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SEASONAL MAINTENANCE PROGRAMS FOR PROFESSIONAL ORNAMENTAL CARE: DISEASE PROGRAMS

Robert E. Partyka

The title of this talk implies that there are seasonal programs. There are two, the work season and the training season. The work season is obvious, that is when plant activity is at its peak. The training season for your employees should practically run the year round.

As an owner of a landscape maintenance company, do you send your employees to school or devote training time to them? Do they ask to go to educational schools and meetings to update themselves? How valuable are winter schools?

Winter schools are usually excellent opportunities to review problems and compare experiences with your colleagues. But review of knowledge should not be limited to the winter schools. A seasonal development program for the work staff will be helpful, presented as mini-schools and in small sections at the times when certain field problems are most apparent. These seasonal training sessions will make the work staff more aware of what to look for and how to cope with it, even though they attended a winter school. There are so many things happening in problem development and control that constant review and update is helpful.

The success of a maintenance program on woody ornamentals requires identification of the customer, plants, diseases, climate, alternatives, and implementation procedures.

The client's basic knowledge of plant problems must be considered. Is he coming to you or are you going to him because of your promotional programs? What does he expect, and can you satisfy those expectations? Your ability to communicate and your knowledge of the situation should be able to establish a reasonable approach to satisfy his needs.

Does your staff have a guide to use to properly identify plant material? Are all common plants recognized in the area? Not recognizing plant material may result in a loss of credibility with a client or possibly plant damage if wrong materials are used.

What are the most common disease problems on the plants and when do they occur? How serious are they and are they controllable? Do you have the means to suppress them? Do all the plants have to be treated? These are some questions that have to be answered.

How do climatic conditions affect disease problems at certain times of the year? Temperature and moisture relationships become very important for short-term disease outbreaks, but they also play a role in long-term effects. What has happened in the past year or two that may influence specific disease problems? Are the disorders pathogenic or physiological?

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Protective sprays are often considered, but is the timing accurate enough to give control? Is there an aesthetic value and cost relationship to be considered? Can susceptible varieties be replaced by resistant plant material? Can vigor of a plant be used to ward off a disease problem by proper fertility practices, or do we need a combination of fertilizer and protective materials? Can the job be done in the time span that is optimum for control and are equipment and manpower available to do it? With these points in mind, let us review some of the problems confronting professional ornamental care.

Failure of plant material to leaf out in the spring must be equated with plant vigor or winter stresses. Plant vigor is often difficult to evaluate because past history may not be known. However, this can often be obtained by communication with the client. It is usually important to know the age of plant material and how long it has been in place. Most problems on new growth are due to transplant failure so that the plant never became established in location to survive the normal winter stress conditions. This can relate to initial vigor of the plant or the cultural practices given to the plant. Of course, the plant may have been dead to begin with and planted in the fall with no chance of becoming established. Unusual weather during the winter may have stressed the plant, resulting in further weakening and failure to grow. This is often common with plant material that may be out of its adaptive zone. Problems of this nature often cannot be corrected, and one must consider replacement with more vigorous or adapted specimens.

Spring foliage problems are often common during periods of excessive moisture. Knowing the plant and disease organisms most prevalent under such conditions can determine what direction one should take in overall maintenance. In general, leaf spots are often unsightly, and how long weather conditions favorable to disease exist will determine whether a protective program is necessary. Plant material will recover with development of new foliage after the weather conditions change. This is often true of anthracnose, a disease that starts early in the season and is often explosive when weather is optimum for it. For apple scab, symptoms tend to develop gradually; often severe defoliation results, with limited foliage recovery. A sparsely foliated plant may be the outcome unless a protective control or resistent varieties are used. Many leaf spot diseases can be reduced in severity by maintaining plants in good vigor, so fertility programs are often a first line of defense if a resistant plant is not used. When limited leaf spotting or defoliation cannot be tolerated because of aesthetic considerations, timely fungicide applications can be used to maintain the majority of the foliage. By no means can one expect to keep all the foliage spot-free, as this is too costly and often not feasible from the standpoint of a maintenance service. However, this understanding must be conveyed to the client at the onset of the program, so he knows what to expect from the protection program. Unusual weather may create heavy disease pressure on susceptible plants at certain times of the year. This possibility needs to be considered by the maintenance service.

As the season progresses, higher temperatures and limited moisture will often create stress conditions in a plant. Many of these stresses are physiological, and one must be a good diagnostician to determine the cause. Once the cause has been established, corrective procedures can be established. However, one also has to determine how far the problem has progressed and whether corrective procedures are advisable. A good example is a young plant that is severely girdled with nylon twine or a large tree in a residential area that has a majority of its root system damaged. Palliative measures can be used and the plant will undoubtedly continue to exist for a time, but there is a question whether one can justify the time spent on plants that undoubtedly will die soon or will be so scarred that they will distract from the landscape. Removal and reestablishment of new plants with emphasis on preventing stress conditions from occurring again is often a more sound way to go. This will require a good discussion with the client and explanation of the reasons for moving in this direction.

Stress conditions can lead to canker problems on many plants that may be insignificant at first but if allowed to develop will often result in branch dieback and disfigurement of plants. Recognizing canker-prone plants can result in early surgery and vigor-improvement practices that can often save the plant. However, one must be attuned to factors in an area that can cause plant stress.

Vascular-type diseases often become established because stress conditions may predispose the plant to pathogen invasion or certain insect vectors may transmit the organisms. Early recognition and positive diagnosis are necessary to initiate proper corrective procedures. The degree of control and the reliability often vary with the plant and specific pathogen involved. In cases of phloem necrosis of elm, there is little hope. Dutch elm disease control with systemic materials is more promising, provided application dates and rates are accurate. One cannot be absolutely certain that control can be maintained, but certain trees may warrant the cost of such practices. Early recognition of Verticillium wilt can often save a plant with proper pruning and fertility practices. However, if the organism becomes established through root invasion, chances are good that it is present in the soil, and weather conditions may predispose the plant to reinvasion in the future. Maintaining vigor in the plant is important to help avoid this reinvasion. The nature of the problem must be fully explained to the client. In some cases, this may be a futile effort because of the mobility of the organism.

Total injury as evident by yellowing or browning of leaves often suggests severe injury to the main trunk or the root system. This can often be related to a specific disease problem triggered by weather, or the plant may be susceptible to a soil-borne pathogen. Determine the cause, recognizing that the plant usually dies, and consider measures to prevent a recurrence when new plant material is put in.

In summary, maintenance of ornamental disease programs requires a good knowledge of plants and their problems throughout the season. The use of timely protective fungicides can help reduce specific problems on many plants in northern areas if environmental conditions are favorable. However, improving plant vigor and maintaining a healthy plant is first and foremost in reducing the incidence of many disease problems pathogenic or physiological in origin.

MODE OF ACTION OF TURF INSECTICIDES

Roscoe Randell

Over a period of time insecticides used to control turfgrass insects have continued to change. In the past 30 years there has been a shift from the use of inorganic insecticides such as lead and calcium arsenate to chlorinated hydrocarbons and then to organic phosphates and carbamates. Most insecticides used today for turfgrass insects are classed as either organic phosphates or carbamates. Organic phosphate insecticides include malathion, Dibrom, diazinon, Dylox or Proxol, parathion, Dursban, Dasanit, and others. Carbamates include Sevin, Furadan, Lannate, and Temik. The chlorinated hydrocarbon group consisted of many insecticides, but those used on turfgrass included DDT, chlordane, dieldrin, aldrin, and heptachlor.

In order to be effective insecticides are supposed to kill insect pests. The organic phosphates and carbamates act as nerve poisons. They block the enzyme action, which breaks down the transmitter fluid at nerve sites. In simple terms, organic phosphates and carbamates cause the nervous activity of an insect to remain at a high pitch. Excitability leads to tremors and eventually death of the insect pest.

To be effective in controlling an insect, an organic phosphate or carbamate must come in contact with the insect's sensory nerves. These may be on the insect's legs, head, or body or even internal. But a lethal dosage must be present as a residue on the grass foliage, or in the soil, to be in contact with the insects' nerve cells in order for the insect population to be controlled. Some insects are not affected by certain insecticides. For example, Sevin will not control aphids and mites. Diazinon is not a good insecticide to control black cutworms on greens. Lannate is not effective against soil insects.

There are a few experimental insecticides today that may be labeled for use on turf in future years. Those being tested will continue to be either organic phosphates, carbamates, or possibly synthetic pyrethroids, a new class of insecticide. Synthetic pyrethroids are highly active at very low rates against certain foliage-feeding caterpillars.

While organic phosphate and carbamate insecticides are toxic to certain insects, their mode of activity to the applicator (person) is very similar to that to insects. They are nerve poisons and should be applied according to label directions. None of the turfgrass insecticides suggested for use by entomologists at the University of Illinois are highly toxic to the user. Some, such as diazinon, Dylox, Proxol, and Dursban, are of moderate toxicity but can be safely applied with reasonable handling and application.

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1979 Turfgrass Insect Control Suggestions

Insects	Insecticide	Lb. of active ingredient per acre	Timing of application
Ants and soil-nesting wasps	diazinon spray	4	Apply when insects are present.
Aphids (greenbug)	malathion spray	1	Apply only when aphids are present.
	diazinon spray	1	
	chlorpyrifos spray	1	
Armyworms and cutworms	carbaryl spray or granules	8	Treat when worms are present.
	trichlorfon spray or granules	5	
	diazinon spray or granules	4	
	chlorpyrifos spray or granules	1	
Chiggers	diazinon	1	Apply to grass area where chiggers have been a problem.
	malathion	1	
Chinch bugs	chlorpyrifos spray	1	Spray when bugs are numerous.
	trichlorfon spray	5	
	Aspon spray	8	
	diazinon	4	
Grubs, including true white, annual white, Japanese beetle, green June beetle	diazinon spray or granules	5	Treat damaged areas and where grubs are present in soil. Water-in very thoroughly.
	trichlorfon spray or granules	8	
Leafhoppers and grasshoppers	carbaryl spray	4	Treatment usually is not necessary unless hoppers are numerous
Millipedes	carbaryl spray	8	Apply to turf where millipedes are migrating across area.
	diazinon spray	4	
Slugs	Mesurol bait		Apply by scattering in grass.
Sod webworms	carbaryl spray or granules	8	Apply in late July or August when worms are present. Use 120 gallons of water per acre.
	diazinon spray or granules	4	
	chlorpyrifos spray or granules	1	
	trichlorfon spray or granules	5	
	Aspon spray	4	

HOW TURFGRASS FUNGICIDES WORK

Robert E. Partyka

Fungicides are chemicals aimed at controlling diseases caused by fungi. Because most turf diseases are caused by fungi, pesticides in this group are commonly used to combat them.

A disease problem generally suggests that a combination of several factors has allowed an organism to become established and aggresive enough to damage the turf. These factors include susceptible varieties, ideal temperature and moisture for growth of the organism, and cultural practices that reduce turfgrass resistance. Preventing disease development by proper manipulation of these factors can go a long way in minimizing injury and reducing the need for a fungicide. As a last defense, fungicides may be used with outstanding results.

Proper use of the fungicides determines in part the control obtained. Proper use requires an understanding of the materials available and their mode of action. Basically there are two types, contact and systemic.

Contact fungicides come in direct association with the organism on the surface of plant tissue. They do not enter into the plant, and therefore are usually not efficient in stopping an existing fungal infection. These materials function best as protective fungicides; that is, they need to be on the plant before the pathogenic spores are deposited. Because the plant has to be covered properly with the fungicide for it to be most efficient, one has to consider application equipment and methods and how to obtain good plant coverage. Properly adjusted equipment is a must, as well as proper gallonage rates to obtain uniform coverage. Too low a rate results in poor coverage and unprotected areas, while excessive rates of liquid can result in run-off and allow the fungicide to be washed from the leaf blades or become deposited in an area where it is no longer effective.

Most contact fungicides have a rather short residual life; that is, they do not last long on the plant tissue. This is good from a safety viewpoint, but it does mean that applications need to be made more frequently to be certain that a protective level of material is present to inhibit fungal growth. The short life of the material is due to the fact that it is outside the plant and subject to water, light (ultra violet and infra red), oxidation, microbial action, dew, plant chemicals, and other factors. In addition, new plant growth is continually forming and needs to be protected, so a regular application schedule is usually necessary (10- to 14-day intervals) when a contact fungicide is used.

To be most effective these fungicides need to be applied before a disease breaks out. One needs to be familiar with conditions that are most favorable for a disease outbreak. Starting too early is wasteful and can be an added detriment to the environment. Waiting until the disease is apparent may create a situation that will get out of control before it gets better.

In the past, much emphasis was put on the use of contact fungicides at protective rates, starting before a disease problem was apparent. Regular protection was then the best method because in many cases little was known about the disease

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and the conditions under which it developed. However, enough knowledge has been obtained on many serious disease problems, and modern technology has helped to keep track of conditions most conducive to disease outbreaks; there are some new thoughts about protective control moving more toward curative treatments.

Curative treatments or higher rates are used after a disease has developed, with the hopes of stopping further development by the fungal organism. Thereafter, protective treatments are used to keep the disease suppressed. Curative treatments reduce the risk that resistant strains may develop after repeated exposure of low rates; they also reduce the risk of affecting other beneficial organisms that may be present and reducing the pathogenic organism; and they can reduce the amount of material needed and reduce costs. However, such practices will require constant attention to the turf, recognizing weather conditions favorable for disease development and understanding the nature of the disease problem. Some diseases that fall into this category include Helminthosporium leafspot, dollar spot, red thread, and rusts. All these diseases depend on certain weather conditions and can be manipulated by nutrient and cultural conditions. Curative rates of a fungicide can be used once or twice to overcome environmental stresses, but sometimes weather conditions change and the disease subsides. Artificial manipulation of the environment can change the situation and force one to use a protective rate for a longer period of time to maintain a quality turf. The degree of quality desired will dictate the control practices.

Unfortunately, some disease problems can develop very quickly with devastating results, almost dictating protection when environmental conditions approach a critical period. This situation could apply to Pythium and brown patch in a golf course. It does not necessarily hold true in home lawns that are under a different management system, although the use of turf varieties in lawns may bring problems in some cases.

Contact fungicides are useful but proper timing is a must for most efficient use.

Systemic fungicides are materials taken up by the plant and distributed within the plant, stopping fungal infections already established and offering protection against further attacks. They may also offer protection similar to that from a contact fungicide if they are on the outside of the plant, depending on the method of application. In general, these fungicides are translocated to the leaf blade tips and margins and are most effective when absorbed by the roots. Application must involve a method that will insure penetration to the root zone where the material can be absorbed by the roots. More water is needed, but this can often be in the form of irrigation water.

Systemic fungicides often cost several times as much as contact fungicides, but their use is warranted because they may be the only materials that will control a specific disease problem. These materials are not broad-spectrum fungicides and are limited to the control of certain diseases. Fungi may become resistant (tolerant) to them if they are used extensively for a long time. It is being suggested that systemic fungicides be used alternately with contact fungicides when possible. In some cases, systemic fungicides can influence the build-up of other diseases for which the systemic material is not effective. Such build-up has been noted with Helminthosporium leafspot in the spring after systemic fungicides were used in the fall. Timing of application therefore has to be adjusted in certain cases to prevent a disease outbreak. Fungicides with a systemic action have been best utilized in the control of the smuts, Fusarium blight, and Fusarium snow mold. At lower rates they control dollar spot and brown patch for a longer time than contact fungicides.

The action of systemic fungicides suggests that one can wait until a disease is present before applying the material. This appears to be true for some diseases, such as dollar spot, brown patch, and smut. There are questions in the case of Fusarium blight when curative rates give suppression,but better control is obtained when a fungicide is used on a protective basis at the onset of weather conditions conducive to a disease outbreak. Furthermore, research in various states suggests that there are some biological activities occurring in the plant debris or thatch that we are not totally aware of, and thus we need to explore the mode of action of these materials more thoroughly.

Fungicides have been welcome chemicals in the arsenal against plant diseases in general and specifically in turf culture. However, at times one may have to question whether fungicides have been comparatively too inexpensive and too readily available. This has created situations in which one ignores many long-standing practices in disease control, such as the manipulation of nutrition and the environment to reduce a disease problem, and instead relies solely on fungicides. This is just the opposite of what should occur; the fungicide should be considered as a last-resort material to be used when other manipulative practices have failed or when disease pressure is so great that a disease outbreak is unavoidable. Reassessing disease problems in the near future may be necessary in view of cost of materials and availability as set forth by EPA standards.

The failure of fungicides to control diseases in specific situations is difficult to assess. Timing, materials, rates, and application methods may often be involved. However, in some cases we may be ignoring the biologically active area of the turf. It is time we look into the total turf environment and see how the various applied materials are affecting the turfgrass, the environment of the turf, and the numerous organisms that make up this environment. It is generally understood that all pesticides are injurious to living plant tissue. The use of specific material is warranted because the result will outweigh the injury factor, and the turf will be protected or cured of the impending problem. The use of many varied materials in a short period of time based on guesswork is not warranted. Where shotgun approaches to control are used and many chemicals are applied with no results, one may want to consider applying activated charcoal and reevaluate disease control by starting over again and considering the right diagnosis, right material, right method, and right timing.

Right diagnosis is a must in disease control since no one fungicide can control all diseases. Unfortunately, disease identification is not a fast process unless one has the necessary know-how and equipment available, and even then it may take several days to identify the pathogen. In the meantime, the organisms can progress to a point of causing extensive damage. The turf specialist therefore has to be very much aware of the conditions that are favorable for specific disease organisms and familiar with their symptoms on the turf in order to apply materials or manipulate controls. At the same time, samples should be sent to a plant diagnostic laboratory to obtain a more accurate read-out as to what is present so this information can be taken into consideration when a similar situation arises. Many symptom patterns are very similar but have a host of causes. Therefore, laboratory techniques are necessary to back up visual, climatic, and cultural information.

Right materials are necessary after a proper diagnosis has been made. The use of a broad-spectrum material in the interim period of diagnosis may be sufficient to suppress the problem until one knows exactly what the problem is. Then follow label directions and rates according to your state's recommendations.

The right method of application for the material and the disease problem must be used. Contact fungicides to protect the foliage must be placed specifically in that area to be effective. Application in any other manner will give disappointing results, waste material, and allow the disease to continue to damage the turf. This often results in more applications and continued poor control.

Right timing is extremely important, based on weather conditions and the material to be used. Therefore, knowledge of environmental conditions for disease development and of the mode of action of the fungicides becomes important.

In summary, one must identify the disease problem and find out why it developed, what could have been done to prevent it, and what course of action to take. Once these points are understood and the need for a fungicide is apparent, then consider the right material, application technique, and timing. Fungicides should be considered as a last resort for disease control and not a first-line item.

COMPATIBILITY OF PESTICIDES AND FERTILIZERS AND TANK MIXTURE PROBLEMS

Robert W. Miller

Mixing pesticides or pesticides and fertilizers in spray tanks reduces labor and equipment costs and, in some cases, increases the effectiveness of the products. Unfortunately, mixing chemicals also may reduce the effectiveness of some materials and may cause damage to the target plant. There are no simple guidelines to use in mixing turfgrass chemicals. Good judgment and a great amount of caution are the best methods to avoid problems from tank mixtures of chemicals.

LEGALITY OF TANK MIXTURES

The Environmental Protection Agency has ruled that tank mixtures of pesticides and pesticides and fertilizers are permissible provided that:

1. The label of any product in the mixture does not state that the pesticide should not be used in mixtures.
2. The use of the mixtures otherwise conforms to all other label restrictions.

The EPA had considered requiring a label for tank mixtures but wisely decided against it because of the inconvenience and unnecessary expense to consumers. Tank mixtures probably will remain legal unless problems develop from widespread misuse of them. Some states require that commercial applicators label tank mixtures of chemicals; however, this process seldom involves more than a simple reporting system in which the applicator registers his intent to use the mixture or mixtures, pays a small registration fee, and reports the content of the mixture on the customer invoice.

TYPES OF TANK MIXTURES

Today, with the vast number of pesticides and pesticide formulations, there are an almost endless number of combinations that you may wish to use. General classifications are:

1. Mixtures of fungicides;
2. Mixtures of insecticides;
3. Mixtures of herbicides;
4. Mixtures of fungicides and insecticides;
5. Mixtures of fungicides and herbicides;
6. Mixtures of herbicides and insecticides;
7. Mixtures of fungicides, herbicides, and insecticides;
8. Mixtures of fertilizer and any one of the above chemicals or combinations of chemicals.

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COMPATIBILITY OF TANK MIXTURES

When pesticides are used in combinations or in a mixture, numerous problems may arise. In such cases the components of a mixture are compatible if they can be used together or incompatible if problems develop from using the combination. If two or more pesticides can be used in combination without impairment of toxicity, physical properties, or plant safety, they are compatible.

PHYSICAL OR CHEMICAL INCOMPATIBILITY

When mixing two or more pesticides reduces the effectiveness of one or all components, the mixture is chemically incompatible. Most organic fungicides and insecticides should not be combined with alkaline compounds with a pH higher than 7.0. Alkaline reactions significantly reduce the effectiveness of carbamate fungicides and the insecticidal value of some compounds. For this reason, lime for the control of algae should not be used with maneb fungicides such as Fore, Manzate, Tersan LSR, and Dithane M-45, or with Dyrene, Zineb, Thiram, Captan, and most organic insecticides.

Dinocap (Karathane), suggested for the control of powdery mildew, is chemically incompatible with Sevin and oil-base sprays.

Chemical incompatibility is frequently the cause of poor performance of multiple pesticide combinations. Other problems may be excessive foaming, salting out, unstable mixtures, and the formation of gelatin-like materials. Before combining any pesticides, read the label on the package or container. If information on compatibility is not specified, you should avoid combination of products until other investigations are completed.

PHYTOTOXIC INCOMPATIBILITY

When two or more compounds used in combination result in plant injury, they are incompatible because of phytotoxic effects. Mixing organic fungicides with emulsifiable concentrates (EC) insecticide formulations when using xylene as the solvent may cause plant injury. When combining fungicides with liquid insecticides, check the label for compatibility to prevent plant injury. When combining pesticides of unknown compatibility, you should try them first on an expendable turf area before using such combinations on large turfgrass areas.

PLACEMENT INCOMPATIBILITY

Incorrect placement of pesticides is frequently the reason for poor disease and insect control. Placement incompatibility, which is less obvious than some other types of incompatibility, is sometimes overlooked. When two or more chemicals are used together and applied in one operation, each must be placed properly if it is to do the job for which it is intended. Some fungicides are protectants and must be uniformly distributed over the leaf surfaces to protect against invasions of pathogens such as Piricularia (Gray leafspot) and Helminthosporium leafspot. Failure to establish a foliar blanket of fungicide protection results in poor control of destructive turfgrass diseases. In order to be effective, insecticides for grub control must be washed off the grass into the soil. Therefore, a combination of maneb (Tersan LSR) for the control of leafspot and diazinon for grub control is ineffective because of placement incompatibility.

Another example of placement incompatibility is broadleaf weed control materials mixed with insecticides that should be watered into the grass or soil.

