller ones. The customers will easily accept the changeover if the change is gradual.

AN ECONOMIC CHOICE

Will we continue to operate as in the past, or will we seize this opportunity LV offers us? It is an economic decision, pure and simple. When I studied economics, the most basic assumption made the first day in Econ 101 was that businessmen make rational decisions based on profit motivation and competition. If a new innovation occurs that enables a product or service to be produced more economically or at a higher profit, that innovation will be used by business.

LV is the innovation in the lawn-care business that cuts costs, increases profits, and gives my company the competitive edge it needs to survive in the 1980s. I believe your decision to switch to LV is inevitable--it is just a matter of time.

AN INTEGRATED APPROACH TO TURFGRASS PEST MANAGEMENT

Alfred J. Turgeon

A turfgrass pest is any organism causing a measurable deterioration in the aesthetic or functional quality of a turf. Turfgrass pests include weeds, disease-inciting organisms, injurious insects and other arthropods, nematodes, and other destructive animals. The susceptibility of a turf to deterioration in association with the activity of pest organisms varies with the turfgrass, the pest, and the natural and culturally modified environment surrounding the turfgrass community.

Usually, any discussion of turfgrass pests includes reference to specific pesticides for achieving control. While pesticide use is an important component of a turfgrass cultural program, pest management also includes: (1) selecting pest-resistant turfgrasses that are well adapted to natural environmental and cultural conditions, (2) following proper establishment procedures, including site preparation and modification and turfgrass propagation techniques, and (3) performing cultural operations that favorably influence turfgrass growth and development.

TURFGRASS PESTS

The principal pest problems of general concern in turf are weeds, disease-inciting organisms, destructive insects, and parasitic nematodes. Their occurrence may simply reflect a particular time of year or a specific set of environmental conditions. Crabgrass and other summer annual weeds typically germinate in spring and die with the first killing frost. Helminthosporium melting-out disease occurs in susceptible cultivars of Kentucky bluegrass under cool, humid conditions in spring. White grubs infest some turfs each summer with monotonous regularity.

The life cycles of many pests are predetermined in accordance with annual fluctuations in temperature, precipitation, and other environmental conditions. Yet, different turfs vary widely in their responses to the presence and activity of these pests; some are virtually destroyed, while others show little or no decline in quality even though symptoms of specific pests can be easily observed. Thus, pest control, whether achieved through the use of pesticides or by some other means, must be regarded as a reduction in the deleterious effects of a pest organism below some critical level, rather than total eradication of the organism from the turf.

TURFGRASS SELECTION

Many turfgrass pest problems can be substantially reduced through the selection and establishment of superior, well-adapted turfgrasses. Turfgrass species that are poorly adapted to local environmental conditions often do not

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perform well because of their inadequate tolerance to cold, heat, drought, shade, traffic, excessive soil acidity or alkalinity, or other site conditions.

Cultivars of the same species have exhibited wide differences in their tolerances to temperature extremes. Especially cold-tolerant turfgrass cultivars include 'Nugget' Kentucky bluegrass, 'Midiron' bermudagrass, and 'Raleigh' St. Augustinegrass.

A principal objective of turfgrass breeding has been superior resistance to common diseases. 'Merion' was the first of the Kentucky bluegrasses recognized for resistance to Helminthosporium melting-out disease. In recent years, considerable effort has been directed toward developing better resistance to rust, powdery mildew, stripe smut, Fusarium blight, and other diseases of this turfgrass. Efforts are currently under way to develop improved disease resistance in other turfgrasses as well. With the exception of some St. Augustinegrass cultivars, few turfgrass cultivars are specifically recommended for resistance to insects, as it has not been a primary objective in most breeding programs. Numerous opportunities exist, however, for improvements in the inherent resistance of turfgrasses to insects as well as to nematodes.

TURFGRASS ENVIRONMENT

The environment surrounding a turfgrass community can be divided into two primary components, naturally occurring and culturally induced. While fluctuations in the natural environment influence turfgrass growth and survival as well as the incidence of various pest problems, cultural operations can have substantial mitigating effects upon the responses of turfgrasses to natural environmental conditions.

Irrigation supplements natural rainfall and thus influences not only the growth of turfgrasses but the survival and population dynamics of pest organisms as well. Excessive irrigation can maintain the soil in a plastic condition for prolonged periods and thus increase the susceptibility of the soil to compaction under traffic. Also, the stress tolerance of intensively irrigated turfgrasses may be substantially reduced. Turfgrasses growing in compacted soils are less vigorous and more prone to pest problems than are turfgrasses in well-structured soils. Measures taken to reduce surface compaction and improve soil drainage may reduce the likelihood of disease (e.g., Pythium blight, snow mold).

Fertilization supplements native soil fertility and is essential for sustaining turfgrass growth at a level that is sufficient to offset the development of many diseases, to compete with weeds, and to outgrow the damage from various insects and other pests. Excessive fertilization, however, may render the turfgrass more susceptible to various diseases (e.g., Helminthosporium melting-out disease, Fusarium blight) and less tolerant of environmental stresses.

Mowing is the cultural analog to grazing. Just as overgrazing can be damaging to pasture grasses and can induce transition to weedy vegetation, improper mowing practices can lead to the deterioration of a turf. Where turfgrasses are sustained at a height that is less than the lower limit of the mowing-tolerance range, pest problems are likely. Closely mown turfs are more susceptible to Rhizoctonia brown patch, Sclerotinia dollar spot, and other diseases than are turfs sustained at moderate mowing heights. Also, weed invasion is more likely under close mowing, especially from annual bluegrass, crabgrass, goosegrass, chickweeds, and white clover.

Mowing with improperly adjusted or dull equipment can cause bruising of the leaves and create infection sites for disease-inciting organisms. Mowing patterns that result in differential soil compaction or excessive turfgrass wear can also render the turf more prone to pest problems. Scalping, or excessive removal of shoot tissue, can reduce the turf's resistance to weed invasion, especially during stress periods.

Failure to control thatch may lead to severe disease incidence. Work at the University of Illinois has shown that thatchy Kentucky bluegrass is more susceptible to Helminthosporium melting-out and stripe smut diseases than is a thatch-free turf. Thatchy turfs are also more susceptible to wilting under midsummer stress, which could lead to substantial losses of turfgrass followed by weed invasion. Cultivation is also important in counteracting the effects of soil compaction, including weed and disease incidence.

While turfgrass selection is an important consideration in establishing a new turf, proper site preparation (i.e., clearing operations, soil tillage, incorporation of soil amendments, grading) is essential to ensure that suitable conditions exist for sustaining healthy turfgrass growth. Many environmental problems leading to severe pest incidence in turf can be avoided, or substantially reduced, through careful management of site conditions prior to planting.

PESTICIDES

Pesticides are chemical agents for controlling pests. They include herbicides, fungicides, insecticides, and nematicides. For satisfactory results, a pesticide must be present at the site of pest activity at an effective concentration for a sufficient period of time.

The amount of applied pesticide that is actually available for controlling pest organisms depends upon numerous environmental factors. Some pesticide may be lost from the target site due to drift, volatilization, photodecomposition, and runoff during or shortly after application. Upon entering the thatch and/or soil, some of the pesticide may be adsorbed so tightly onto colloidal surfaces that it is essentially inactivated. Some pesticide absorption by plants and soil fauna may also reduce the active concentration at the site of pest activity. Depending upon soil conditions and water percolation, some of the pesticide may leach through the soil profile and thus become diluted at the soil surface. Finally, chemical and microbial decomposition processes will reduce the pesticide concentration further until, in most cases, it essentially disappears.

Desirable attributes of pesticides include efficacy toward the pest organism, selectivity with respect to target and nontarget species, persistence limited to the required control period, and minimal hazard to humans and other nontarget organisms.

Effective control of pest organisms with pesticides does not mean eradication; rather, it is a reduction of the pest population or its activity to a level that does not cause damage to the turfgrass and does not reduce turf quality. For example, the presence of a few potentially damaging insects in a turf may not require treatment with an insecticide; only when insect populations develop sufficiently to cause significant damage should pesticides be applied.

Some pest problems occur so routinely and damage is so severe, however, that a preventive approach to control is warranted. Examples include Sclerotinia dollar spot in greens and crabgrass in some lawns. Where a history of these and other pest problems exists, treatment with appropriate pesticides prior to observable incidences may be the best means for sustaining the turf at a desired level of quality. Otherwise, pesticide treatment should be withheld until early symptoms of the pest indicate that unacceptable damage may occur. This is called the curative approach to pest control.

