1966

Earl P. Grey
William Teece
David Dunlavey
Paul White
Oliver Leech

See next page for additional authors

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G.C.S.A.A. SCHOLARSHIP AWARDS

Mr. Richard Blake, a Director of the National G.C.S.A.A., is shown on the left presenting the G.C.S.A.A. scholarships to Robert Heeley, John Barry and Charles Martineau, two-year students.
TURF MANAGEMENT SENIORS
Row 4 K. Paolini, P. Couture, T. Rockwood, P. Campbell, J. Beasley, D. Marcotte.

TURF MANAGEMENT FRESHMEN
Row 1 (left to right) P. Barratt, D. Frigo, D. Lamson, R. Francis, J. Hunt, D. Obrien, B. Pollard, S. Humphreys, R. Hansen.
Row 5 P. Kearns, C. Percelle, F. Maynard
To form a bond of common interest between the Turf Management Club, the alumni of the Stockbridge and Winter School Turf Majors and all interested friends of the University of Massachusetts Turf program.

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Picture - G.C.S.A.A. Scholarship Awards
Picture - Turf Management Seniors and Freshmen

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PROPER WATERING

Earl P. Grey

Turfgrasses are injured as often by improper irrigation as by failure to irrigate soon enough. Many of the old timers, as well as the young, tend to water turf by habit rather than by seeing whether irrigation is really needed. Too many fail to realize that proper use of water is one of the most important management practices required to maintain beautiful grassed areas. This is all leading to the question, and the main point I want to stress.

How much should you water?

There isn't any definite answer to this question. You simply cannot rely on definite amounts of water that you read about in some magazine. Rather, you should realize that your irrigation problem is unique. It depends on your grass, the weather in your vicinity, your soil, the irrigation equipment, and many other conditions. These are things you should consider in order to determine how much water should be applied to your course. Only when you have established these basic factors can you go ahead and further answer the question by saying that any irrigation depends also on the water retention characteristics of the soil and on the extent to which the grass roots have extracted the water from the soil.

Since the larger particles of sandy soils retain less water, application of a given quantity of water will wet sands deeper than it will the finer textured soils. The drier the soil at the time of irrigation, the more water is required to wet to a given depth. If the soil has been dried until the grass has begun to show wilting, the amount of water that must soak into that soil is approximately equal to the quantity of available water held by the soil within the depth depleted of moisture by the grass roots. The quantities of water required, which must soak into typical soils to wet them to certain depths, are given in charts.

Another point I would like to bring out in regard to sprinkler systems is that you can determine the right running time for your sprinkler system. First, let the grass remove the soil moisture and reach the point of dryness which you will habitually select for beginning irrigation. Turn on your sprinkler to give good overlapping coverage. Record the time required to restore the moisture in the root zone by using a sampling tool, shovel, or sharp-pointed probe.

You will also be surprised at how long it takes to apply the right depths of water. For example, to wet a one-foot depth of loam soil that has been dried approximately to the wilting point requires about 1.5 hours, if the application rate is 1-inch per hour, or 6 hours if the rate is 0.3 inches per hour. To wet equal depths of sandy soils would require approximately one-half as much time. Clay soils would require approximately twice as long.

In closing I would like you to remember these two cautions: first of all, do not leave sprinklers unattended for long periods. If there is a surplus of water, it will be wasted and at the same time carry the plant nutrients away. Then, do not turn sprinklers on for just a few minutes. Most of this water will be wasted by evaporation. Wetting soil to shallow depths develops shallow grass roots and in time causes a weak, weed-infested lawn.
The golf course superintendent is often confronted with problems concerning plant hardiness and the proper way of protecting plants during the winter. The following paragraphs contain a few practical applications concerning plant feeding and protection.

Roots grow during the dormant season as long as the soil temperature in the root area does not fall below 45 degrees. At that temperature roots will absorb plant food and move it to the top of the tree or shrub. The physical structure of the soil is especially important. Generally, an open, gritty, well-drained soil is better for the more tender plants than a clayey, water-saturated soil.

Winter sun may be more damaging to evergreens than cold. A combination of the two in March is especially bad. Perhaps you might have noticed that evergreens growing on a course protected by large trees are better looking than those growing in unprotected areas. The larger trees offer protection from the quick changes in temperature caused by the warm March sun, followed by a rapid drop in temperature.

On many courses tree feeding is completely ignored; however, the response from fall feeding is considerable. Each tree should be given four pounds of a 5-10-5 fertilizer for each inch of diameter of the trunk. Fertilizers should be added to holes made with a bar, out under the drip line of the branches. Each hole should be eighteen inches deep for each pound of fertilizer given. Trees fed in the fall will make more spring growth than those that are fed in the spring.

Practically all courses have rodent pests, borers, or rabbits. Wrapping the trunk of recently transplanted deciduous trees, particularly thin-barked ones, with burlap or other protective covers is recommended. This protects against sun scald, borer attacks, and somewhat against rodent attack. A wire screen at the base of the tree is better to deter the last-named pests from destructive gnawing.

Mulches should be applied to newly planted trees and shrubs after the ground is frozen. This reduces thermal changes in the soil and prevents heaving of shallow rooted plants, thus holding moisture and eliminating deep freezing of the soil. Pine needles or oak leaves are all useful mulches for this purpose.

Latex anti-desiccants used in sprays are effective in reducing moisture loss through the needles of conifers and the foliage of broadleaf evergreens. This material, mixed with water and sprayed on the foliage when the temperature is above 40 degrees, should be delayed until December, if possible.

These are some practical and fairly inexpensive ways in which trees and shrubs can be protected. Of course, the selection of trees for golf courses is based on their particular requirements and needs. In many cases, trees are soil and weather resistant; however, as newly transplanted trees, they should receive some care and supplementary nutrients until they are established.
POWER GOLF CARTS: A BLESSING OR A CURSE?

David Dunlavey

Because of the great need in the game of golf for a means by which the game can be speeded up and thus provide more playing time, the power golf cart has come into existence. Through its use the slow, torturous movement of golfers can be speeded up and thus allow more people on the course during the course of a day.

Now the question has presented itself: is the power golf cart a worthwhile and useful innovation, or is it simply a nuisance?

Most people who have used the carts are inclined to agree with the former statement. They believe that the carts do help in speeding up the game. Not only do they conserve the energy of the golfer but they also add a touch of elegance to the game.

What most golfers do not think about are the things that the carts accomplish that they don't notice. When the careless golfer drives his cart out into the middle of the fairway, he is leaving a trail of compaction behind him. When the carts are driven down the same side of the fairway day after day, the turf is compacted and the grass is crushed slightly each time a cart passes over. One cart certainly could not do much damage, but when a course has a dozen or more carts in use all day every day, damage can be done. These are just two of the ways the cart can be and is being misused. Tees, collars, traps, greens, and approaches are a few of the other places where the carts do not belong, but where they can be found when in the control of a careless golfer.

Some of the larger courses which have carts are providing roadways or paths for the carts, but these paths tend to mar the beauty of a course, and to the golfer who doesn't care, they were made not to be used.

In any case, a golf course superintendent or professional who has carts on the course should try to educate the membership in the proper use of the carts. The membership should understand fully the damage that a cart can do if it is carelessly used and in places where a cart does not belong.

In the final analysis carts can be useful and pleasurable machines, if they are used carefully and considerately.

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A COMPARISON

Paul White

The students now enrolled in the Turf Management major at the Stockbridge School are, for the most part, residents of Massachusetts. Because of this I felt it might be interesting for them to hear about conditions in another geographical area of North America. Since I live in Ontario, where I have worked on several golf courses, I shall attempt a comparison of problems and their effect on management practices.

As a result of the Ice Age, the soils of Massachusetts are made up basically of sand and the coarser soils which were dropped by the glaciers as end
moraines. The soils of Ontario, however, have different characteristics. The soils of Ontario are mostly clay with scattered patches of sand which were dropped by the glaciers as ground moraine. This is a direct contrast and results in some differences.

The most obvious difference is that the capacity for the retention of available water will differ. The sand soils of Massachusetts will retain less water, while the clay soils of Ontario retain more water, and hence are capable of supporting a larger amount of vegetation. We also know that the cation exchange capacity of clay is much higher than that of sand. The result of this is that the nutrients required by plants are more readily available. The management will differ in that less fertilizer will be required in Ontario because the cation exchange capacity is greater and also because there will be less leaching.

Massachusetts soils are acid with a pH of less than seven. Again there is a distinct difference. The soils of Ontario tend to be very alkaline. Even the water of Ontario is very alkaline. On one occasion, a local club was having a great deal of difficulty with its newly laid irrigation system. After a thorough investigation, they found that the alkaline water was reacting with the aluminum pipes and rotting them away. This difference, of course, necessitates a difference in management practices. While the superintendent in Massachusetts is applying lime to correct his acid soils, his counterpart north of the border is applying acid-reacting fertilizer to change his alkaline soil to a more agreeable pH.

The summer growing season is somewhat the same in both locations, although on the average Ontario is slightly cooler. The growing season for Massachusetts is four to seven months, while in most of Ontario it is less than four months.

This short growing season has considerable effect on the preparations for the winter and the winter management practices. The bentgrass fairways in Ontario require great care and treatment for the prevention of snow mold. Since the snow falls earlier in Ontario than in Massachusetts, it has more time to accumulate, so that the spring thaws provide a tremendous amount of moisture which is exactly what the snow mold organism requires to live and reproduce.

There is, however, a brighter side to the story, for this early fall of snow provides more protective covering than is supplied to the Massachusetts courses. Desiccation results when the cold dry winds of winter lash the land drawing all the moisture out of the ground. In Ontario we find that desiccation is greatly reduced by this blanket of protective snow.

Winter has still another effect on the problems of an Ontario superintendent. The winter temperatures drop so low that the machinery must be adapted to these extremes by the use of more expensive petroleum products, such as heavy duty grease and special purpose oils. These extra expenses are not as common in Massachusetts because the temperatures are more moderate. The length of winter will also have a very definite effect on machinery management. Fuel must be completely drained from all machinery and it must be specially treated because of the length of time that it sits idle. The fuel, if left in, would turn to varnish and gum up the entire working part of the engine. For these reasons, the superintendent of an Ontario course finds his winter expenses
are higher while the Massachusetts counterpart runs his machines later into the winter and gets them started earlier in the spring, so that his costs of winter operation would be less.

The comparisons I have made are rather general, but, as you see, there are differences in our management practices.

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TREES ON A GOLF COURSE

Oliver Leach

Trees may be used on a golf course for any number of reasons. The right tree used in the right place can make a golf course more beautiful at any time of the year. In the spring, a pink flowering tree will help make a course a little more beautiful. In the summer, you would look for a tree with good foliage color. In the fall, you might pick out trees that change color nicely. During the late fall and winter months, you would use a tree with good twig color or habit of growth.

In planting trees it is important to find ones that take the least amount of care. You do not want a tree that needs a lot of pruning each year. You do not want trees with insect or disease problems. But are there any plants that do not have one or the other of these problems? Well no, there is no perfect plant, but you can look for the ones with the least of these problems.

A good golf course with the best grass, but with bad trees and shrubs, is just as bad as an expensive house with cheap or tasteless landscaping. Trees set off a golf course.