TIMING INCOMPATIBILITY

Another type of incompatibility sometimes overlooked is the mixing of two or more components that are effective at different times of the year. An example of this type of incompatibility is the use of a preemergence herbicide for crabgrass control and an insecticide for grub control. If the herbicide for crabgrass control is applied at the proper time, the insecticide for grub control will not be effective because the application must be made too early in the year.

DAMAGE POTENTIAL OF MIXTURES

Although a combination of materials is compatible, using a combination increases the probability of turfgrass injury compared to using each component a few days apart. This additive effect occurs if each component is applied separately at one time or if they are applied in a mixture. Under adverse conditions, such as high temperatures or moisture stress, a mixture of chemicals that would be safe to use under good conditions, may cause injury. You must use common sense in determining when mixtures can be used without undue risks.

That you have successfully mixed chemicals in the past does not guarantee that you can continue to do so in the future. Although active ingredients are seldom incompatible, the chemicals used to formulate the product change from time to time.

COMPATIBILITY TESTS

The first thing to do to determine compatibility is to read the label. If the label states that a pesticide or other product should not be mixed, then do not mix it. However, the label will not always tell you if the product can be mixed with other chemicals. In these cases, first make a jar test. Simply make the mixture in a quart jar and observe what happens over the next half hour. If unusual separation or settling out of materials occurs, you probably should not use the mixture.

The second test is to try the mixture on a small area of grass where you will not be disturbed if problems occur. You always should follow this procedure when using a mixture for the first time.

Compatibility charts are available from several sources and serve as a valuable aid. They are not all inclusive and they do not include all formulations of a product. You should use the grass test even if the chart shows the mixture to be compatible.

PRECAUTIONS FOR MIXING PESTICIDES

There are several general precautions you should use when mixing pesticides. Some are:

1. Never mix pesticides in concentrated form. Mix them in the tank already filled with water and with the agitation system running.
2. Do not mix organic fungicides with other pesticides that contain xylene as a solvent.
3. When mixing pesticides of different formulation, the order of mixing should be wettable powders followed in order by flowable products, water soluble powders, surfactants, and emulsifiable concentrates.

4. Do not mix pesticides with materials that cause high tank pH levels without thoroughly investigating compatibility.
5. When using a pesticide mixture for the first time, do a jar test and a grass test before using the mixture on critical grass areas.
6. When tank-mixing pesticides and fertilizers, use urea as the source of water-soluble nitrogen.

EFFECT OF LATE FALL NITROGEN FERTILIZATION ON QUALITY OF KENTUCKY BLUEGRASS

H.L. Portz

Research at Southern Illinois University-Carbondale and at other universities in the East and Transition Zone has indicated that late fall is the time to apply soluble nitrogen (N) to a Kentucky bluegrass turf. Hanson and Juska [2], studying winter root activity, noted a fourfold increase in root weight from December to April. Powell *et al.* [4] found that late fall N increased turf density without promoting leaf growth and did not seriously deplete carbohydrate reserves. Ledeboer and Skogley [3] found that September was best for a complete-analysis fertilizer to increase rhizome and root growth and should be used in conjunction with a late fall application of soluble N. Evans and Portz [1] found that 1.5 pounds of N per 1,000 square feet and a November 13 date gave the most sustained color and quality of Kentucky bluegrass with only moderate reduction of carbohydrate reserves.

Despite these results favoring fall fertilization, spring fertilization is still common in our area. This practice does not coincide with the physiological needs of the plant although it may meet the homeowner's natural urge for spring activity. The overstimulation of already abundant spring shoot growth weakens the plant and lowers its ability to meet summer heat, drouth, and disease stresses. So there is a need to sell a fall fertilization program to homeowners, fertilizer salesmen, garden and lawn centers, and lawn care services.

The application of a complete-analysis fertilizer in September helps build a healthy, vigorous plant, a "big pantry," and the November application of soluble N fills the pantry. Advantages of this late fall nitrogen are good winter color, earlier spring greenup, improved turf quality, and more uniform spring growth.

Current trials at Southern Illinois University at Carbondale are on a silty clay loam soil with a Kentucky bluegrass blend of Adelphi, Aquila, and Parade. The annual nitrogen application has been between 4 and 5 1/2 pounds per 1,000 square feet, depending on treatment. Cutting height has been between 2 1/4 and 2 1/2 inches, no clippings have been removed, only broadleaf weed control has been used, and irrigation has been limited to severe drouth periods.

Treatments in 1977-78 compared two rates of nitrogen (rate 1 = 1 1/2 pounds of N per 1,000 square feet and rate 2 = 3 pounds) and nine application dates--four fall, two winter, and three spring. Supplemental slow-release N at 1 1/2 pounds was applied in mid-April. Chlorophyll and carbohydrate contents were determined throughout late winter and early spring. Visual color and quality ratings as well as growth measurements were also taken.

Results showed chlorophyll content in March was highest from fall and winter applications and at rate 2 (Table 1). Spring applications gave best color in mid-April. Fall applications gave color comparable to that from spring applications from May through July (Fig. 1). The 3-pound rate, although providing higher chlorophyll content, resulted in excessive shoot growth and a lighter green appearance in April than the 1 1/2-pound fall rate (Table 2), so a lower color rating was given to the 3-pound rate.

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Table 1. Chlorophyll Content of Leaves Sampled March 11

Treatment date	Dry weight, mg./gm. Rate 1		Rate 2	
Control	9.36	g[1]	9.80	fg
October 29	11.76	de	13.50	abc
November 5	12.50	cd	13.86	a
November 12	12.46	cd	13.30	abc
November 19	11.70	de	14.06	a
December 17	12.70	bcd	13.66	ab
February 11	12.63	bcd	13.00	abc
March 4	13.10	abc	11.80	de
March 29	10.23	fg	10.80	ef
April 15	10.26	fg	9.96	fg
Rate mean	11.67	*	12.37	

[1]Means for each sampling date not followed by a letter in common are significantly different at the 5% level of Duncan's Multiple Range Test.

*Means for rate 1 and 2 are significantly different at the 5% level of probability.

Table 2. Color Ratings and Correlation Between Chlorophyll Content

Treatment date	Observation date: March 14 Rate 1	March 14 Rate 2	April 11 Rate 1	April 11 Rate 2
Control	3.3[1]	4.0	7.0	6.7
October 29	5.7	7.3	8.0	7.0[2]
November 5	5.7	7.7	8.0	7.0[2]
November 12	6.3	8.0	8.0	7.0[2]
November 19	6.0	7.7	7.7	7.0[2]
December 17	6.7	8.0	8.0	7.7
February 11	5.7	6.3	8.0	8.3
March 4	4.3	4.3	8.3	8.0
March 29	4.3	5.0	9.0	9.0
r	.86[3]			

[1]Rating scale: 9 = Dark green; 1 = Light green.
[2]Lighter green appearance due to excessive shoot growth.
[3]Coefficient of correlation between color ratings and chlorophyll.

The soluble carbohydrate content of basal stem tissue in spring was somewhat lower where applications of nitrogen were made in fall and winter than where application was made in spring or where nitrogen had not yet been applied (Table 3). The differences were greater for the 3-pound rate than for the 1 1/2-pound rate. By May 13, however, there was no difference in the carbohydrate reserves (Fig. 2).

Density of turfgrass in April as determined by weight and number of tillers per 2 1/4-inch plug (Table 4) was better from fall applications of nitrogen than from winter or spring applications. Visual quality ratings also were best for fall applications, with some advantages from the higher nitrogen rate (Table 5). Application of IBDU (a slow release nitrogen carrier) on May 17 continued to enhance color in all plots through August 5. There was no excessive stimulation of shoot growth during the summer, and the Kentucky bluegrass showed a slow, steady growth response.

In conclusion, the advantages of late fall nitrogen fertilization--winter color, earlier spring greenup, and equal or better turf color and quality throughout the year--can be realized by shifting from spring to predominately fall fertilization.

The recommendations are:

- 1 to 1 1/2 pounds of N (includes P and K) per 1,000 square feet in September.
- 1 1/2 pounds of N (soluble form) per 1,000 square feet in November.
- 1 to 1 1/2 pounds of N (slow release form) per 1,000 square feet in May.

These fertilization practices have been tested primarily in the transition zone. Are they applicable to colder climates?

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Table 3. Percent Soluble Carbohydrate Content of Basal Stem Tissue, Fresh weight, March 11

Treatment date	Rate 1	Rate 2
Control	3.25 ab[1]	3.74 ab
October 29	2.49 cde	1.86 efgh
November 5	1.98 efgh	2.00 efgh
November 12	2.48 cde	1.77 fgh
November 19	2.53 cde	1.49 gh
December 17	2.16 defg	1.57 gh
February 11	2.35 def	1.34 h
March 4	1.97 efgh	1.85 efgh
March 29	2.72 bcd	3.09 abc
April 15	3.35 ab	3.49 a
Rate mean	2.53 *	2.22

[1]Means for each sampling date not followed by a letter in common are significantly different at the 5% level of Duncan's Multiple Range Test.

*Means for rate 1 and 2 are significantly different at the 5% level of probability.

Table 4. Weight and Number of Tillers per Plug, Sampled April 22

Treatment	Weight, gm.		Number	
season	Rate 1	Rate 2	Rate 1	Rate 2
Control	1.08		59.6	
Fall	1.23	1.08	77.7	80.6
Winter	1.08	1.08	67.5	71.0
Spring	.95	.94	61.8	62.7
Rate mean	1.09	1.03	69.0	71.4

Table 5. Visual Quality Ratings[1]

Treament	March 30		August 31	
season	Rate 1	Rate 2	Rate 1	Rate 2
Control	4.8		4.8	
Fall	7.0	8.0	6.8	7.9
Winter	6.6	7.5	6.0	7.2
Spring	5.8[2]	6.0[2]	6.8	7.2

[1]9 = Highest quality; 1 = Lowest quality.
[2]April 15 application not yet made.

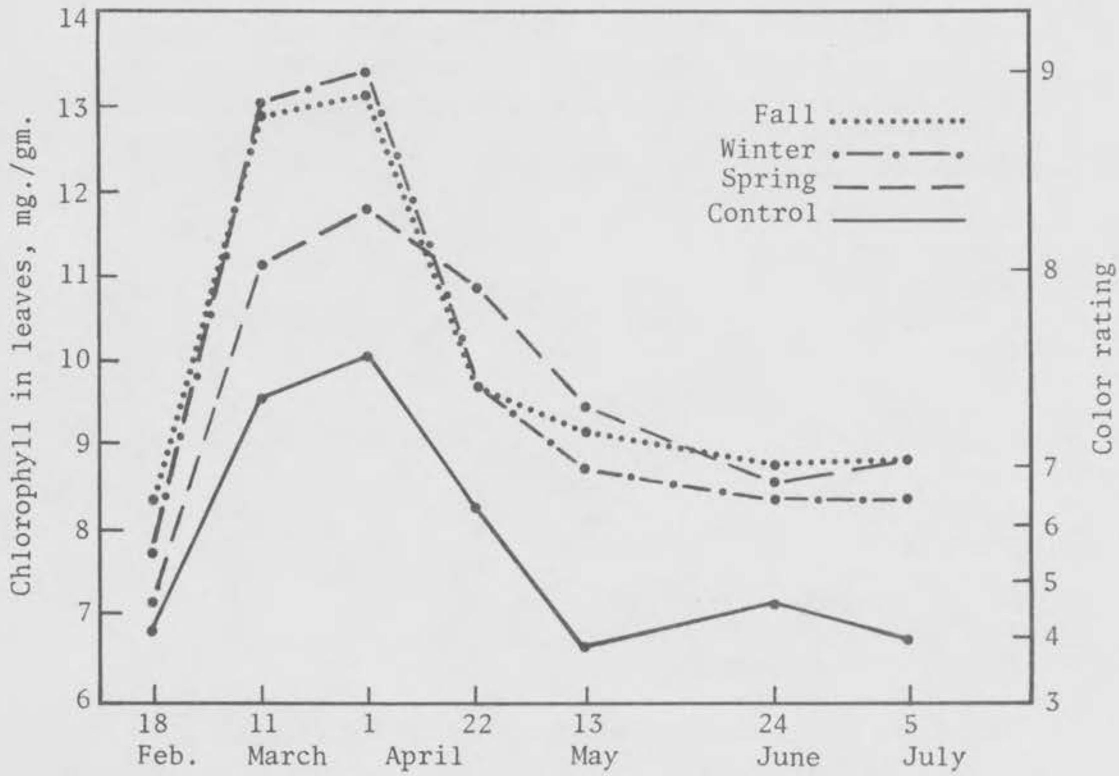

Figure 1. Chlorophyll Content and Color Ratings From February Through July, Average of Rates 1 and 2.

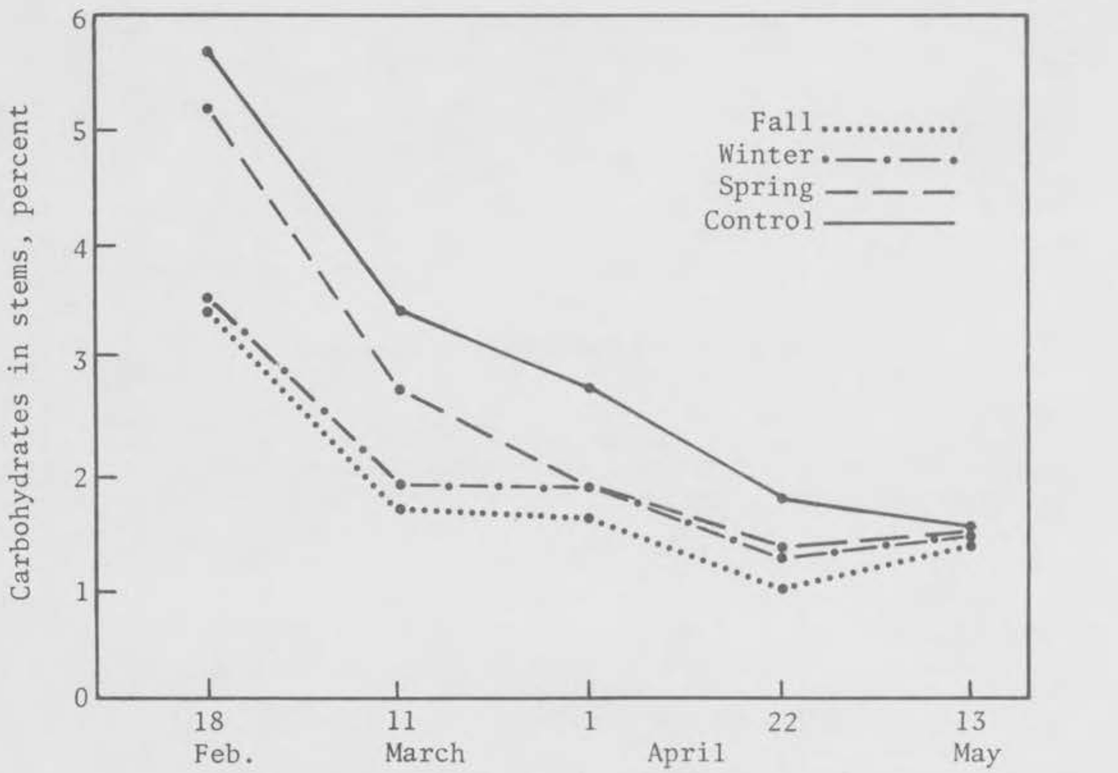

Figure 2. Carbohydrate Content From February Through May, Average of Rates 1 and 2.

THE VALUE OF SOIL TESTING FOR TURFGRASS MANAGEMENT

Gordon V. Johnson

Soil testing is a process that provides descriptive information about soils. Although many properties of soils can be tested, those of most value to the turfgrass manager are soil texture, soil pH and soluble salt content, nutrient availability, and organic matter content. All of these properties can be accurately measured by laboratory techniques. Limitations in their usefulness or in how these test values can benefit the turfgrass manager depend upon many factors. The more important factors include:

1. How well the sample analyzed represents the area of soil you wish to describe.

2. The degree of influence turfgrass cultural practices and conditions have on changing the soil property with time.

3. The purpose for which the soil is being tested.

4. Methods and interpretation of results.

For some situations these factors are easy to control, for others they are not. In some situations the factors are interrelated and their control is very difficult.

SAMPLING

Get a representative sample. You have probably heard this request before; nonetheless, the need for good sampling and the consequences of poor sampling cannot be overemphasized. Results of previous soil tests or observations of variability in turf performance of an area are good indicators of soil variability.

For the golf superintendent wanting to test the soil in a putting green, a representative sample may be easy to obtain. Soil variability in putting greens is usually low, especially when USGA recommendations are followed in construction and the area is small. Consequently when several subsamples are taken (such as with a small-diameter probe) and combined, the composite sample usually is representative of the green. As the size of the area sampled increases, the chance for variability in the soil represented by the composite sample also increases. If the sample is to represent a fairway, cemetery, park, or other large area, many subsamples may have to be taken to obtain a representative composite sample. Analyses of the composite sample will provide average values for the area. These average values will be acceptable when soil variability is known to be low or when the test results will be used as a basis for a single uniform soil treatment. For example, if one application rate of nitrogen fertilizer is to be determined for the entire area, then only one representative sample is necessary. If major variability in some soil property (such as available soil nitrogen) can be accounted for by

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differences between two portions of the large area, then these should be tested separately, provided you are able to treat (fertilize) them separately.

VARIABILITY WITH TIME

Except for available nitrogen, most soil properties do not normally change significantly during a single season. Over a period of several seasons, soil organic matter, soluble salt content, pH, available phosphorus, and potassium will change only slightly under turf management conditions if no fertilizer is added. Nutrient availability, of course, will increase immediately after fertilizer addition. However, unless excessive amounts are added, the levels of available nutrients other than nitrogen will return to approximately the same at the end of a season as they were initially. Thus it is not necessary to test each area annually for phosphorus or potassium. Nitrogen should be tested whenever there is a question concerning available soil levels or when the turf does not respond to management.

PURPOSE

The degree to which soil tests can serve you also depends upon your reasons for testing. Soil testing is not the solution to all problems. Soil test values are extremely useful in diagnosing existing problems and in preventing future problems. But soil test values should not be expected to always tell you what the problem is or what future problems may be.

Just as it is important for a physician or dentist to routinely examine you on a somewhat regular basis to become familiar with your physical, biological, and chemical makeup, regular routine soil testing can help you become familiar with changes, limitations, and potential of your soils.

When you test the soil to diagnose a problem, you should also sample adjacent soil where there is no apparent problem. By comparison, the results from the normal soil can be used to indicate what is wrong with the soil where you have a problem. An example of this is a situation where excess of one nutrient (such as nitrogen) causes excessive growth and demand for a second nutrient (such as iron). In this case the turf will exhibit iron chlorosis; however, the cause of the iron chlorosis is the excess nitrogen. The soil test would indicate a sufficient level of iron but excess nitrogen. The immediate solution to the problem is to apply an iron fertilizer, but the long-term solution is to apply less nitrogen. Without the soil tests you would assume by the appearance of the turf that the soil was deficient in iron when in fact this was not the cause of the problem.

Keeping a record of soil test results from past years will be helpful in determining if the soil properties tested are changing significantly. The change or lack of it will indicate whether your management practices need to be altered or maintained.

METHODS AND INTERPRETATIONS

Soil test methods differ from one geographical area to another in relation to major soil differences. Methods used at the University of Arizona have been developed at the University for testing Arizona soils. Consequently, laboratories using these methods will be able to best provide Arizona superintendents with useful test results.

Even the best soil test value, by itself, cannot tell you how much of a fertilizer or soil amendment should be applied or when to apply it. The soil test results must be interpreted with consideration of climate, your turf cultural practices (past and future), and the anticipated use of the turf. Thus the person making the interpretation and recommendations must be familiar with the tests used as well as your local situation if you are to obtain the most benefit from soil testing.

In addition to the laboratory tests commonly used to test soils, you can field test your soils by leaving check areas. The check area is merely a small area of turf to which you do not apply fertilizer or soil amendments. By comparing turf response and performance of treated areas with performance on the check area you can see what benefits result from the treatment. This type of soil test has the advantage of being made under your specific conditions of climate, management, and turf use.

SUMMARY

Soil tests can best serve you when you follow these guidelines:

1. Sample soil properly.

2. Use soil test results to help diagnose problems.

3. Use soil test results to become familiar with characteristics of your soil and their change with time.

4. Become familiar with and be able to recognize turf problems caused by soil.

5. Use local laboratories to test your soil and local soils and turf specialists to interpret results and make recommendations.

THE ROLE OF MINOR ELEMENTS IN TURF CULTURE

George R. McVey

Research in plant nutrition has shown that twelve elements are essential for plant growth and development (Table 1). The primary and secondary elements are used in greatest quantity by plants while the minor elements, as the name implies, are required in lower amounts. For example, in the course of a growing season an acre of bluegrass turf will remove as much as 80 pounds of N from the soil and only 0.3 pound of iron (Table 2).

Table 1. Essential Plant Nutrients for Turf Growth and Development[a]

Primary	Secondary	Minor
Nitrogen (N)	Calcium (Ca)	Iron (Fe)
Phosphorus (P)	Magnesium (Mg)	Manganese (Mn)
Potassium (K)	Sulfur (S)	Zinc (Zn)
		Copper (Cu)
		Boron (B)
		Molybdenum (Mo)

[a]Carbon (C), Hydrogen (H), and Oxygen (O) are also essential elements which are rarely limiting.

Table 2. Nutrients Removed by Bluegrass Maintained on a Good Fertility Program

Nutrient	Symbol	Typical analysis, percent	Lb. removed per acre per year[a]
Nitrogen	N	4.00	80
Phosphorus	P	.35	7
Potassium	K	2.50	50
Calcium	Ca	.60	12
Magnesium	Mg	.35	7
Sulfur	S	..	..
Iron	Fe	.0150	.300
Manganese	Mn	.0060	.120
Zinc	Zn	.0050	.100
Copper	Cu	.0015	.030
Boron	B	.0020	.040
Molybdenum	Mo	.0003	.006

[a]Based on 2,000 lb. of clippings (dry weight) removed per acre.

I want to review the role of minor elements in turf culture, including function, prevention, correction, plant tolerance, and soil and tissue analysis interpretation. This research has been carried out over a ten-year period under a broad range of environmental conditions on a number of turfgrass types.

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SPECIFIC FUNCTION OF MINOR ELEMENTS IN TURF GROWTH

As shown in Table 3, minor elements are part of or closely associated with enzyme systems. These elements are required only in molecular amounts, but if lacking or in excess, they can have dramatic effects on plant growth.

Table 3. Minor Elements and Some of Their Functions in Plants

Element	Function	Constituent of
Iron	Chlorophyll formation and NO_3 reduction	Enzymes
Manganese	Plays a role in photosynthesis	Catalyst of enzymes
Zinc	Synthesis of growth regulators	Enzymes
Copper	Maintains normal nitrogen metabolism	Enzymes
Boron	Translocation of sugars	Unknown
Molybdenum	Nitrate reduction to proteins	Enzymes

While basic nutritional investigations have established the importance of minor elements for growth and development of many plants, the picture of the need for minor elements on turfgrass is more complicated.