Herbicides

Herbicides that are applied prior to the emergence of weed species are called preemergence herbicides. Once weeds have emerged, these herbicides are usually ineffective in controlling them. Weed control occurs after absorption of the herbicide by emerging root and/or shoot organs. Preemergence herbicides are primarily used for controlling annual grasses; however, these herbicides are often effective in controlling annual broadleaf species as well.

Postemergence herbicides are applied after emergence of weed species; efficacy is usually a function of absorption by plant foliage and possibly translocation to a site of action within the plant. If translocated within the plant, they are referred to as systemic herbicides, whereas nontranslocated materials are called contact herbicides.

Herbicides are also categorized on the basis of their selectivity within a mixed plant community. Used properly, selective herbicides control susceptible weed species and cause no injury to desirable turfgrasses. Nonselective herbicides are used for spot treatment of weeds that cannot be controlled selectively (primarily perennial grasses) or for general turf renovation.

Fungicides

The two basic types of fungicides are contact and systemic. Contact fungicides are applied to turfgrass shoots to prevent fungi from infecting the plants. With the emergence of new, unprotected leaves and the removal of older leaves by mowing, it is necessary to apply contact fungicides frequently (every 7 to 14 days) during periods of disease activity. While contact fungicides control a broad array of infectious fungi that attack turfgrass foliage, they do not protect below-ground portions of the plants.

Systemic fungicides are absorbed by turfgrass roots and translocated acropetally through the system. Even newly emerging leaves are protected from infection, as the fungicide is thoroughly distributed within the plants. They cannot be washed from leaf surfaces or removed with mowing, thus providing a much longer control of diseases than do contacts. Systemic fungicides have a narrower spectrum of control than do contacts; and, because of their specific mechanism of action, the likelihood of encountering resistant strains of the pathogen is greater.

Contact fungicides must be applied with a sufficient amount of water to thoroughly cover foliar surfaces where infections occur. Systemic fungicides may also be applied this way, but their persistence and activity tend to imitate those of the contacts unless the application is soon followed by irrigation to wash fungicide into the rootzone. Subsequent root absorption and upward translocation of the fungicide enables it to function systemically. Application of systemic fungicides should also be preceded by an irrigation to reduce adherence of the fungicide to plant and soil surfaces.

Insecticides

The proper method for applying insecticides depends upon the type of insect to be controlled. For root-feeding and burrowing insects, insecticide application should be followed by irrigation with one to two centimeters of water to move the insecticide to the feeding site. Shoot-feeding insects ingest insecticide residues adhering to the turfgrass leaves; therefore, their control requires avoidance of irrigation (and rainfall) for at least 24 hours following application.

Nematicides

Control of nematode populations is difficult, especially in fine-textured soils, because of their distribution throughout the turfgrass rootzone. However, nematicides are useful in reducing large populations of destructive ectoparasitic nematodes in established turfs and in controlling nematode populations in soil prior to turf establishment.

The two types of nematicides are soil fumigants and contacts. Fumigants are generally more effective than contacts because of the rapid distribution of the gas in soil; however, they are highly toxic to turfgrasses and can only be used prior to planting. Soil fumigants include methyl bromide, chloropicrin, metham, and vorlex.

Contact nematicides are nonvolatile and therefore must be washed into the rootzone of established turfs. Liquid formulations should be irrigated in immediately following application to reduce the potential of foliar burn. Granular formulations are generally safer to both the turfgrass and the applicator. Examples of contact nematicides include diazinon, disulfoton, ethoprop, fenamiphos, and fensulfothion.

FUTURE RESEARCH

There is considerable room for improvement in the science and technology of turfgrass pest management, which can be brought about through research on turfgrasses, pest ecology, and pesticides.

There are two fundamental approaches to improving the pest resistance of turfgrasses: one is through breeding, and the other is through the development of improved cultural techniques.

Much progress has been made in breeding disease-resistant turfgrasses. Disease resistance is, in some instances, associated with improved adaptation to prevailing environmental conditions. Therefore, breeding for improved tolerance to cold, heat, drought, salinity, shade, and other environmental stresses may yield cultivars that are less disease prone in specific situations.

Insect resistance is an objective that has received too little attention in breeding programs. Yet, specific examples exist that clearly indicate that this objective is achievable. One notable example is the resistance of 'Floratam' St. Augustinegrass to chinchbugs.

Resistance to weed invasion is often associated with the use of turfgrasses that are well adapted to prevailing environmental conditions. Given a suitable cultural program, these turfgrasses will maintain sufficient growth to prevent weeds from becoming established or from spreading within the turfgrass community.

In addition to breeding, improved turfgrass cultural techniques could contribute substantially to achieving pest-management objectives. Better methods for controlling thatch, soil compaction, and other adverse influences on turfgrass growth--and therefore on the inherent resistance of the turf to pest problems--is possible through research directed toward these objectives.

Little detailed information exists on the ecology of pest organisms in turf, yet it is generally known that many pests are highly susceptible to desiccation and various control measures at certain times in their life cycles. Thus, research to acquire specific information of this type could lead to an enhanced ability of turfgrass managers to implement highly effective control measures through careful monitoring and simple adjustments in the cultural program.

In the disease-control area, techniques for monitoring spore-population levels and conditions that are conducive to disease development would provide the turfgrass manager with a valuable tool for predicting when disease incidence is likely and therefore when fungicides should be applied. This would result in more efficient use of fungicides and more effective disease control.

Effective measures for monitoring insect population dynamics could likewise result in reduced use of insecticides and improved efficacy when insecticides are used.

Many of the technological advances in turfgrass pest management have been achieved through the development and marketing of improved pesticides.

However, with the tremendous increase in the cost of pesticide development, the likelihood of acquiring many new materials has been substantially reduced.

Another approach to achieving improved efficacy and selectivity of pesticides is through the development of new formulations of existing materials. For example, the control gained from the use of preemergence herbicides could be extended through the development of suitable controlled-release formulations. They would reduce the amount of available herbicide in the turf immediately following application but maintain an efficacious concentration of the herbicide throughout the germination period of weed seeds. Thus, an inherently nonpersistent herbicide could be formulated to be more persistent and the need for successive applications reduced, through the use of controlled-released formulations. The same approach could be applied to systemic fungicides, insecticides used for controlling root-feeding insects, and possibly nematicides.

Clearly, there is need for considerable fundamental research in many facets of turfgrass science in order to accumulate an information base from which future directions in turfgrass pest management can be developed. Much of the success resulting from contemporary methods in pest management is largely due to the skill, acquired through study and experience, of turfgrass managers. A more scientific approach, developed from in-depth research, can provide an even more effective pest-management system while realizing efficiencies in the use of cultural resources, including pesticides.

DEGRADATION OF DACTHAL AND DIAZINON USING MODEL ECOSYSTEMS

Bruce Branham

Studies were initiated in August of 1981 to determine the effect of thatch, soil type, and irrigation frequency on the degradation of Dacthal. Another study was begun in May of 1982 to determine the effect of thatch and irrigation frequency on the persistence of the insecticide diazinon. The results of these studies are reported here.

The model ecosystems were placed inside a Scher-Gillette controlled-environment chamber with a 12-hour day-night cycle. The temperature in the controlled-environment chamber was 21±1° C during the day and 14±1° C during the night. The air temperature inside the model ecosystems averaged 24±1.8° C during the day and 16±1.5° C during the night.

DACTHAL

Procedures

The six treatments used in the Dacthal experiments were turf growing on:

1. Sandy soil, with thatch layer, irrigated every four days
2. Sandy soil, without thatch, irrigated every four days
3. Mineral soil, with a 25- to 35-millimeter thatch layer, irrigated every four days
4. Mineral soil, without thatch, irrigated every four days
5. Mineral soil, without thatch, irrigated daily
6. Mineral soil, without thatch, not irrigated and held at -3 bars soil moisture or less

Dacthal was applied as a 5 percent granule formulated on a 40/60 mesh montmorillonite clay carrier. Technical grade Dacthal was combined with uniformly ring-labeled ^{14}C-labeled Dacthal to produce a 5 percent granule. The material was applied at the recommended rate of 11.8 kilograms active ingredient per hectare. At this rate, 4.0 microcuries of ^{14}C-labeled Dacthal was applied to each model ecosystem. Irrigation was supplied at a rate of 0.5 centimeters of water per application. Five randomly chosen soil cores (from each model ecosystem) were removed at 0, 1, 2, 4, 6, and 8 weeks after application of the Dacthal.