I would now like to discuss some of the trees I would use on a golf course, and where I would use these trees. I certainly would not use an apple tree near a green, or a willow near water pipes. Good trees for the border of a golf course are maples, oaks, elms, poplars, and, perhaps, willows. These trees will provide good shade in the summer and good foliage in the fall. For a vista, for example, looking down a fairway, maples, male ginko, or maybe a beech might be used but are slow growing. Near a pond, the best trees would be willows, the weeping form, or poplars. Good evergreens could be mixed with the deciduous trees that have good fall foliage color. The beautiful orange yellow of sugar maples mixed with the green of pines provides a pleasant view. Some of the smaller trees that have good spring flowers can be used on the course. These might include dogwood, magnolia, eastern redbud, crabapple, and cherry. Any of these can be used to face the other fall ones I mentioned earlier. They also can be used around the greens or ponds on the course to add to the color in the spring. These flowering trees will cast a light shade, and therefore cause few problems in growing grass under them. Most of the large trees I have discussed do not cast a really dense shade, and therefore a good strain of velvet bent will do fine under them. These trees may be pruned so that you will no lower branches and mowing will be quite easy. You may find you need a hedge or barrier. Yews are the best for this purpose. For example, if you needed a hedge along a road, you might use an arborvitae, a poplar, a yew, and even some flowering shrubs. For a low hedge a barberry or privet will be good. Forsythias might be used as a barrier to border a green, which would add color in the spring months.

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TURF MANAGEMENT MAJORS WANT A GOLF TEAM

Richard Rossiter
Captain, Turf Management Golf Team

It would not be at all unusual for interested turf management classes to always have a minimum of seven good golfers, the number necessary for a golf team. As it is with this year's senior class there are 19 enthusiastic golfers of which there are about 10 who are quite capable of breaking 80. The freshmen turf class has also indicated that their group has quite a number of enterprising golfers who would be anxious to carry on a golf team next year. Freshmen are unable to play this year because they are out on placement training.

Realizing that a golf team representing the turf management majors has long been overdue, this year's senior class under the guidance of Dr. Troll is making an all out effort towards the organization and official recognition of a golf team. At the present time we are in the process of scheduling matches with surrounding colleges, in hopes that even though our scheduling is late, that they will be able to fit us into their schedule as a practise round. Our home course is the Jabish Brook Country Club in Belchertown, Mass. This course sports large Penncross greens and Merion tees while the fairways are what you might call "rugged rock grass." It will certainly be a challenge to any unfamiliar golfer.

It should also be mentioned that Dr. Troll has consented to allotting his Wednesday class time to us so that we may go as a group to practice sessions, thus establishing a sort of golf education which is a necessity for today's golf course superintendents towards understanding the golfer's problems. A future turf curriculum may demand golf education as a requirement for turf management majors. This could easily fit into their required physical education course which they have to take during their freshmen year.

Although this year's team was unable to receive official sanction from the University, meaning we must be responsible for our own transportation and financial expenditures, the stage is being set for next year's golf team. Dean Jeffrey, Director of the Stockbridge School of Agriculture, is sponsoring this program to the University Athletic Council for official sanction and recognition in next year's proposed budget. In the event that next year's team receives this University recognition, the team title may be changed, out of necessity, to the Stockbridge Golf Team. Even so, the general feeling is that the turf management majors will probably dominate this sport here at Stockbridge.

The members of the 1966 Turf Management Golf Team extend their wishes and hopes that future "turfers" will have the interest and potential to carry on this team with the goal of furthering the dignity and respect of the turf managers not only here at Stockbridge but throughout New England.

The Turf Management Golf Team: Terrance Rockwood, Dave Marcotte, Pat Dipietro, Armand Le Sage, John Barry, Jack Ellis, John Charron, Paul Couture, Tom Ryan, Richard Pemble, Bill Dickie, Jon Deary, Larry Anshewitz, Fred Meda, Ken Paolini, Robert Savolainen, Tom Comalli, Chuck Martineau and Rick Rossiter.
<table>
<thead>
<tr>
<th>Name</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larry Anshewitz</td>
<td>finally leaves the telephone.</td>
</tr>
<tr>
<td>John Barry</td>
<td>leaves to play football for Andover High.</td>
</tr>
<tr>
<td>Joe Beasley</td>
<td>leaves the treasury.</td>
</tr>
<tr>
<td>Pete Campbell</td>
<td>leaves his crash helmet to some deserving freshman.</td>
</tr>
<tr>
<td>John Charron</td>
<td>leaves the bowling alley.</td>
</tr>
<tr>
<td>Tom Comalli</td>
<td>leaves his Turf Club presidency for a seat on a bulldozer.</td>
</tr>
<tr>
<td>Ken Cominsky</td>
<td>leaves his dictionary.</td>
</tr>
<tr>
<td>Paul Couture</td>
<td>leaves for the Red Barn.</td>
</tr>
<tr>
<td>Jim Deary</td>
<td>leaves quietly.</td>
</tr>
<tr>
<td>Pat DiPietro</td>
<td>leaves the frat house to Mooney.</td>
</tr>
<tr>
<td>Bill Dickie</td>
<td>leaves Russ to his own work.</td>
</tr>
<tr>
<td>Dave Donnelly</td>
<td>leaves with the Wall Street Journal.</td>
</tr>
<tr>
<td>Bob Heeley</td>
<td>leaves with a little less hair.</td>
</tr>
<tr>
<td>Bob Hughes</td>
<td>leaves to get some sleep.</td>
</tr>
<tr>
<td>Armand Lesage</td>
<td>leaves his body to Harvard.</td>
</tr>
<tr>
<td>John Lynch</td>
<td>leaves second floor of Middlesex to a worthy freshman.</td>
</tr>
<tr>
<td>Dave Marcotte</td>
<td>leaves with his lunch.</td>
</tr>
<tr>
<td>Chuck Martineau</td>
<td>leaves for another weekend in Boston.</td>
</tr>
<tr>
<td>Fred Meda</td>
<td>leaves without &quot;Liz.&quot;</td>
</tr>
<tr>
<td>Russ Milne</td>
<td>leaves Mr. Silva a hard time.</td>
</tr>
<tr>
<td>Jack Nugnes</td>
<td>leaves without his attendance sheet.</td>
</tr>
<tr>
<td>Ken Paolini</td>
<td>leaves his glasses at the Town Optician.</td>
</tr>
<tr>
<td>Dick Pemble</td>
<td>leaves his bed in the Amherst jail.</td>
</tr>
<tr>
<td>&quot;Terry&quot; Rockwood</td>
<td>leaves his affection for &quot;Ma&quot; DuBois.</td>
</tr>
<tr>
<td>&quot;Rick&quot; Rossiter</td>
<td>leaves Mr. Troll with his New Hampshire accent.</td>
</tr>
<tr>
<td>Tom Ryan</td>
<td>leaves M.J.</td>
</tr>
<tr>
<td>Bob Savolainen</td>
<td>leaves Mr. Troll without a green.</td>
</tr>
<tr>
<td>John Slusz</td>
<td>leaves all the old tests for the freshmen.</td>
</tr>
<tr>
<td>Bill Stinson</td>
<td>leaves his apartment to the mice.</td>
</tr>
<tr>
<td>George Brothers</td>
<td>finally leaves.</td>
</tr>
<tr>
<td>Fran Thomits</td>
<td>leaves his seat at the Drake.</td>
</tr>
<tr>
<td>Name</td>
<td>Comment</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Larry Anshewitz</td>
<td>-- I have to stay in the dorm, Cheryl is calling.</td>
</tr>
<tr>
<td>John Barry</td>
<td>-- You know Pete, he's a good guy.</td>
</tr>
<tr>
<td>Joe Beasley</td>
<td>-- OH BUB BAH!!!</td>
</tr>
<tr>
<td>Pete Campbell</td>
<td>-- Where is Bobby?</td>
</tr>
<tr>
<td>John Charron</td>
<td>-- Let's go to the Hatch for coffee!</td>
</tr>
<tr>
<td>Tom Comalli</td>
<td>-- What did Pemble do now?</td>
</tr>
<tr>
<td>Ken Cominsky</td>
<td>-- Hey! Does anyone know how to spell this word?</td>
</tr>
<tr>
<td>Paul Couture</td>
<td>-- Where is Stinson sitting?</td>
</tr>
<tr>
<td>Jim Deary</td>
<td>-- Where is Pemble? Who's buying?</td>
</tr>
<tr>
<td>Pat DiPietro</td>
<td>-- That is a sleezy trick!</td>
</tr>
<tr>
<td>Bill Dickie</td>
<td>-- Oh my word!</td>
</tr>
<tr>
<td>Dave Donnelly</td>
<td>-- What?</td>
</tr>
<tr>
<td>John Ellis</td>
<td>-- Mr. Johnson! We got our engine running!</td>
</tr>
<tr>
<td>Bob Hughes</td>
<td>-- Like my boots?</td>
</tr>
<tr>
<td>Bob Heeley</td>
<td>-- Where is Ovian, Mr. Whitney?</td>
</tr>
<tr>
<td>Armand Lesage</td>
<td>-- Get me a date too!</td>
</tr>
<tr>
<td>Jay Lynch</td>
<td>-- No smoking during Turf Club meetings!</td>
</tr>
<tr>
<td>Dave Marcotte</td>
<td>-- Please repeat that.</td>
</tr>
<tr>
<td>Chuck Martineau</td>
<td>-- Where is the Northampton Golf Club?</td>
</tr>
<tr>
<td>Fred Meda</td>
<td>-- I'll call up Page.</td>
</tr>
<tr>
<td>Russ Milne</td>
<td>-- Do I have to scrape those dishes again?</td>
</tr>
<tr>
<td>Jack Nugnes</td>
<td>-- Where is DiPietro?</td>
</tr>
<tr>
<td>Ken Paolini</td>
<td>-- Where is my check book?</td>
</tr>
<tr>
<td>Dick Pemble</td>
<td>-- I'm not guilty!</td>
</tr>
<tr>
<td>&quot;Rocky&quot; Rockwood</td>
<td>-- Hey Rick!</td>
</tr>
<tr>
<td>Dick Rossiter</td>
<td>-- Hi Rocky!</td>
</tr>
<tr>
<td>Tom Ryan</td>
<td>-- My coat is in the bedroom!</td>
</tr>
<tr>
<td>Bob Savolainen</td>
<td>-- Has anyone got any tests?</td>
</tr>
<tr>
<td>John Slusz</td>
<td>-- You got the test, did you see the test?</td>
</tr>
<tr>
<td>Bill Stinson</td>
<td>-- Hey guys, there is a party at my place.</td>
</tr>
<tr>
<td>Fran Thomits</td>
<td>-- Carmen, I'll meet you at the Drake.</td>
</tr>
</tbody>
</table>
TURF MAJORS AT WORK

WINTER SCHOOL STUDENTS

Row 1 (left to right) J. Slavitsko, D. Cooper, T. Fletcher, E. Kish, W. Dean, D. Burr, R. Lowell, A. Konesni.

Row 2 J. Leeper, D. Lough, J. Brown, T. Schofield, J. Parker, D. Tyler, Dr. Joseph Troll.


Row 4 R. Kosten, S. Richards, Dr. William Colby.
His Vacation??

Church Choir

Another Report

Turf Conference Banquet
Conference presentations have been approved by the individual speakers.