TOLERANCE OF TURF TO MINOR ELEMENTS

Since tolerance is a major consideration in minor element use, I would first like to review results of our tolerance studies and what this may mean to the turf manager.

Tolerance of Penncross bentgrass to a minor element package applied to moist foliage as a slowly soluble glass matrix or in a highly soluble form was studied. The slowly soluble form was applied as FTE 503, while the highly soluble form consisted of sulfates of iron, manganese, copper and zinc, boric acid, and molybdic acid. As shown in Table 4, the minor element package applied as a slowly soluble form was safe up to a 1x rate (1 pound of B and Cu, 6 pounds Fe, 2.5 pounds Mn, .066 pound Mo, and 2.3 pounds Zn) based on initial injury. Subsequent injury was less than 10 percent regardless of rate (1/2x to 4x). In contrast, when the turf was treated with highly soluble sources of minor elements, extreme injury resulted even at the 1x rate that was objectionable for the duration of the test (48 days).

In a second study, minor elements in a highly soluble form were formulated on vermiculite and applied individually to Penncross bentgrass. The formulations were applied at six-month intervals and watered in immediately after application. As shown in Table 5, injury recorded nine days after the third application of minors was very severe at the 1x rate only when the turf was treated with boron (3 pounds B per acre). At the 10x rate, zinc and molybdenum induced only moderate injury (13 percent with 60 pounds Zn and 0.5 pound Mo per acre), while Cu and B caused severe damage (53 percent and 95 percent injury, respectively, at 30 pounds of Cu or B per acre). In contrast, turf treated with iron and manganese exhibited no injury even when treated with 40 to 50 pounds of Fe and Mn per acre every six months for one year.

Table 4. Tolerance of Penncross Bentgrass to Slowly Soluble and Highly Soluble Sources of Minor Elements Applied as a Granular Product to Moist Foliage Under Greenhouse Conditions[a]

	Days after treating					
	5		18		48	
Rate	Slowly soluble[b]	Highly soluble[c]	Slowly soluble	Highly soluble	Slowly soluble	Highly soluble
			(percent injury)			
0x	0	0	0	0	2	2
1/2x	1	28	0	1	2	13
1x	9	62	0	27	7	23
2x	27	68	0	25	3	10
4x	38	90	0	88	0	35

[a]Grown in a 7-2-1 sand-peat-silty clay loam mix (pH 7.7) and fertilized monthly with 0.9 lb. N per 1,000 sq. ft.

[b]A 1x rate delivers 5, 4, 1, 1, 6, 2.5, .066, and 2.3 lb. of Ca, Mg, B, Cu, Fe, Mn, Mo, and Zn per acre, respectively, as calcium sulfate, magnesium sulfate, and FTE 503.

[c]A 1x rate delivers the same rate of secondary and minor elements as the slowly soluble form; however, the source is calcium sulfate, magnesium sulfate, boric acid, copper sulfate, iron sulfate, manganese sulfate, molybdic acid, and zinc sulfate.

Table 5. Tolerance of Penncross Bentgrass to Six Essential Minor Elements Under Greenhouse Conditions[a]

	Metal, lb./acre		Injury,[c] percent	
Minor element source[b]	1x	10x	1x	10x
Fe as Ferrous ammonium sulfate	4	40	0	0
Mn as Manganese sulfate	5	50	0	0
Zn as Zinc sulfate	6	60	0	13
Cu as Copper sulfate	3	30	0	53
B as Sodium borate	3	30	70	95
Mo as Sodium molybdate	.05	.5	0	13
Control	0	0	0	0

[a]Grown in a 7-2-1 sand-peat-silty clay loam mixture (pH 7.7) and fertilized every 3 weeks with 0.9 lb. N per 1,000 sq. ft. with a slow-release fertilizer.

[b]Applied as a vermiculite formulation to dry foliage and watered in on January 28, 1971; August 11, 1971; and January 11, 1972.

[c]Recorded 9 days after the third application.

In a third study, Windsor Kentucky bluegrass was treated with highly soluble sources of minor elements. In contrast to the bentgrass test, the vermiculite formulations of individual minor elements were applied at seeding time and also at approximately six-month intervals to dry foliage and watered in. As shown in Table 6, the same minor elements caused injury; only the degree of injury varied.

Table 6. Tolerance of Windsor Kentucky Bluegrass to Six Essential Minor Elements Under Greenhouse Conditions[a]

Minor element source[b]	Metal, lb./acre		Injury,[c] percent	
	1x	10x	1x	10x
Fe as Ferrous ammonium sulfate	4	40	0	0
Mn as Manganese sulfate	5	50	0	0
Zn as Zinc sulfate	6	60	0	1
Cu as Copper sulfate	3	30	15	72
B as Sodium borate	3	30	43	60
Mo as Sodium molybdate	.05	.5	0	6
Control	0	0	0	0

[a]Grown on a silty clay loam (pH 8.1) and fertilized every 9 weeks with 2.5 lb. N per 1,000 sq. ft. as a slow-release fertilizer.
[b]Applied as a vermiculite formulation to dry foliage and watered in. Applied at seeding time (12/30/69) and to dry foliage on 7/8/70, 12/21/70, and 7/14/71.
[c]Recorded one month after the third application.

The general conclusions drawn from these tolerance studies were:

1. Minor elements combined in a complete formulation and applied in a slowly soluble glass matrix to moist bentgrass foliage were found to cause much less injury than the water soluble forms combined in a complete formulation and applied in the same manner.

2. When individual water soluble sources of minors were applied to dry foliage and watered in, much higher rates could be tolerated than when a complete minor element mix was applied to moist foliage.

Based on these greenhouse studies, minor elements applied at a ratio which provided 1 pound B and Cu, 6 pounds Fe, 2.5 pounds Mn, .066 pound Mo, and 2.3 pounds Zn per acre can be safely applied to moist bentgrass turf at the rate indicated in Table 7. As shown in this table, slowly soluble minor elements are approximately four times as safe as water soluble sources.

When individual minor elements were applied to turf, much higher rates could be tolerated. These studies indicate that a high margin of safety can be realized if the minor elements are applied at rates suggested in Table 8.

TURFGRASS RESPONSE TO MINOR ELEMENTS

Vegetative growth response to minor elements is difficult to induce with certain minor elements. In order to induce a minor element deficiency, Windsor Kentucky bluegrass was grown on pure silica sand, and each minor element under evaluation was independently withheld from the solution. As shown in Table 9, we were able to induce a boron deficiency in four months and a manganese deficiency in three months. In contrast, under the conditions of this study, iron, zinc, copper, and molybdenum deficiencies were difficult to induce.

Penncross bentgrass grown on a 7-2-1 sand-peat-silty clay loam soil mix, however, was found to be responsive to a complete minor element package. When a slowly soluble minor element source was used, growth was improved with increasing rates up to 2x. In contrast, a highly soluble minor element source caused an

Table 7. Pounds of Minor Elements Applied as a Complete Package Which Were Found to Have Good Safety When Applied to Moist Bentgrass Turf

Minor element	Slowly soluble,[a] lb./acre	Highly soluble,[b] lb./acre
Fe	1.50	.38
Mn	.62	.16
Zn	.58	.15
Cu	.25	.06
B	.25	.06
Mo	.02	.005

[a]Applied as a complete vermiculite package using FTE 503.
[b]Applied as a complete vermiculite package using boric acid, copper sulfate, iron sulfate, manganese sulfate, molybdic acid, and zinc sulfate.

Table 8. Pounds of Minor Elements Applied as Individual Components Which Were Found to Have a Good Margin of Safety When Applied as a Granular Formulation to Dry Foliage and Watered In

Source	Chemical formula	Active	Lb. active per acre
Ferrous ammonium sulfate	$FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$	14% Fe	10
Manganese sulfate	$MnSO_4 \cdot 4H_2O$	25% Mn	12
Zinc sulfate	$ZnSO_4 \cdot 7H_2O$	23% Zn	10
Copper sulfate	$CuSO_4 \cdot 5H_2O$	25% Cu	5
Sodium borate	$Na_2B_4O_7 \cdot 5H_2O$&$Na_2B_{10}O_{16} \cdot 10H_2O$	20% B	1/4
Sodium molybdate	$Na_2Mo_4 \cdot 2H_2O$	40% Mo	1/10

Table 9. Fresh Weight of Windsor Kentucky Bluegrass Grown in Silica Sand and Maintained on Various Modified Hoagland Solutions

	Fresh weight, grams					
	Days after initiation of test					
Modified Hoagland[a]	30	67	94	122	150	Ave.
Complete Hoagland	1.65	2.00	2.17	1.77	1.91	1.90
Minus Fe	1.75	2.34	2.06	1.70	2.08	1.99
Minus Zn	2.05	2.22	1.98	1.90	2.19	2.07
Minus B	1.77	2.27	2.07	1.40	1.65	1.83
Minus Mn	1.60	1.95	1.73	1.24	.75	1.45
Minus Cu	1.73	2.30	2.00	1.93	1.95	1.98
Minus Mo	2.09	2.33	1.93	1.87	2.05	2.05

[a]Watered weekly with 100 ml. per .08 sq. ft. This delivers 2.3, 1.7, 3.7, lb. N, P_2O_5, and K_2O per 1,000 sq. ft. per month and 2.5, .025, .25, .25, .01, and .005 lb. of Fe, Zn, B, Mn, Cu, and Mo per acre per month, respectively.

initial inhibition of growth at all rates (1/2x to 4x) followed by a stimulation of growth at 1/2x to 2x as compared with turf not receiving the minor element package. It appears that highly modified soils with a high pH are responsive to certain minor elements (Table 10).

Table 10. Growth Response of Penncross Bentgrass to Slowly Soluble and Highly Soluble Sources of Minor Elements Applied as a Granular Product to Moist Foliage Under Greenhouse Conditions[a]

	Fresh weight, grams			
	18 days after treating		36 days after treating	
Rate[b]	Slowly soluble[b]	Highly soluble[c]	Slowly soluble	Highly soluble
0x	1.80	1.80	2.05	2.05
1/2x	1.53	1.30	2.21	2.38
1x	1.82	.80	2.48	3.12
2x	1.72	.38	2.88	2.69
4x	1.28	.02	2.87	1.56

[a]Grown in a 7-2-1 sand-peat-silty clay loam mix (pH 7.7) and fertilized on day 1 and 30 with 0.9 lb. N per 1,000 sq. ft.

[b]A 1x rate delivers 5, 4, 1, 1, 6, 2.5, .066, and 2.3 lb. of Ca, Mg, B, Cu, Fe, Mn, Mo, and Zn per acre, respectively, as calcium sulfate, magnesium sulfate, and FTE 503.

[c]A 1x rate delivers the same rate of secondary and minor elements as the slowly soluble form; however, the source is calcium sulfate, magnesium sulfate, boric acid, copper sulfate, iron sulfate, manganese sulfate, molybdic acid, and zinc sulfate.

Warm-season grasses have been found to be more responsive to minor elements than cool-season grasses. As shown in Table 11, when bahia was maintained on a low-iron regime, chlorosis and reduction in fresh weight were very evident as compared with turf sprayed with ferrous sulfate at 2 pounds per acre.

Table 11. Response of Iron Deficient Argentine Bahia to Foliar Sprays of Ferrous Sulfate,[a] Recorded November 11, 1978

Iron source	Color (10-Best > 1-Worst)	Fresh weight of tops, grams
Ferrous sulfate[b]	7.5	5.6
Control	2.0	1.7

[a]Maintained on a complete Hoagland solution using one-fifth the normal iron rate. Turf was grown in silica sand.

[b]Applied at the equivalent rate of 2 lb. Fe per acre using a spray volume of 2 gallons per 1,000 sq. ft. on August 16 and September 27, 1978.

Bermuda is also very responsive to iron and manganese. As shown in Table 12, a formulation containing nitrogen, iron, and manganese applied in mid-November and early January improved color of the turf dramatically at six locations in southern Florida. In contrast, turf receiving a single application of nitrogen, iron, and manganese in November followed by nitrogen and potassium in January exhibited a slight improvement in turf color but did not reach an acceptable color level. It appears that repeated applications of iron and manganese are required to maintain quality bermuda turf in southern Florida. High soil pH and the naturally low levels of iron and manganese in the soil reduce total nutrient availability to the turf.

Table 12. Response of Bermuda Fairways to Manganese and Iron Applied to Dry Foliage as a Granular Formulation at Six Locations in Southern Florida,[a] Recorded Two Weeks After Test Application

Initial application (11/15/75), lb./acre			Last application (1/8/76), lb./acre				Color (10 > 1)[a]						
							Locations in Southern Florida						
							A	B	C	D	E	F	Ave.
N	Fe	Mn	N	K20	Fe	Mn							
39	2	4	39	0	4	10	9.0	10.0	9.0	10.0	8.4	10.0	9.4
39	2	4	59	20	0	0	6.3	3.5	3.8	7.0	4.3	7.9	5.5
0	0	0	0	0	0	0	1.3	1.8	1.8	1.0	1.0	5.0	2.0

[a]A color reading of 8 or greater is an acceptable response.

Manganese source can also be critical (Table 13). Manganese sulfate was much more effective than manganese oxide in correcting manganese deficiencies.

Table 13. Response of Tifdwarf and Common Bermudagrass Grown Under Fairway Conditions in Southern Florida to Two Manganese Sources, Recorded Two Weeks After Treating

Manganese source[a]	Mn/acre, lb.	Color (10 > 1)[b] Tifdwarf	Common	Average
Manganese sulfate	8	9.5	8.0	8.8
Manganese oxide	8	6.0	5.0	5.5
None	0	4.0	3.0	3.5

[a]Applied as a granular formulation to dry turf (soil pH 7.4).
[b]A color reading of 8 or greater is an acceptable response.

SOIL AND TISSUE ANALYSIS

Soil and tissue analysis can be used as a guideline for applying minor elements. A series of studies was initiated to establish the correlation between soil and tissue analysis. Penncross bentgrass was grown in a 7-2-1 putting green mix (pH 7.7) and fertilized with two levels of minor elements. Windsor Kentucky bluegrass was grown under a comparable program, but the soil was a silty clay loam (pH 8.1).

As shown in Tables 14 and 15, soil and tissue analysis increased with increasing rates of minors. The difference between rates (0, 1x, and 10x) was most dramatic with boron, manganese > molybdenum, copper, and zinc > iron based on tissue analysis. The addition of iron and manganese did not change the availability of these elements in the soil dramatically; however, copper and zinc levels increased with increasing rates of these elements. This suggests that either soil or tissue analysis would be helpful in determining the need for or an excess level of copper, zinc, or boron (boron not shown in table). However, tissue analysis for manganese is more indicative of the nutritional status of the turf than soil analysis. Soil and tissue analysis of iron does not appear to reflect the amount of this element applied.

Excessive levels of minor elements in the soil can be partially to completely deactivated by increasing the pH above 6.5. The addition of phosphorus will also reduce minor element absorption. Iron, manganese, zinc, and copper are

Table 14. Response of Penncross Bentgrass Grown in a Putting Green Soil Mix to Six Essential Minor Elements[a]

Minor element source[b]	Metal, lb./acre		Tissue analysis metal, ppm, 8/24/71			Soil analysis metal, ppm, 8/3/72		
	1x	10x	0x	1x	10x	0x	1x	10x
Fe as Ferrous ammonium sulfate	4	40	145	175	206	21	27	28
Mn as Manganese sulfate	5	50	38	185	352	2	2	4
Zn as Zinc sulfate	6	60	47	104	156	2	6	10
Cu as Copper sulfate	3	30	9	26	40	1	5	27
B as Sodium borate	3	30	21	313	306	..	..	..
Mo as Sodium molybdate	.05	0.5	1	2	6	..	..	..
Control	0	0						

[a]Penncross bentgrass grown on a 7-2-1 sand-peat-silty clay loam mixture. Started 1/28/71 as bareroot plugs; pH 7.7; 5 lb. P, 30 lb. K, 270 lb. Mg, and 400 lb. Ca per acre. Fertilized every 3 weeks with 0.9 lb. N per 1,000 sq. ft. as a complete fertilizer (32-5-3).
[b]Applied as a dry vermiculite formulation to dry foliage and watered in. Application dates 2/23/71, 5/11/71, and 1/11/72.

Table 15. Response of Windsor Kentucky Bluegrass Grown on a Silt Clay Loam to Six Essential Minor Elements[a]

Minor element source[b]	Metal, lb./acre		Tissue analysis metal, ppm, 8/12/71			Soil analysis metal, ppm, 9/3/72		
	1x	10x	0x	1x	10x	0x	1x	10x
Fe as Ferrous ammonium sulfate	4	40	74	97	118	37	44	42
Mn as Manganese sulfate	5	50	21	142	232	10	11	10
Zn as Zinc sulfate	6	60	27	93	106	3	6	10
Cu as Copper sulfate	3	30	9	21	22	3	6	25
B as Sodium borate	3	30	18	198	307	..	..	..
Mo as Sodium molybdate	.05	.5	1	2	4	..	..	..
Control	0	0						

[a]Windsor Kentucky bluegrass seeded 12/30/71 on a silty clay loam soil; pH 8.1; 10 lb. P, 50 lb. K, 600 lb. Mg, and 4,000 lb. Ca per acre.
[b]Applied at seeding time (12/30/69) and on 7/8/70, 12/21/70, 7/14/71, and 1/11/72 as a dry vermiculite formulation to dry foliage and watered in. Fertilized every 9 weeks with 2.5 lb. N per 1,000 sq. ft. as 32-5-3.

antagonistic. Increasing one of these elements can reduce the uptake of the others (for example, iron can be used to reduce copper and zinc toxicity). Some of these interactions are shown in Table 16 and should be used in interpreting soil analysis.

Based on our research program, we have established guidelines for interpreting soil and tissue analysis. As shown in Table 17, optimum and excessive ranges vary with each element. It is highly probable that these ranges will change as more research is done under a wider range of environmental conditions.

Table 16. Factors to Consider in Interpreting Minor Element Soil Analysis

Iron	High levels (96 ppm) can suppress Mn, Zn & Cu uptake
Manganese	High levels (48 ppm) can suppress Fe, Zn & Cu uptake
Zinc	High levels (12 ppm) can suppress Fe, Mn & Cu uptake
Copper	High levels (5 ppm) can suppress Fe, Mn & Zn uptake and also cause phytotoxicity
Boron	High levels (9 ppm) can be very phytotoxic

Table 17. Ranges of Various Minor Elements in the Soil and Plant Tissue Considered Optimum and Excessive

	Soil analysis, ppm		Tissue analysis, ppm[a]	
	Optimum	Excessive	Optimum	Excessive
Iron (Fe)	12-18	96	125-175	300
Manganese (Mn)	12-18	48	60-90	250
Zinc (Zn)	2-4	12	80-120	150
Copper (Cu)	1-2	5	15-20	40
Boron (B)	1-3	9	20-40	100

[a]Bentgrass Putting Green (7-2-1 mix).

CORRECTING OR PREVENTING MINOR ELEMENT DEFICIENCIES

Under field turf conditions, minor element deficiencies, when they occur, will most likely be found under the following conditions: 1) in high-sand-content soils with a pH greater than 7.5 and a low cation exchange capacity (less than 8.0), and 2) in highly calcareous soils with a pH greater than 7.5 and irrigated with high pH water (greater than 7.5). In addition, a number of fertilizer specialists suggest that greens constructed of high-sand fractions and combined with intensive maintenance to force a high growth rate may represent another site where minor elements could become limiting. The continued and essential practice of removing clippings, and the low mowing which restricts root growth would also be expected to contribute to minor element deficiencies.

Iron is the most frequently reported minor element that is limiting for turf growth. Many fertilizer products formulated for lawns and professional turf areas contain iron. Such products are widely used across the southern United States, in arid plains, and along the West Coast. Iron-containing products are well adapted for application on greens across the basic North during the growing season and are often used for holding turf color, thus reducing nitrogen requirements.

Manganese represents the second minor element that has been observed to be limiting. Products containing manganese are used most widely in the South Atlantic area, peninsular Florida, and the Southwest.

Some golf greens, regardless of location in the United States, represent a potential area where minor elements can become limiting. The practice of periodic applications of a complete minor element package along with major nutrient elements is felt to provide a good preventive approach to avoiding minor element deficiencies. In addition, it is essential to maintain a pH range between 5.2 and 6.5; avoid excessive applications of phosphorus and lime, and hold a proper soil balance of minor elements (Tables 17 and 18).

Table 18. Guidelines for Correcting or Preventing Minor Element Deficiencies with Granular Formulation

	Corrective, lb./acre[a]	Preventive, lb./acre/year[b]
Iron (Fe)	4	1
Manganese (Mn)	4	1/2
Zinc (Zn)	4	1/2
Copper (Cu)	1	1/2
Boron (B)	1/4	1/4

[a]Apply granular products to moist foliage or use half the recommended rate if foliar sprays are preferred. A lower rate is required to prevent foliar discoloration.

[b]Apply one-fourth the recommended rate four times during the growing season (early spring, late spring, late summer, and mid-fall).

Correcting minor element deficiencies by just applying the minor elements will often be difficult. It is equally important to maintain good chemical and physical soil properties as indicated above.

Soil analysis can be very beneficial in determining the status of minor elements in your soils. Where minor element deficiencies are suspected, a soil analysis should be carried out for confirmation. Tissue analysis can also be helpful, particularly where serious minor element problems occur.

We have noted an increase in reports of phytotoxicity induced by minor elements. This most frequently occurs where organic materials (such as sludge products) are used in top-dressing of greens. If sludge products are used, it is very important to have an analysis carried out to determine the minor element levels. Zinc and copper are the two elements often found at high levels in sludges.

Careful use of metal-containing fungicides should also be given attention. Avoid continuous heavy use of such products. When used in combination with nonmetal-containing fungicides at proper dosages, chances of problems from minor element phytotoxicity should be lessened.

SUMMARY

The minor element requirements of turfgrasses have been studied over a ten-year period on a wide range of plant material and under extremes of soil and climatic conditions. The following conclusions can be made:

Turf Tolerance

1. Turfgrasses are much more tolerant to minor elements applied as a single element than to a package containing all six minor elements in a water soluble form.

2. Minor elements can induce severe damage to turf if improperly used. Correction of excessively high levels of minor elements is difficult. The most phytotoxic minor element is boron, followed by copper, zinc, and molybdenum. Iron and manganese are the least phytotoxic.

3. Phytotoxicity can be dramatically reduced by using a slowly soluble glass matrix containing minor elements or by using water soluble sources judiciously.

Turf Response

1. Warm-season grasses are much more responsive to minor elements than cool-season grasses.

2. Iron and manganese are the most limiting of the minor elements essential for turfgrass growth and development.

3. Iron will correct chlorosis of turf caused by an iron deficiency and will enhance color of turf that is not apparently deficient in iron (Hidden Hunger).

Soil and Tissue Analysis

Soil and tissue analysis can be used as a tool to determine minor element deficiencies or excesses. This is particularly true with boron, manganese, molybdenum, copper, and zinc, although iron analysis is of less value in predicting nutrient needs.

Correcting and Preventing Minor Element Deficiencies

1. Maintaining minor elements at a proper balance in the soil and providing a good soil environment for maximum nutrient uptake are essential. If these conditions are not obtained, correction of deficiencies is only temporary.