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Results

The percentage of Dacthal remaining in the soil during the experiment is shown in Table 1. Several comparisons should be made among the various treatments. The effect of irrigation can be seen by comparing the turf irrigated daily, turf irrigated every four days, and turf that is not irrigated. A steady increase in degradation with increasing irrigation was seen. This trend would be expected since Dacthal is degraded by microbes, and increasing soil moisture content would increase microbial populations. The surprising result was that the differences between the treatments were not great. The unirrigated turf was held at -3 bars soil moisture or less, which would be in the moist to fairly dry range, so very little degradation would be expected. The other two treatments, turf irrigated daily and turf irrigated every four days, show no differences in Dacthal degradation after four weeks. After eight weeks, 67.6 percent Dacthal remained in the turf irrigated daily, and 81.2 percent Dacthal remained in the turf irrigated every fourth day.

Table 1. Degradation of Dacthal in Relation to Thatch and Irrigation

Treatments	Percent Dacthal Remaining in Soil			
	Weeks After Application			
	2	4	6	8
Sandy soil, without thatch, irrigated every fourth day	95.4	93.5	88.7	85.2
Mineral soil, without thatch, irrigated daily	97.9	91.8	80.7	67.6
Mineral soil, with thatch, irrigated every fourth day	98.0	97.2	94.0	90.6
Sandy soil, with thatch, irrigated every fourth day	89.8	73.7	72.5	47.1
Mineral soil, without thatch, not irrigated (soil moisture -3 bars or less)	98.0	95.7	93.5	95.4
Mineral soil, without thatch, irrigated every fourth day	97.5	91.6	88.4	81.2

In most treatments tested, Dacthal degradation increased rapidly in the last four weeks of the experiment, with an even sharper increase in the last two weeks. The inferences to be drawn are that there is a lag phase needed to build up microorganisms to degrade Dacthal and that the half-life of Dacthal in the soil may be increased by judiciously using water throughout the growing season.

Another comparison to be made is the effect of thatch. Two thatch types were used in the experiment. The first was developed in a heavy clay soil and was thick (25 to 35 millimeters), coarse, and fibrous. The degradation that occurred in this particular thatch was slight, with 90.6 percent of the Dacthal remaining after eight weeks. The other thatch was developed from a muck sod placed on a sandy soil. In this thatch, only 47 percent of the Dacthal remained after eight weeks, the most degradation in any of the treatments tested.

This apparent anomaly may be explained by the fact that the turf with the smaller thatch layer was taken from a site where a muck sod was placed on top of a pure sand soil and that the thatch that developed there contained some of the organic (muck) soil. It is known that some organic soils cause rapid breakdown of Dacthal,* and the organic soil in the thatch layer may be more responsible for the observed degradation rate than the thatch itself. In the heavy thatch layer, the fact that Dacthal is immobile means that the Dacthal is isolated from the soil-thatch interface where the microbial activity is greatest. The top of a heavy thatch layer may have a relatively low rate of microbial activity, because the very porous, coarse nature of thatch makes it a very dry environment. Another possible explanation is that organic matter in the thatch over sandy soil has modified the thatch so that its properties are vastly different from those of the thatch over mineral soil. The large water-holding capacity of organic soils may transform the thatch into an environment where degradation can occur rapidly. In other words, the organic soil may not be directly degrading Dacthal but rather be changing the environment of thatch from dry and barren to moist and more microbially active.

The comparison of sandy soil to mineral soil showed little difference, with 85.2 percent Dacthal remaining after eight weeks in the sandy soil and 81.2 percent Dacthal remaining in the mineral soil. A sandy soil would be expected to have less microbial activity than a mineral soil; more Dacthal should therefore be found in the sandy soil. In this experiment, the trend toward more Dacthal remaining in a sandy soil was barely discernible after eight weeks. It is possible that the difference between the two soils would have been greater if the experiment had lasted longer.

Conclusions

Soil type and irrigation amount and frequency are very important in determining the degradation rate of Dacthal. The ultimate factor determining the rate is the presence of a microbial population capable of degrading Dacthal. Soil moisture and type determine the microbial status of the particular soil environment. It is possible that organic soils tightly bind the Dacthal and somehow facilitate its breakdown.

The effect of thatch in these experiments is variable. If the thatch layer is heavy, the top of the layer may have a much drier environment than the bottom of the layer. The bottom is more decomposed and resembles humus, while the upper layer is very porous, fibrous, and in some cases hydrophobic. With this type of thatch layer, the degradation may be very slow, with a half-life exceeding 100 days.

*Diamond Shamrock Corporation; personal communication.

DIAZINON

Procedures

In the diazinon experiments, the following four treatments were used on turf growing on:

1. Mineral soil, without thatch, irrigated daily

2. Mineral soil, without thatch, irrigated every four days

3. Mineral soil, with thatch, irrigated daily

4. Mineral soil, with thatch, irrigated every four days

Diazinon was applied as a 2 percent granule formulated on a 40/60 mesh corncob carrier. Technical grade diazinon and ^{14}C-labeled diazinon were combined to form the 2 percent granule mixture; the application rate was 4.89 kilograms of active ingredient per hectare. Soil cores were taken at 0, 1, 2, and 3 weeks after application and analyzed for the diazinon remaining.

Results

The percentage of diazinon remaining in the soil and the accumulation of metabolites throughout the experiment are shown in Table 2. Diazinon is a much more active compound than Dacthal, with volatilization, leaching, and production of $^{14}CO_2$ from degradation of the diazinon occurring.

The presence of thatch significantly increased the rate of diazinon degradation; this effect was apparent under both irrigation treatments. The $^{14}CO_2$ evolution from the microbial degradation of diazinon was most affected by the thatch treatments. The turf with thatch had a greater $^{14}CO_2$ production from the microbial degradation of ^{14}C-diazinon than the turf without thatch, regardless of irrigation treatment. The practical implications of the $^{14}CO_2$ evolution are that the turf with thatch treatment has a more responsive population of microbes, which can readily adapt to a new carbon source, in this case, diazinon. This could lead to a more rapid depletion of diazinon and less effective or ineffective control of the target pest. The extrapolation of these results to all types of thatch would be premature.

The effect of thatch was apparent on the leaching of diazinon from the media profile. In the turf without thatch treatments, there was more leaching of diazinon than from a turf with thatch, 3.4 times more on turf irrigated daily and twice as much on turf irrigated every four days. The greater leaching in turf without thatch was probably due to a tighter binding of the diazinon to thatch than to soil (Niemczyk et al. 1977). The ability of diazinon to be an effective white grub (*Ataenius spretulus*) control in a thatched situation must be questioned in light of its more rapid breakdown and decreased movement.

The effect of irrigation on diazinon degradation was also interesting. In the turf with thatch, the effect of irrigation caused a statistically significant difference in the amount of degradation occurring in the two

Table 2. Distribution of Diazinon and Metabolites throughout the Model Ecosystem*

Treatments	Weeks After Application	$^{14}CO_2$ Losses	Leaching Losses	Volatilization Losses	Soil Unextractables	Metabolite G-27750	Diazinon Remaining
Mineral soil, with thatch, irrigated daily	1	5.5	0.2	1.1	7.9	1.0	84.4
	2	38.0	0.6	1.6	19.0	1.0	39.8
	3	54.9	1.0	1.6	35.4	0	7.1
Mineral soil, with thatch, irrigated every fourth day	1	2.8	0.3	1.4	7.1	1.9	86.4
	2	22.1	0.4	2.3	19.4	2.2	53.5
	3	39.7	0.6	2.3	23.7	1.1	32.6
Mineral soil, without thatch, irrigated daily	1	0.3	1.4	1.1	11.1	3.5	82.6
	2	7.5	2.6	1.7	20.1	4.2	63.9
	3	31.5	3.4	1.7	26.5	1.2	35.7
Mineral soil, without thatch, irrigated every fourth day	1	0.3	0.5	1.3	16.2	6.1	75.6
	2	4.4	0.9	2.0	16.3	7.3	69.1
	3	22.2	1.2	2.0	23.4	4.0	47.2

*Total Diazinon recoveries do not add up to 100% due to an inefficiency in the analysis procedure.

treatments. In the turf without thatch, a difference in degradation amount was seen, but it was not significantly different between the two treatments.

Conclusions

Thatch absorbs diazinon more strongly than does mineral soil and causes more rapid breakdown, probably due to higher microbial activity than in soil.

Increased irrigation caused an increased rate of diazinon degradation; the effect was more pronounced in turf with thatch than in turf without thatch.

In a thatchy situation, diazinon should be heavily watered into the turf in the first week after application. Since there was little difference in the percentage degradation among the treatments during the first week, increasing irrigation will move more diazinon through the thatch, although the amount reaching the soil will not be as much as in turf without thatch.