The various topics are presented for your information as follows:

- Turf Heating with Electric Cables by J.R. Barrett, Jr. and W.H. Daniel  
- Poa Annua Restriction by C. F. Kerr and W. H. Daniel  
- Phosphorus by Marvin H. Ferguson  
- Role of Potassium in Turf Grass Management by R. E. Wagner  
- Role of Minor Elements in Turfgrass Management by Alexander M. Radko  
- Rhizoctonia Brown Patch and Pythium Disease by Malcolm C. Shurtleff  
- Sclerotinia Dollar Spot and "Snow Mold" by Noel Jackson  
- Fusarium Blight - Disease of Turf Grasses by George A. Bean  
- Observing the Weather - Old and New Techniques by Robert C. Copeland  
- Water Supply by Allan Grieve, Jr.  
- Establishment and Maintenance of Campus Turf by William A. Lambert  
- Athletic Field Management by J. T. Williams
TURF HEATING WITH ELECTRIC CABLES

J. R. Barrett, Jr. and W. H. Daniel

Turf heating involves adding heat to the rootzone of turfgrass plants to keep the soil from freezing, keep the turf greener, promote new root growth and blade extension, and help melt snow. This practice, used in Britain and Sweden, now seems adequately tested for acceptance as a part of turf management programs in the United States. The first major electrically heated turfgrass area in this country will be the playing field in the Civic Center Busch Memorial Stadium, St. Louis, Missouri. This installation is to be completed by mid-1966.

The fundamental requirements for installation and management of electric soil warming systems in the North Central States have been determined through cooperative investigations made by the Purdue University Departments of Agronomy and Agricultural Engineering and the Farm Electrification Research Branch, AERD, ARS, USDA.

EFFECTS OF TEMPERATURE ON GRASSES

The influence of temperature on grasses common to turf areas has been studied in detail. Blackman (3) reports from work in England that Lolium perenne (perennial ryegrass), Poa trivialis (roughstalk bluegrass) and Agrostis spp. (bentgrasses and redtop) made no herbage growth when 4-inch temperatures at 9 AM were below 40°F, grew at a greater rate than the control with temperatures between 42-47°F if nitrogen was available, but at higher temperatures herbage growth rates were similar. Brown (5) found that roots and rhizomes of Poa pratensis (Kentucky bluegrass) had maximum rate of growth at 60°F and that the temperature of the soil near the surface appeared to exert a greater influence on growth than at lower depths. Brown (6) later found that Kentucky bluegrass made very little top growth until the average soil temperature at one-half inch rose above 50°F. Root and rhizome extension by dense swards was greatest when temperatures ranged from 40-75°F in the spring and 70-50°F in the fall. Rhizomes developed best in laboratory tests at 60°F, chlorophyll was lost between 40-50°F, maximum top growth occurred from 80-90°F and after one week at 100°F growth stopped. Others have indicated that soil temperature is probably the major factor in root, rhizome and blade development, or loss.

AGRICULTURAL USES OF HEATING CABLES

The use of electric heating cables in agricultural applications is not a new development. Hineton and MacGillivray (11) used lead cables to heat the soil in hotbeds, reported in 1936. Other reports date from as early as 1927. Stanley (14) recommended the use of plastic or lead cables for

2. The authors are respectively Agricultural Engineer, Purdue Dept. of Agr. Engr. and Farm Elect. Res. Branch, AERD, ARS, USDA, and Turf Specialist, Purdue Dept. of Agron., Lafayette, Indiana.
3. Numbers in parentheses refer to appended references.
electric heating of hotbeds. McCune (13) reported accelerated rooting and growth of nursery stock. Taylor and Johnson (15) discussed the design requirements for electric underfloor heat brooding of pigs.

SOIL WARMING IN BRITAIN, SWEDEN AND CANADA

The Sports Turf Research Institute at Bingley, England, has reported on test installations studied to determine the feasibility of using electric cables to thaw turf areas prior to sports events (8). They state that electric soil warming, efficiently managed, can be relied on to assure soft turf regardless of the time of year, and recommended using soil heating at 10 watts per square foot during periods when lower "off-peak" electric rates exist. A maximum of 30 hours was needed to thaw the frozen turf. Escritt (9) further reports that cables placed 6-9 inches apart and 6 inches deep, to give 10 watts of heat per square foot, kept turf areas thawed when used "off-peak" 12 hours a night. Escritt (10) later reported that liquid expansion thermostats, set at 35°F and placed at the surface of the ground were used as controls in addition to time clocks. The varieties of grasses were not identified although earlier than normal growth was observed in the spring. Frost prevention and removal were the primary objectives of these studies.

Several electric heating installations are used in England to guarantee frost-free turf in even the coldest winters. Everton Football Club was the first to install soil warming in their ground at Goodison Park. Edinburgh's Murryfield rugby ground was equipped in 1959 and electric "off-peak" pitch warming is built into the Arsenal ground at Highbury (1). At least one stadium in Sweden has electric, and another warm-water, soil warming.

Lebeau (12), at Lethbridge, Alberta, Canada, has studied the effect of controlled minimum temperatures on grass plots during winter. Results of three years of research showed that raising soil temperatures a few degrees in field plots brought nonhardy turfgrass through the winter in southern Alberta in a lush, vigorous condition. Merion bluegrass, annual bluegrass and creeping bentgrass (Penncross) were lush and green throughout the winter in plots with minimum controlled temperatures of 32°F and above. Lebeau further comments that raising soil temperatures a few degrees would extend the growing season of many herbaceous perennials and give them a vigorous start in the spring. As a result, longer use of turfgrass areas could be made during the season. He states that extended use of this method (adding supplementary heat) will depend largely on the future cost of supplying heat energy.

SOIL WARMING IN THE UNITED STATES

Soil warming research in the United States has been oriented toward improving turf in critical-use areas in addition to assuring frost-free playing conditions. Responses of bermuda grass (New Mexico and Texas A & M), Merion bluegrass (U. of Minn.), St. Augustine grass (Texas A & M), bent-grasses (Toro, Minneapolis), Kentucky bluegrass (Purdue) and zoysia (Links Nursery, St. Louis) are being investigated. These are the major turfgrasses used in football fields, baseball parks, and golf greens and fairways.
Progress reports (7, 2) concerning work at Purdue present factors investigated to gain information about energy input relations to temperature, performance of cable types, installation procedure, control systems and grass response.

Daniel, et al, (7) report that Kentucky bluegrass sod had increased rootgrowth during the winter, had extended growth period in the fall, had earlier growth in the spring, and, in high-wattage areas, had growth throughout the winter. Plastic coverings reduced electric energy requirements, maintained greater greeness in blades, and favored growth. However, extra attention to remove and replace covers to avoid excessively high temperatures and disease buildup was necessary during variable spring weather.

In a later report, Barrett and Daniel (2) confirm that soil warming as a turf management tool can improve adverse conditions by thawing soil, melting snow and maintaining a more vigorous turf.

SYSTEM DESIGN CONSIDERATIONS

The exact design of each installation will depend on the extent of, and use for, each turf area, the climatic location, the availability of power, and the grass species used. The following are general guidelines to be considered.

HEATING CABLE TYPE: Both polyvinyl-chloride insulated nylon-jacketed cables (PVC) and mineral-insulated copper-clad cables (MI) have performed satisfactorily. PVC cable is easier to install and costs less than MI. Cables should be insulated and installed in a manner satisfactory for underground feeder application. Cables must not be modified to exceed the manufacturer's rated power per linear foot by lowering the total resistance through shortening or by raising the voltage, nor may cables be spaced closer than one inch. PVC cables are limited to 5 watts-per-linear-foot heat output. If at all possible, the junctions between the heating cable and the cold leads should be made and checked by the manufacturer.

INSTALLATION PARAMETERS: There has been little observed difference in soil or turf condition above cables 4, 6 and 8 inches deep. Cables should be placed at least 6 inches deep for protection from mechanical damage and associated electrical hazards.

Freezing has not been observed at Purdue between operating cables spaced up to 18 inches apart. Spacing in the range from 6 to 18 inches is recommended. The exact spacing must be determined by considering the amount of heat to be added and cable output.

Power supply circuits should be arranged so that individual cables may be inspected to insure proper operational characteristics by checking current flow or power transmission. All leads carrying a potential to ground should have disconnect switches.

Controls: Soil thermostats installed just below the sod, at 1-inch depth,
have not given adequate anticipation of changing weather conditions, although temperatures in the soil adequately define the heat reserve.

Air temperature has been found to be the best indicator of when heat should be applied. Air thermostats should be shaded and exposed to free air movement that will indicate changing weather conditions. No more than a 3°F differential between "off" and "on" is desired. A sensor elevation of five feet has been satisfactory.

Soil thermostats placed one inch below the soil-thatch interface are recommended and may be of the liquid expansion, differential metal expansion, or resistance types. Again, a 3°F differential is the maximum allowable. These thermostats function as limit switches, permitting addition of heat only when the soil temperature drops below some particular level. Soil temperature sensors should be placed to control groups of cables in areas having similar use or similar soil conditions as affected by soil type, shade, surface cover, etc. Examples are bare soil sections of a football field, or the football-field area within a baseball park.

Use of time clocks permits advantage to be taken of lower "off-peak" electrical rates.

Thermostats should be easily adjustable, with their operation either monitored or calibration checked periodically to assure reliability. In large systems both temperatures and times of operation should be automatically recorded to check the efficiency of the installation.

POWER DENSITIES: The density of heat applied will depend on the weather conditions at a particular location and the condition desired for the turf area. At Lafayette, Indiana, power densities of 4.5 and 9 watts per square foot have given satisfactory results. Even 2.5, on continuously, kept the soil thawed 87% of the days from 1/1 through 3/31/64.

A density of about 10 watts per square foot is recommended to sustain Kentucky bluegrass in an active, but not vigorous, growth state throughout the winter. If such a system is limited to operate 10 hours per night "off-peak" when the air temperature is below 40°F and the 1-inch soil temperature is below 50°F, the 1-inch soil temperature can be expected to range from 40 to 55°F. A green, thaved bluegrass turf with less growth can be maintained by applying heat only when the 1-inch soil temperature is below 40°F. With this limit setting, temperatures can be expected to range from 35 to 45°F.

A density of about 5 watts per square foot is suitable to sustain a green, thaved Kentucky bluegrass turf in climates similar to or warmer than Central Indiana. Heat should be applied if the air temperature is less than 40°F and the 1-inch soil temperature is less than 45°F. One-inch temperatures can be expected to range from 35 to 50°F. Operation can be limited to "off-peak" times, especially if field covers can be utilized before scheduled turf use to retard heat loss during extremely cold weather.

No advantage appears to result from applying heat at low rates for long periods of time when compared with high rates for short periods of time. However, continuous warming at low wattage densities may be utilized in situations where availability of power is limited or installation costs of
a higher capacity system are prohibitive. Results are directly related to total energy added. Less temperature variation occurs when the heat is applied while the air is coldest and incoming solar radiation is minimum.

PROGRAM OF OPERATION

Use of turf area will determine the program of operation. The application of heat should begin as the earth cools if improved conditions are desired for an extended fall season. For this circumstance the system is used to buffer a heat loss. The advantage of early spring application can be best utilized by warming the soil preceding normal soil temperature buildup.

In areas used for both football and baseball, supplementary heat can be used to sustain a frost-free growing turf until the close of the fall season, then turned off, or used in minimum amounts to help the turf repair itself, until air temperatures warm up in the spring. Then the turf can be thawed, or warmed up, and active growth forced as much as 4-6 weeks prior to opening of the baseball season.