2. Slowly soluble glass matrix containing minor elements has been found to be effective in preventing minor element deficiencies, provided severe imbalances in soil nutrient and pH do not occur. For correcting deficiencies, highly soluble sources of minor elements are preferred.

COMMERCIAL LAWN SERVICES

Robert W. Miller

Lawn service companies are just beginning to find their place in the turfgrass industry. Although lawn care companies in some form may have existed for many years, they did not become prominent until pesticides became a major factor in agriculture. Early lawn services were largely an extension of other horticultural activities. Only in the last ten years have lawn care companies operated on a regional or national scale.

LAWN SERVICES TODAY

Several types of lawn care companies are now in operation. Perhaps the most numerous type is mowing and grooming, which may be operated either by students and others on a part-time basis, or by full-time commercial companies that may offer other services in addition to mowing. Although mowing services are mostly local and small, the total expenditure for this type of service is undoubtedly large.

In some areas of the country, lawn service companies specialize in pest control. Often these operations are a part of structural pest control services or other related businesses. These services are prominent in Florida and other locations where chinch bugs or other insects are especially troublesome.

Several regional and national companies sell franchises to an individual to operate a lawn service business in one location. The parent company usually helps in establishing accounting and operating procedures and may sell chemicals to the franchise. However, a recent court decision ruled that a franchise had the right to purchase materials on the open market and is not obligated to purchase from the parent company.

Franchise operators offer a wide range of services. Most of them apply fertilizers and various pesticides. Some of them overseed, spike, aerify, and offer other services. Special equipment that does several operations at one time often is included in the franchise cost. In most instances, an individual franchise remains small because of boundary restrictions that are a part of the franchise agreement.

Another type of lawn care service is operated by the owner on a local level. Local lawn service companies operate in many different ways. This type of company may be small to medium and may service from a few hundred to ten thousand or more customers. These companies offer a wide range of services depending on the individual operation. Mowing, landscape maintenance, and other services may be included in a base price or may be offered as optional services at additional cost.

In the last ten years, some lawn care companies have operated in several cities on a regional or national level. Each branch is company-owned and is operated by company employees. Some of these companies utilize part-time employees, others do not.

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The type of service offered by the regional or national companies varies almost as much as service options of local firms. Most of them, however, apply fertilizers, herbicides, and insecticides as required by local conditions. A few companies apply fungicides on a programmed basis, but most do not unless there are unusual disease problems.

Some companies offer a complete package at an annual cost. Others charge separately for each component of the program.

The amount and kind of fertilizer and other chemicals used differ among companies. Some use soluble and water insoluble nitrogen sources, while others use only soluble materials. Phosphorus and potassium may or may not be included in all applications. Lime, where needed, is applied by some companies; others either omit a lime treatment or use one of the so-called "liquid lime substitutes." Some companies include "soil conditioners" in their programs. These conditioners may be anything from potassium carbonate to one of several liquid materials on the market.

CONTRACTS AND PRICING

Lawn service companies may either require an annual contract with or without prepayment, or they may operate without contracts and charge only after applications are made. Costs of services vary several hundred percent among companies. Costs for chemical applications to an 8,000 sq. ft. lawn vary from as little as $85 to as much as $300 for 4 to 6 scheduled annual treatments. Some lawn care companies make service calls and apply supplementary applications at no additional cost to their customers; others offer limited service without additional charges; and some charge for all service calls.

LAWN CARE AS A SERVICE

The most important item that any lawn care company has to sell is service. Homeowners are not particularly interested in what products are applied to their lawns. They are interested in a nice-appearing lawn, free from weeds and other problems. They expect the company to respond quickly to service calls, and they expect prompt corrective action if they have problems. Many of their questions are related to trees, shrubs, and other landscape plantings. Customers want qualified people with professional equipment to make applications, and they expect the treatment to be made with care--care for both the lawn and for surrounding plants and properties. Service is the name of the business.

OBSERVATIONS ABOUT LAWN SERVICES

Two points should be obvious from the previous discussion. First, the lawn service industry is unorganized, and there is little chance that it will be organized in the near future. Secondly, there is no standard of quality for the industry. It is unlikely that standards could be agreed on and even less likely that they could be put into effect. State and federal requirements for pesticide operators' license and label restrictions for the use of pesticides have hampered marginal operations. Also, some states require that the invoice must state the amount of fertilizer applied to a lawn. Other than these restrictions, the only standards are those set by leaders in the industry. An individual selecting a lawn care company should have a clear understanding of the services offered by the company, the materials that will be applied to the lawn, and the reputation of the company in question.

ADVERTISING TECHNIQUES FOR THE LAWN CARE INDUSTRY

Robert Early

We asked our readers if they advertise: 76 percent of the chemical lawn care companies said "yes"; 68 percent of mowing/maintenance companies said "yes."

When we asked them what advertising mediums they used as their primary source, 27 percent said Yellow Pages, 21 percent said direct mail, 18 percent said newspaper, 16 percent said door hangers, 5 percent said phone solicitations, 5 percent said television, and 5 percent said radio.

When we asked them what their annual ad budget was, we got answers all the way from $1,000 to $105,000. The average answer was $5,900, but two-thirds of the answers were $3,000 or less. Since the average yearly gross of respondents to our survey was $199,000, the average ad expenditure of $5,900 is about 3 percent of the average gross.

We surveyed a cross-section of consumers, and asked them which would be the best way to reach them with a lawn care ad: 44 percent said direct mail, 27 percent said personal solicitation, 15 percent said door hanger, 12 percent said newspaper, 8 percent said Yellow Pages, 8 percent said a home and garden show display, 1 percent said radio, and not one person said phone solicitation.

In the same survey, we asked consumers what were the main ways they rated a lawn care company when determining if they wanted to hire it. In order, the consumers listed (1) reputation, (2) recommendation from a neighbor or associate, (3) price, (4) worker/equipment appearance, (5) advertising.

It is interesting to note that price is only third on the list and that advertising is fifth. But it is reasonable to ask, "How do you get a reputation or recommendation in the first place unless you use advertising to get your first customers?"

USING YOUR CUSTOMER TO SELL. Ask just about any lawn care businessman how he gets most of his customers and he will say by word-of-mouth or referrals. Another way some lawn care businessmen have tried to assure that their present customers will give referrals is by offering rebates. One company offered a $5 referral fee to customers who recommended people who eventually signed up. The present customer pays the full fee and then receives a rebate. One company paid out $1,000 last year, but feels the program is worth it.

DO YOU NEED AN AD AGENCY? Probably not. One lawn care businessman said that all he found an agency he hired was doing was asking him for suggestions, and then coming back and offering those original suggestions in a slick package. He said he felt he could have done the same job himself a lot cheaper.

One area where you may need professional help is in creation of a logo. You should probably hire a professional graphics designer who also produces the design.

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A combination graphic designer and producer will keep an eye on dollars when asked for an idea. A simple graphics designer may just think of something pretty and develop a logo that might be too expensive. The cost of developing a logo can be as low as $100, but should not run more than between $300 and $500.

When designing your advertising, remember the old dictum K-I-S-S -- "Keep it simple, stupid." Nothing is worse than cluttered advertising or logo.

The logo design does not have to be anything elaborate. Just use it constantly. A company logo has a wide variety of uses. It can be displayed on uniforms, vehicles, outdoor signs, Yellow Pages ads, television commercials, stationery, invoices, novelty items such as matchbooks, or pencils.

The most important point is to use it over and over again. Repetition of the image--even if it is bad--is the key.

CONCENTRATION. Most lawn care companies concentrate their advertising in the better parts of town. Define your market and concentrate your efforts to get the best results. Metro newspapers reach a larger audience; weeklies are more likely to hit your prospective customers. Build customer lists where you already have customers. Have your technicians drop off literature on their routes. First, the person receives the literature. Then he may see your technician out on his neighbor's lawn, and this reinforces the message. Finally, he may ask a neighbor receiving the service about your company, and receive the best advertisement of all--the recommendation of a satisfied customer.

Many companies do what they call "cloverleafing"--handing out brochures to customers on either side of and across the street from existing customers. One company recently told us they doubled their business one spring, and that 65 percent of this increase was due simply to a door-to-door leafletting campaign in areas where they already had customers.

Another lawn care businessman suggests that when you go into an area, don't do it haphazardly. Concentrate on it. Talk at garden club meetings, Lions Clubs, and Jaycees, offer services to fertilize the local high school football field in exchange for a mention in the program, etc. It is a write-off on taxes and can establish you in a community.

Although another lawn care businessman's philosophy is to try to keep as concentrated as possible, he is not afraid to break in a new territory that he feels has potential. He takes on customers 30 to 40 minutes away from his office, then puts on a big push to build up business in that area to make it profitable. Once he gets a few customers, he advertises heavily to get more as soon as possible. This particular businessman has 2,000 customers and spends $15,000 a year on advertising, most of it on 70,000 mailings--30,000 in spring and fall to the best prospects, and 10,000 for a third mailing to the really good areas.

DISTINGUISHING BETWEEN MARKETS. In a relatively new lawn care market where you are dealing with many potential "first-users" of a lawn care service, your job is educating the customer to lawn care. In a more competitive market, your job is to differentiate between you and your competition. In a competitive market, it is important to stress price to show that you are in the same ballpark, but don't sell and differentiate yourself on price alone. At some time you have to come up with a different approach, a different tone for your promotional strategy. Differentiation can be achieved by extras added on to your service--like liming, soil testing, seeding--free in some cases.

Most serious lawn care companies have printed brochures that explain to the customer the problems a lawn will encounter in the course of a year and how the customer and company working together can deal with them. Many also have included tips in these brochures explaining irrigation and mowing practices that the customer must do to keep the lawn healthy between visits by the lawn care company. Other companies have separate mailings at different times of the year when particular problems such as disease might develop. These mailings inform the customer of the potential problem, then tell the customer what they can do about it, or offer the services of the lawn care company.

YELLOW PAGES. Yellow Pages advertising is a mainstay of lawn care companies and others in the service field. In metropolitan areas, small display ads can cost $50 a month. A typical 3-1/2 inch by 5-inch ad can cost up to $3,000 a year. Make the space count.

Larger display ads permit use of more copy, illustrative material, etc. But even those who invest in larger space often prefer to keep copy brief, surrounding it with lots of white space, feeling it results in more impact.

One lawn care businessman said he keeps uppermost in his mind the fact that his ad will be surrounded by those of his competitors, and that is all the stimulation he needs to prepare the best ad possible to make it different and stand out.

Build your ad carefully. Be specific. Concentrate on the essentials. Avoid tricky phrases. Generalizing in ads only leads to unwanted calls. People look for guidance and information in ads. One lawn care businessman said he writes his ad copy as he would a telegram.

Don't be bashful about seeking the help of the Yellow Pages ad reps. They can offer help on elements such as typeface, borders, even illustrations. But don't be too quick to accept all of their recommendations. Above all, avoid turning the entire matter of putting the ad together over to the reps, or your ad will end up looking like all of the others in the Yellow Pages. Remember, if you have a service or two that makes you different, include it.

It is important that you check ad proofs of your copy carefully for errors or omissions like a wrong number or address. You will have to live with mistakes for a whole year.

Here are some tips you might find useful in composing your ad for the Yellow Pages: (1) Explain your coverage; it is important that you target the area you want to serve, so that you do not get unwanted calls. (2) Stress your company's longevity if that is a factor. (3) Explain fully the major services you furnish. (4) Highlight your firm name, address, and phone number in bold type. (5) Explain special customer handling features such as "no contract required" or "call for price quote, no obligation." (6) Use artwork for impact.

One lawn care company believes in splashing what his company does rather than company name across the top of the ad. He has "lawn spraying" in large letters and his company name in smaller ones. He also has attractive artwork of a man spraying a lawn and a spray truck. This leaves no doubt as to what the company does.

One more suggestion--have a woman make initial contact with callers from your ad. It is sound public relations. People naturally react favorably to a friendly, pleasing feminine voice coming on the phone first.

DIRECT MAIL. Newspaper is a shotgun approach to lawn care advertising, direct mail is a rifle shot. Most companies expect a response between 1-1/2 and 3 percent on their direct mail ads, and expect to close between 65 and 80 percent of the leads they get. Many companies send out 60 percent of their direct mail pieces in the spring, another 20 percent in the fall, and the rest spread out over the rest of the year.

Many lawn care businessmen are leary of using services to distribute their brochures, because they feel there is often no guarantee they are being delivered. It costs about 4 cents to distribute brochures through a service, about 9 cents for bulk mail, and 15 cents first class. Most use bulk mail for their brochures and some utilize first class for prime areas. It depends on your situation.

Many businessmen keep a list of past customers and inquirees even if they did not sign up the first time. People are funny, they might skip a year and then come back with your service.

PHONE SOLICITATION. Lawn care businessmen feel strongly about phone solicitations--both pro and con. One lawn businessman added 1,600 customers this past spring using 10 persons who hung door hangers by day and made phone calls at night. Others pay about $3.50 an hour for phone solicitors, requiring an average of two leads for each hour spent on the phone. Some pay 25 cents a lead, others pay $1 per sale.

Others say they would never use phone solicitations, because leads are frightfully expensive if you don't convert them to a sale. One lawn businessman said that a phone lead is four times as hard to sell as a direct mail lead.

TV AND RADIO. Television advertising makes a tremendous impact, but the cost is naturally very high. Only larger companies can really afford to use this kind of advertising. Radio is a little more within the reach of the ad budget of the smaller lawn businessman. For a small suburban station, the average is $10 per minute. Major markets cost about $30 a minute.

CHANGING TRENDS IN TURFGRASS PESTICIDE FORMULATION AND APPLICATION PROGRAMS

A. J. Turgeon

Contemporary turfgrass managers are fortunate in having a wide assortment of pesticides for controlling weeds, diseases, and insect pests. Most of the current inventory of commercially available pesticides was developed in the 1950s and 1960s when agricultural chemical companies were introducing many products arising from their synthesis and evaluation programs. In recent years, however, introductions of new pesticides have slowed because of higher development costs and competition from currently available materials. Consequently, one facet of pesticide research that is receiving increasing attention is the development of innovative formulation methods to modify the interactions between a pesticide and the crop system to which it is applied. Formulation measures that are effective in controlling pesticide bioavailability and mobility can substantially improve performance characteristics and thus provide better materials at lower development costs.

At the University of Illinois, cooperative work with USDA personnel has been in progress for two years to evaluate the potential of controlled-release preemergence herbicide formulations for annual grass control in turf. These have included a sludge polymer material in which pesticides are embedded and released in conjunction with microbial decomposition of the sludge matrix, and a starch xanthate material in which pesticides are entrapped and released through a combination of diffusion and matrix decomposition processes. Two years of field testing showed the sludge polymer formulation to be unsuitable for use with preemergence herbicides because of severe turfgrass injury following application. The starch xanthate formulation, although not entirely satisfactory, did show promise for regulating the bioavailability of the herbicides. Intensive research is currently under way to determine mechanisms of release and means by which the formulation can be modified to provide satisfactory pesticide-release rates.

To understand how controlled-release herbicide formulations can be used satisfactorily, it is important to review the general fate of a preemergence herbicide following its application to turf. Numerous forces continually act upon a residual herbicide to reduce and eventually deplete its concentration at the weed seed germination plane. Depending upon the herbicide, these may include volatilization, runoff, photodecomposition, absorption, adsorption, leaching, chemical reaction, and microbial degradation.

Conversion of a pesticide to the gaseous form and its subsequent loss to the atmosphere is termed *volatilization*. The potential for volatilization loss depends upon the vapor pressure of the pesticide, temperature, and possibly other environmental conditions. The precipitation rate from irrigation or rainfall, slope angle, and solubility of the pesticide influence *runoff*, the lateral movement of the pesticide from points of application to other locations. *Photodecomposition* is the process by which a pesticide is transformed under the influence of light. Although difficult to measure and separate from other types of pesticide decomposition, photodecomposition is recognized as a significant depleting factor with

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some pesticides. *Absorption* is the uptake and removal of a portion of the pesticide by microorganisms, germinating and mature plants, and other organisms. In contrast, *adsorption* is the physical binding of a pesticide to colloidal surfaces, including clay and organic colloids. Depending upon soil texture and organic matter content, the amount of a pesticide required for weed control can vary by 50 percent or more. Downward movement of a pesticide in the soil is termed *leaching*. Factors influencing leaching potential include: pesticide solubility, soil texture, adsorptive tie-up of the pesticide by soil constituents, and the amount of water received by, and percolating through, the soil. *Chemical reaction* refers to nonbiological transformations of the pesticide; it can include such processes as oxidation, reduction, and hydrolysis. *Microbial decomposition* refers to processes by which pesticides are transformed by bacteria and other microorganisms. Usually, these processes result in a reduction or elimination of pesticide activity, and they are often associated with a breakdown of the pesticide's chemical structure and the production of small carbon compounds similar to, or the same as, other naturally occurring compounds.

The fate of preemergence herbicides in turf, then, includes all avenues by which the pesticide is moved away from the weed seed germination plane or chemically transformed to reduce its activity. Entrapment and application of a herbicide in a controlled-release formulation isolate the herbicide from the environment until it is released; its mobility is thus reduced and its persistence increased, resulting in a potentially more favorable interaction between the herbicide and the ecosystem to which it has been applied. An effective controlled-release formulation must release the herbicide fast enough to achieve a concentration sufficient to control weeds; this has been termed the "threshold concentration for efficacy" (TC_e). However, if the bioavailable concentration of some preemergence herbicides is too high, injury to turfgrass may result. The concentration above which injury occurs is the threshold concentration for phytotoxicity (TC_p). Ideally, the bioavailable herbicide concentration should be just above TC_e and remain at that level throughout the germination period of target weeds. With continued research, perhaps this ideal can be approached and the turfgrass manager better served with the development of controlled-release formulations of herbicides and other pesticides.

RESEARCH NEEDS OF THE LAWN CARE INDUSTRY

James F. Wilkinson

The lawn care industry is expanding at a tremendous rate. Few people, even as recently as three to four years ago, would have anticipated the growth the industry is now experiencing. Most people would now agree that lawn care is becoming a vital part of the total turfgrass industry.

Lawn care services have been available to homeowners for many years; however, until recently, few professionally trained turfgrass managers were involved in the lawn care industry. Many operations in the past consisted of one man, a pickup truck, and a fertilizer spreader. The recent surge in the lawn care industry has been backed in most cases by professionally trained turfgrass personnel. As a result, more questions than ever are being raised regarding the various programs and products being used. This article discusses research needs that have not been totally met or that have been ignored by turfgrass research in the past.

Although turfgrass research began as early as the 1880's, major strides were not made until the late 1950's with the introduction of new pesticides and improved cultivars. Both university and industry research have contributed strongly to turfgrass science. University research has contributed most heavily in the areas of turfgrass breeding, fertility, nutrition, and management, whereas industry has made major advances in the development of new pesticides for weed, insect, and disease control.

Despite many major achievements in turfgrass science, numerous areas remain a concern to the turf industry as a whole: the development of disease-resistant cultivars and cultivars tolerant to low fertility and drought stress; fertility problems relating to more efficient use of N, P, and K coupled with improved diagnostic methods (soil and tissue) to evaluate nutrient requirements; better understanding of insect problems, life cycles, and control; new or recently recognized disease problems such as anthracnose and red leaf spot, and insect problems such as the Ateanius grub; and the need for more thorough investigation of problems relating to management--mowing and thatch, establishment, renovation, and cultivation.

SPECIAL RESEARCH PROBLEMS

The lawn care industry also has many research needs, pertaining to a particular segment of the industry. These needs are the result of several factors.

1. Most lawn care companies schedule visits to a lawn from six- to twelve-weeks apart. This situation creates the need to insure adequate residues of both fertilizers and pesticides to last through this six- to twelve-week interval. In addition, working on such a schedule often means that a company representative is not on a lawn frequently enough to spot developing problems. As a result, a lawn care service often is called back to a lawn by the homeowner after a particular weed, insect, or disease problem has gone beyond the point of easy control.

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2. Lawn care companies must maintain a multitude of homelawn situations. Many different microenvironments, soils, species, and cultivars are encountered. Turfgrass management is made easier in many ways when the manager, for example a golf course superintendent, works with a limited number of species, soils, etc. Many lawn care companies are modifying programs to fit sun vs. shade conditions or species differences, and are utilizing soil tests to make supplemental applications of lime, P, and K when needed. However, there is a great need to improve programs to meet the special requirements of individual lawns.

3. Because of several distinct operational advantages, many companies are successfully utilizing liquid systems to deliver soluble and insoluble fertilizers and pesticides. This practice is relatively new in turf management although liquid fertilizers are being used extensively in agriculture. The liquid application technique for fertilization has not been researched to the same extent as the application of dry fertilizers.

4. Most companies today, whether utilizing liquid or dry programs, are applying a number of different fertilizers and pesticides in one pass over a lawn. This combining of materials leads to two situations that can create problems: (a) chemical incompatibility, where materials are not compatible within the same spray tank, and (b) placement incompatibility, where different materials applied together are aimed at targets at different locations within the turf microenvironment. For example, the combined use of a broadleaf herbicide and an insecticide for grub control, whether applied liquid or dry, would present placement problems. The herbicide should remain on the foliage to achieve maximum control, whereas an insecticide should be watered into the soil.

SPECIFIC CHALLENGES FOR LAWN CARE RESEARCH

A very limited number of lawn care companies today support active research programs, and few if any university research programs are aimed directly at the special problems of the lawn care industry. However, as many companies grow within the rapidly expanding lawn care market, more and more of them will recognize the research needs of the industry. If the industry is going to reach its full potential, the following areas will require research attention.

1. How can we more closely adjust programs to meet the specific problems of different locations, soil types, microenvironments, species and cultivars, present pest problems, etc.? We would require a highly trained applicator who could adjust programs as the different situations from lawn to lawn dictate. Specialized application equipment must be developed to accomplish this: delivery systems which would enable the applicator to adjust programs from one lawn to the next would be a boon to the industry.

2. Liquid fertility programs require a substantial research effort. Fertility research has traditionally been based on dry programs. Much research conducted utilizing dry fertilizers and pesticides is not completely valid, and many established ideas must be reevaluated.

3. Coupled with liquid fertility research, the mechanism of physiological burn and materials that produce burn will be a continuing problem. New materials and old materials in new combinations will have to be constantly evaluated for burn potential. One serious problem that exists in this area is that we often recognize the problems leading to burn; however, we are not always able to adjust our production schedule or materials rapidly enough to avoid burn totally.

4. Understanding tank-mix compatibility is an area which has been given little attention in the past. More and more lawn care companies are utilizing liquid programs, combining several different fertilizer and pesticide materials in one spray tank. Several articles have recently appeared in trade magazines regarding tank mixing; however, these have often contained old, erroneous information leading to confusion within the industry. Most lawn care companies unfortunately have taken a "try it and see" attitude. Especially as new products become available, much more knowledge needs to be gained regarding tank mixes and their chemical and physical compatibilities. In addition, companies with dry programs often utilize fertilizer and pesticide combinations that have not been thoroughly evaluated for pesticide efficiency.