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UPDATE ON LAWN TURFGRASSES FOR SOUTHERN ILLINOIS

Joon Soo Choi and Herbert L. Portz

FINE-TEXTURED TALL FESCUES

Tall fescue is becoming more important in southern Illinois lawns because of the poor quality of Kentucky bluegrass during hot, dry summers. Some advantages of tall fescue over Kentucky bluegrass are greater tolerance to heat and drought and less susceptibility to disease. Other characteristics of tall fescue, however, need to be improved; leaf texture should be finer, and growth habit should be less of a bunch-type. The turf quality can be improved through selecting finer types and by mixing with about 10 percent Kentucky bluegrass. Another temporary solution has been high seeding rates. The results from the past few years were summarized last year at the Illinois Turfgrass Conference.

In 1982 five new finer-textured cultivars were tested along with 'Kentucky 31' at Southern Illinois University at Carbondale (SIU-C). Different seeding rates were used to test heat and drought tolerance of the seedlings. Tall fescue cultivars used were 'Kentucky-31', 'Galway', 'Houndog', 'Olympic', 'Rebel', and 'Falcon'. The number of seedlings and tillers was considerably higher for heavier seeding rates, as shown in Table 1. The seedlings and tillers in the lower-rate plots might, however, have better growth and therefore increased tolerance to heat and drought. To provide the stress condition, the plots were not irrigated except for initial establishment.

'Rebel' and 'Olympic' showed slightly better quality and coverage among the six cultivars (see Table 2). In the early summer there were significant differences in percent coverage between seeding rates. For example, Olympic showed 41.7 percent coverage for the 1-pound rate, 51.7 percent coverage for the 3-pound rate, and 78.3 percent coverage for the 5-pound rate. But in late summer (September), there were no significant differences between seeding rates, i.e., 85 percent coverage for the 1-pound, 87.5 percent for the 3-pound, and 85 percent for the 5-pound rates. Quality ratings showed the same trends, which may indicate that there was more competition between seedlings at the higher seeding rates. From these early data only, a recommended seeding rate of three to five pounds per 1,000 square feet seems appropriate.

Mixtures with Kentucky bluegrass showed better early coverage and quality; however, mixtures did not show much higher quality than tall fescue alone in late summer. The possible effects of seeding rates on winter frost heaving are being tested by a late-fall seeding (14 October) at Southern Illinois University's Belleville Research Center.

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Table 1. Seedling Count and Height of Tall Fescue Cultivars at Different Seeding Rates*

Cultivar	Seeding Rate			
	grams per square meter	pounds per 1,000 square feet	Seedlings/Tillers (per 625 square centimeters)	Seedling Height (centimeters)
Kentucky 31	5	1	157	17.0
	15	3	324	14.8
	25	5	564	15.6
Galway	5	1	123	9.8
	15	3	154	12.8
	25	5	346	12.8
Houndog	5	1	159	13.0
	15	3	287	14.0
	25	5	449	13.6
Olympic	5	1	192	12.2
	15	3	262	16.4
	25	5	513	11.4
Rebel	5	1	170	14.6
	15	3	395	17.0
	25	5	459	16.2
Falcon	15	3	268	11.2
Average	5	1	111.4	13.3
	15	3	284.4	15.0
	25	5	466.2	13.9

*Tests were carried out at the Horticulture Research Center at Southern Illinois University at Carbondale. The plots were seeded on 23 April 1982 and counted on 26 May 1982.

Table 2. Percent Coverage and Turf Quality of Tall Fescue Cultivars at Different Seeding Rates*

Tall Fescue Cultivars	Seeding Rate (pounds per 1,000 square feet)	Percent Coverage		Quality†	
		May	September	July	September
Kentucky 31	1	31.7	75.8	3.8	3.6
	3	65.0	78.3	4.2	4.2
	5	83.3	78.3	4.5	4.0
Galway	1	18.3	76.7	3.2	3.8
	3	26.6	76.7	3.8	3.6
	5	45.0	80.8	4.5	4.2
Houndog	1	23.3	81.7	3.6	4.2
	3	38.3	83.3	4.6	4.3
	5	53.3	83.3	4.8	4.3
Olympic	1	41.7	85.0	4.3	4.4
	3	51.7	87.5	5.0	4.7
	5	78.3	85.0	5.7	4.6
Rebel	1	31.7	84.2	4.3	4.3
	3	53.3	85.8	5.2	4.8
	5	61.7	83.3	4.9	4.6
Falcon	3	45.0	80.8	4.7	4.2
Average of all rates (with Kentucky bluegrass)			84.3a**	5.0a	4.5a
Average of all rates (tall fescue only)			81.9b	4.4b	4.2b

* Tests were carried out at the Horticulture Research Center at Southern Illinois University at Carbondale.

† Quality rating: 1 = very poor; 9 = excellent

** Means within columns followed by the same letter are not significantly different at the 5 percent level as determined by Duncan's Multiple Range Test.

SEEDED AND VEGETATIVE ZOYSIAGRASS

Another way to improve turfgrass quality during the hot, dry summer is by using zoysiagrass. Zoysiagrass is a tough, hardy, warm-season turfgrass that is well adapted to the transition zone. It has had limited use because of difficulties in establishment. Seed came into the United States in the late 1890s and early 1900s; but, because of low germination rates, it was used minimally for direct seeding. United States Department of Agriculture (USDA) researchers (Forbes, Ferguson, Grau, and others), however, used seed for breeding and selection of such cultivars as 'Meyer', 'Midwest', and 'Emerald'. These cultivars are fine leaved and have better color and turf quality than the coarser Korean type. Vegetative propagation has been used in lieu of seeding. Some commonly used vegetative propagation methods include sodding, plugging, and stolonizing.

The difficulties for zoysiagrass seed germination are caused by a hard seed covering and deep dormancy that requires a light treatment in order to be broken. To overcome these problems, a series of studies has been carried out in Korea and in the United States. Getting more than 90 percent germination is not difficult now.

The seed treatment process can be summarized in two steps. The first step is eliminating the blocking effect of the hard seed covering by a scarification with KOH or NaOH; this can be partially substituted by mechanical decoating. The next step is a light treatment while soaking for 24 to 48 hours.

The best seeding rates and methods have been determined by experiments at SIU-C and USDA-Beltsville from 1979 to 1981. The best and most economical seeding rates were found to be between 3/4 and one pound per 1,000 square feet (seeding should be followed by rolling with a smooth or Brillion roller), which resulted in more than 90 percent coverage in 12 weeks. At Dixon Springs Agricultural Center in 1981, treating with glyphosate followed by vertical mowing was the best combination for establishment in an existing sod.

In June 1982, seed was harvested from 'Korean', 'Meyer', and 'Midwest' zoysiagrass and a USDA selection, '52-22(24)'. Existing sod was killed completely by applying glyphosate (three times), and a 1/2-pound seeding rate was used. Seeds were treated with NaOH and then drop-seeded, and each plot was either vertically mowed or flex-harrowed. As shown in Table 3, vertical cutting was significantly better than flex-harrowing. 'Meyer' showed the least percent coverage and had the most genetic variation.

Two experiments were carried out to find faster rooting conditions for stolons of 'Meyer'. Stolons were collected by vertical mowing and treated with such chemicals as NaOH (1 percent), NH_4NO_3 (5 percent), and NAA (1,000 ppm). After the stolons were spread, mulching materials were distributed over the stolon to reduce moisture loss. Mulches were wood fiber, zoysiagrass clippings, and Terra-Sorb. These plots were irrigated by an automatic irrigation system about three times a day, so water was adequate. Results are summarized in Table 4. There were no statistically significant differences between pretreatments. Posttreatment with clippings, however, resulted in a significantly poorer stand. Even though there was enough moisture, perhaps the partial exclusion of light was a critical factor.

Table 3. Zoysiagrass Establishment with Freshly Harvested and Treated Seed*

Zoysiagrass Seed Parent	Seeding Method	Percent Ground Cover		Rust†
		13 August	10 September	14 September
Meyer	Verticut	40.8	72.5	4.0
	Flex-Harrowed	35.0	57.7	
Midwest	Verticut	59.2	84.6	6.8
	Flex-Harrowed	52.5	81.3	
USDA 52-22(24)	Verticut	56.3	68.8	9.0
Korean (1980 seed from Korea)	Verticut	62.5	87.9	4.1
	Flex-Harrowed	51.3	81.3	

*Seed was harvested 18 June 1982, treated, and planted 9 July 1982 at Southern Illinois University at Carbondale.

†Rust Rating: 1 = no rust; 9 = almost all leaves infected.

Table 4. Percent Coverage in Eight Weeks by Zoysiagrass Stolons with Different Pretreatments and Posttreatments*

Posttreatment	Pretreatment				
	None	NH_4NO_3	NaOH	NAA	Average
None	52.9	50.4	45.8	54.6	50.9a†
Wood Fiber	47.1	56.7	41.0	54.2	48.3a
Terra-Sorb	52.1	58.7	48.3	43.3	50.6a
Clippings	37.9	34.2	25.8	27.9	31.4b
Average	47.5ab	50.0a	40.2b	45.0ab	45.3

*Stolonized 15 June 1982 at Southern Illinois University at Carbondale.