Management of golf greens would be similar, practice greens can be available for play whenever weather permits outdoor activity. Heating golf greens at low wattage densities may improve winter survival and avoid winter-kill.

The biggest single consideration with large heated areas involves economics, both installation and operational costs. Approximately 600 KW power capacity is needed to heat a football field turf area at 10 watts per square foot. This is comparable in size to a field lighting system; in fact, the switch gear for field lighting can be used for warming systems. In smaller areas, with less investment and more return per square foot of heated turf, the relation between costs and return is more favorable.

INSTALLATION PROCEDURE

Plastic insulated cables can be installed under existing turf using a modified sub-soiling tool preceded by a rolling coulter to slice the sod. A rigid metal tube guides the cable to desired depth. With ample rolling and watering, the turf can be made smooth enough for use immediately after burial.

Trenching is required for burial of MI cables; therefore, more time is required for the turf to repair itself.

Utmost care must be taken to prevent damage during installation. All cables should be inspected for insulation damage during the laying process. Prior to application of power, each cable should be further checked to detect any damage that may have occurred during installation.

MAINTENANCE PRECAUTIONS

One major problem involves protecting a system from mechanical damage during the normal maintenance and repair of the turf area. Management must recognize the possible damage and injury that can result from shoveling,
deep aerating or staking. Warning lights should indicate to workmen and users of the turf areas when the heating system is energized.

SOIL SURFACE COVER EFFECT

Bouyoucos (4) recognized and reported that soil surface condition and cover were two of the most important factors influencing soil temperature. Both natural and artificial soil covers will affect the performance of a soil warming system. Dense turf with medium thatch is approximately equal to a plastic cover in reducing heat loss. The bare uncovered, but heated, center portion of the Purdue football practice field was frequently frozen at 8 AM during the 1964-65 winter. Utilization of a clear plastic covering kept this area as warm as heated turf-covered sections. The effect of the use of clear plastic covers on heated turf is discussed by Daniel, et al. (7). The use of covers is recommended in cases of very severe weather conditions to assure the desired turf conditions.

Snow cover insulates the soil, thereby reducing the rate of heat transfer through the turf zone. Application of heat necessary to melt snow as it falls is not practical. A snow-free turf cannot be assured, although the rate of melting can be increased. However, if excess snow is removed, snow in the bladezone can be easily melted.

TURF TEMPERATURES

During a mid-winter period at Lafayette, Indiana, it was found that temperatures at 8 AM (CDT) were generally the coldest and 4 PM the warmest for a 24-hour period. The monthly average temperatures at Lafayette, 1 inch under turf and 5 feet in the air are tabulated as follows:

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>TEMPERATURES IN °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov 64</td>
</tr>
<tr>
<td>9 w/sq ft</td>
<td>53</td>
</tr>
<tr>
<td>4.5 w/sq ft **</td>
<td>49</td>
</tr>
<tr>
<td>Unheated</td>
<td>44</td>
</tr>
<tr>
<td>Air at 5'</td>
<td>40</td>
</tr>
</tbody>
</table>

* Heat applied 10 hours each night if air temperature was less than 40°F and soil temperature was less than 60°F.
** Heat applied any time air temperature was less than 40°F and soil temperature was less than 60°F.

The 9 watt-per-square foot treatment area averaged operating about 80% of the time, or 8 hours nightly during 152 days, 1964-65. The 4.5 q/sq ft treatment area averaged operating about 75% of the time, or 18 hours each 24-hour period.

AGRONOMIC CONSIDERATIONS

Turf heating offers several agronomic benefits which have not been previously mentioned. Rejuvenation of existing turf can be accelerated,
and new sod or new seedings stimulated. For example, ryegrass overseeded December 1, 1964, was 3 inches high by December 30 on heated soil covered by plastic, while unheated soil repeatedly heaved and thawed and seed did not germinate. Heating makes natural rejuvenation of heavy-use areas possible where none would otherwise occur. At the Air Force Academy, for instance, hard frosts occur in the stadium before the first football game of the season is played. Another potential benefit is the possibility of combining warm-season grasses having greater wear resistance, with cool-season grasses for an improved turf in cooler areas of the country.

No winter irrigation of heated plots was required during the 3 years of tests at Purdue. Apparently the additional infiltration of moisture from rain and melting of snow adequately offsets any increase in evaporation which might be anticipated as the result of heating. Lebeau's heated plots also did not dry out during the winter despite a small amount of precipitation (12).

Certain potential difficulties must be recognized. Bluegrass plants can be overstimulated when temperatures above 50°F are maintained at 1-inch depth and are susceptible to frost injury in sudden severe cold weather. When surface temperatures are maintained just above freezing with little air circulation, particularly under snow cover, injury from "snow mold" is possible. Lebeau (12) has published information which points out this potential problem. He states that regulation of temperatures in conjunction with application of fungicides should insure complete protection of turfgrass from damage caused by psychrophilic pathogens.

FURTHER INVESTIGATIONS

Continued investigations are being made to refine installation techniques, further check the system of controls, determine the responses of different turf grasses and develop a method to estimate demand. Data are needed on demand, both on a heating season basis and under various climatic conditions. Data to complement findings at Purdue are being taken at USDA installations at St. Paul, Minn. and Beltsville, Md.

CIVIC CENTER BUSCH MEMORIAL STADIUM

The playing field of this new stadium will be equipped with electric soil heating cables placed approximately 8 inches below the sod and spaced 1 foot apart. Heat output of these polyvinyl-chloride insulated cables is to be 5 watts per linear foot while operating at 277/480 v AC. The system will operate "off-peak" to heat the soil when the outdoor air temperature drops below 40°F and when the soil temperature at 1 inch falls below 44°F.

A mixture of 70-80% zoysia (Midwest and Meyer) and 20-30% bluegrass (Kentucky, Delta, Merion, Newport and Windsor) will be used for the turf. These grasses are expected to complement each other with the zoysia most active in the summer and early fall, and the bluegrass predominating in the winter and early spring. The heat added will stimulate the zoysia into early spring growth and later fall activity, while the bluegrass will remain active in the winter instead of becoming dormant.

IN CONCLUSION

The application of heat to the rootzone of turfgrass plants involves
both engineering and agronomic considerations. Research in both disciplines has led to acceptance of turf heating as a management tool in England and Sweden. The potential for use in the United States is vast, ranging from installations in golf green areas to large multiple-sport arenas. Surely other agricultural applications involving the modification of temperatures in plant-supporting mediums will be conceived. Although considerable research has been done concerning grass responses, heat transfer in soil, and soil warming, individually, more investigations need to be made to correlate findings and define management techniques.

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POA ANNUA RESTRICTION
in existing turf
for golf courses, athletic areas and fine lawns
by Cecil F. Kerr of Chipman Chemical Company
with Editing by Dr. W. H. Daniel
Purdue University

INTRODUCTION

Why control Poa annua? It infests finer turf grasses, grows vigorously, produces seedheads and then fails if drought, disease or winterkill comes. For those wanting more uniform, dependable turf, restriction and control of Poa annua can be achieved. A review, some case histories, and action programs follows.

DESCRIPTION

Poa annua can produce seed within two months of germination. It may seed some in the fall, and will seed profusely in the spring. Seed germinates quickly, thus it infests worn areas or thin turf readily. It makes tillers, but not rhizomes, and is as shade tolerant as any grass. Individual plants may exist for years as new stems, crowns and roots continue to develop along old and new stems. The turf manager recognizes it by its light green color, clump growth, profuse seedheads and tendency to wilt under stress.

BACKGROUND

Although much about arsenic toxicity has been known and was reported more than thirty years ago by Grau, Welton, Monteith, Crafts and others, comparatively little arsenic was utilized for selective weed control. When chlorinated hydrocarbons were introduced, they greatly reduced the use of arsenicals as an insecticide. At Purdue University research was initiated for control of Poa annua in 1951 with lead arsenate and results have been observed since 1952. Starting in 1954 tri-calcium arsenate was tested as a formulation for crabgrass and Poa annua control. By 1958 10 out of 17 tests applied at recommended rates, of four arsenical formulations, averaged 98% crabgrass reduction.

FORMULATIONS

For many years calcium and lead arsenates were available as dry, fine powders. (Approximately 50,000,000 pounds of each are produced annually in United States.) By 1959 pelletized calcium arsenate formulations were labeled for turf use. In 1960 calcium arsenate was granulated on a vermiculite base which afforded more uniform application and a more gradual release.

ARSENIC-PHOSPHORUS

Arsenic ions can substitute for phosphorus ions in root uptake. With
low phosphorus availability less arsenic is required; whereas, a higher concentration of phosphorus reduces or off-sets the initial effectiveness of arsenicals. Once arsenic is present at toxic levels in the rootzone, it persists and only gradually dissipates. Therefore, toxicity can be maintained by light annual additions - one-fourth the initial application.

Fortunately, the major lawn grasses (bluegrass, bentgrass, bermuda and Zoysia) are tolerant to arsenic formulations. Meanwhile, arsenic toxicity will control smooth and hairy crabgrass, foxtails, common and mouse-eared chickweed and Poa annua species.

Some of the early users applied full, even excessive, dosage of arsenics and immediately eliminated all Poa annua. In most cases irrigation was unavailable and it was difficult to establish new turf in the large bare areas of dead Poa annua. Only gradually were toxic areas filled in with desired grasses. Brief case histories of various users illustrate both problems and progress.

CASE HISTORIES

1. James W. Brandt of Danville Country Club, Danville, Illinois, initiated eight (8) crabgrass control tests using calcium arsenate in 4 separate locations. Plots consisted of 2 parallel 10 foot strips across the width of fairways.

The plots showed dramatic control of crabgrass, therefore, in March 1959, all fairways were treated with 435 pounds per acre of 85% tri-calcium arsenate, 10 pounds per 1,000 sq ft. (Material was applied as a dry powder in split applications - first down, then cross the fairways.)

In April of 1959 some stripping of bluegrass was apparent in the plots having tri-calcium arsenate also applied in 1958. Strips were injured due to applying the dry powder in bands under each opening of the hopper type spreader.

Although 1960 was an excellent year for crabgrass, no additional arsenic was used and control was excellent. In 1961 all fairways received 80 pounds tri-calcium arsenate per acre as a booster.

In 1962 - no arsenicals were applied - no crabgrass in treated areas.

In 1964 - used 80 pounds of 48% granular tri-calcium arsenate. Jim Brandt commented that he believes that one fourth of the original rate of application every other year will be sufficient to give excellent control of crabgrass on unwatered fairways.

2. One of the early cooperators was Jim Cooper of Maketawah County Club, Cincinnati, Ohio. In the fall of 1959 these fairways were aerified seven times, then 15 pounds of 85% tri-calcium arsenate powder per 1,000 sq ft. was spread and a blend of bluegrass seeded. The fall of 1959 was extremely dry. With no irrigation the bluegrass germination was poor. He re-seeded in the spring of '60.

In the fall of 1960 used 5 pounds per 1,000 sq ft. of 85% tri-calcium arsenate powder.
In 1961 used 5 pounds of tri-calcium arsenate. In 1962 used 3 pounds of tri-calcium arsenate. In 1963 one-half pound of 48% tri-calcium granular was applied. Jim plans on applying 6 pounds of 48% tri-calcium arsenate granular per 1,000 sq.ft. in 1966.