5. New and improved fertilizer materials need to be discovered, especially in the utilization of fertilizer materials in liquid programs. A liquid slow-release nitrogen source would find wide acceptance in the lawn care industry. Another important area would be the development of slow-release nitrogen sources with improved release properties that would fit into production schedules better. Questions relating to efficient fertilizer utilization must also be answered.

6. Weed and insect control programs will need continual improvement. Many hard-to-kill weeds are special problems. In addition, applying herbicides and insecticides on a six- to twelve-week production schedule presents several problems for the lawn care industry. For example, applying an insecticide that has a critical timing requirement becomes difficult. Other examples of problems include the application of a preemergent herbicide to every lawn in the spring prior to annual grass germination, short insecticide residual, and movement of insecticides through thatch for grub control where irrigation generally is not available. Alternative pest control measures, such as controlled release of encapsulated pesticides, may provide part of the answer.

7. Few people within the lawn care industry have given sufficient attention to the long-term effects of fertilizer and pesticide programs. Although some recognition is now given to the possible detrimental effects of continual preemergent herbicide usage, more research is required. Alternative approaches to annual grass control may be needed. Other pesticides also may be causing long-term detrimental effects. Continual use of improper fertility programs which initially appear suitable could lead to the long-term degradation of a lawn.

8. New products that require evaluation will continue to become available. Despite the availability of many excellent pesticides, the pesticide industry recognizes the tremendous potential for sales within the lawn care industry. Alternative products, often economically attractive compared to older materials, will become available on a continuing basis. Also, newer materials such as spray adjuvants, wetting agents, and antidrift agents will be introduced to the industry, all requiring substantial testing and evaluation.

CONCLUSION

The lawn care industry has a huge expansion potential; however, the industry as a whole must provide high-quality services and programs to the homeowner. A few companies providing inferior programs could rapidly attach a bad reputation to the entire industry. Only through research to answer some of the above questions can the lawn care industry be continuously evaluated and upgraded.

CONCERNS IN GOLF GREEN CONSTRUCTION

James L. Holmes

In 1953 when I first became familiar with green construction and maintenance, the more enlightened people kept telling me that the single most important consideration was drainage, both air and water. Now, in 1978, after I have built many greens and helped to bring in and maintain some of them, the more enlightened people keep telling me that the single most important consideration in green construction is drainage, both air and water.

BUILDERS

Most proper green construction results from a mixture of 70 percent common sense and 30 percent scientific knowledge and experimental expertise. The technical knowledge is of paramount importance, especially to the man who "brings in" and maintains the area. And later on to the golfer.

I have learned that water infiltration and percolation up to 15 inches per hour will perch adequately to establish grass. Research and experience show that infiltration will decrease significantly in three to four years. Consequently, not only are we no longer afraid to utilize this rapid-draining soil medium for green construction, but informed builders and designers insist upon it. Of course subsurface drainage is built in and exists.

It is demanding and difficult work to make certain that greens are constructed accordingly. Many builders do not bid the job high enough to finish it properly and do not have the technical knowledge to follow through, sometimes resulting in an attitude of "What difference does it make?" Examples come to mind immediately.

> A set of greens was constructed using a mixture that met drainage specifications, with tile and an adequate gravel layer installed. An "agronomist" employed by a farm equipment manufacturer looked over the area and said, "Materials seem O.K., but we can't have this layered effect." So a large tractor-drawn rototiller was brought in and the entire profile, including some tile, was mixed together.
>
> Eighteen greens were finished and properly constructed. Another contractor was finishing out the surrounding area. He simply dragged "topsoil" over most of, and in some cases all of, the finished putting surfaces.
>
> Another set of greens was built properly and seeded with bentgrass. When the surrounding area was seeded with bermudagrass, all greens were also seeded with the bermudagrass.
>
> I repeatedly see greens that have an appalling lack of surface drainage. Actual sink holes or lakes are developed. Of course both the builder and the architect, if they are not the same, disavow responsibility. The golf course superintendent is usually left with the problem of correction.

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Not only are the constructors not properly informed but, most important, they simply do not know how to follow up the work properly or care to. The most glaring weaknesses might be listed as:

1. Not bidding or figuring properly.
2. Lacking technical or scientific knowledge.
3. Lacking practical experience and refusing to locate experience.
4. Cutting corners or having an attitude of "What difference does it make?"
5. Not paying enough attention to surface drainage.
6. Failing to hire a reliable golf course superintendent at the onset of construction. Or, if rebuilding, failing to make certain that the existing superintendent is informed and consulted throughout.

DESIGNER OR ARCHITECT

They come in all shapes, sizes, and degrees of expertise. Many actually look with disdain on agronomic knowledge--they are "artists." So how do they know what a construction party is really up to in green-building? Are they there to witness the short-cuts?

Numerous greens are still being built larger than 12,000 square feet. Do we really need all that putting surface and can we afford to maintain it? On the other hand, some greens are built or rebuilt with less than 2,000 square feet of putting surface.

Often it is obvious that a slight or even major change in design will not only save a significant amount of construction dollars but will be shown to improve upon the design, once the area is observed "on the ground," as it naturally exists, rather than on paper. But many designers will insist that the paper plan be followed. Examples where changes may help are: existence of rack ledges, boggy wet locations, presence of a superb tree or trees, improvement in air drainage, safety considerations, size of green, accessibility for equipment, major water line locations, locations of underground utilities, and of course many others. Green location and design should and must be the deciding factor.

CONCLUSION

I know that every golf course superintendent who has gone through any kind of construction or reconstruction can add to what I have said. Even while I was writing this paper, other things came to mind, such as: misuse of equipment, not properly finishing out the putting surface before seeding, taking no precautions against erosion, inadequate removal of stumps, inadequate drainage of sand bunkers, and on and on. Some of these are facets of the an attitude, "What difference does it make?"

FREQUENT TOPDRESSING OF GOLF GREENS

Victor A. Gibeault

The golf course putting green is certainly an intensively maintained grass sward. It is usually mowed daily, irrigated and fertilized frequently, and cored, vertical-mowed, and treated for pests as needed. Commonly, a green is topdressed once or twice a year to make the putting surface firm and even and to create a microenvironment more conducive to thatch breakdown. These expensive maintenance practices are needed because of the tremendous increase in wear and compaction, and the increased desire for high quality turf that has followed the growing popularity of golf.

Research conducted by Dr. John Madison and Mr. William Davis of the University of California at Davis investigated the problem of maintaining turf under high-trafficked situations. They found that topdressing could be the most important practice under such conditions, especially if the proper topdressing material is applied at an optimum frequency. They noted that a good topdressing program reduced the need for other maintenance practices, that it produced the best putting surface, and that it provided maximum playability. There was also a reduction of thatch layering as well as a reduced concern with activity of pests in soil, air, and water. For these positive results to occur, certain criteria are necessary: the topdressing must be applied at a frequency that is associated with the growth rate of the grass; the topdressing material must be sand with a definite particle size distribution range; the topdressing must be applied lightly at each application time; and a cushion must be maintained that will moderate the effects of wear.

The frequency of topdressing is directly governed by the growth rate of the grass because this program attempts to intermingle sand grains uniformly with newly produced plant parts (that would accumulate to produce a thatch/mat layer). Under test conditions in certain California climates, a light topdressing every three weeks was optimum during times of rapidly creeping bentgrass growth. This frequency decreased to every several weeks as growth slowed during the winter months in California. Of course, with winter conditions in Illinois, no topdressing would be applied.

The sand that is used for topdressing was found to be a very important aspect of the program. A sand with the largest fraction in the medium range and next greatest fraction in the fine range is desirable. Sands having limited coarse and very fine sand fractions could be accepted, as indicated in Table 1, prepared by Madison and Davis. They found that additions of organic material to the sand were not needed.

The topdressing application rate is in the range of 2 to 3 cu. ft. per 1000 sq.ft. of green surface. Topdressing applied at this rate can be easily moved downward and out of sight by a single brushing, dragging, or light irrigation. If topdressing is applied properly, afternoon players are unaware that the green

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Table 1. Sand Particles Size Distribution

Sieve Opening mm	U.S. Standard Sieve No.	U.S.D.A. Class	Golf Green Construction Desired	Golf Green Construction Accepted	Golf Green Topdressing Desired	Golf Green Topdressing Accepted
2.38	8	Fine				
2.00	10	Gravel				
1.68	12	Very				
1.41	14	Coarse		0-10%		
1.19	16	Sand				
1.00	18					
.841	20					
.707	25	Coarse				
.595	30	Sand	0-15%	80-90%		0-15%
.500	35					
.420	40					
.354	45	Medium				
.297	50	Sand	80-85%		100%	75+%
.250	60					
.210	70					
.177	80					
.149	100	Fine				
.125	120	Sand				
.105	140					
.088	170					
.074	200	Very				
.063	230	Fine	4-8%	5-10%		0-8%
.053	270	Sand				
.044	325					
.037	400	Silt and Clay				

was topdressed that morning. Excellent topdressing application can be accomplished with commercially available spreaders operated by a knowledgeable person.

If sand topdressing is applied too frequently and too thickly, the sand particles produce a layer of pure sand instead of intermixing with recently produced plant parts. Such a layer can be hard and abrasive to the more delicate grass leaves immediately above. Damage to grass blades, which usually results from this misapplication, shows ball marks and the effects of foot and equipment traffic. Also, because the putting surface is too hard, the greens are fast and will not hold a well-placed golf shot.

In summary, I have attempted to outline some of the basic aspects of frequent topdressing for greens maintenanace. As was discussed at the turfgrass conference, I feel that superintendents should try this program on practice or nursery greens to evaluate the results and then experiment with methods before embarking on a course-wide treatment. Also, it would be advantageous to work with university personnel and other superintendents through association meetings to discuss approaches, successes, and failures in your area.

GOLF COURSE PROBLEMS—WHAT ARE THE ANSWERS?

Jack D. Butler

The problems facing the golf course superintendent are too numerous to identify. The very nature of a golf course causes more problems with greater diversity than face almost any other agricultural enterprise. The presence and involvement of large numbers of people as an integral part of the golfing business cause major problems--the problem of doing maintenance at the best time, significant wear and compaction problems, the problem that administrators (greens committees, superintendents of parks, etc.) may not thoroughly understand the superintendent's problems, and the problem of employer/employee flux. There is no way to eliminate people problems on a golf course. People pressure will only increase.

In addition to being a practicing psychologist, the superintendent must be a businessman and scientist, and it might even help if he were an artist. On a given day a superintendent may deal with the electronics of an automatic irrigation system or a complex pesticide which if used properly may save the turf or if used improperly may kill it. At the same time he may be seeking a practical solution for coping with mudhens or armadillos that are destroying the turf. With situations that present such complexity and diversity, the superintendent must assign priorities, and in most instances be the manager rather than the "doer."

No one would question that much, if not most, of the superintendent's time is spent on nondirect turf endeavours. But the measure of professionalism, whether imposed by himself or others, of the superintendent most likely is his ability to produce a high-quality turf. The superintendent must be able to manipulate conditions to grow and maintain turf of the quality that is expected.

The problems associated with keeping fine turf are too numerous to list. These might be categorized under such topics as turfgrasses, soils and fertilizers, irrigation and drainage, and pest control. In order to illustrate the complexity and extent of golf course turf problems, let us examine the topic of soils and fertilizers. Only a few considerations of this broad category will be possible.

Many of the early golf courses in the United States were built upon very good field soils. These courses were constructed with little disturbance of native, productive soils. And to this day these courses, in general, are well turfed -- even with common-type grasses--and usually not too difficult to keep.

Today golf courses are quite often constructed on very poor soils--rocky, marshy, salty, etc. In addition, because of the availability of heavy equipment, the soil is often greatly disturbed to improve the facility, although there seems to be a trend to salvage the topsoil for capping the course after shaping. When you compare the nutritional and physical (drainage and aeration) condition of the topsoil with that of the subsoil, it seems reasonable to go to great length to save and replace topsoil. No one doubts that a good soil greatly reduces turf problems.

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The use of sand as the primary ingredient for greens construciton and for topdressing has become an accepted practice. Sand size suggested for golf course use may vary (a fairly uniform sand with particles between 0.1 and 1.0 millimeter would seem to be acceptable) from one authority to another. An "ideal" sand is often not available or practical for use in large quantities for construction, but it may be reasonable to seek it out for topdressing. Research with growing mediums (artificial soils) has provided criteria for selecting satisfactory sand for golf course purposes.

Peat moss and other organic amendments are often blended with sand for constructing and for topdressing golf greens. There is great variability with organic materials and a tendency to overlook possible problems (after all, isn't it wise to use organic materials?) associated with their use. Granted, some areas have readily available and good-quality organic materials, but other areas have problems such as "peat" with only 20 percent organic matter and a lot of clay. When such a material was mixed 8:2 (sand to peat), it provided a mix that percolated only a few hundredths of an inch of water an hour, and the problem created was very expensive to correct. In another instance, manure was used to "improve" fairway soil. The manure was high in salts, and its incorrect use caused fairways to have to be stripped and resurfaced.

In some instances, field soils are used in some proportion for greens construction and topdressing. Field soils are complex, and many problems could develop from their use. It is surprising, especially in view of today's knowledge and practices, just how good many of the old greens are that were constructed of straight field soil. No doubt future studies will lead to the development of even better growing mediums than we now use for easier and better turf production.

Soil chemical properties often vary greatly from one site or area to another. Greens and other growing areas of "pure" sand require close attention to fertilizer programs. Compared with greens containing appreciable amounts of field soil, those of sand require different maintenance procedures--less fertilizer more often or the use of controlled released materials--and usually close attention to macronutrient and micronutrient needs.

Soil chemical conditions, like soil physical characteristics, normally become poorer below the topsoil. In humid areas, the pH is frequently lower below the topsoil, while in arid regions the pH tends to be higher below the topsoil. When soil is removed or disturbed, the chemical characteristics of the resulting soil are usually poorer than those of topsoil.

In arid regions high soil salts are frequently detrimental to turfgrass production. In dry areas heavy, poorly drained soils are frequentlt high in salts. Improved drainage, water of rather good quality for leaching, and gypsum, if sodium is a problem, may be utilized to correct soil salt problems. In some instances a change in turfgrass from Kentucky bluegrass to fine or tall fescue, perennial ryegrass, or even alkaligrass may help solve the problem.

Soil pH, because of its influence on nutrient availability, can induce significant turf problems. On alkaline soils, the lack of adequate available iron to meet turfgrass needs is common, while potassium is likely to be available in adequate or high amounts. Thus a fertilizer that might perform quite well on acid soils might be poor for alkaline soils.

In much of the western United States, supplemental iron applications are required for high-quality turfgrass. Under certain conditions, the benefits achieved by using iron seem to equal or even surpass those derived from nitrogen.

Pesticide residues can cause adverse soil conditions. The influence of various chemicals on turf root development, seed germination, thatch accumulation, etc., has often been observed. Rather limited efforts have been made to develop means of "turning off" pesticides in the soil. Activated charcoal has proven practical as an inactivator of certain pesticides. It and other materials may prove quite practical to turn off pesticides to speed up soil reinfestation by earthworms. The earthworms would in turn cause rapid thatch breakdown and reduced turf problems.

Soil tests are routinely done for pH, phosphorus, and potassium and often for soluble salts. Testing procedures and determinations vary with laboratories and regions. In the semi-arid regions, tests routinely determine soil available iron. Such tests provide valuable information for fertilizer selection, and they can assist in selecting cultivars. For example Adelphi, Merion, and Sydsport Kentucky bluegrass may remain green at moderately low levels of available iron; Delta and Park may be rather chlorotic at similar levels. Soil testing, especially in problem situations, can be a valuable diagnostic tool. Tissue analysis, properly used, can also help to solve turf problems.

This discussion about soil chemical conditions has dealt with only a few problems. There are many other problems. What is the best level of available zinc, as determined by a given soil test? Which of today's cultivars of perennial ryegrass are best for use at a soil salt level of 22 mmhos? These are, although perhaps not recognized, items that could be of concern to many turf producers. Thus it is apparent that to become very proficient in soils as they relate to the golf course continuous and serious effort would be required by the superintendent.

Some common limitations felt by turfgrass managers are inadequate time or money to do the job or insufficient knowledge of turfgrass science. The rapid rate of knowledge gathering and transferral will answer problems and cause additional problems. Anyone who tries to keep up to date by reading current publications on turfgrass knows that this is almost a full-time job. There seems to be a definite need for computerization and good retrieval procedures for available turf information. This would be helpful in formulating better answers to specific turf questions.

A job description for a golf course superintendent is necessarily very broad. Have you ever read or prepared one which you felt covered it all? Is it possible to be proficient in so many things or to adequately solve problems in so many areas? Most problems faced by the superintendent may not be directly related to keeping high-quality turf and the profession is fraught with problems, but would you really have it any other way?

TURFGRASS SELECTION FOR SPORT TURF FACILITIES

J.R. Street

One of the major differences between maintaining turfgrasses for functional and ornamental purposes and maintaining them for recreational or sport purposes is the degree of traffic. Recreational and sport sites are people-oriented sites, and people-oriented activities imply traffic. Two major problems associated with traffic on turfgrass sites are wear injury and soil compaction. As traffic intensity increases on sport facilities, there is usually a corresponding increase in both wear injury and soil compaction. Sport facilities are becoming overused as school enrollments increase and as young men and women and adults of all ages become more interested in athletics and physical fitness.

Selection of turfgrass for sport facilities must include consideration of environmental adaptation, intensity of culture, wear tolerance, and recuperative potential. The principal cool-season turfgrasses used on sport turf in the Midwest include Kentucky bluegrass, creeping bentgrass, perennial ryegrass, and tall fescue. Bermudagrass is used to some extent in the southern portion of the Midwest region.

KENTUCKY BLUEGRASS *(Poa pratensis)*

Kentucky bluegrass is the principal turfgrass used in Illinois. Adapted to a wide range of environmental conditions, it provides an attractive turf under proper cultural conditions. Kentucky bluegrass has good tolerance to wear and good recuperative potential because of its vigorous rhizome system. It forms a strong sod that does not tear, slip, or lift easily under the twisting and turning action of foot traffic. It also provides a resilient surface that reduces injury in contact sports.

Many cultivars of Kentucky bluegrass are available. They differ widely in characteristics such as the shade of green, texture, density, environmental and cultural adaptation, and disease susceptibility. The cultivars fall into two general groups, those susceptible to Helminthosporium leaf spot and those resistant to it.

Cultivars Susceptible to Leaf Spot

The first group includes cultivars that are susceptible to Helminthosporium leaf spot, for example, Park, Kenblue, Delta, and Newport (Table 1). Helminthosporium organisms cause leaf spot and melting-out, both of which are serious disease problems of Kentucky bluegrass in the Midwest. These diseases tend to occur more readily on heavily fertilized turf that is closely mowed. Fair to good performance can be expected from these cultivars if they are not overfertilized, particularly in the spring, and if they are mowed at a height of 2 to 2 1/2 inches. Close mowing, high fertility, and supplemental irrigation are considered advantageous in

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maintaining good playability characteristics on sport turfs. Thus a dichotomy exists between the use of these latter Kentucky bluegrass cultivars and maintenance regimes to sustain high-quality sport turf. In addition, these latter cultivars are not as inherently aggressive or vigorous as some of the newer, improved Kentucky bluegrass cultivars.

Cultivars Resistant To Leaf Spot

The second group of Kentucky bluegrass cultivars includes most of the newer or improved cultivars, all of which have some degree of resistance to Helminthosporium disease (Table 1). The resistant cultivars (A-20, A-34, Adelphi, Baron, Bonnieblue, Cheri, Glade, Majestic. Parade, Touchdown, and Victa) perform best under a medium to high cultural intensity. Some cultivars can tolerate mowing heights of less than 1 inch. These cultivars are recommended for situations where turf of medium to high quality is desired or aggressiveness and recuperative potential are essential (for example, sport turf).

Blends of Cultivars

Using a blend (a combination of several cultivars within a species) of Kentucky bluegrass cultivars is recommended for establishing turf in Illinois. A combination of 2 to 4 cultivars is suggested. Blends provide greater genetic variability, which improves disease resistance and the general adaptation of the turf under differing environmental conditions. Blending superior cultivars allows the desired features of each component to be incorporated while reducing the effects of specific weaknesses on general turfgrass quality.

The performance of any cultivar or blend of cultivars will depend to a large extent on how intensive the culture is (Table 2). Many cultivars of Kentucky bluegrass perform well when cultured at a moderate intensity. However, as cultural intensity is increased or decreased, fewer cultivars are well adapted. Cultural studies at the University of Illinois using A-20, Fylking, Kenblue, Merion, Nugget, Pennstar, and Windsor indicate that the quality of turfgrass is largely affected by disease incidence, which is related to the mowing height and fertilization rate. For example, low nitrogen rates, especially on closely clipped turf, increase the tendency for the infestation of dollar spot. High nitrogen rates and close mowing, especially during the spring, favor the incidence of Fusarium blight and Helminthosporium leaf spot on susceptible cultivars.

In 1975 a study was initiated at Illinois to evaluate the performance of twenty-one cultivars of Kentucky bluegrass under five different cultural intensities (Table 2): 3/4-inch mowing height and 4 pounds of N per 1,000 square feet per year, 3/4-inch mowing height and 8 pounds of N per 1,000 square feet per year, 1 1/2-inch mowing height and 4 pounds of N per 1,000 square feet per year, 1 1/2-inch mowing height and 8 pounds of N per 1,000 square feet per year, and 3-inch mowing height and 1 pound of N per 1,000 square feet per year (not included in Table 2). The mowing was done two or three times a week at 3/4 inch and 1 1/2 inches, and once a week at 3 inches. Fertilization was 1- or 2-pound nitrogen increments in April, May, August, and September. The 3-inch plots were fertilized in April. Plots were irrigated as needed to prevent wilting, except the 3-inch plots, which were unirrigated.