†Means with the same letters are not significantly different at the 5 percent level as determined by Duncan's Multiple Range Test.

The second experiment was similar, except for the use of hydrostolonizing for more efficiency. Stolons were hydrostolonized at the rate of 1.5 bushels per 1,000 square feet. Wood fiber was spread by the same hydroseeder over some stolonized plots. Irrigation was reduced to three times during the first week and then infrequently except for natural rainfall. Results in Table 5 indicate that wood-fiber plots were superior to others and that water was more critical than light in this experiment.

Some physiological and anatomical studies of stolons (such as observing cut stolons with transmission electron microscopy and observing the epidermis of stolons after scarification by scanning electron microscopy) will be conducted to find out the origin of roots and other anatomical characteristics. These studies may be the basis for additional laboratory and field experiments.

LOW-MAINTENANCE KENTUCKY BLUEGRASS

Another very important grass for southern Illinois lawns is Kentucky bluegrass, but drought stress, heat stress, and diseases are major problems. The type of maintenance, however, such as watering, cutting height, and fertilization, must be considered. Studies on these problems were reported at last year's Illinois Turfgrass Conference, and observations on quality of turf were continued through 1982 (Table 6). Results can be summarized as follows:

1. Crabgrass continued to recur in the low-cut (1-1/4 inches), irrigated plots.

2. The *Fusarium*-damaged turf of 1980 under conditions of low cut and no irrigation was nearly recovered by 1982.

3. The high-cut (2-1/4 inches) plots continued to be superior to low-cut plots.

4. There was generally low to medium quality of all cultivars in August 1982 after some spring disease and a rather hot summer.

Table 5. Number of Live Zoysiagrass Stolons Following Pretreatments and Posttreatments*

Posttreatment	Pretreatment (Number of Live Stolons per 0.25 square meter)		
	None	NAA	Average
None	14.1	7.1	10.6b†
Terra-Sorb	11.9	4.8	8.4b
Wood Fiber	30.7	16.6	23.7a

*Hydrostolonized 17 and 18 August 1982 at Southern Illinois University at Carbondale.

†Means with the same letters are not significantly different at the 5 percent level as determined by Duncan's Multiple Range Test.

Table 6. Effects of Irrigation and Cutting Height on Quality of Kentucky Bluegrass Turf*

Cultivar	Irrigated†		Nonirrigated	
	Low Cut**	High Cut	Low Cut	High Cut
Brunswick	6.0	5.7	5.3	5.7
Sydsport	5.0	5.0	5.7	6.0
W-A-20	6.0	6.0	6.3	6.0
Baron	5.7	6.0	5.3	6.3
Vantage	4.0	6.7	5.6	7.0
Majestic	5.0	6.0	5.3	6.3
Common	4.7	6.0	5.3	6.3
Bensun(A-34)	5.7	5.7	5.6	5.3
Cheri	4.7	6.0	5.7	6.0
Touchdown	5.7	5.0	4.0	5.3
Adelphi	6.0	6.0	6.6	6.0
Parade	5.7	6.0	6.3	6.0
Bristol	5.0	6.0	6.3	6.0
W-H-7	6.0	5.7	5.7	5.3
Average	5.4	5.8	5.7	5.8

*Ratings were done on 6 August 1982 on a scale of 1 to 9.

†Not irrigated until early August 1982.

**Plots had considerable crabgrass in 1982 as well as a heavy infestation in 1981.

AN EVALUATION OF LIQUID NITROGEN FERTILIZERS FOR HOME LAWNS

Bruce Spangenberg, Thomas W. Fermanian, and David J. Wehner

There is a wide variety of nitrogen fertilizer materials, in both liquid and granular form, available for use on turf. A growing lawn-care industry has increased the demand for liquid forms, because they can offer advantages of reduced labor, ease of handling, and more efficient calibration. Much of the research on the performances of the newer liquid-applied nitrogen materials has been conducted by private industry, and the results are not readily accessible to others. The objective of this study was to evaluate various liquid and granular nitrogen fertilizers for use on home lawns.

MATERIALS AND METHODS

The study was initiated on 1 May 1981 and carried through the 1982 season. Plots were laid out on an established stand of 'Columbia-Touchdown' Kentucky bluegrass (*Poa pratensis* L.) at the Ornamental Horticulture Research Center in Urbana, Illinois. Treatments were applied to 3-by-10-foot plots and replicated three times in a randomized, complete-block design. Liquid materials were applied using a CO_2 backpack sprayer with an 8015E nozzle, with a final spray volume of four gallons per 1,000 square feet. Granular materials were applied by hand. Application dates in 1981 were 1 May, 18 June, 6 August, and 9 October. Dates in 1982 were 21 April, 18 June, 19 August, and 15 October. These dates were set up to resemble those a home-lawn-care company would follow.

The liquid-applied materials used in this study are Folian (12-4-4 and 12-4-6), Formolene, FLUF, Nitroform, urea-ammonium nitrate (UAN), and urea. Granular materials include ammonium nitrate, ammonium sulfate, ammonium sulfate with an inhibitor, sulfur-coated urea (LESCO), urea, and urea with an inhibitor. Folian is a 12 percent nitrogen solution of totally soluble materials, consisting of free urea along with phosphorus, potassium, and small percentages of sulfur and iron. Formolene is a 30 percent nitrogen solution consisting of both free urea and short-chain ureaformaldehyde compounds. FLUF, or flowable liquid ureaform, is a flowable suspension of free urea and ureaformaldehyde compounds that contains 18 percent nitrogen. Nitroform (Powder Blue), applied as a suspension, consists of long-chain ureaformaldehyde compounds (giving long residual effects) and contains 38 percent nitrogen. The UAN material used in this study was a 28 percent nitrogen solution consisting of a combination of urea and ammonium nitrate.

Additionally, urea was mixed with some of the slower-acting nitrogen sources to add a greater amount of quick-release nitrogen. Chelated iron was used with all of the liquid-applied sources (except Nitroform and UAN) for a quick color response, lowering the amount of nitrogen applied. Nitrogen rates

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are generally one pound of actual nitrogen per 1,000 square feet per application, except for sulfur-coated urea, which was two pounds per 1,000 square feet in April and August only. On the iron-combination plots, only one-half pound of actual nitrogen per 1,000 square feet was applied. Therefore, on a yearly basis, the iron/nitrogen plots received three pounds of nitrogen per 1,000 square feet, whereas all other plots (all nitrogen) received four pounds of nitrogen per 1,000 square feet.

The principal parameters being monitored in this study were color and growth rate of the turf and efficiency of the fertilizer materials. Color was measured on a visual rating scale of one to nine, with nine being ideal turf color. Color ratings in 1982 were taken daily for two weeks after each application, then weekly until the next application. Growth rate was measured by fresh clipping weights taken approximately every two weeks. Fertilizer efficiency is determined by the percent total nitrogen found in oven-dried clippings using the Kjeldahl method. Additional data collected in this study include thatch accumulation, turf density, phytotoxicity after application, and any disease occurrence. Quality ratings were taken in 1981 but not in 1982, since the main variable component of quality seemed to be color. Thus, only color ratings were taken in 1982.

RESULTS

When looking at color response curves, the differences between soluble and slow-release sources become readily apparent. A characteristic curve of a soluble material, such as urea, comes to a peak shortly after application and drops sharply as time after application increases. This pattern is repeated with the second and third applications; although, as the season goes on, the peaks do not rise as much as the time before. In contrast, the color response curve of a slow-release material, such as Nitroform, shows a rather straight line which gradually rises throughout the season. This reflects the residual effects of ureaformaldehyde compounds, as well as the better condition of the turf as heat- and drought-stress periods occur.

Rather than comparing color response curves of all materials, color data is compared to the response of liquid urea. Liquid urea was chosen since it was the early standard of the industry and is still widely used in home lawn care. The comparisons are shown in Table 1, which consists of three sets of three columns. The column headings R1, R2, and R3 represent Round 1, Round 2, and Round 3. A round is the period following an application until the day before the next application. Round 4 is not used in the table because there was not enough time to gather sufficient data before the turf went dormant.

The first set is the number of days until the response was equal to or better than that of liquid urea. The second set of three columns is the percentage of each round for which each material had a color response equal to or better than that of liquid urea. The third set of columns contains the percentage of observation dates for which the response was statistically greater than liquid urea at the five percent level.