This program eliminated chickweed, Poa annua and crabgrass. Application of the powder was accomplished by mixing with milorganite and spreading with an E-Z Flo spreader. This was a very difficult process. Jim would have had less problems establishing new grass if he had watered fairways. If Jim could relive this -

1. He would establish watered fairways.
2. Have adequate aeration.
3. Seed prior to chemical application.
4. Use a gradual application of tri-calcium arsenate granular over a period of years until arsenic toxicity was achieved, then use four pounds of granular tri-calcium arsenate annually.

3. Charles and Joy Oliver of Standard Country Club, Louisville, Kentucky treated their Zoysia tees and around their green with an initial application of 18 pounds per 1,000 square feet of tri-calcium arsenate. They have applied 5 pounds of tri-calcium arsenate granular for maintenance dosage for each of five years, with excellent results.

4. At Lafayette Country Club, Superintendent Earl Dowell has gradually expanded his arsenic control. Initially 10,000 square feet of approach to each green was spray treated with tri-calcium arsenate at 10 pounds per 1,000 square feet. Later in 1960, parts of fairways were treated. In 1964 he retreated one side of each fairway and in 1965 he retreated at half rate the 10,000 square feet approach to each green. As elsewhere, without irrigation, starting new bluegrass has been very slow.

5. On the fairways of South Course of Purdue University, all fairways were initially treated with 12 lbs. per 1,000 square feet in the fall of 1960. These were retreated in 1962 at half rate and in 1964 at quarter rate. Since bluegrass was uniform and crabgrass was the major competitor, the elimination of the crabgrass resulted in uniform fairways.

6. Donald A. Clemans, Golf Course Superintendent, Norwood Hills Country Club, Normandy, Missouri, relates his experiences with tri-calcium arsenate.

"My first experience with tri-calcium arsenate was at the Country Club of Indianapolis. I applied 48% tri-calcium arsenate granular at full recommended rate (18 pounds per 1,000 sq.ft.) in the spring of 1961. That summer I had complete control of crabgrass and goosegrass. The next spring I applied one quarter recommended rate, and still maintained crabgrass and goosegrass control. By the second summer I noticed definite retardation in Poa annua vigor and the bluegrass turf continued to improve. By 1963, with continued use of one quarter rate of tri-calcium arsenate, the undesirable grasses were under control and near 100% Kentucky Bluegrass turf was a reality."

Don Clemans continued his program after moving to Norwood Hills Country Club - applying 10 pounds 85% powder, the full recommended rate of tri-calcium arsenate powder on April 15, 1964 to forty acres. On April 16, 1964, a gentle rain washed the tri-calcium arsenate into the soil's surface. The
chickweed, Poa annua, knotweed seedlings and crabgrass seedlings all died. The treatment line was very distinct. Norwood Hills fairways were 60% Kentucky Bluegrass and 40% weeds and grasses. Perfect control of undesirable species with the exception of knotweed lasted all season. Don is maintaining toxicity with one quarter rate application.

Many courses throughout the Midwest are in the process of gradual removal of Poa annua.

7. Charles Tadge, Superintendent Miami Valley Golf Club, Dayton, Ohio has initiated a gradual program of Poa annua restriction.

August 15, 1964 Mr. Tadge aeriated and seeded his eighteen fairways to a blend of Kentucky Bluegrasses. After the bluegrasses germinated, at the approximately two-leaf stage, 4 pounds of 85% tri-calcium arsenate was applied in September. In the spring of 1965 four and one-half pounds of 85% tri-calcium arsenate was applied. In Mid-August Tadge again overseeded with bluegrasses. The seed germinated - in late October again four and one-half pounds of 85% tri-calcium arsenate was applied. Poa annua is gradually being eliminated and bluegrass has filled in at a surprising rate. 300 pounds of tri-calcium arsenate powder was mixed in a 250 gallon tank.

8. Norman Kramer, Superintendent of Point O'Woods Country Club, Benton Harbor, Michigan applied 5 pounds per 1,000 square feet in the spring and again in fall of 1964 (85% tri-calcium arsenate powder). The Poa annua control was good and reseeding germinated well. In the spring of 1965 germination problems were noted in some strips of application pattern.

"Spring and fall applications were applied under very dry conditions with water applied by irrigation. About a week after the fall applications on the fairways we had a fine rain and after this we applied tri-calcium arsenate on our practice fairway - same type of application with a broadcast spreader."

"Results were excellent and we had no trouble with germination."

"We have applied tri-calcium arsenate powder since with fine results; making certain beforehand that soil moisture content is near field capacity."

9. Carl Springer, owner of Valley View Golf Course, Akron, Ohio applied 12 pounds calcium arsenate granular in the spring of 1965 and 10 pounds per 1,000 square feet in September.

10. Lester Bishop, Edgewood Golf Course, North Canton, Ohio applied 8 pounds of tri-calcium arsenate granular the spring of 1965 and again 8 pounds per 1,000 square feet the fall of 1965. Both Mr. Springer and Mr. Bishop reported less vigor, and less seeding of Poa annua throughout the summer, thereby providing a more desirable playing surface.

11. Don Figuerlla, Brookside Country Club, Canton, Ohio and Bob Figurella, Fairlawn Country Club, Akron, Ohio have also launched on a gradual Poa annua restriction program using 48% tri-calcium arsenate granular.

12. William Mihelich, Research and Sales Division of Mihelich Nurseries Detroit, Michigan has had years of practical experience applying 48% tri-
calcium arsenate granular on a gradual basis to bent. He initiated a program of applying one third rate over a three year period in 1958. His results have been positive and favorable on beautiful bent estates.

Leonard Hazlett, Jr., The Country Club, Cleveland, Ohio; Ray Phillips, Louisville Country Club, Louisville, Kentucky; Gordon Duguid, Big Springs Country Club, Louisville, Kentucky; Al Hoffman, Ohio State University Course, Columbus, Ohio; Ted Woehrle, Beverly Country Club, Chicago, Illinois; Roy Peck, Kalamazoo Country Club, Kalamazoo, Michigan; Harold Peck, Battle Creek Country Club, Battle Creek, Michigan; Joel Case, Riverside Country Club, Battle Creek, Michigan; Owen Gridley of Chickaming Country Club, Lakeside, Michigan and Michael Sopko of Pepper Pike Country Club, Cleveland, Ohio have started test programs with granular 48% tri-calcium arsenate.

COMMENTS ON CASE HISTORIES

Since powder formulations are more concentrated and more economical, they have often been used. However, uniform distribution is a big problem. If used with dry dilution (as Milorganite at 1-1) extra hopper agitation and breakup of drop below each opening is necessary. If used in liquid dispersion then large screen openings, or no screens, excellent agitation and large nozzle openings are necessary. Because of such problems many who first use powder for economy have turned to granulars for ease of application.

For golfers and golf course superintendents the biggest problem has occurred when complete crabgrass and Poa annua control left large bare areas. Although existing grasses slowly fill in, the establishment of new seedlings has often been inadequate even with repeat overseedings. This gradual approach overcomes this problem to a large extent.

ACTION PROGRAM

If Poa annua is one of the main grasses, it is better to slowly accumulate arsenicals until the desired toxicity has been attained. If treatment is started in early spring using 48% tri-calcium arsenate granular, apply 6 to 10 pounds per 1,000 square feet as early as possible in March or April. If crabgrass is a problem, repeat at 3 to 4 pounds per 1,000 square feet again two weeks later. Then, between August 15 to October 15 apply 6 to 10 pounds to achieve toxicity to Poa annua. The following spring again apply 4 to 5 pounds. This program should be maintained with 3 to 5 pounds of 48% tri-calcium arsenate granular applied either spring or fall annually. If the program is started in the fall, then the gradual buildup should have toxicity by spring for crabgrass with 8 to 10 pounds in early fall, plus 4 to 5 pounds next spring. Then August 15 to September 15 apply 4 to 8 pounds to achieve Poa annua toxicity.

Vertical cutting and overseeding would be encouraged preferably before or even during buildup of toxicity. Plugging, sodding, or vegetative improvement may also be desired.

In this paper only 20 golf courses are referred to. However, over 100 in the Midwest have some treatments underway. The elimination of Poa annua is another step, just as dandelion control was, in producing the finest turf. It is hoped that this article will provide ideas that will aid turf managers to initiate a program for a test fairway and eventually the treatment of the entire course.
The major fertilizer elements are considered to be nitrogen, phosphorus, and potash. While it is recognized that a shortage of any element, whether used in large or small quantities, can be detrimental to plant health, we think of these as the "big three." All are used by plants in relatively large quantities and these, together with lime, constitute the nutrient additions most often applied to plants.

The source of most fertilizer phosphorus is phosphate rock or calcium phosphate. Sometimes ground phosphate rock is used as a fertilizer but because of the fact that phosphorus from this source becomes available quite slowly, it must be applied in relatively large quantities.

Superphosphate and treble superphosphate are the most widely used forms of fertilizer phosphorus. Superphosphate is produced by treating phosphate rock with sulfuric acid. Such treatment renders the phosphorus much more readily available to plants. Superphosphate normally contains 16 to 20% phosphorus (expressed as P$_2$O$_5$). Treble superphosphate, or concentrated superphosphate, is manufactured by treating phosphate rock with phosphoric acid. It usually contains 42 - 52% P$_2$O$_5$.

Ammonium phosphates have come into more prominence in recent years. In keeping with the general trend toward higher analysis materials, these products offer both nitrogen and phosphorus and the combination may offer a total nutrient concentration of more than 60%.

Fertilizer technology is advancing rapidly and new products may be expected to add to the variety of materials available. One interesting development is related to the treating of phosphate rock with a mixture of nitric and phosphoric acids. This process permits the formulation of nitrogen-phosphorus ratios relatively higher in nitrogen than is possible with the ammonium phosphates.

When phosphorus is applied to the soil, it is likely to become "fixed" quite readily. The phosphate ions which exist in a form usable by the plant react with cations such as aluminum, calcium, and iron. The compounds formed vary in solubility but the overall effect is one of removing the available phosphorus from the soil solution. For this reason it is sometimes necessary to continue using small amounts of phosphorus fertilizer regularly even though large quantities may have been applied earlier.

With respect to its utilization in plant growth, phosphorus has been called the "keystone" element. It enters into several plant compounds and is involved with a number of life processes. Phosphorus is necessary to the process of photosynthesis. And photosynthesis is regarded as the basic process upon which all life depends.

Phosphorus enters into the process whereby carbohydrates and other materials are broken down for the release of energy in plants. It is concerned with the transfer of energy within the plant.
Cell division, with all its implications, such as the transfer of hereditary characters is dependent upon adequate supplies of phosphorus. It is interesting to consider that the phosphorus content of plants is usually higher in the growing plants, where cell division is most rapid. Phosphorus is a mobile element that will be transferred from older to younger tissues in situations where phosphorus is deficient.

In turfgrass itself, we are not concerned with maturity and the setting of seeds and fruits. This is another area, however, where phosphorus fulfills an important function. Neither are we concerned especially with legume crops but phosphorus serves a role in the fixation of nitrogen by symbiotic bacteria associated with legume crops.