After four years, this study indicates that cultivars vary widely in their adaptation to different cultural regimes. The amount of annual bluegrass invasion is a good indicator of the adaptability of a cultivar to a particular cultural

Table 1. Kentucky Bluegrass Cultivars and Their Major Characteristics

Cultivar[a]	Resistance to: Leaf spot	Stripe smut	Fusarium blight	Dollar spot	Thatching tendency	Spring greenup
Campina	Poor	Exc.	Good	Good	Low	Exc.
Delft	Fair	Exc.	Poor	Exc.	Low	Exc.
Kenblue	Poor	Exc.	Fair	Good	Low	Good
Park	Poor	Poor	Fair	Exc.	Low	Exc.
A-20	Exc.	Exc.	Good	Exc.	Med.	Good
A-34	Good	Exc.	Good	Exc.	Med.	Good
Adelphi	Exc.	Exc.	Good	Exc.	Med.	Exc.
Baron	Good	Good	Good	Exc.	Med.	Fair
Bonnieblue	Exc.	Exc.	Good	Exc.	Low	Good
Brunswick	Good	Exc.	Fair	Fair	High	Exc.
Fylking	Exc.	Good	Poor	Good	Med.	Fair
Galaxy	Exc.	Fair	Fair	Exc.	Med.	Good
Geronimo	Good	Poor	Poor	Poor	Med.	Good
Glade	Good	Exc.	Good	Fair	High	Good
Majestic	Exc.	Exc.	Good	Exc.	Med.	Exc.
Merion	Exc.	Poor	Fair	Good	Med.	Good
Monopoly	Exc.	Exc.	Good	Exc.	Low	Exc.
Nugget	Exc.	Exc.	Fair	Poor	High	Poor
Parade	Exc.	Good	Good	Fair	Low	Exc.
Pennstar	Exc.	Fair	Fair	Exc.	Med.	Fair
Plush	Good	Exc.	Poor	Exc.	Med.	Good
Sodco	Good	Good	Good	Exc.	Med.	Good
Sydsport	Exc.	Exc.	Good	Exc.	Med.	Fair
Touchdown	Exc.	Exc.	Good	Exc.	High	Good
Vantage	Fair	Exc.	Good	Exc.	Low	Good
Victa	Exc.	Exc.	Good	Exc.	Med.	Fair
Windsor	Fair	Poor	Good	Exc.	Med.	Good

[a]Kentucky bluegrass varieties are maintained at 4 pounds of nitrogen per 1,000 square feet per year and are mowed 2 or 3 times per week at a height 1 1/2 inches. The turf is irrigated as needed to prevent wilt. Varietal performance may vary significantly under a more or less intensive management program.

intensity (Table 2). Brunswick, A-34, and Touchdown were superior at the highest cultural intensity. These cultivars had less than 10 percent annual bluegrass. Most of the cultivars performed well at the intermediate cultural intensities. For example, Glade and Parade had 78 and 47 percent annual bluegrass, respectively, at the highest cultural intensity (3/4 inch and 8 pounds of N per 1,000 square feet per year), but they had only 7 and 8 percent, respectively, at a more moderate cultural intensity (3/4 inch and 4 pounds of N per 1,000 square feet per year). Aquilla, Vantage, Birka, and Code 95 provided fair quality and appeared to be better adapted to the lowest cultural intensity. This information suggests that the selection of specific cultivars for blends should take into account the relative performance of Kentucky bluegrass cultivars at the specific cultural intensity intended on the planting site.

Table 2. Annual Bluegrass Infestation of Several Kentucky Bluegrass Cultivars Under Several Cultural Intensities[a]

Cultivar	Cultural intensity[b]			
	A	B	C	D
	Percent annual bluegrass			
A-20	83	21	13	0
A-34	8	0	6	1
Adelphi	47	22	22	12
Aquilla	88	23	12	12
Baron	90	20	15	9
Birka	93	14	18	0
Bonnieblue	63	22	11	4
Brunswick	7	1	1	0
Cheri	82	5	10	5
Glade	78	9	7	0
Majestic	82	33	20	5
Merion	70	9	13	3
Nugget	83	13	22	10
Touchdown	10	4	1	0
Parade	47	2	8	0
Pennstar	92	35	23	18
Sydsport	48	8	7	0
Vantage	88	32	22	18
Victa	57	18	22	8

[a]Annual bluegrass percentage was determined four years after the initiation of treatments.
[b]Cultural intensities: A--mowing height 3/4 in., 8 lb. N/1,000 sq. ft.
B--mowing height 1 1/2 in., 8 lb. N/1,000 sq. ft.
C--mowing height 3/4 in., 4 lb. N/1,000 sq. ft.
D--mowing height 1 1/2 in., 4 lb. N/1,000 sq. ft.

Perennial Ryegrass *(Lolium perenne)*

The cultivars of perennial ryegrass available before the late 1960's were not compatible in mixtures with Kentucky bluegrass or acceptable alone for high-quality turf. These older cultivars had an upright growth habit, low density, coarse texture, poor mowing quality, short persistence, and light-green color. During the late 1960's, cultivars referred to as improved, turf-type, fine-leaved perennial ryegrasses were released. Manhattan and Pennfine were two of the first cultivars described as turf-type perennial ryegrass. Additional turf-type perennial ryegrasses on the market today include Birdie, Blazer, Caravelle, Citation, Dasher, Derby, Diplomat, Fiesta, Loretta, Omega, Pennant, Regal, Yorktown, and Yorktown II. These new cultivars are referred to as "turf-type" because of their higher turf density, improved mowing quality, longer persistence, better disease resistance, slower rate of vertical shoot growth, darker color of green, and finer leaf texture than the older perennial ryegrass cultivars like common and Linn perennial ryegrasses. These turf-type perennial ryegrasses have challenged the traditional image and use considerations of perennial ryegrass.

One of the traditional advantages of perennial ryegrass is its quick germination and establishment rates. Perennial ryegrass can germinate within five days if moisture and temperature are favorable. A good turfgrass cover can be expected to develop within three to four weeks under optimum weather and maintenance. This rapid establishment has made perennial ryegrasses extremely desirable where quick cover is wanted for soil stabilization, repair of damaged athletic fields and golf course tees, temporary cover during unfavorable growing weather, and customer satisfaction. Perennial ryegrass is commonly used for annual overseeding on sports turf, such as tees and athletic fields, where heavy traffic and continual use limit the time needed for establishment of other cool-season turfgrasses. In addition, the plant vigor of the turf-type perennial ryegrasses enhances their establishment success under adverse moisture conditions, within thatch, and in moderately compacted soils that normally result in failure for other species. Under these less than optimum growing conditions, perennial ryegrass is sometimes basically being used as an annual or semipermanent turfgrass. The rapid establishment characteristics also make the turf-type ryegrasses good competitors against annual bluegrass in overseeding programs. The use of perennial ryegrass in these latter situations as well as in mixtures with Kentucky bluegrass and other cool-season turfgrasses is less objectionable today because of its finer texture, darker color of green, and lower growth habit. The turf-type perennial ryegrasses are commonly confused with Kentucky bluegrass.

The rapid germination and vigorous seedling growth of perennial ryegrass is a concern in species mixtures because of the potential domination if the ryegrass is seeded too heavily or if it comprises too high a percentage of the mixture by weight. In Illinois studies, combinations of Kentucky bluegrass and perennial ryegrass at different percentages by seed weight (5, 10, 15, 20, 25, or 50 percent perennial ryegrass) yielded different proportions of the two species, varying with cultivars selected (Figure 1). For example, A-34 Kentucky bluegrass was more competitive than Fylking. Pennfine perennial ryegrass was more competitive than Citation. The differences were most striking at the 5-percent level of perennial ryegrass in the seed mixture. After three years, the Pennfine-Fylking mixture was nearly 50 percent perennial ryegrass, while the A-34-Citation mixture was less than 5 percent perennial ryegrass. Less than 20 percent perennial ryegrass occurred in stands resulting from 50:50 mixtures of A-34 and Citation by seed weight. Thus where Kentucky bluegrass is predominantly desired, the selection of less aggressive perennial ryegrass cultivars and more aggressive Kentucky bluegrass cultivars should be considered. A general standard has been to include 10 to 20 percent of ryegrass in Kentucky bluegrass mixtures for establishment. The final percentage of perennial ryegrass, however, will apparently depend on both the perennial ryegrass and the Kentucky bluegrass cultivars selected. In contrast, the more aggressive perennial ryegrass cultivars may be a better choice for overseeding programs on established turfgrass sites.

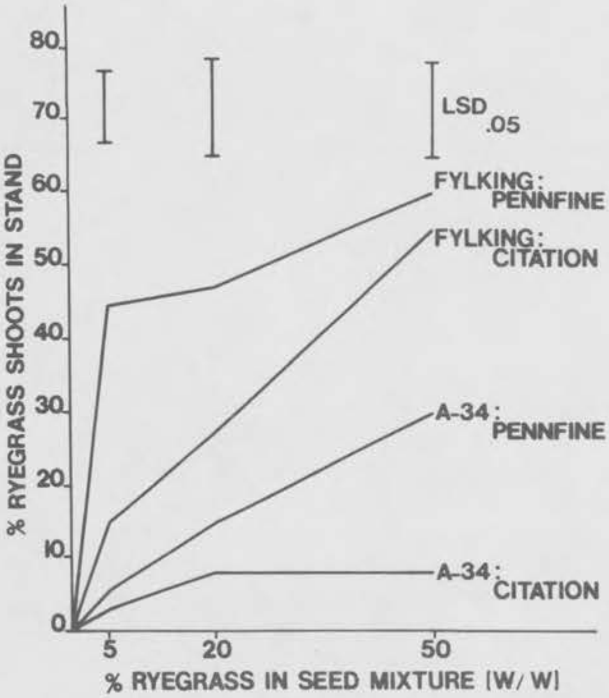

Figure 1. Effects of cultivars and percent of ryegrass seed by weight on the ryegrass component in ryegrass-Kentucky bluegrass communities.

Wear tolerance of the turf-type perennial ryegrasses is considered good to excellent. Mixed with Kentucky bluegrass, these cultivars are performing satisfactorily on sport turfs and other heavily trafficked areas and in overseeding programs on sport turfs. The recuperative potential and surface-matting characteristics of perennial ryegrass, however, fall below those of Kentucky bluegrass. A recent research report [2] indicates that perennial ryegrass does not exhibit the lateral healing potential of Kentucky bluegrass (Table 3). In this study, cup-cutter plugs were removed from various cultivars of Kentucky bluegrass and perennial ryegrass and the soil replaced in such a manner as to allow normal lateral growth from the resulting artificial divot. The percent of lateral growth from the divot was measured 50 days later. Lateral growth of Kentucky bluegrass was at least two to three times that of perennial ryegrass.

Table 3. The 50-day Lateral Growth Recovery of Several Kentucky Bluegrass and Perennial Ryegrass Cultivars During the Summer of 1975 [2]

Cultivar	Percent of artificial divot healed
Merion	89
Baron	82
Kenblue	75
Derby	30
Manhattan	27
NK-200	13

Tillers of turf-type perennial ryegrasses grow in a semiprostrate fashion. Several cultivars have been observed to produce subsurface tillers that emerge from the soil several inches from the parent plant. This semiprostrate growth habit is one characteristic that enables perennial ryegrass to tolerate somewhat lower mowing heights than Kentucky bluegrass. It appears to tolerate mowing heights of 1/2 inch during the cooler periods of spring and fall and 3/4 to 1 inch during the summer. The mowing quality of the turf-type perennial ryegrasses, however, is not quite equal to that of Kentucky bluegrass, especially during June, July, and August. Loretta is considered to exhibit the best mowing quality during cool weather [1].

Additional disadvantages of perennial ryegrass that have been observed under research and field evaluations are disease susceptibility, poorer summer and winter hardiness than Kentucky bluegrass, and lack of long-term drought tolerance. These disadvantages are considered the major drawbacks to the use of perennial ryegrass monostands. The perennial ryegrasses are inherently weak against Pythium and Rhizoctonia diseases. Pythium blight is a serious threat to seedling stands of perennial ryegrass and established stands during hot weather, especially in low-lying areas or wet areas. The Rhizoctonia brown patch disease, favored by warm, humid weather and high nitrogen fertility, can frequently cause serious damage to perennial ryegrass. Brown patch has been observed to cause serious thinning of perennial ryegrass stands in southern Illinois. Information from Rutgers University [1,3] indicates that some perennial ryegrass cultivars are less susceptible to brown patch than others (Table 4). The turf-type perennial ryegrass cultivars are also susceptible to dollar spot, snow mold, red thread, rust, and leafspot.

Table 4. Susceptibility Ratings of Perennial Ryegrass Cultivars to Rhizoctonia Brown Patch at Adelphia, New Jersey, [1]

Cultivar	Percent disease, July, 1974	Cultivar	Percent disease, July, 1974
Yorktown II	3	Servo	81
Citation	10	NK 100	83
Pennfine	10	Pelo	86
Derby	11	Sportiva	89
Omega	13	Parcour	91
Diplomat	17	Endura	91
Yorktown	22	Splendor	92
Manhattan	32	Caprice	92
Eton	61	Compas	93
NK 200	68	Combi	94
Linn	73	L.S.D. at 5%	11

The summer heat tolerance, drought tolerance, and winter hardiness of the turf-type perennial ryegrasses are considered to be below those of Kentucky bluegrass. In general, the newer perennial ryegrasses have exhibited good short-term drought tolerance. Initial evaluations suggest that they have less ability to withstand a prolonged drought than Kentucky bluegrass. Some of the turf-type rye-grasses showing significant improvements in heat tolerance and summer performance are Pennant, Citation, Pennfine, Birdie, Yorktown II, Diplomat, Omega, Fiesta, Dasher, Blazer, Derby, and Regal. Ryegrasses showing significant improvements in winter performance include Manhattan, Yorktown II, Yorktown, Omega, Loretta, and Diplomat [1,3]. In Illinois trials, Manhattan has performed best during cool periods, and Pennfine has performed best during warm periods.

TALL FESCUE *(Festuca arundinacea)*

Tall fescue has traditionally been used as a low-maintenance turfgrass in the Midwest. It tolerates soils of low fertility and has excellent resistance to summer heat and drought. Tall fescue's ability to tolerate low-maintenance regimes and its excellent wear tolerance make it a possible choice for low-maintenance athletic fields and other recreational sites. For acceptable turf quality, a heavy seeding rate of 6 to 8 pounds per 1,000 square feet is recommended. This will produce a dense turf that helps to compensate for the lack of rhizomatous and stoloniferous growth. Tall fescue is prone to injury by low temperatures, a major drawback to its use in the cooler portions of the cool humid region. Kentucky 31 tall fescue is the most widely available and acceptable of the tall fescue cultivars.

CREEPING BENTGRASS *(Agrostis palustris)*

Few developments have occurred in bentgrass breeding programs in the last several years. Penncross creeping bentgrass has been the standard seeded bentgrass, and Cohansey and Toronto have been the more widely used vegetative bents. The vegetative types have been used almost solely as a putting green turf with some limited use on tees. Penncross has been widely used on greens and tees and to a lesser extent on fairways. Seaside creeping bentgrass alone or in combination with Astoria and Highland colonial bentgrass has been commonly used on fairways. Recently, Penneagle creeping bentgrass (PBCB) was released from the breeding program at Pennsylvania State University. It has performed well in initial testing at various locations throughout the country. Penneagle is touted as being somewhat less aggressive than Penncross.

BERMUDAGRASS *(Cynodon spp.)*

Bermudagrass is a warm-season turfgrass used occasionally in southern Illinois. Bermudagrasses provide a good playing surface for athletic fields, tees, fairways, and other recreational sites because of the excellent tolerance to wear and recuperative potential. Bermudagrass dormancy in the fall and early spring can result in serious thinning of athletic turfs subjected to concentrated traffic at these times. The heat and drought tolerance of the bermudagrasses is excellent, but poor cold tolerance has severely limited their widespread use in the southern portions of the Midwest. Midiron cultivar has the best winter hardiness. Westwood bermudagrass also appears to be persisting well under winter conditions in southern Illinois.

CONCLUSION

Many improved cultivars of Kentucky bluegrass and perennial ryegrass have come on the market in the last several years. Improvements in the quality characteristics of the perennial ryegrasses have been quite striking. The major drawbacks of the improved, turf-type perennial ryegrasses are more disease susceptibility and less stress tolerance than Kentucky bluegrass. The role of perennial ryegrass appears to be well established as a support or specialty turfgrass, but the latter drawbacks produce questions as to their suitability as a dominant component in established turfgrass stands, especially under environmental stress and a less-than-optimum maintenance program. A blend of the improved Kentucky bluegrass cultivars appears to provide a greater degree of safety at the present time. Breeding programs are also under way at several universities to develop improved cultivars of bentgrass, tall fescue, and bermudagrass. The future for new turfgrass cultivar releases looks promising and exciting.

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WATER AND WATER RESOURCES IN ILLINOIS— A PERSPECTIVE

Wyndham J. Roberts

Illinois is almost surrounded by an abundance of fresh water in the Mississippi River, the Ohio and Wabash Rivers, and Lake Michigan. Within the state are large rivers such as the Illinois, the Kaskaskia, the Rock, and the Embarras. In addition there are about 1,000 lakes and reservoirs that are used for water supply.

Below the land surface are the ground waters, high-yielding aquifers found in deposits of sand and gravel, sandstone, or limestone. Adequate sources of ground water are generally found in the glaciated northern parts of the state, but they become unfavorable west of the Illinois River and in the southern tip of the state.

These sources of water are renewed by an annual inflow of moist air over the state which averages 2,000 billion gallons per day. Much of this moisture passes over Illinois; of the 100 billion gallons that fall as precipitation 77 billion gallons return to the atmosphere, 44 billion by evaporation and 33 billion by transpiration. The remaining 23 billion gallons either become streamflow or percolate by gravity to replenish ground water aquifers. It is estimated that the amount of water available to users in Illinois is over three times the present usage. Unfortunately, this water is not uniformly distributed in locations, time, or quality. To a certain extent, variations are cyclic through the year with great deviations during floods and droughts.

Illinois has excellent records of its water resources in addition to ample data on precipitation and streamflow. Rainfall and snowfall data, which are observed at hundreds of locations throughout the state, are printed on a monthly and annual basis in *Climatological Data*, a publication of the National Weather Service. Annual rainfall varies from about 46 inches in the south to about 32 inches in the northern part of the state. Streamflow is recorded at more than 150 recorder stations located along the state's streams. There are about 100 sets of records at gaging stations for the period 1950-1978. The United States Geological Survey operates the stations, but one-half the cost is shared by state and local agencies. Most streams average about 9 inches of runoff per year in northern and central Illinois. In southern Illinois the average is nearer 15 inches. These data are published annually in Water Supply Bulletins of the U.S. Geological Survey.

Runoff can be taken directly from a stream and distributed immediately, or it can be impounded in an artificial lake and pumped when the demand requires it. The variability of streamflow, which determines whether water can be pumped directly from a river, is expressed as the probability that a specific flow will be present in the stream. Thus the more variable the streamflow, the less dependable will be its supply and the greater the need for an impounding reservoir.

Stored water tends to evaporate. The average annual evaporation from a water surface varies from about 30 inches in northern Illinois to 38 inches in southern parts of the state.

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Any impoundment built across a flowing stream will collect a varying amount of sediment. The State Water Survey has made more than 140 sedimentation surveys on Illinois lakes. The well-designed reservoir has its size balanced with the area contributing runoff so that the reservoir will have a long, useful life. When the capacity-watershed ratio can be determined, it is possible to predict the reservoir capacity loss from sedimentation and thus forecast the rate at which the impoundment will lose its ability to store water. Conservation programs on watersheds can reduce soil losses in amounts varying from 43 to 92 percent. Reservoirs can be temporarily restored to their original capacities by raising of their spillway elevations. Often a 5-foot increase in lake elevation will almost double the capacity of the impoundment. However, unless soil conservation measures are practiced, sediment deposition can eventually destroy the lake.

The fundamental factor in determining the ground water resources of Illinois is a knowledge of the distribution of aquifers throughout the state. Most aspects of water resources are related to geology. The nature of surface earth materials influences the pattern of precipitation infiltration. The amount of ground water available is determined by the rate of infiltration and properties of formations that store water and allow it to flow to wells. Formations or aquifers that yield water to wells are distributed unevenly so that the availability of ground water is good in some areas and poor in others.

The most favorable conditions are found in the northern one-third of Illinois, where there are dependable sandstone and limestone aquifers in the bedrock, as well as extensive sand and gravel deposits. Potable water supplies are found at depths to 1,500 feet in the bedrock formations that are extensively developed. A common source of small to moderately large water supplies is the dolomite that lies directly beneath the drift.

Principal sand and gravel aquifers underlie only about 25 percent of the total land area of Illinois. The most important water-bearing sand and gravel aquifers are located along major bedrock valleys and major rivers. The principal bedrock aquifers in central and southern Illinois are thin beds of sandstone and limestone. It has not been feasible to develop large well supplies because the permeabilities of these rocks are low.

Areas favorable for development of wells for turfgrass are generally associated with the principal aquifers. Depths of individual wells depend on the geologic environment that governs the occurrence of the water-bearing deposits the wells penetrate.

Before a well is drilled the owner may obtain reports from the State Geological Survey and the State Water Survey on the geology and hydrology of the site. Records are available on the occurrence, quantity, and quality of water obtained from wells in every square mile of Illinois. Before a well is put into production it should be tested both for productivity and water quality. A well test will determine the safe pumping rate to ensure a long productive life, and a determination of the minerals present will decide whether the water is safe for its intended use. For a mineral analysis, a one-gallon sample should be sent to the State Water Survey, P.O. Box 232, Urbana, Illinois 61801. You must identify the sample with the well location by section, township, and range and include information on the well's depth and diameter, and related data.

In much of the southern one-half of the state, only surface water is available. There are over 150 smaller water bodies from which communities obtain their water supplies. One of these, Rend Lake, with a capacity of nearly 300,000 acre-feet, provides water for 55 communities and water districts in southern Illinois.

Some towns, such as Carlinville, Oakland, and Paris have found their lake water supplies failing because of sedimentation and have resorted to dredging to restore their dwindling lake capacities. The sediments in some central Illinois lakes contain nutrients which, when applied to the soil, permit growth of winter wheat without additional fertilizer.

Illinois has plenty of water to meet its present and future needs. There are distribution problems that can be met by formation of water districts and extensions of city water mains. However, agricultural interests are aware that they cannot operate without adequate water supplies, and there will be increasing pressure for access to a larger part of the state's water resources. Committees of the state legislature have been working on the formation of a state water authority which would administer all the state's water resources in a fair and efficient manner. At the present time the Illinois legislature has not voted on state water authority legislation, and regulation is primarily by rules of law promulgated by the supreme and appellate courts.

SOIL-PLANT WATER RELATIONSHIPS

L. Art Spomer

Water is the commonest liquid on earth and as such exerts an overwhelming influence on plant growth and survival. Plants contain and use large quantities of water during growth. This water is more than merely an inert filler; probably every plant growth process is directly or indirectly influenced by the status of plant water, which depends primarily on the balance between water absorption from the soil and water loss to the atmosphere. Because of the importance of water, a lack of water is probably the most common limiting growth factor. This article briefly discusses water in plants and its absorption from the soil.

Plants grow by accumulating raw materials (for example, carbon dioxide, water, minerals, and oxygen) which they assimilate, utilizing energy from the sun, into the structure and function that we recognize as the plant. Of all the raw materials essential for plant growth and function, water is required in the greatest amounts. Most actively growing turfgrass tissues (leaves, stems, roots, etc.) consist of about 90 percent water by weight. This is a lot of water! To demonstrate just how much, weigh a heavy cardboard container (such as a mailing tube). Cap one end, fill it with water, and reweigh it. You will find that when full of water, it also consists of 85 to 90 percent water by weight. Plants are literally living, growing containers of water. Even woody tissues often contain 40 to 60 percent water. If plants actually contain this much water, why isn't it readily apparent? A bluegrass plant, for example, consists of about 90 percent water, yet it looks and feels somewhat woody. When the grass is cut or mowed, water does not run out as it would from other containers. The only noticeable water is a moistness at the cut surfaces. Why? The plant is not a single, large container but is composed of billions of microscopic containers, called cells, which are cemented together to form the plant body familiar to us. When a stem or leaf is cut, relatively few cells are cut open and only a little water leaks out. If all of the plant's cell walls and other solids could somehow be made transparent, the plant would appear as the continuous, nearly solid body of water it actually is.