Table 1. Comparison of Color Response of Kentucky Bluegrass Turf to Nitrogen Fertilizers and Liquid Urea in 1982

Treatment*	Days Until Response Equalled or Exceeded that for Liquid Urea			Percentage of Days Equal or in Excess of that for Liquid Urea			Percentage of Observation Dates Greater than Liquid Urea at 5 Percent Level		
	R1**	R2	R3	R1	R2	R3	R1	R2	R3
Granular-applied									
Urea	1	1	1	84	100	100	10	20	25
Urea with inhibitor	1	1	1	100	100	100	43	40	25
Ammonium sulfate	3	1	2	73	93	57	5	27	0
Ammonium sulfate with inhibitor	28	1	12	29	72	46	0	27	0
Ammonium nitrate	1	1	1	100	100	100	5	20	31
Sulfur-coated urea[1]	13	1	1	71	47	100	19	7	88
Liquid-applied									
Formolene	1	1	1	45	85	64	5	0	0
Formolene/urea[2]	1	3	1	46	53	80	0	0	0
Formolene/iron[4]	1	1	2	25	8	52	10	0	0
Formolene/WIN	14	1	1	75	65	100	10	0	0
FLUF	3	1	1	34	38	100	5	0	13
FLUF/urea 2:2[2]	1	3	1	20	60	46	0	0	0
FLUF/urea 3:1[3]	4	1	3	16	23	88	0	0	6
FLUF/iron 1&2[4]	2	1	2	11	5	50	0	0	0
FLUF/iron 2&3[5]	1	1	1	0	12	91	0	0	50
Nitroform	3	1	1	7	52	100	5	7	75
Nitroform/urea1[6]	1	1	1	34	100	38	10	53	19
Nitroform/urea2[7]	1	3	1	21	55	86	5	0	13
Urea/iron 1&2[4]	1	1	2	48	23	46	10	0	0
Urea/iron 2&3[5]	1	1	1	45	17	64	0	0	31
UAN	1	6	14	57	37	27	0	0	0

*All treatments consisted of one pound of nitrogen per 1,000 square feet per application, except as noted:

[1] 2.0 lb N/1,000 sq ft for R1 and R3

[2] 0.5 lb N/1,000 sq ft from each source for all rounds

[3] 0.75 lb N/1,000 sq ft of FLUF, 0.25 lb N/1,000 sq ft of urea for all rounds

[4] 0.5 lb N/1,000 sq ft, 0.75 oz iron/1,000 sq ft for R1 and R2; 1.0 lb N/1,000 sq ft for R3 and R4

[5] 0.5 lb N/1,000 sq ft, 0.75 oz iron/1,000 sq ft for R2 and R3; 1.0 lb N/1,000 sq ft for R1 and R4

[6] 0.5 lb N/1,000 sq ft urea for R1; 1.5 lb N/1,000 sq ft Nitroform, 0.25 lb N/1,000 sq ft urea for R2; and 1.25 lb N/1,000 sq ft Nitroform, 0.50 lb N/1,000 sq ft urea for R4

[7] 0.5 lb N/1,000 sq ft urea for R1; 0.5 lb N/1,000 sq ft from each for R2 and R3; and 1.0 lb N/1,000 sq ft Nitroform, 0.5 lb N/1,000 sq ft urea for R4

**R1 - 21 April to 17 June; R2 - 18 June to 18 August; R3 - 19 August to 14 October

Most of the granular materials showed equal or better responses than that of liquid urea throughout the season. Granular urea showed a higher peak response than liquid-applied urea. The addition of iron showed a rapid color improvement of the turf following application, but this response was relatively short. An exception to this result occurred after the third application in 1982. Iron combinations with FLUF and urea both showed a somewhat sustained period of favorable response. Furthermore, the ureaformaldehyde compounds (FLUF, Nitroform) showed an increase in favorable response as the season progressed, with optimum response occurring in late summer (Round 3). Sulfur-coated urea, applied only twice (two pounds per application), showed the most consistent favorable response over the two seasons of this study.

Thatch accumulation was recorded at the end of the second season, and results are shown in Table 2. Thatch accumulation was expressed in millimeters of compressed thatch, using the mean of the values of nine sample plugs. Ammonium sulfate plots showed the greatest accumulation; these plots also had significantly lower soil pH values than all other plots after two seasons. Somewhat surprisingly, FLUF showed a slight tendency for thatch buildup, but not at a problem level. Both Formolene and Nitroform showed thatch levels equal to plots that received no fertilization.

Table 2. Thatch Accumulation of Kentucky Bluegrass Turf after Two Seasons of Treatment with Nitrogen Fertilizers

Treatment*	Compressed Thatch (mm)**
Ammonium sulfate	19.3a
Ammonium sulfate with inhibitor	19.2a
Ammonium nitrate	15.9ab
Sulfur-coated urea	14.0a-d
FLUF	12.6b-e
Urea	11.2b-f
Formolene	7.9c-f
Nitroform	7.0ef
Check (no fertilizer)	7.9c-f

*All treatments supply four pounds of nitrogen per 1,000 square feet per year.

**Mean of nine plugs. Values followed by the same letter are not significantly different at the five percent level as determined by Duncan's Multiple Range Test.

NITROGEN CARRIER RATES STUDY

A second study, begun in 1982, compared the application of one pound of nitrogen at different carrier rates. FLUF, Folian (12-4-6), Formolene, UAN, and urea were used in this study. The totally soluble materials (Folian, urea, and UAN) were applied at carrier rates of 5, 3, 2, and 1 gallons per 1,000 square feet. Materials with slow-release characteristics were applied at 3, 2, 1, and 0.50 (Formolene) and 3, 2, 1, and 0.59 (FLUF) gallons per 1,000 square feet. Applications were made following a schedule similar to that of the main study. Data recorded in this study were percent tip burn on the turf during the week that followed each application.

Results from 1982 are shown graphically in Figure 1. The graph shows percent tip-burn injury on the vertical axis and the corresponding carrier rate on the horizontal axis. Results show a clear difference between the three soluble sources and the two slow-release sources. An injury rating of five percent or lower is the acceptable value in this study, so it becomes clear that both FLUF and Formolene can be applied safely at low carrier rates. Note, however, that in the 1982 season there was not much stress around the application dates. It is possible that hot, dry conditions could produce higher injury ratings than those that occurred in 1982.

ACKNOWLEDGMENTS

I would like to thank the following companies for their interest and support in this two-year study: Allied Chemicals, BFC Chemicals, W. A. Cleary, ChemLawn Corporation, and Hawkeye Chemical Company. With their cooperation, pertinent information was obtained and recorded for future home lawn-care use.