The requirement of turfgrasses for phosphorus is relatively small in spite of the many roles that the element performs in plant growth. Ranges of phosphorus content in the dry matter of turfgrass leaves have been reported from a low of .10 percent in Canada bluegrass to as much as .54 percent in heavily fertilized Zoysia. It appears that a phosphorus content of dry matter in the range of .2 percent is sufficient for vegetative growth of most grasses.

Because of the fact that phosphorus tends to react with cations to form insoluble compounds, the pH of the soil is important in relation to phosphorus availability. It appears that pH 6.5 is optimum for phosphorus availability, but some variation in either direction may pose no serious problems.

It has been suggested that phosphorus contributes to deep rooting and the proliferation of the root system. It is believed that this theory stems from the fact that years ago some investigators found that ample phosphorus caused a response in such crops as mangle, turnips and beets. Thus, it was surmised that phosphorus was a root growth element. It appears that if adequate nutrients are available in the root zone, additional amounts of phosphorus are not likely to cause any additional root development.

There is a theory that high amounts of phosphorus in soil encourages clover in turf. While it is true that clover responds to ample phosphorus levels, if other nutrients are adequate, the grasses are quite able to hold their own.

Some recent work in California has demonstrated a relationship between high phosphorus and iron-deficiency chlorosis. This bears out some long held theories by observers of turf areas. Quite often an application of fertilizer containing a large percentage of phosphorus is followed by a rain and in turn by severe chlorosis. This situation is reported frequently through the Midwest.

The relationship of phosphorus in the soil to the effectiveness of lead arsenate applications is another interesting facet of this element's behavior. Some work at Purdue a few years ago indicated that the effects of applications of lead arsenate sufficient to seriously retard the growth and development of Poa annua could be almost completely negated by subsequent applications of Phosphorus. This work, together with subsequent studies wherein arsenic compounds containing radioactively tagged elements have been traced, suggests that arsenic interferes in some way with the mechanisms whereby carbohydrates are broken down. Inasmuch as phosphorus plays an important role in this process, it seems reasonable to expect that this is the site of the apparent antagonism.
While considering the relationship of phosphorus and arsenic compounds it may be well to mention the complications introduced into soil testing by the presence of both elements in the soil. The phosphorus tests which make use of the molybdenum blue technique may be confounded to some degree by the presence of arsenic. Arsenic is known to provide the same blue color in this test as is produced by phosphorus. Thus we may see that a putting green which has been fertilized moderately with phosphorus, on which a substantial part of the available phosphorus applied has been tied up, and which has been treated with lead arsenate over a long period of time, may not have enough available phosphorus in relation to the arsenic present. Yet soils from this green may show test results indicating a sufficiency of phosphorus. In such a case, the application of a strip of phosphorus fertilizer across the area in question may tell you much more than did the soil test.

In this brief discussion, we have noted that there are many facets to be considered in the use of phosphorus fertilizers. Not only its multiple roles within the plant, but its propensity to react with other elements concerned with plant growth provides a complexity that distinguishes phosphorus as a turf management tool. The user can waste a great deal of money applying phosphorus that is unneeded or in such quantities that most of it is tied up in unavailable form. On the other hand, an unrecognized phosphorus deficiency can lead to a great many problems.

The name "keystone element" is an apt one for describing phosphorus.

ROLE OF POTASSIUM IN TURF GRASS MANAGEMENT

R. E. Wagner
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Is it a time for a change in turf fertilization? Yesterday's turf fertilizers were N-6-4, N-10-5 or something similar. Today's turf fertilizers too commonly are N-6-4, N-10-5 or something similar. Proportions of phosphorus and potassium in the fertilizers have changed very little.

The major changes have been in amount and kind of nitrogen. As Dr. H. B. Musser says in his book Turf Management, "Nitrogen is the key element in turf production." Response to nitrogen is outwardly spectacular -- often so great we tend to forget that other things also are important.

OUT OF BALANCE

It is important to remember, however, that for quality turf nothing substitutes for a balanced fertility program. Two points are especially pertinent. (1) The more nitrogen you use the greater is the need for a balanced supply of phosphorus and potassium. (2) Turf grasses remove one-fourth to one-half as much P2O5 as N, up to two-thirds as much K2O as N, and two to three times as much K2O as P2O5.

Problems in turf grass management that have grown out of imbalanced fertility programs -- especially too much N to K or P to K -- have prompted
some of our universities as well as segments of the industry to recommend
turf fertilizers that have potassium equal to or somewhat in excess of
phosphorus, such as N-10-10, N-8-8, N-5-10, or N-4-8, or something
similar. Experience has shown that these proportions more nearly meet the
needs of quality turf, although the ratio can vary depending on clipping
practices, turf use, and soil test levels.

Here are examples of what university turf specialists are saying
about ratios. From E. C. Roberts, Iowa State University, "On soils
naturally low in potassium, a 3-1-2 ratio of nutrients may serve well.
Many turf specialists recommend 4-1-2 or 3-1-2 ratio fertilizers for
repeated use under these conditions. On irrigated lawns and golf greens,
extra potassium is especially needed to offset leaching, fixation and plant
absorption."

Roy L. Goss, Washington State University says "A vigorous healthy
turf will respond to management and resist disease attacks. Hence, for
the average conditions of the Northwest, a fertilizer with about a 3-1-2
ratio of nitrogen, phosphorus and potassium will give this health and
vigor if the level is kept high enough and no serious deficiencies were
apparent initially."

Comments from W. R. Pritchett, University of Florida, "In an article
in the 1961 Florida Turf Grass Proceedings, it was calculated that 10.8
- 2.3 - 4.6 pounds of N - P₂O₅ - K₂O per 1,000 square feet per year were
removed in clippings from a vigorous bermudagrass lawn. This is about
a 4-1-2 ratio. The ratio stays about the same, but the amounts are reduced,
if the clippings are not removed. We feel that for most home lawns the
ratio of N can be reduced to about a 3-1-2. If the owner wants an exception-
ional lawn, he can use dressings of N in addition to the complete fertilizer --
giving him a final ratio of about 4-1-2 or 5-1-2."

WHAT IS THE EVIDENCE?

One of the best measures we have of the right ratio -- the right pro-
portions of N, P, and K -- to use on turf is what is in the plant. Figures
for bermudagrass reported by W. B. Pritchett are given above. E. C. Roberts
of Iowa State University has shown the ratio of N-P₂O₅ - K₂O to be 10-2-5
in Kentucky bluegrass foliage. O. J. Noer of the Milwaukee Sewerage Com-
misson reported that during a 6-month season 4.83 pounds nitrogen, 1.8
pounds P₂O₅, and 3.24 pounds K₂O per 1,000 square feet were removed in the
clippings of a bentgrass green.

Most soil test surveys provide evidence to support the need for more
potassium. Most show that a substantial percentage of lawn soils are low
to medium in K. This is especially true on lawns or other turf where clip-
pings are removed. Golf greens are notoriously low because they are clipped
frequently and all clippings taken off. Frequent watering also is a factor.

In more than 5500 turf samples analyzed by Pennsylvania State Univer-
sity, 84 percent of those from golf greens and over 65 percent from lawns were
found inadequate in potash. Much the same thing holds true across the
country. Following are some examples of the percentage of soil samples
testing low to medium in potash and comparisons with phosphate.
These striking figures strongly suggest that we should take a closer look at the "third number" on the fertilizer bag.

REASONS FOR LOW K

Why are we running low on K in turf? More and more homeowners are removing clippings from their lawns. Removal of clippings is standard procedure on greens. Under such conditions, sizable quantities of nutrients are taken from the soil and it is especially critical that appropriate attention be given to phosphorus and potassium, particularly the latter.

Dr. H. L. Dunton, Head of the Department of Agronomy at Virginia Polytechnic Institute, recently told us that the potash level in his lawn was declining even though he had been using a 1-1 ratio of phosphate to potash. His soil test taken this past fall showed very high in phosphate and calcium, high in magnesium, and low plus in potash. He takes off all the clippings and plans to continue to do so. He says "My guess is that as time goes on more and more people will remove clippings because if we do not, on the top lawns we will develop quite a problem with thatch and increase our disease problem."

On new lawns, the usual procedure of grading away the topsoil exposes the bare subsoil that is usually low in all nutrients. The use of low potassium fertilizer accentuates the problem.

Even on established lawns where clippings are not removed, K deficiency can be a problem. Continued use of fertilizers with a high proportion of P to K can promote phosphate build up and potash depletion.

Nitrogen can influence potassium requirement in two important ways whether it is on golf greens, new lawns, or established lawns. First, nitrogen affects the amount of potassium removed by the grass. For example, on timothy in Maine as nitrogen applications were increased from 0 to 300 pounds per acre the amount of potassium in the grass increased from 95 to 245 pounds per acre.

Secondly, nitrogen can increase leaching losses of K from turf soils under some conditions. The process is rather simple. Frequent use of ammoniacal nitrogen in the form of ammonium sulphate or urea replaces the K from the soil colloid or particle. The K is then free to be washed out of the root zone by watering or by rainfall. Because good greens demand frequent nitrogen dressings and watering, some K can be lost. The same principle applies to lawns that are irrigated or those in heavy rainfall areas.
WHAT POTASSIUM DOES

Increasing evidence of low potassium conditions in turf has led researchers at state universities and the U. S. Department of Agriculture to give more attention to the role of K in turf management. This research shows how potassium can (1) help build winter hardiness into grass, (2) help it to resist disease, (3) help it through the summer heat, (4) help tide it over dry periods, and (5) help to make a denser and tougher turf with more vigor and better color.

Before considering these points individually, let's look inside the plant for clues to help explain why we get these responses from K.

Potassium is unique in that it never combines with anything else in the plant although it is essential for the formation of many compounds. It always is found unattached in the plant sap. Perhaps partly because it is free to roam around in the plant, it gets involved in many metabolic processes.

A very basic job that potassium does is to aid in the food manufacturing process - photosynthesis. It also helps to transport food from the leaves to the roots and back again as needed.

Potassium acts as a regulator or a catalyst and has been called a "chemical policeman" for directing chemical traffic. In its role as chemical policeman, potassium becomes involved in many enzyme actions. There is a specific enzyme for every metabolic reaction in the plant. Just how many of these K influences is not well known, but evidence indicates at least 25.

Enzymes spark reactions that hook together carbon units produced in photosynthesis -- to each other and to other types of materials. In this way, organic compounds are synthesized including sugar, cellulose, lignin, amino acids, proteins, and many others, all of which are building blocks of the plant. Grass low in K not only has fewer blocks available to build the plant but it also accumulates certain free amino acids and intermediate nitrogen compounds that tend to disrupt its metabolism.

WINTER HARDINESS. Turf fertility plots at Auburn University illustrated last winter how important potassium can be to winter survival. Both bermudagrass and zoysia were almost completely killed where potassium was low. Full stands were maintained with adequate potassium levels. There is less clear-cut evidence that K builds winter hardiness into northern grasses, but increasing numbers of reports suggest it can be a significant factor.

A look inside the plant gives us some of the ways in which potassium functions to increase winter hardiness. It is well known that storage of food in the plant is essential to winter survival. We already have mentioned that potassium takes part in the manufacturing of food and in translocating it from leaves to roots and back again or to places of storage to be used later as needed. There are times in the life of the plant when it has the ability to manufacture more organic compounds than it needs at the time. Grasses store these compounds as reserve sugars or related carbohydrates in the roots, rhizomes, stolons, and lower stems. Nature planned it this way so there would be reserves that the plant could call on during periods of
stress -- when it uses more food than it is manufacturing. Such times are during the winter, in the spring when the plant breaks dormancy and begins rapid growth, and the regrowth period following each cutting.