Although plant water content averages 80 to 90 percent, it actually ranges from less than 5 percent (dry seeds, bud scales, dry bark) to 95 percent (actively growing tissues, succulent tissues, etc.). In general, the more actively growing the plant or plant part, the higher its water content. Water content within a given tissue, however, can significantly vary over a short period as evidenced by rapid wilting or flagging and recovery within a matter of minutes or hours in many cases.

Plants not only contain tremendous quantities of water, but they also often use over a hundred times as much during growth. Why is so much water necessary? What does water do in plants?

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Water has at least four direct functions in plants in relation to growth:

1. Water is the hydraulic agent that maintains cells in the fully expanded or turgid condition necessary for the support of leaves and flowers, for the opening of buds and flowers, and for growth in size of all plant parts. Water is drawn into the cells by its attraction to the salts and other materials found there. Since salts cannot readily move out of the cells, this absorbed water exerts pressure that stretches the cell walls, causing the cells to grow larger, like swelling balloons.

2. Water is also a solvent and transport agent in which all nutrients and plant products move into and throughout the plant.

3. Water is the main constituent of the cell protoplasm, where it is both a filler and a structural component; most essential plant activities including the production and utilization of "food" occur in the protoplasm, and the delicate structure of the protoplasmic machinery responsible for these activities is partially maintained by the water.

4. Water in the protoplasm also functions as a raw material in the plant's chemical processes. The most significant reaction in which water is involved is food-making or photosynthesis (which also directly or indirectly supplies all of the food consumed by humans). Photosynthesis, by the way, is the most efficient and most significant means available for converting solar energy into usable energy. Not only a source of food, photosynthesis is also the basic process responsible for the production of all of the fossil fuels (gas, coal, petroleum) that we use and that are of such great importance today.

In addition to these direct functions of water in plants, it also indirectly affects plant growth by conditioning the plant's environment and buffering the plant from rapid or extreme temperature changes. Water affects the plant's physical, chemical, and biological environment (both above ground and below ground). Water also has a high heat capacity (exchanges large amounts of heat energy per degree of temperature change) and a high latent heat of vaporization (absorbs a tremendous amount of heat energy upon evaporation--has a great cooling effect). Plants' high water content gives them a high heat capacity (they resist rapid temperature changes), and the evaporation or transpiration of water from plant surfaces cools the plant and prevents heat damage under high light conditions.

What happens when plants do not get enough water? Since water is so important for plant growth, a lack of water (called water stress or water deficit) will affect growth. A water deficit occurs whenever the plant requires more water than it absorbs. The overall effect of a water deficit is reduced growth, injury, or death. Most turfgrass plants experience a frequent or nearly continuous water deficit or stress of varying degree during growth. This is especially true during daylight hours (sunny periods). Well-watered turfgrass plants usually do not experience water stress at night, as evidenced by the exudation or guttation of water droplets at their leaf tips (often mistaken for dew).

The overall effect of this prevalent water deficit depends on its severity, duration, and frequency and on the plant species, growth stage, and culture. The first effect of a water deficit is wilting (loss of turgidity) as indicated by sagging or drooping leaves and stems. Wilting causes expansion growth (growth in size) to slow or stop and usually also reduces photosynthesis (food production).

So the first and most common effect of a water deficit is reduced plant size. As water stress becomes more severe or prolonged, more and more plant processes are affected until the plant is permanently injured, as evidenced by browning and die-back. Most plants, however, adapt in various ways and to varying degrees in order to survive repeated or prolonged periods of water stress. Some even survive water losses of 30 percent or more. On the other hand, in some cases moderate water stress may actually enhance plant quality by increasing the plant's resistance to further water stress. Plants highly resistant to water stress are called xerophytes and include cacti, succulents, and sagebrush. Turfgrasses are generally only moderately resistant to water stress--especially if we want them to remain green and usable. Many turfgrasses survive severe water deficit by going dormant. This usually means the leaves cease growing and turn brown. Many plants survive water stress by developing more extensive root systems (increasing the volume of soil reservoir available to the plant). Most turfgrasses, however, are limited in this respect by their fibrous root systems, which are primarily distributed in the upper layers of soil. Overall, the actual effects of water deficit in any specific case depend on the severity of the stress and upon the species and growing conditions preceding, during, and following this period of stress. In all cases, however, *growth is reduced*.

Turfgrass plants can also "suffer" from too much water, resulting in growth that is too soft or too succulent. In addition, excessive soil moisture results in poor aeration, which may cause poor root growth, poor water and mineral absorption, increased disease susceptibility, and even outright death of the plant. Successful plant growth depends upon a plant's tolerance to both too little and too much water and the ability of the greenskeeper to maintain the water supply within a particular plant's tolerances.

How much water is required for turfgrass growth and survival? The plant's water requirement is the minimum amount of water required to provide optimal or adequate growth. You can see right away that this is variable, depending upon the species or variety, the purpose for which it is being grown, and the meteorological and other environmental conditions prevalent during growth. In general, the more water supplied to turfgrass, the more water it uses, often without any corresponding increase in growth. Very little of this applied water is actually used for growth; often less than one one-hundredth of the amount absorbed is actually retained by the plant for growth. The great bulk of absorbed water is evaporated or transpired into the atmosphere. Turfgrass water requirement therefore depends primarily upon local climatological conditions and only secondarily on variety or species.

In summary, water is quantitatively and qualitatively the most important nutrient required for turfgrass plant growth. Water affects every aspect of plant growth and is truly the life substance of plants. We do not have enough information about minimum water requirements for turfgrass to give blanket recommendations. But research is being conducted to develop more reliable methods of determining turfgrass water requirements in order to ensure maximum irrigation efficiency. The one thing we can do to maximize efficient water utilization is to understand the processes of soil water storage and plant water absorption.

Essentially all of the large quantity of water required for turfgrass growth and survival is absorbed from the soil; any factor affecting soil water availability for plant absorption will therefore also affect plant growth. "Soil water availability" is a somewhat nebulous concept because it is a measure of the ease with which a plant can absorb soil water as the plant requires it. So both plant and soil factors can affect soil water availability. Plant factors include plant water requirement and root extent and permeability. For a given quantity of water in the soil, its availability increases as plant water requirement (or demand) decreases and as root extent (total contact of absorbing surface with the water) and permeability (ease with which water passes into the root) increase. Soil factors include the amount of water present (water content), its degree of retention in the soil (water potential), and its ability to move through the soil to the root surface (water flux). Soil environmental factors affecting root growth and function (aeration, mineral nutrition, pH, impedence to root growth, etc.) can also affect soil water availability; in general, as soil water content, water potential, water flux, and environmental factors favorable to root growth and function decrease, soil water availability decreases.

Plants develop extensive surfaces to absorb the raw materials they need for growth. For example, the leaf area on most plants is several times the ground area covered by the plant. This is necessary to absorb the carbon dioxide present in the atmosphere at concentrations of about 300 parts per million parts of air (ppm) and to absorb the light also necessary for growth. The larger the leaf area, the greater the plant's ability to absorb an adequate supply of these materials. Although atmospheric carbon dioxide concentrations are low, the total supply of carbon dioxide potentially available to plants is very large, and plant leaves are well exposed to this supply. When the carbon dioxide at the leaf's surface is depleted, it is readily replaced by diffusion and air movement. However, soils are inherently poor water and mineral reservoirs in relation to plant absorption because mineral concentrations are typically even lower than the very low carbon dioxide concentration in the atmosphere. For example, plants extract phosphorus from the soil solution in which it typically occurs in concentrations of about 1 ppm (or 300 times less than atmospheric carbon dioxide). As this minute supply of minerals is depleted at the root's surface, its replacement by movement through the soil is extremely slow. In addition, movement of capillary water (water stored in the soil that is available for plant use) through the soil is also extremely slow. Therefore, in contrast with the leaf, which is rarely in prolonged contact with the same volume of air for more than a short period of time, the root must absorb substances that are relatively immobile in the soil.

Plants have compensated for this unfavorable water and mineral supply environment by producing tremendous root surfaces, which extensively permeate the soil to maximize plant-soil reservoir contact. The actual size of the root surface in most plants is estimated to be many times that of the shoot surface.

Roots also tend to proliferate in soil zones having the most favorable conditions for growth (optimum water, fertilizer, soil structure, etc.). This has lead to the erroneous concept that roots "seek out" optimum conditions, when what actually happens is that roots merely grow better and faster under good soil conditions and grow poorly under poor soil conditions. A lawn or crop that is given frequent, light waterings responds in this way to develop a root system close to the soil surface (which is the only portion of the soil wetted during watering). However, a lawn or crop given less frequent, heavy waterings will tend to develop a deeper, more desirable root system.

In conclusion, turfgrass plants require tremendous amounts of water for growth and survival. All of this water is absorbed from the soil reservoir, which is an inherently poor supplier. In order for plants to survive under these conditions, they must produce extensive, functioning root systems. Most of our cultural practices to ensure an adequate water supply are concerned with irrigation management and soil physical amendment (to provide a proper root growth environment).

will create maintenance problems. There is a possibility of retro-fitting the system with moisture-sensing devices, which could eliminate much of those type of problem.

During the break-in period, the program has to be fine-tuned so that the running time per station for the areas is not too long or too short and the running frequency is proper. Also, the programming must be set so that the irrigation is done at the proper time. To me, an improper time would be during high-water-demand periods, day-time hours, or when there is heavy wind.

CONDITION CHANGES AT SITE

Even when the three major problems areas we have talked about are covered, problems can still result. These problems are created by condition changes at the site.

A fairly frequent condition change is a drop in static pressure due to higher water demands in the project area, which increase the friction loss in the city mains, resulting in lower available pressure. Correcting this condition is much like correcting the condition of poor design where pressure is too low. It might be possible to change to lower gpm sprinklers that have the same radius specifications. Remember, however, that the running time would have to be increased proportionally. Another possibility would be to see if the pressure losses can be reduced in the irrigation system by using larger valves, piping, or water meter. There is always a possibility of incorporating an in-line booster pump to increase the pressure. If none of these possibilities is practical, then some sprinklers will have to be deleted from each section and formed into new sections to lower the GPM demand, thereby reducing friction losses.

In very rare cases there can be a radical increase in static pressure. Irrigation systems have a range of pressures in which they perform properly. Too high a pressure is just as detrimental as too low a pressure. If a high pressure does come about, the system should be adjusted by the use of any type of valve that will reduce the operating pressure. This could be a throttling valve, pressure regulating valve, or flow-control vavle. Many sprinklers have a pressure adjustment incorporated into them, which can be used. If these two suggestions do not solve the problem, an in-line pressure regulator should be installed.

In the past few years, we have seen another problem that can change the conditions on an irrigation system--mandated watering limitations. Although we hope these do not happen too often, they are a very real possibility. If limitations are imposed, naturally all automatic controllers must be reprogrammed to fit into the limitations. Where water usage must be decreased, the best thing to do is to work on increasing the efficiency of your irrigation system by reducing run off, reducing excessively deep percolation, reducing low head drainage, eliminating daytime watering, and reducing overthrow onto unnecessary areas. Unfortunately, most water-limitation programs penalize the already efficient systems. But even the most efficient systems can be made more efficient with a little study and a lot of common sense.

CONCLUSION

An added advantage of increased efficiency is that regular maintenance of the landscaped area can be reduced. Sometimes it takes a little front money to incorporate efficiencies into the system. When water was plentiful and cheap, these incorporations would never have been thought of. As water becomes more expensive and harder to come by, these efficiencies must be incorporated to help us all conserve a natural resource that we once considered unlimited.

DROUGHT TOLERANCE AND WATER RELATIONSHIPS OF TURFGRASS

Jack D. Butler and Charles M. Feldhake

Throughout the United States, regardless of yearly precipitation, water availability and conservation has become a common topic of discussion by turf professionals. In a recently published priority list of major issues facing society, "national water supply and demand" was listed first.

The need to carefully plan water use is evident if one considers that the dependable supply of water, as well as man's ability to store and transport it, is limited. An estimated 42 percent of the total municipal and industrial water supply in Denver, Colorado, is used to irrigate lawns [4]. The direct cost of water for irrigating a golf course in an arid or semi-arid region may be as much as $90,000 per year. In addition, the cost of energy and equipment required to move water must be considered in planning and locating large turf installations. In arid regions, like Colorado, when priorities for water use have been established, water for turf irrigation has normally been given a very low priority. It is evident that water must be used as efficiently as possible, especially in drier areas, through the use of efficient irrigation equipment and programs, effluent and other low-quality water, and drought-tolerant plants.

DROUGHT TOLERANCE OF TURFGRASSES

In the past, grasses used for quality turf have not varied much if any between areas that receive adequate or near adequate precipitation and areas of serious moisture deficits.

In cooler and rather dry areas of western United States, grasses such as buffalograss, blue grama, crested and western wheatgrass, and sometimes even Kentucky bluegrass and bermudagrass may persist without supplemental water. The value of these grasses for turf--except, of course, Kentucky bluegrass and bermudagrass--in areas where drought is the result of erratic but usually adequate rainfall would be questionable. Buffalograss, a warm-season grass that produces a wear-resistant turf, is nonagressive and poorly adapted to shady sites. Although this grass has been found as a native as far east as Illinois, competition by cool-season turfgrasses and weeds would probably restrict its use. Trials now under way on the east and west coasts with this and other grasses used for droughty sites in semi-arid regions should provide some conclusive information on their adaptability. The characteristics and adaptations of blue grama are rather similar to those of buffalograss. Crested and western wheat are cool-season grasses that might prove useful for mixture plantings for erosion control on very dry sites in the Midwest and Northeast, but turf quality of these grasses is not good.

In much of western United States, the ability of a turfgrass to remain alive through drought periods of several months is often considered more important than the ability to remain green for a few weeks into a drought, then die. Grasses

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such as tall fescue with its deep root system that are found to be drought-tolerant in humid areas, usually do not persist under extended droughts in semi-arid climates.

For the cool, humid regions of the United States, there is a need for grasses that will perform well by remaining green through the drought stresses of a few weeks, whether winter or summer. There are, of course, grasses grown in these regions that now have satisfactory performance under "droughty conditions." Bermudagrass and zoysias can have good drought tolerance, but their lack of tolerance to cold, their browning-out in cold weather, and their weedy nature are problems. Tall fescue and smooth bromegrass will remain green through extended periods in the Midwest, but they often are considered weedy because of coarse texture; and the strong rhizomes of smooth brome and bunchy nature of tall fescue that often develops a rough turf can be objectionable. Since these grasses are available and generally have acceptable pest resistance, it seems that developments such as improved cold hardiness of bermuda and zoysia, finer-textured smooth brome and tall fescue, and a moderately fast sod-forming tall fescue would help meet the needs for drought-tolerant turfgrasses for the cool humid region.

Kentucky bluegrass is usually considered very intolerant to drought. However, it is found persisting in areas that receive only 12 to 15 inches of yearly precipitation. Kentucky bluegrass often goes dormant during prolonged dry periods, but individual plants may remain green well into an extended drought. In 1974 some 200 Kentucky bluegrass selections were made from unirrigated sites in Colorado. Some of these have been tested in Colorado, in the Midwest (where a few performed rather well under droughty conditions), and in the Pacific northwest for seed production. Suitability of a cultivar for the Rocky Mountain region, where droughts are frequent and extreme and the plants can be hardened for drought, will likely be different from that for the cool, humid regions, where diseases are frequently serious and precipitation may not allow for hardening for the infrequent droughts.

Research at Colorado State University on the drought tolerance of Kentucky bluegrass indicates that, through conditioning, this grass can provide an acceptable turf through 2 to 3 weeks or more of drought without watering. In 1975, Dernoeden [1] did extensive work to determine the drought tolerance of many cultivars of Kentucky bluegrass. In general, with the exception of Merion, "common" types exhibited the best drought tolerance. Unfortunately, these common types do not possess the turf characteristics that are normally desirable, such as good color, density, and disease resistance. Except for areas where water is especially scarce for quality turf, savings on water from the use of common types could be offset by increased cost for pest control.

WATER RELATIONSHIPS OF TURFGRASSES

Decisions on how much water to apply to keep turf are becoming more difficult as pressure increases for efficient water utilization. The physiological nature of turf and the effect of environmental factors on evapotranspiration (E.T.) should be understood if quality turf is to be maintained without the traditional excessive applications of water.

Good fertility management and effective pest control need to be implemented before one attempts to develop an efficient irrigation schedule. Turf is capable of adapting to different irrigation programs and may grow satisfactorily with frequent and well-timed irrigation, or it may come to depend on frequent excessive irrigation.

Knowledge of the soil texture is essential in developing an efficient irrigation program. Sandy soils have a low water-holding capacity, a high infiltration rate, and good aeration. Turf grown on sandy soil readily develops an extensive root system. To use water efficiently, determine as well as possible the depth of the root system, allow the roots to deplete most of the water in this zone, and irrigate only enough to fill this zone. In drier areas it may be necessary to overwater occasionally to reduce salt buildup. Excessive water will flow to the water table, increasing nutrient removal through leaching.

Soils high in clay have a high water-holding capacity, low infiltration rate, and poor aeration. If clay soils are kept too wet, turf will not develop a deep, extensive root system. Adequate aeration to stimulate good root growth can take place only if these soils are maintained under a schedule that allows reasonable drying between waterings. In the absence of a drying cycle, the roots will develop in the top few inches of soil, and this layer is quickly depleted of water in hot weather. The shallow root system results in little drought tolerance and a dependence on frequent irrigation.

Maintaining turf at the highest reasonable mowing height will increase exposure to convective energy. This increases E.T. slightly. However, the increase in E.T. is more than offset by the ability of the longer-cut turf to photosynthesize more, and as a result develop a deeper, more extensive root system. A deeper root system decreases the probability of losing water to the water table and decreases the frequency with which irrigation is needed. Dernoeden [1] found that Kentucky bluegrass cut at 1½ inches was more drought-tolerant than that cut at 3/4 inch.

A good rule of thumb is, don't irrigate until the grass shows stress, then add only enough water to bring the root zone to field capacity.

It is not always practical to dig holes or take soil cores to determine soil moisture depletion. The above-ground environment can be used as a guide to when to irrigate since that is where most of the water goes. Weather conditions can be used to estimate how much water turf is transpiring. Solar radiation, wind velocity, relative humidity, air temperature, and day-length data have been used to develop equations that give a reasonable prediction of E.T.

One popular equation for predicting E.T. is the Jensen-Haise method [3]:

$$\text{E.T.} = (0.014T - 0.37)\ R_s$$

where T = mean air temperature

R_s = evaporation equivalent of the solar radiation

Figure 1 [2] gives the E.T. for the summer of 1977 in Ft. Collins, Colorado. The modified Jensen-Haise method of calculation is compared with actual E.T. measurements made by using small bucket-type weighing lysimeters. The two methods do not coincide exactly, but the results generally are within the same range. These E.T. equations provide a practical means of keeping track of depletion of soil water. More complicated equations are commonly used in the arid west, with the aid of computers, to monitor the use of water by field crops.

Some location effects need to be considered in evaluating the water needs of turf. Shading from the sun and shielding from the wind by trees or hills can decrease E.T. Turf located near large parking lots or on the south side of buildings may have increased E.T. due to a heat buildup. Smog may decrease solar radiation enough to decrease E.T. Areas subject to high foot traffic may need more water to allow for more vigorous growth to maintain an attractive appearance.

A study made in Colorado during the summer of 1977 correlated the quality of urban lawns with water-application rates. The project entailed metering outside faucets on 57 homes for the summer and dividing the water used by the lawn area. Use of water for purposes other than lawn watering was determined to be insignificant.

Two cities were utilized for the study: Ft. Collins, where homeowners paid a flat rate for water; and Northglenn, where water was billed according to metered use. The lawns were rated on a scale of 0 to 10, where 0 was bare soil, 5 was poor-quality turf, 7 was satisfactory, and 10 was excellent. In Northglenn water was a limiting factor, and lawn quality increased with water increases (Fig. 2). In Ft. Collins water applications ranged from 3 to 10 mm per day with no trend of increased quality with increased application rates. Some people applied three times more water than was necessary for a healthy lawn. Maintenance practices other than irrigation rates had the most influence on lawn quality.

Adequate water of acceptable quality has become a major concern for those who keep quality turfgrass. The use of available grasses and the development of "new" grasses for use under droughty conditions can help conserve water. Proper maintenance, such as fertilization and mowing, can be utilized to save water. Irrigation practices can generally be greatly improved upon by closely monitoring the soil and turf and meeting the E.T. needs.

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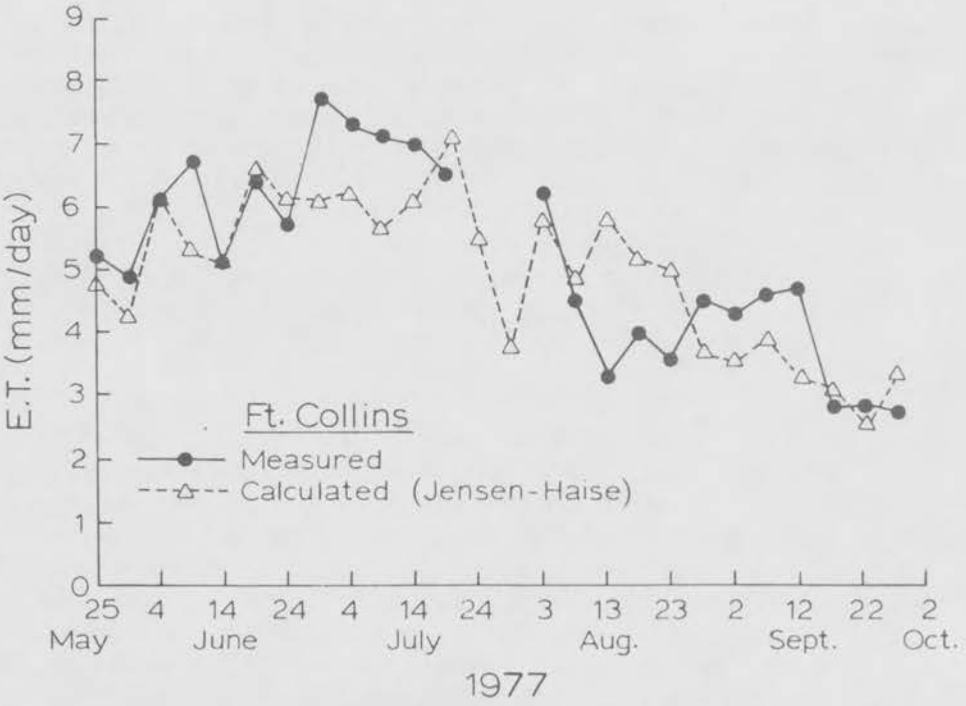

Figure 1. Evapotranspiration for the summer of 1977 in Ft. Collins, Colorado, as determined by bucket-type weighing lysimeters and by calculation using a modified Jensen-Haise equation.