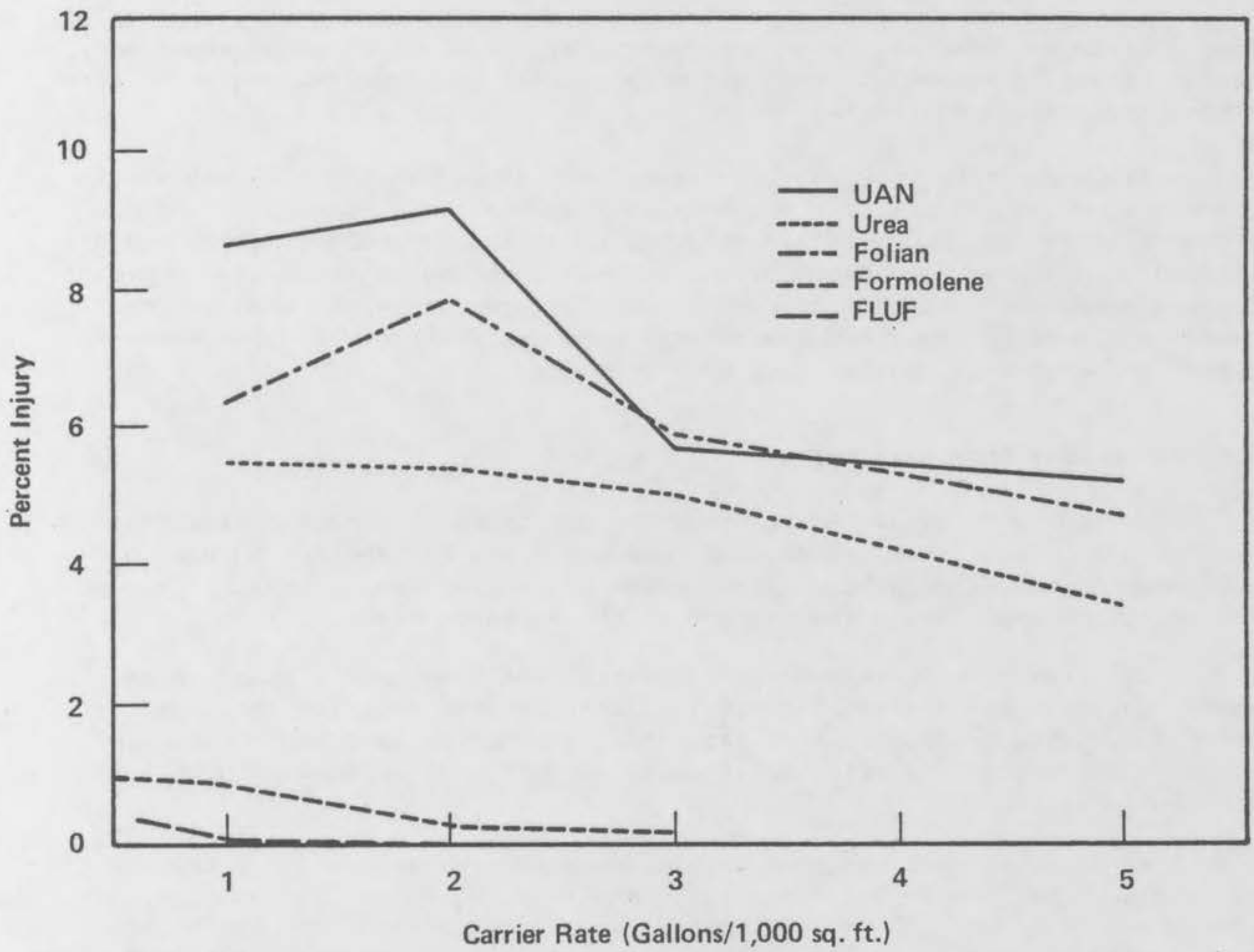

Figure 1. Effect of carrier rate on leaf injury in 1982.

DRIVING THAT DIRT TO DRINK AND DRAIN: WATER MANAGEMENT AND SOIL WETTING AGENTS

Demie S. Moore Powell

My topic has quite a lot to do with tying together the many aspects of your jobs as professional lawn-care operators. What you do about water management directly affects the results of your lawn-care program, which in turn affect your entire business.

Earlier in the program, Dr. James Beard addressed the 1980 key words, conservation and efficiency. You have been exposed to some current and new angles on plant pathology and insects, again aiming for effectiveness and efficiency. You have also heard Dr. Al Turgeon speak on an integrated approach to pest management. I want to sum these up by presenting you with an integrated approach to lawn turf management in general, which will also serve to answer a lot of your regular lawn turf problems.

INTEGRATED LAWN TURF MANAGEMENT

In your work as lawn-care operators you function almost exclusively on the surface. Fertilizer, pesticides, and water are all applied to the turf surface. On the other hand, the turfgrass plant functions primarily (except for photosynthesis) below the surface in the rootzone area.

The link that integrates your function and the plant's function is water. Water takes your surface-applied turf program into the rootzone for the plant. Thus, rootzone water management becomes an important concern. Without proper rootzone water management, many of your surface efforts will not be adequate.

Water management can be a problem because the one area of turfgrass maintenance that you do not control is watering. No matter how much you advise your customers to water properly, you do not control the sprinkler. What I want to suggest to you is that integrated turf management for lawn care makes use of soil wetting agents to control water and to ensure the integration between your surface-applied program and your target, the rootzone.

To understand this better, let us take a new look at water management. By water management we mean the movement of water in soil and its availability to the plant--which directly affect the movement and availability of your lawn-care chemicals.

An article by Dr. Sheffer in last spring's *Golf Course Management* magazine discussed the soil-plant-atmosphere continuum to explain water movement from the plant scientist's viewpoint. Dr. Sheffer described a continuum of moisture from the atmosphere to and through the soil, to and through the plant, and back to the atmosphere--a continuing cycle. In his words: "Water movement through the plant can be visualized as being elastic. As water is

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lost from the leaf, a tension is created in the plant. This tension is transmitted down the plant until it reaches the roots. The roots absorb water from the soil *if* sufficient moisture is present." In many respects, your lawn-care program depends on the same continuity. The results of a recent national survey, however, show that the major water-related problems in turf all cause or can result in insufficient or unavailable soil moisture in the rootzone. These major water-related problems are localized dry spots, poor drainage, slow infiltration, and puddling. For your situations, I know we can add thatch to the list.

If these problems result in less than optimum rootzone moisture, your lawn-care program is not going to give the results you expect. You may be forced to use more chemicals than you should in hopes that some will get to the target. This in turn can result in greater problems, such as excessive thatch buildup, so you are in a vicious cycle.

How can you ensure sufficient moisture in the rootzone to link and so integrate the turfgrass system you are managing? Increasing or ensuring available rootzone soil moisture depends on three factors: infiltration, drainage, and uniform wetting. The first point is water infiltration. Water on the surface is of little or no value to the turf; your treatments may even run off. Two of the chief water-related problems in the national survey were slow infiltration and puddling; and a key lawn-care problem is thatch, which inhibits infiltration as well.

Once you have infiltration, you need drainage. Infiltrating water into the rootzone with poor drainage leads to wet rootzones, which can result in root rots, compaction, and other problems. Drainage is also needed to provide soil air, since the roots cannot absorb water and nutrients without oxygen. Poor drainage is also high on the list of problems in the country. These two extremes, not enough water and too much water, can seriously affect the results of your lawn-care program and are very common problems.

The third factor, uniform profile wetting, is the most important on a day-to-day basis. Even if you have good infiltration and good internal drainage, you are going to have localized dry spots if the water channels through the soil and does not wet uniformly. Localized dry spots do not have sufficient moisture present at the roots of the turf; and, as Dr. Sheffer states, the turf will respond to this stress by first slowing growth, next wilting, and eventually going dormant or dying. The efficacy of your fertilizer and pesticide programs will be somewhat the same. The most common water-related problem by far in turfgrass management is localized dry spots.

WETTING AGENTS

So there you are in the vicious cycle; you need to control water but cannot. The very circumstances required for good control of water are regular problems, and the attempted solutions may even increase the problems. Here is where soil wetting agents come into the picture.

A lot of "miracles and mystery" talk has surrounded the use of wetting agents. If you have been turned off by that, please turn on again to hear some results (and reasons for them) that you can get with the proper use of soil wetting agents. Take a new look and listen again about a tool that is your key to water control, which is your link for integrated turf management.

Just how does a soil wetting agent work? You probably know that one of the main factors in poor infiltration, poor internal drainage, and poor profile wetting is the tension of water itself. Water's tendency is to cling to itself first. This very high surface tension does not allow the droplets to wet and penetrate soil and thatch. Wetting agents simply reduce this tension of water and allow the individual molecules to slip easily into and through thatch and soils that normally would not wet. The soil is the same; the water is different.

Through the proper use of soil wetting agents you can improve the infiltration of the surface-applied irrigation water or rainfall that carries your lawn-care program to its target. In so doing, you can eliminate certain water-related problems and meet the first condition for sufficient rootzone moisture.

Once water wets soil, it sometimes clings very tightly in the soil and will not drain; fine-textured clays, compacted soils, and poorly aerated soils are good examples. This lack of drainage also interferes with the efficiency of your lawn-care program, and here again the soil wetting agent can be beneficial if it adsorbs on the soil particles. With the adsorption of the soil wetting agent on the soil particles, the soil-water tensions continue to be broken, so water cannot cling as tightly. Dr. John Law's data show that treating soil with wetting agents allows moisture to be more easily released to the plant. Because it cannot cling so tightly, a greater percentage of the potential is available to the plant. Field capacity is also slightly lower, providing more rootzone aeration. The increase in percentage of moisture availability easily offsets the decrease in moisture-holding capacity.

So far I have shown how and why the proper use of soil wetting agents can ensure that the surface-applied water first gets into the rootzone and then drains to provide good availability and aeration.

Let us now address the third factor, the need for uniform wetting, which is the most important point for you since you must apply the same basic lawn-care program to different lawns with different conditions and different waterers. Uniformity is your goal, so uniform wetting is an important requirement.

The best documented use of wetting agents is for the elimination of localized dry spots caused by hydrophobic soils. We have already discussed other causes of localized dry spots: stratified soils, compaction, runoff, and thatch, which are directly related to infiltration and drainage. In any case, the same principles apply: the lowering of water tensions permits penetration into hydrophobic areas as well as the lateral spreading of the wetting front. Aerifying does not produce uniform wetting. When soils are treated with wetting agents, however, rootzone wetting is much more efficient and rooting is heavier as well.

When talking about water movement, we must concern ourselves with the entire rootzone, not just the surface or the 7 to 10 percent that aerification involves. The end result of using a soil wetting agent is a uniformly wet, well-drained, and well-aerated rootzone profile. The turfgrass plant naturally responds to this better rootzone environment, giving you uniform results from lawn to lawn with the same basic program.