Obviously, it is essential to have a way to transport food and water throughout the plant. Leaves and roots are connected by conductive tissue or "pipelines." Work at the University of Maryland on one set of these pipelines -- xylem vessels -- in alfalfa roots showed that plants starved for K have fewer and smaller than normal pipelines and they tend to cluster to the center of the root. Roots well-supplied with K have less cellular breakdown with more vessels that are better distributed and larger and less subject to clogging. Minerals and other foods can move more freely in them. Increased winter hardiness results.

The effect of potassium on winter hardiness has also been attributed to the increased concentration of dissolved substances, including carbohydrates and minerals or salts, in the cell sap. The effect is similar to placing anti-freeze in your automobile radiator. The more concentrated the dissolved materials are in the plant the less likely the solution is to freeze and cause cells to rupture.

The growth and extension of roots which are promoted by potassium are particularly important to winter survival. Heavy nitrogen without adequate K can result in succulent growth of the tops at the expense of root reserves and root development. Recently, Juska and others at Beltsville, Maryland, showed that lack of K sharply reduced weight of Kentucky bluegrass roots. With K, root growth was stimulated more than top growth. Plants with restricted roots are subject to more damage from many hazards, of which cold weather is only one.

DISEASE RESISTANCE. Evidence is accumulating that potassium helps to withstand attacks of disease organisms. W. M. Laughlin of the Alaska Experiment Station has just reported that he was able to practically eliminate leaf spot (Heterosporium phlei) on timothy with adequate K. On low K plots in Maine, timothy showed severe Helminthosporium leaf spot. Plots with 200 pounds per acre of K₂O appeared normal.

Recent work in Florida showed strikingly less dollar spot on potassium fertilized turf than on adjacent areas without potassium. Sulfur is also believed to be a factor in the better resistance shown in these plots. Researchers at Auburn University reported that the severity of leaf spot on bermudagrass was directly related to degree of potassium deficiency. Spots per leaf averaged 13.5 in plots that received the N-P-K-L treatment, but averaged 147.5 spots per leaf when potassium was omitted in the N-P-L plots.

This influence may be due in part to the soft easily crushed leaves of potassium deficient plants enabling the pathogens to gain entrance. However, the effect of K on chemical balance within the plants should not be overlooked as a possible mechanism for imparting disease resistance. For example, it has been reported that K deficient plants contain high concentrations of sugars and nitrates which make more favorable media for the development of organisms.

Large "pipelines" associated with potassium are not as easily restricted by vascular disorders. Probably this is part of what we mean when we say
that sometimes a good vigorous turf is able to outgrow the disease. Organisms entering small vessels can clog them quickly under some conditions.

Dr. Mark Stahmann, University of Wisconsin Biochemist, has been studying disease resistance as related to plant biochemistry. He says that invasion of a disease organism sets up a chemical battle within a plant. The invader secretes enzymes outside of the cell that break down the plant tissue giving the invading parasite an easy pathway to penetrate deeper into the plant. Secretion of the enzyme sets up a counterattack by the plant. The plant cells secrete other enzymes which form chemicals that combine with protein and neutralize the enzymes of the invader. The chemicals that neutralize the invading disease enzymes work in much the same way as antibodies in the blood stream of animals. With potassium's known effect on enzymes, could it be that its influence on disease resistance is brought about by aiding the activity of the counteracting enzymes?

Potassium fertilizer should not be expected to eliminate the need for controlling diseases, but it can make such outbreaks less disastrous and more easily controlled. Any practice that promotes the vigor of plants will help combat disease. Undoubtedly this is part of the answer to potassium's effect on disease reaction, but it could also have some special ways that it acts.

**SUMMER HEAT.** Hot weather reduces growth rate of cool season grasses such as bluegrass and encourages weed encroachment. Even where lawns are properly watered, high temperatures of mid-summer may cause turf stands to thin.

Applying nitrogen alone in the summer months can induce a nitrogen-potassium imbalance and greater heat damage to turf. Many turf managers recognize this and reduce or withhold nitrogen during the hot months. Work at Iowa State University showed that bluegrass supplied with relatively low nitrogen and phosphorus and high potassium withstood hot weather better than when all three were high or when potassium was low.

**DROUGHT.** Dry weather frequently plagues turf managers. Potassium can help. Plants well supplied with K have more extensive root systems which help tide them over dry periods. Also, they maintain turgor and lose less water through transpiration than soft wilted plants low in K. Potassium helps to keep turgid the guard cells surrounding the stomata (the openings through which water is lost from plants). Turgid guard cells open and close the stomata as needed. Guard cells in a wilted plant cannot close the openings, resulting in excessive water loss.

**A DENSE, TOUGH TURF.** As pointed out earlier, potassium is essential to formation of carbohydrates of all kinds. One of these is lignin and it is this compound that contributes strength to stems and leaves. A. G. Hampton of Texas A & M University says "Turf plants deficient in potassium are soft and lush. The leaves are lacking in turgor and the blades are neither erect enough nor stiff enough to present a desirable putting surface. The leaves are easily bruised by traffic. The correct ratio of potassium to other nutrients particularly nitrogen will do much to harden and stiffen the turf."

Few homeowners, golf course superintendents, or turf managers have run into one or more of the problems discussed here. Few would expect to solve their problems with potassium alone. Many management practices go into the
formula for good turf. But it does seem safe to say that the proper use of potassium in turf management has been overlooked in the past, and there is growing evidence that it will be a more powerful weapon in the turf managers' arsenal in the future.

ROLE OF MINOR ELEMENTS IN TURFGRASS MANAGEMENT

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There are some 40 of the known elements that have been identified by chemical analysis as occurring in plants according to Meyer and Anderson in their Plant Physiology text from which we quote as follows: "These elements include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, chlorine, silicon, aluminum, manganese, sodium, boron, caesium, lithium, fluorine, rubidium, barium, strontium, bromine, mercury, zinc, tin, lead, thallium, titanium, arsenic, selenium, iodine, chromium, cobalt, vanadium, copper and silver. Of this list only the first 15 of these elements are found regularly in plants in appreciable quantities and several of these are apparently not essential. On the other hand, certain other elements which are seldom present in more than minute traces are indispensable, at least for the continued growth of some species."

The major elements are nitrogen, phosphorus, and potassium, so called because they are required in the largest amounts. Carbon, hydrogen, and oxygen are normally obtained from water and air and seldom are a factor in plant growth. Our discussion here will deal with the other elements listed with which we have had some experience, or to references in research.

Calcium, magnesium and sulphur are grouped together more and more because they are required in quantities somewhat less than the major elements but more than the amounts required of other elements listed. Until recently these three elements were supplied in good quantities in the form of impurities in mixed goods of major elements, and, so when N-P-K fertilizers were applied, calcium, sulphur, and magnesium too were applied as an "impurity bonus." Now however, with improved techniques in processing, such impurities now are being eliminated, and must now be applied separately as required.

To date comparatively little research has been done with minor element research. Dr. Marvin H. Ferguson reported on some work in 1950 with Meyer Zoysia and more recently Dr. James R. Love, of the University of Wisconsin, has reported the work that he did in Gofdom, the September 1962 issue; and one of his graduate students, Roger Larsen, presented a paper on "Minor Element Deficiency" at the GCSAA Conference in Kansas City this year. We strongly urge those interested to avail themselves of these articles as part of your permanent file.

It isn't easy to recognize symptoms of nutrient deficiencies, but it is important that you be aware that this possibility exists when you examine
sick turf. While chances are rare that minor element deficiency would naturally occur in our Northeastern soils, they may be induced by management techniques, or may occur on highly alkaline or highly acid soils, on sandy soils, or soils very high in organic matter. There are a number of conditions under which some temporary tie-up or release might take place and it is important to have some knowledge of these conditions.

What are the minor elements that are important in turfgrass management? They are iron, manganese, copper, boron, zinc, sulphur, magnesium, and molybdenum. But before we can talk about these we must consider the all important factor of pH and its effect upon the availability of minor elements. Magnesium's availability increases as we raise the pH from 4 to 6.5 and thereafter it remains similarly available on up to very high pH readings while the availability of iron to the plant is good at from a pH of 4 through a reading of 6.5 where it then begins to decrease steadily on up through the extremely high pH readings. Generally the best range for all minor nutrients is between the 5.5 and 6.5 range.

A minor element deficiency also could result because of:

(1) The soil may lack the minor element and so the plant would be unable to get it and therefore would weaken or die. This could occur in soils that are very high in sand.

(2) The soil may contain good amounts of the minor element but if the element is tied-up, the plant will not be able to extract it from the soil. This occurs at readings of high pH.

(3) Micro-organisms may also enter the picture and compete with plants for elements.

(4) Competition between plants could be a factor -- some strains or types might be able to utilize minor elements more efficiently, or might require less than other grasses.

(5) Minor elements could be tied-up in the organic matter fraction of the soil and be unavailable to the plant.

(6) Because of some imbalance of other elements.

We now quote from the article by Dr. Love as follows:

"The purpose of this study, sponsored by the O. J. Noer Research Foundation, was to determine the foliar deficiency symptoms of the three major nutrient elements: nitrogen, phosphorus, and potassium; and of the three secondary elements: calcium, magnesium, and sulfur. Three cool-season grasses were used as the indicator plants: Seaside creeping bent, Merion Kentucky bluegrass, and Pennlawn creeping red fescue.

Calcium: Symptoms are the same for all three grasses. As noted earlier, the symptoms in young plants are quite different from older ones.

The first signs of calcium deficiency in older plants is the appear-
ance of a reddish-brown discoloration in the tissue between the veins along the margin of the blade in the young (upper) leaves, extending gradually to the mid-vein. Colors fade to lighter shades of red, predominantly rose red. The tips take on a withered or fired condition.

**MAGNESIUM:** The symptoms are similar for all three grasses and resemble those for calcium. To the casual observer, the deficiencies of calcium and magnesium appear to be identical. In contrast to calcium deficiency symptoms, however, those for magnesium usually appear first in the older (lower) leaves and the initial discoloration is more cherry red. Also, in approximately 30 to 50 per cent of the affected leaves the coloring is blotchy, giving rise to a banded appearance which never occurs in the calcium deficient plants.

**SULFUR:** Seaside and Pennlawn deficiency symptoms were similar. Like calcium and magnesium, symptoms of sulfur deficiency are late developing and, as a consequence, have only a slight effect on growth.

The initial symptom is the general paling of the leaves. As it progresses, the blades take on a pale yellow-green cast. Accompanying this is the appearance of a faint scorching at the tip of the blade that advances toward the leaf base in a thin line along each margin. The border enlarges gradually until finally the entire leaf blade becomes fired and withered.

In Merion bluegrass the shortage of sulfur manifests itself in two ways. As the chlorotic condition develops, the veins, especially the mid-vein, remain green, giving the leaf a striped appearance. Eventually the mid-vein loses its color and the entire blade fires. The other characteristic sign, noted time and again, is the great susceptibility of these plants to powdery mildew.

Now turning to an article written by Dr. Roy A. Bair, of the Everglades Experiment Station, Florida, which appeared in the March-April 1948 issue of the "Greenkeepers' Reporter."