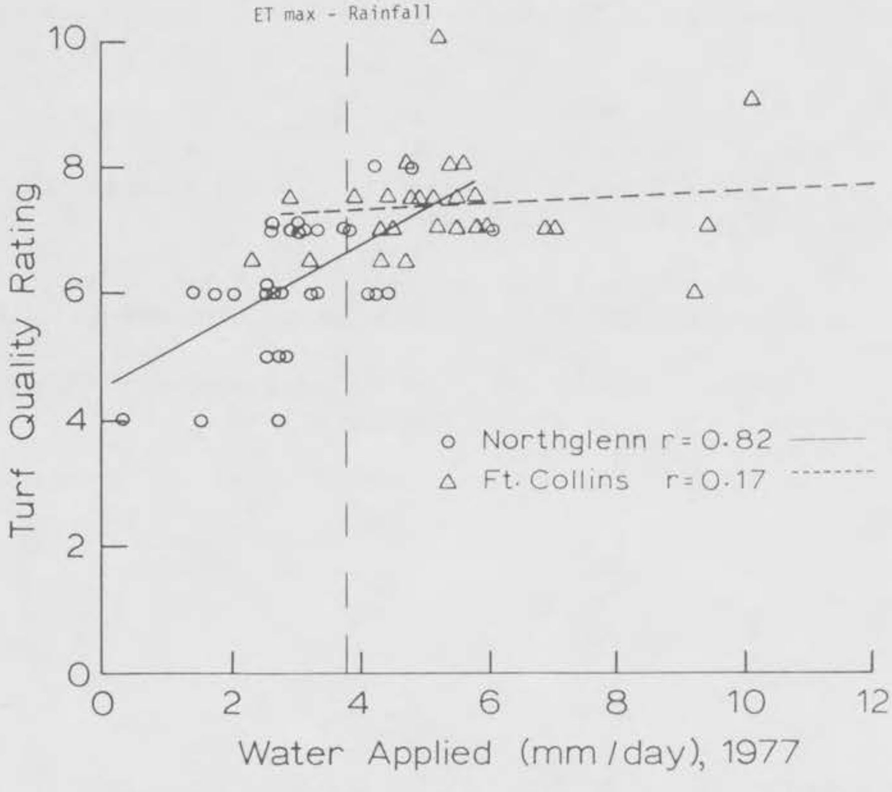

Figure 2. Turf quality plotted against average daily water application rate for the summer of 1977. An application rate of 3.8 mm per day in addition to rainfall was the maximum usable rate as determined by bucket-type weighing lysimeter. Application rates above this value resulted in no trend of improved appearance.

INCREASING IRRIGATION EFFICIENCY

Victor A. Gibeault

The time has arrived in turfgrass irrigation procedures when one can no longer solely rely on his instinctive judgment in the design, installation, or use of sophisticated irrigation equipment. Instead, decisions must be based on knowledge of the grass being grown, the characteristics of on-site soil, the rate of water use, and, ultimately, the resupply of water by irrigation to insure an adequate soil-water reservoir.

If one observes turfgrass "in profile," then the infiltration of water into the profile, the percolation of water through the profile, the depth of roots in the profile, and the water-holding capacity of the soil are important in determining the design and use of an irrigation system

INFILTRATION AND PERCOLATION

Water must first enter the soil through the process of infiltration. Variation in infiltration rates depends on soil texture, topography, thatch accumulation and its degree of wetness, and level of compaction. For example, a relatively level, sand-based putting green with limited thatch can have infiltration rates ranging from 1 to 20 inches per hour. In contrast, a clay loam soil on a rolling, moderately compact fairway can have an infiltration rate of 0.10 inch per hour or less. Irrigation equipment *must be designed and used* with knowledge of this ultimate infiltration rate. Water applied at rates in excess of the infiltration rate results in ponding and runoff, with all their accompanying problems.

If soil is of uniform texture and acceptable depth, percolation rates are seldom a limiting factor in irrigation practices. Variables such as shallow soils or layered soils of different texture, however, must be considered if they are a component in the water reservoir profile.

WATER AVAILABILITY

All soils contain two water fractions when viewed in terms of plant absorption. The first, unavailable water, is tightly held by mineral and organic particles and is unavailable for plant use. The second, available water, is the amount that the plant can absorb for transpiration and metabolism. The amount of available and unavailable water differs with different soil textures. Table 1 gives a general relationship between soil moisture characteristics and soil texture.

Table 1. Available and Unavailable Water per Foot of Soil

	Inches per foot	
Soil texture	Available	Unavailable
Sand	0.4-1.0	0.2-0.8
Sand and loam	0.9-1.3	0.9-1.4
Loam	1.3-2.0	1.4-2.0
Silt loam	2.0-2.1	2.0-2.4
Clay loam	1.8-2.1	2.4-2.7
Clay	1.8-1.9	2.7-2.9

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These data are approximate but nevertheless give an insight into the amount of water that is available per unit depth for plant use. This information, in conjunction with a knowledge of root depth, gives an indication of the amount of water that should be resupplied by irrigation if plants need more water.

TURFGRASS SPECIES

When considering turfgrass in profile, one must remember that turf species naturally differ in their rooting ability. In addition to species differences, root depths are affected by seasonal fluctuation (greatest root growth occurs in fall, winter, and spring), management practices such as mowing and fertilization, and on-site soil compaction. Although the best method to determine root depth in a particular location is through physical inspection, a general guide to root depths is given in Table 2.

Table 2. Relative Root Depths of Cool- and Warm-Season Turfgrasses Under Conditions of Normal Use

Cool-season grasses	Root depth
Kentucky bluegrass	Shallow
Creeping bentgrass	"
Colonial bentgrass	"
Red fescue	"
Tall fescue	Intermediate
Annual bluegrass	Shallow
Warm-season grasses	
Bermudagrass	Deep
Zoysiagrass	Deep
St. Augustinegrass	Intermediate

Rooting depths can vary from a few inches to many feet. Because irrigation should supply water throughout the root system, root depths and soil texture play an important role in the amount of water to apply per irrigation and in the frequency of irrigation.

Up to this point I have been concerned with water entry into the soil, the water-holding characteristics of soils, and the rooting depths of turfgrass species. With this background one can picture water use more clearly.

WATER USE

Water is used or lost from a turfgrass area in four ways: percolation below the root system; runoff because of a differential between application and infiltration rates; evaporation from the soil surface and plant leaves; and transpiration and metabolism through the plant. Evaporation and transpiration generally describe water use and, together, are referred to as evapotranspiration. Water use by evapotranspiration is affected by the folllowing conditions:

1. Radiation--as the total radiant energy that reaches the turf increases, water use will increase (more water is used during long, clear days than during short, overcast days).

2. Temperature--water use increases as temperatures increase.

3. Wind--as wind increases, water use increases.

4. Humidity--water use decreases as humidity increases.

Other conditions such as rainfall, soil fertility, and growing season also affect water use. The average daily water use of turf for each area in the United States differs, of course; but the estimated amount should be available from your state university. By using the estimated daily water-use figures, a "ballpark" idea of irrigation amount and frequency can be calculated. For example, a cool-season grass with a 6-inch effective root system growing on a soil with 1-1/2 inches of available water per foot of soil would have the following soil-water reservoir:

H_20 available/ft. (inches) X root depth (feet) = soil water reservoir

e.g., 1.5 inches water X 0.5 feet of root depth = 0.75 inch available water per foot of soil

If the daily water use is 0.15 inch (March through May in Southern California), then

$$\frac{\text{soil-water reservoir}}{\text{water use}} = \text{irrigation frequency}$$

$$\text{e.g., } \frac{\text{0.75 inch available}}{\text{0.15 inch/day}} = \text{5-day water supply}$$

The amount of water to be resupplied would be equal to, or slightly greater than, the amount used in that unit of time.

In addition to the preceding mathematical method to determine irrigation needs, soil-moisture measuring devices such as tensiometers or soil probes can be used. Tensiometers also are useful to identify dry or wet spots in a landscape where special irrigation design and programming may be necessary.

Other methods that can increase watering efficiency are listed below.

- Late night or early morning irrigation is most effective. At these times water loss by evaporation is minimal and distribution is usually effective because of good water pressure and limited wind.

- Avoid runoff by matching water application rates to soil infiltration and percolation rates. Cycle applications of water if necessary to ensure infiltration.

- Practice effective weed control methods. If weeds are not controlled, the weeds, not the desired turf species, will use the water.

- Calibrate all parts of the irrigation system so that water application amounts and distribution are known. A can test is useful in measuring amounts.

- Because shaded areas use much less water than turf in open sun, they require less irrigation. Tensiometers can be used to determine water needs of shaded areas.

In conclusion, turfgrass irrigation, like all turf management, is a combination of science and art. As in any science, the important factors must be segmented into recognizable parts that are easily comprehended. As in any art, the end product results from vision and a working understanding of the materials.

THE USE OF EFFLUENT WATER FOR GOLF COURSE IRRIGATION

Gordon V. Johnson

Irrigating golf courses or recreational turf with sewage effluent that has received proper treatment becomes more common and more important each year as costs for irrigation and fertilizer continue to increase and the problems associated with disposing of treated sewage effluent become more difficult. If you are considering using sewage effluent for irrigation of your course, then the benefits and the problems must be weighed in making the final decision. Some of the aspects of sewage effluent which need to be considered are:

1. Availability of the effluent;
2. Quality of the effluent;
3. Benefits of using the effluent;
4. Problems you might encouter.

Availability of sewage effluent is usually not a problem because near golf courses there is normally a sizeable population which generates an adequate volume of effluent. Quality of sewage effluent also is usually not a problem because the input quality of water as well as the treatment of the effluent is controlled by government standards. The only exception to this generalization is in the case of industrial effluents where the amount of heavy metals or other materials may be much higher than in effluents resulting from domestic water use.

From the standpoint of water quality, the major concern is that of total soluble salt content, SAR, and the nutrient concentrations, particularly nitrogen, phosphorus, and potassium. Most effluents have a total soluble salt level of about 600-700 ppm, nitrogen levels of about 20-40 ppm, and variable but small amounts of phosphorus and potassium.

The balance sheet below identifies the major considerations in determining the value of the effluent.

+Cost of irrigation water
+Cost of replenishing soil-deficient nutrients present in the effluent
-Cost of effluent
-Cost of dealing with undesirable constituents or characteristics of the effluent
Equals value of effluent

The actual numbers that would be put into this balance sheet vary a great deal from one location to another, and each location must be evaluated individually. Generally, the value of irrigation water can be estimated from records of recent irrigation water cost. The next item, the cost of soil-deficient nutrients, can also be estimated based on the recent records of fertilizer cost. These first two items should have a positive value and save money.

The third item, the cost of the effluent, is difficult to estimate in many areas because the effluent is not readily available at the golf course site. In

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these situations estimates have to be made based upon the cost of installing the effluent pipeline to the golf course. This is a one-time cost and has to be amortized over the life expectancy of the pipeline or the period over which effluent is expected to be used. In addition to the pipeline cost, the actual cost for effluent must be included if there is one. In some instances effluent will be available without charge. In other cases it may have to be paid for.

The last item is one of the most difficult on which to put a dollar value. In the first place, the quality of the effluent delivered determines to a large degree the cost of dealing with problems associated with its use. If the effluent is a clear solution low in suspended material or oils, there will be very little problem using it. Some effluents, however, have sufficient amounts of oils and greases in them that special values must be used in the irrigation system. In addition to this type of problem, additional expenses may be incurred for removal of algae and scum which accumulate on water hazards. While this type of offensive material on water hazards is common where effluent is not used, its presence becomes much more offensive if the members discover that effluent has been pumped into the lakes. Another problem that must be considered is an excess of effluent in areas where irrigation is used to supplement nearly adequate levels of normal rainfall. This problem is incurred in situations where effluent can be obtained only by a long-term commitment to using a specified volume of effluent. Water hazards and other types of holding reservoirs must be able to contain effluent that cannot be applied during wet, rainy weather. This problem is worsened in areas where the soil is medium to heavy textured and infiltration rates are low. If the soil is coarse textured and has a good infiltration rate, then effluent may be applied even during wet, rainy weather, and the nutrients in the effluent will be of benefit to the course even though the water is not required.

In considering the various benefits from irrigation with effluent, the greatest benefit is the value of the plant nutrients in the effluent in areas where rainfall is adequate for turf maintenance. In arid and semiarid regions the reverse is more likely to be true; that is, the water itself is of the greatest value. The nutrient value of effluent is illustrated by the following example. Effluent that contains 30 ppm nitrogen would add almost seven pounds of available nitrogen per acre to the soil for each inch of water that was applied. At today's cost this nitrogen would be worth about $1.20. If three inches of irrigation with this effluent were applied to an 80-acre golf course, the value of the nitrogen alone would be nearly $290.

The potential for irrigating golf courses with treated sewage effluent is still very great. This practice offers a means for decreasing golf course budgets over a long period of time. Local and state health boards and offices should be contacted for advice and assistance early in the planning of sewage effluent irrigation on golf courses. In some cases assistance may be obtained as a result of EPA support for this type of effluent disposal.

SUMMARY

1. Properly treated sewage effluent from domestic use is good-quality irrigation water.
2. Major problems include
   - A. Algae on water hazards;
   - B. Teaching potential users to accept effluent as a source of irrigation water;
   - C. Getting the effluent to your course;
   - D. Adequate drainage.
3. Major benefits include low-cost water and nitrogen.

IRRIGATION DESIGN AND RENOVATION CONCEPTS FOR SMALL-SCALE LANDSCAPE FOR MAXIMUM WATER EFFICIENCY

Bruce C. Camenga

Irrigation is a tool for turf and landscape management, and like any tool it must be properly designed, properly built, and properly used to do an efficient job. Any improper design, product, or operation will mean wasted water. My discussion on how to recognize and cure problems in installed systems where efficiency is poor will cover design problems, installation problems, operational problems, and changes in conditions.

DESIGN PROBLEMS

Design problems are normally caused by errors in judgment or execution by the designer and can generally be classified into four areas.

1. *Gallonage demand is too high, operating pressure is too low, or piping is undersized.* These conditions are caused by inaccurate information given to the designer or simply by designer error. All result in poor coverage because the sprinklers do not perform as they should. There are three solutions to this problem. One is to change to a sprinkler having a lower gpm with the same radius specifications. However, if this is done, the running time must be proportionally increased because less water is being applied to the turf. Another solution is to determine whether the pressure losses can be reduced or the available pressure raised by an adjustment to a pressure-regulating valve or by the addition of a booster pump. The final solution is to delete some of the sprinklers from each section and form new sections to lower the gpm demand, a very time-consuming and expensive method of correction. It means adding new sections, which mean more valves, which mean more stations on the controller. Sometimes the controller has no room for expansion, so a second controller must be added or a controller with more stations must be brought in.

2. *Sprinkler heads are spaced too far apart.* This is another area in which the design is at fault and which usually is the fault of the designer misapplying the equipment. Too wide a spacing results in poor coverage--sometimes with little or no water being applied in the areas between the sprinklers--and usually is compensated for by running the sprinklers much longer than they should be run. To correct this type of problem, you can either change the sprinklers to a different nozzle or use a different sprinkler that has a larger radius with the same gpm. If the gpm increases, there can be a corresponding increase in pressure losses, which means the operating pressure will drop and the radius may be even less than the original. Once again, if the sprinkler heads or nozzles are changed, the precipitation rate must be checked to see if the running time must be changed for the sprinklers. Another method of correcting this problem is to increase the pressure--if possible. This change might increase the radius of the sprinkler, but would also increase the gallonage demand, which would increase the pressure losses. This type of correction must be approached with caution because the necessary increase in pressure could cause other problems. If the sprinkler is already working at optimum pressure, the increase in pressure may cause a break-up

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of the water pattern and actually reduce the radius of the sprinkler. The increased pressure and gallonage could also cause a velocity higher than would be considered safe for irrigation design.

3. *Different types of sprinklers or areas to be covered are mixed together on one station.* This is almost always a designer error. If spray and rotary sprinklers are on the same irrigation station, a mismatched precipitation rate is created as spray heads normally have a precipitation rate of 1 to 2 inches per hour, but most rotaries have a precipitation rate of around 1/2 inch per hour. As a result, the entire station must be run long enough so that the rotary sprinklers are putting enough water on the landscape. This means the area in which the sprays are located will be overwatered. In order to correct this problem, the types of sprinklers must be changed so that they are compatible or they must be separated from that station and put on an independent station or a station that already has a similar type of sprinklers. Designers often treat turf and ground cover the same, which means one station could be covering both areas at one time. This is usually very inefficient because ground cover normally needs less frequent applications of water than most turf does. The correction is to physically separate the two types of areas being covered. This normally means another valve and another controller station. Quite similar is a situation in which shady areas are on the same station with a sunny area. When this happens, the watering schedule has to be set for the sunny area to keep the landscape in good condition. The sprinklers on the same station in the shady area then are over-watering that area. Where different types of soil exist, design should take this variation into consideration so that one section does not cover more than one soil type. When more than one type is covered, you can often get run-off from a rather impermeable soil while the water is being absorbed nicely in another area. Unfortunately the system has to be set up for the area that is absorbing water nicely, which means run-off will occur in the other area. The same type of situation applies where there are slopes and level areas in one project. If one station covers both a slope and level area, you will have run-off on the slope even though insufficient water has been applied to the level area.

4. *Materials selected are not proper for the job, creating maintenance problems.* Selection of materials is another area in which the designer can go wrong. Among improper selection would be selection of flush-type or non-pop-up sprinklers for use in turf areas, which would require that a moat or cement collar be placed around each sprinkler so the turf will not interfere with the throw of the sprinkler. Another improper selection would be high risers in shrub areas, especially along sidewalks and curbs. High risers are ugly, distracting from an otherwise pleasant landscape, and subject to both unintentional damage and vandalism. The possibility of lawsuits resulting from people cutting a corner and tripping over these risers is also very real. Equipment is now on the market that will allow the sprinklers to be placed at a level below the shrub or ground cover and, when the sprinklers are activated, will pop up above the shrubs or ground cover. A poor selection of materials and swing joints or the entire lack of them or flexible risers results in a maintenance problem when people or vehicles hit the sprinklers or risers extending above grade. If a suitable swing joint or flexible riser is not specified and installed, the sprinkler pipe is normally damaged, creating a large maintenance problem. Where there are slopes, low head drainage is always a maintenance concern. It causes wet areas, which turn into quagmires as traffic passes through them. There is also a potential hazard created by low head drainage. The hazard and maintenance problem can be eliminated by the addition of check valves in the line or risers that drain normally. Since most sprinklers

have a higher precipitation rate than the infiltration rate of the soil onto which they are throwing water, the controller must have a capability of being multi-cycled. By multiple cycling, the sprinklers run several times for rather short periods. This allows the water to infiltrate the soil. Multi-cycling has a further benefit in that it can be used to proportionately reduce the running time--and thus the water applied--to all the stations as the climatic conditions change. If a designer does not feel comfortable with the information about a sprinkler, especially the distribution pattern, he should obtain the necessary information or bypass that particular product. If the coefficient of uniformity of sprinklers in pattern is poor, improper coverage will be the result, which will create a tremendous maintenance problem for the owner and will certainly decrease the designer's reputation.

INSTALLATION PROBLEMS

Let's make a rather large assumption that all of the above problems over which a designer could stumble have been overcome. He has designed the system properly as far as hydraulics are concerned, spaced the heads according to the manufacturer's recommendations, has not mixed the type of sprinklers or areas covered, and has made a good selection of equipment. The next problem then becomes what happens when the system is installed.

Sometimes the pressure at the sprinkler heads is reduced but the reduction is not related to design. The controllers or valves may have malfunctioned or nozzles may have become plugged. Improper installation could result in debris finding its way into the pipeline; if not properly flushed out, the debris could plug the sprinklers and valves and even create problems in the controllers.

Further, there could be deviations from the design; a contractor might use smaller pipe than shown on the design, either intentionally or unintentionally. Sprinkler heads could also be improperly spaced, resulting in poor coverage. There is always the possibility of the wrong sprinklers being installed in the wrong places. Naturally, these can be avoided with proper inspection of the job. This, however, is not always available.

As the control lines for the system are put in, the wire runs are sometimes too long or the wire is too small. A voltage drop could result that could keep the electric valves from operating. Poorly insulated wire connectors and damaged wire insulation can also create a voltage drop leading to malfunctioning valves. If the control lines are hydraulic rather than electric, leaks in the tubing, either the supply or the control lines, would create operational problems. Plugged or kinked tubing can cause malfunctions.

It is the duty of the contractor to make sure that the electrical source for the controller is proper and that the controller is programmed correctly. Excessive voltage could blow the controller apart and cause a fire hazard, whereas low voltage would keep the controller from operating properly.

OPERATIONAL PROBLEMS

Getting back to some wild assumptions, let us now say that the system was designed properly and installed properly. But still we are not home free. It must be operated properly.

As climatic conditions change, the program should be changed. If the program isn't, either too much or too little water will be applied--either of which will create maintenance problems. There is a possibility of retro-fitting the system with moisture-sensing devices, which could eliminate much of this type of problem.

During the break-in period, the program has to be fine-tuned so that the running time per station for the areas is not too long or too short and the running frequency is proper. Also, the programming must be set so that the irrigation is done at the proper time. To me, an improper time would be during high-water-demand periods, day-time hours, or when there is heavy wind.

CONDITION CHANGES AT SITE

Even when the three major problems areas we have talked about are covered problems can still result. These problems are created by condition changes at the site.

A fairly frequent condition change is a drop in static pressure due to higher water demands in the project area, which increase the friction loss in the city mains, resulting in lower available pressure. Correcting this condition is much like correcting the condition of poor design where pressure is too low. It might be possible to change to lower gpm sprinklers that have the same radius specifications. Remember, however, that the running time would have to be increased proportionally. Another possibility would be to see if the pressure losses can be reduced in the irrigation system by using larger valves, piping, or water meter. There is always a possibility of incorporating an in-line booster pump to increase the pressure. If none of these possibilities is practical, then some sprinklers will have to be deleted from each section and formed into new sections to lower the gpm demand, thereby reducing friction losses.

In very rare cases there can be a radical increase in static pressure. Irrigation systems have a range of pressures in which they perform properly. Too high a pressure is just as detrimental as too low a pressure. If a high pressure does come about, the system should be adjusted by the use of any type of valve that will reduce the operating pressure. This could be a throttling valve, pressure regulating valve, or flow-control valve. Many sprinklers have a pressure adjustment incorporated into them, which can be used. If these two suggestions do not solve the problem, an in-line pressure regulator should be installed.

In the past few years, we have seen another problem that can change the conditions on an irrigation system--mandated watering limitations. Although we hope these do not happen too often, they are a very real possibility. If limitations are imposed, naturally all automatic controllers must be reprogrammed to fit into the limitations. Where water usage must be decreased, the best thing to do is to work on increasing the efficiency of your irrigation system by reducing run off, reducing excessively deep percolation, reducing low head drainage, eliminating daytime watering, and reducing overthrow onto unnecessary areas. Unfortunately, most water-limitation programs penalize the already efficient systems. But even the most efficient systems can be made more efficient with a little study and a lot of common sense.

CONCLUSION

An added advantage of increased efficiency is that regular maintenance of the landscaped area can be reduced. Sometimes it takes a little front money to incorporate efficiencies into the system. When water was plentiful and cheap, these incorporations would never have been thought of. As water becomes more expensive and harder to come by, these efficiencies must be incorporated to help us all conserve a natural resource that we once considered unlimited.