Recent data from Virginia Polytechnic Institute emphasize the difference water movement and availability can make; heavier rooting (higher root-pull number) was obtained with applications of a spreadable soil wetting agent on newly laid sod, due to improved moisture conditions.

I hope I have given you all some idea of how the proper use of soil wetting agents can improve the effectiveness of your surface-applied programs by managing the entire rootzone. Good infiltration that uniformly wets the profile and freely drains creates an environment for good root development and permanence, which will sustain the turf you are managing. Soil wetting agents help tremendously to ensure such a rootzone environment.

PRODUCTS

Test plots at Michigan State University showed that some treatments damaged the turf. There are two major areas for concern: (1) percent active ingredient, and (2) type of active ingredient. First, the available university data indicate that you need a sufficient amount of active ingredient in the soil to get the desired control (about eight ounces of active ingredient per 1,000 square feet). Unfortunately, most materials on the market contain some water--some up to 80 or 90 percent water. Wetting agents generally all have the same recommended rates. It follows, and the data show, that the diluted materials do not give equivalent performance unless used at many times their recommended rates. Know what you are buying, read the label, and ask questions.

The other point of concern is type of active ingredient and where that active ingredient goes in the soil-plant-atmosphere continuum. Dr. John Kaufmann's data from his work at Michigan State University indicate that the continued use of some types of wetting agents can have a detrimental effect on the physiology of the turf in the form of reduced photosynthesis (up to 50 percent) and can cause some morphological changes. It seems that wetting agents that are not soil oriented, ones that are not adsorbed at low concentrations and do not stay adsorbed on the soil, may remain in the soil solution and be translocated into the plant. The presence of too much wetting agent within the plant seems to be detrimental. One of the wetting agents in Dr. Kaufmann's work performed this way. The other wetting agent in Dr. Kaufmann's test, which has been shown by the University of California data to be irreversibly adsorbed on the soil at very low concentrations, showed little or no reduction in photosynthesis or distortion of the morphology of the turf.

So, be an educated buyer. Know the active ingredient content, and know the performance and adsorption characteristics of the product you are considering using.

SUMMARY

In summary, a good soil wetting agent is a valuable and basic tool that allows you to practice integrated lawn-turf management. The soil wetting agent adsorbed onto the soil in the rootzone prepares the soil to receive the rest of your lawn-care program. The continued presence of the soil wetting agent gives *you* control of water because it ensures continued infiltration, drainage, and uniform wetting--the solution to so many of your lawn-care problems. In essence, a good soil wetting agent does "drive that dirt to drink and drain."

MANAGEMENT FOR BETTER ROOTS

Stanley J. Zontek

Golfers often measure the overall condition of the golf course by the appearance and playability of the turf. In reality, they are looking at and playing on the grass blades and stems. Except for replacing a divot, the average golfer never sees or is at all concerned about the rooting system that is in the soil, caring only for the plant parts that are on top of the soil.

On the other hand, the golf course superintendent must be supremely interested in what is under the grass canopy--the rooting system of the grass. One good measure of the health, vigor, and reliability of a grass plant is the extent of its rooting system. Therefore, golf course superintendents must manage both the top of the grass plant for the golfers and the bottom of the plant for themselves.

The purpose of this presentation is to discuss some of the rules of thumb or guidelines to consider when managing your turf for better roots.

SOIL AERATION

Roots grow in between soil particles. One of the basic laws of physics is that two objects cannot occupy the same space at the same time. While it is true that the root tip can push aside the soil particles, it is equally true that when soils are compacted, the roots cannot move through the soil. Therefore, air spaces large enough for the root to move must be provided. There are two ways to provide these air spaces. The first is at the time of original construction. Soils that are properly formulated to current specifications ideally have a total of 50 percent air space, equally divided between small pores (micropores) and large pores (macropores). It is in well-aerated soils, with these macropores, that the best rooting occurs. Therefore, the first opportunity to provide a soil that will allow for a good rooting system will be during original construction.

Soils that do not enjoy good natural aeration must be mechanically aerated. In recent years, the hollow-tined aerator has come into common usage on golf courses as one positive method of providing air spaces in the soil for grass roots. If you ever want to appreciate the value of a good aeration program, just look at the solid mass of white, healthy roots growing in these aerator holes following a coring operation. For good roots, soil compaction must be controlled. A loose soil with good aeration is one of the most important prerequisites for a deep and fibrous rooting system.

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WATER CONTROL

Exercise good water control. How you manage the water that is applied to the turf can often help determine the extent of the rooting system in the soil. For example, overirrigated turf, no matter how good the soil structure, will not have as deep and as fibrous a rooting system as a similar soil where good water management is exercised. It is very difficult to say in a presentation such as this exactly how best to water a grass plant. Indeed, entire conference programs have been devoted to irrigation; I will attempt in this article only to offer some guidelines on how to manage your water for a better rooting system.

It is a recognized fact that withholding irrigation in the spring will help the grass plant develop a deeper rooting system. Early irrigation, unless you are attempting to water in fertilizer or pesticide, germinate seed, or help the turf recover from winter injury, can only keep the roots near the surface. In the spring, the grass plants naturally extend their root systems into the soil. If the soil is soggy, it only makes sense that roots will not penetrate into the soil. A soil must have oxygen in it for a root to penetrate, and excessive spring moisture often replaces this oxygen so that the grass roots just will not penetrate into the soil. Therefore, we are seeing many golf courses withhold irrigation in the spring until June. This is a guideline, but again the key is not to overirrigate the turf at any time, especially in the early spring when the rooting system is extending.

Irrigate to the depth of the rooting system. If you have a short root system, then long, soaking irrigations really are not needed. Monitor the depth of the grass roots, and apply the irrigation water accordingly.

In the heat of the summer, do not oversyringe the turf. A syringe program on a golf course can be a very effective tool in maintaining grasses such as *Poa annua* through the summer stress period. During the summer, the rooting system of *Poa annua* can become critically short, and these light afternoon cooling syringes help to cool the grass plant, as well as to supply a light splash of water to the grass when its rooting system is quite short. With the advent of the modern irrigation systems, these syringes are becoming very practical and, when properly managed, can help the turf. The key is *light* applications of water.

"Irrigate only as fast and use only as much water as the soil will accept." This is a good commonsense quote. Overirrigation to the point of runoff and puddled water can only cause problems, be they from wet wilt, scald, or disease. Besides, excessive runoff only wastes water. Therefore, know your soils (sandy soils will take more water than silt or clay-based soils), and program your irrigation cycles accordingly. Remember that water replaces air in the soil, so do not maintain your soil too wet for too long or the roots will suffer.

FERTILIZATION

Do not overfertilize the grass. Nitrogen fertilizers especially stimulate green color and leaf growth. Excessive nitrogen fertilization can be devastating to grass roots. It forces the grass plant to use stored carbohydrates, so high levels of fertilization can give you a green, lush turf (which many golfers like), but only at the expense of the grass roots. Generally, it is better to use lighter and more frequent applications of fertilizers when the soil temperatures are above 70° F. than to apply heavy rates on an infrequent basis. This is especially true under summer conditions.

In recent years, research data and field work have indicated that late fall or dormant applications of fertilizer can improve the roots. You may want to try this program and see how it works for you.

Finally, when it comes to applying fertilizer, be sure to be on a good soil test program. If a nutrient is out of balance or deficient, the rooting system of the grass can suffer. A soil test will let you know and allow you to correct any imbalances or deficiencies in the soil.

MONITORING

Continually monitor your grass roots; they change. Know when they change, know when they should be penetrating deeper in the soil, know when they generally age and become shorter, and know when something is not right with them. Stunted, knobby roots may be an indication of herbicide damage. They could also indicate activity of nematodes or insects. Carry a knife or a soil probe. Do not just accept a little wilt here and there--it could be an isolated dry spot (which can be managed), *Ataenius* grubs, Japanese beetle grubs, European chafers, or nematodes. All of these can have an effect on the rooting system and can manifest themselves in shallow roots, stress, and wilt. The proper diagnosis of these problems can do much to help you maintain a better rooting system the entire season long.

CONCLUSION

Golf course superintendents today face many challenges on the golf course. They must provide good playing conditions early in the spring, through the summer stress period, and late into the fall. Golf is played on grass, and one of the most basic of all of the plant parts that will give you the type of grass on which golfers enjoy playing is the rooting system. It is unseen by the average golfer, but to the agronomist and turfgrass manager, it is in many ways *the* most important part of the grass plant to be managed. Good aeration, good water control, balanced fertility, and controlled outside agencies (such as insects) can all help the superintendent develop the rooting system and thus the grass plant on which the game is played.