"We have a lot of problems down in our part of the country with grasses that probably are not the best grasses. Bermuda may be one of them. We have certain deficiencies to contend with which must be met. The usual reaction is one of lethargy, not paying more attention to the problem, refusing to admit that it exists. I encounter the same attitude over the rest of the country when this minor element problem is even broached. The prevailing attitude through states other than Florida is, "It can't happen here."

I would like to start with an analogy. Suppose you started out in life and knew that for the rest of your days you would have plenty of potatoes to eat, an unlimited supply, but one carrot a day for vitamins. You would get along fine on that amount of vitamins, but suppose in the course of time, you increase your family to the point where you have to feed eighteen or twenty mouths. You would still have plenty of potatoes, but that one carrot would have to be sliced up and prorated among the family. We know what happens when people do not get the amount of vitamins they should have. They are not healthy. There would be all sorts of problems."
Let's now consult the renowned physiologists Dr. Meyer and Dr. Anderson with regard to their findings for the role of minor elements in their book universally used as a college text entitled "Plant Physiology" and referring to Table 41 entitled "Symptoms of Mineral Element Deficiency in Plants."

SULFUR
Leaves - Yellowish chlorosis, showing first along veins, at least in some species.
Stems - Often relatively slender, sometimes elongate.

CALCIUM
Plant as a whole - Stunted, stiff, woody. Tendency for symptoms to appear first in younger parts. Plants often die prematurely.
Leaves - Hard and stiff, often yellowish. Mottling or brown spots common.
Stem - Short, stiff and woody, often yellowish. Stem tips die.
Roots - Stubby, profusely branched. Meristematic cells die at root tips.

IRON
Plant as a whole - Tendency for chlorosis of all aerial parts.
Leaves - Uniform or at first mottled yellowish or white chlorosis over entire leaf, appearing first in younger leaves. Often necrotic areas in leaves.

MAGNESIUM
Plant as a whole - Stunted with differential chlorosis as described in the next column.
Leaves - Mottled chlorosis develops first in older leaves. Veins remain green while leaf web tissue turns yellow or whitish.
Roots - Usually stunted and sparsely branched.

MANGANESE
Plant as a whole - Differential chlorosis first apparent in growing tips and younger leaves; may later spread to older leaves. Top of plant may thus be yellowish while the lower portions remain green.
Leaves - Mottled chlorosis — veins green, leaf web tissue yellow or white, first appearing in younger leaves. Often necrotic areas in leaves.
Stems - Yellowish green, often hard and woody.

BORON
Plant as a whole - Growth of plant retarded.
Leaves - Often burned or spotted.
Stems - Apical meristems blacken and die. Stems and petioles often brittle.
Roots - Growth checked. Root branches short, stubby and brownish. Root tips often die."

Please note the similarities in the deficiency symptoms reported above on plants in general and those reported by Dr. Love on turf.

How does this minor element picture affect you as a turf manager? Some specific examples in the golf turf field are:

(1) Velvet bentgrass is a notable victim of iron chlorosis. This strain needs iron added several times yearly.

A-25
(2) Iron chlorosis is induced by heavy applications of lime or phosphate fertilizers. This tie-up of iron may be temporary but the grass could weaken quickly unless iron is applied.

(3) Iron chlorosis is also noted on turf areas that are overly wet. If turf is watered too much, or if soils are poorly drained, or if heavy rains cause water to remain for long periods, iron chlorosis could result.

(4) Gypsum (calcium sulphate) is used in some programs to help with internal drainage, soil improvement, and has somewhat the same effect as adding calcium and sulphur to the soil.

(5) In the spring when color is lacking in greens and your better judgment tells you not to fertilize, iron sulphate could be applied to add color without stimulating plants too much, and without favoring or boosting Poa annua before the bentgrass is ready to grow.

(6) Sulphur becomes available to the plant as a companion element when sulphate of potash is used to provide the potassium the plant requires.

(7) To get the most out of fertilizers applied, lime too must be applied. Lime makes other elements available too, and more efficiently utilized by the plant.

(8) Magnesium is supplied when dolomitic limestone is applied to turf areas.

(9) There have been reports of stimulation and improved color as a result of very light applications of sodium arsenite on bentgrass turf when used in the attempt to reduce Poa annua growth.

(10) Dr. William Daniel reported a tie-up of arsenic when soil contained high phosphorus rendering the arsenic ineffective in Poa annua control.

These are but a few examples of how turf managers cope with minor element requirements in fine turf culture. Minor elements though required in minute quantities, nevertheless are very important to turf health. For the most part the soils in the Northeast contain adequate quantities of all minor elements; however, temporary tie-up may result because of excesses in management programs.
INTRODUCTION

Brown Patch and Pythium Disease are considered together here because (a) they both are active in hot, muggy weather, (2) are checked by the same cultural management practices, and (3) both may appear at the same time and place. Both diseases also produce a cobwebby, fungus growth on the surface of infected grass blades.

BROWN PATCH

Symptoms - Roughly circular, brown patches from a few inches to 3 feet or more in diameter, form in closely mowed turf areas. Infected grass leaves are first water-soaked and dark, but soon dry and turn light brown. On bent grasses -- when disease is active -- a dark, grayish-purple to black ring of wilting grass ("cob-webbed together"), 1/2 to 2 inches wide, borders the actively advancing diseased area. This "ring" disappears as the sun comes out and the air becomes drier. Turf generally recovers from brown patch within 2 or 3 weeks. When disease attacks are prolonged and severe, however, the roots, rhizomes (stolons), and crowns may rot. Such turf is killed or thinned out, invaded by weeds, and recovers slowly over a period of months.

The same fungus is also a cause of seedling blight or damping-off. Grass seedlings turn yellow to brown, collapse, wither, and die in irregular patches.

Grasses Attacked - All fine turf and lawn or fairway grasses are infected in warm (70° to about 95°F.), humid weather. Colonial and velvet bents are generally considered more susceptible than creeping bents which in turn are more susceptible than bluegrasses, fescues, ryegrasses, and other coarser grasses. This is no consolation, but crabgrasses are the most resistant grasses known!

Cause - Brown patch is caused by the very common soil-borne fungus Rhizoctonia solani. This fungus is present in most fertile soils throughout the world. Rhizoctonia is composed of an infinite number of strains (races) or biologic forms that attack hundreds of different kinds of plants including trees and shrubs, vines, vegetables, fruits, flowers, house plants, and even weeds. Rhizoctonia can also survive in soil for months or years by feeding on decaying organic matter. The fungus is believed to overwinter in northern turf areas primarily as small, hard, brown to black bodies, called sclerotia. These measure about 1/16th of an inch in diameter. Sclerotia are formed on the crowns of infected grass plants or in the top 1/2 inch of soil. Sclerotia are extremely resistant to heat, cold, drought, and most chemicals including fungicides. During moist periods (from rain or irrigation), when the soil temperature is about 65°F. or above, the sclerotia send out threadlike filaments called hyphae that may grow 1/2 of an inch per day through the soil. The fungus hyphae can be seen on grass blades following warm (70°F. or over), humid nights as delicate threads "bridging" between grass blades, in guttated
water or droplets of dew, and growing an inch or more per night. As
the grass leaves dry, the fungus threads rapidly shrivel and disappear.

**Disease Requirements** - For the brown patch fungus to become active,
"attack" or infect grass leaves, four conditions must be fulfilled:

1. The presence of the active Rhizoctonia fungus in the soil or turf
mat.
2. A dense, lush growth of a susceptible grass.
3. Dew or a film of moisture on the foliage and a moisture-saturated
atmosphere.
4. The maintenance of a temperature of 70° to 95° F. for at least
several hours.

If any one of these conditions is missing, brown patch will not develop
or disease damage will be mild.

**Disease Development** - When a sclerotium germinates (much like a sprout­
ing seed with multiple shoots), infections are believed to occur in a film
of moisture through the lower grass blades touching the soil or a mat of dead
grass. The fungus grows throughout the leaf blade and progresses up the
grass plant to the leaf tip. Its spread to adjacent leaf tips then occurs
by hyphae growing in and through drops of dew or guttated water which contain
dissolved sugars, amino acids, salts, and other growth factors needed by the
Rhizoctonia fungus.

Sclerotia are difficult to kill by most fungicides. Mercury-containing
products are more effective than other fungicides. Killing sclerotia is
important since they may germinate repeatedly and cause infection an indefi­
nite number of times (possibly 30 or more) and may survive in soil for a
number of years.

The Rhizoctonia fungus is easily spread in infected grass clippings
on shoes, mowing or irrigating equipment, blowing about by the wind, etc.
The fungus is capable of remaining alive in dried grass clippings for 1/2
months or longer.

Well fertilized (especially high nitrogen) and watered dense turf is
most susceptible to brown patch. Turfgrasses are more susceptible when
grown at a normal balanced fertility than when N is low and P and K are
normal. Susceptibility increases with high N and normal levels of P and K.
Resistance increases (within limits) if P and especially K are increased or
N is decreased.

The brown patch fungus will grow at any soil pH, temperature, and
moisture level that will support fine turf and alwn-type grasses.

**Control** -

**A. Cultural Practices** -

1. Avoid overwatering and as much late afternoon or evening watering
as possible in hot weather -- especially if the turf is not adequa­
tely protected with a mercury-containing or other "brown patch fungi­
cide." Water as infrequently as possible to maintain vigorous growth.
Where possible, water in the morning or early afternoon so grass
blades will be dry before evening.
2. Avoid overfeeding, especially with quickly available nitrogen, during the summer months. Keep P and K levels up.

3. Prune dense trees and shrubs around pocketed greens and other turf areas. Increase air circulation and reduce shade. Put new tees and greens where they will dry rapidly; not down in a hollow where they "look pretty" (and where the golf architect or green committee chairman, who don't have to maintain them, may want them!)

4. Keep thatch at a minimum by frequent top dressing, aerifying, and use of a dethatching machine or "power rake." Follow local recommendations.

5. Pole, hose, brush, or otherwise remove the dew and guttated water from grass blades as early in the morning as possible. Remember, without this moisture the Rhizoctonia fungus cannot spread rapidly. (As a trial in a corner of the nursery, apply a nonionic wetting agent at about 7 to 14 day intervals to keep dew from "sticking" to the grass blades. No dew - no brown patch!)

6. Provide for excellent soil drainage when establishing a new turf area. Drainage should be in more than one direction whenever possible. Remove the clippings except on fairways and other large turf areas.

B. Chemicals -
1. Spray every 5 to 10 days in hot, humid weather using one of the fungicides listed below. Apply strictly according to manufacturer's directions.

2. Use Calo-clor, Calocure, Fungchex, Tersan OM, Thimer, Ortho Lawn and Turf Fungicide, Dyrene, Daconil 2787 (Forturf), difolatan, Panogen Turf Spray, Dithane M-45 (Fore), PCNB (Ultraclor or Terraclor). Apply sprays in early morning, or late afternoon or evening, using at least 5 gallons of water per 1,000 square feet (10 or more gallons is better, especially at temperatures above 75° to 80° F.). You will get the best control, with the least chance of injury, if you split the spray application -- half in one direction; the remainder applied at right angles. Strive for uniform coverage.

3. If rainfall has been above normal, or if you have applied a lot of water to greens and tees to keep them soft, remember to shorten the interval between sprays. Spray applications should be timed to give good fungicide coverage of leaves and sheaths during climatic conditions favorable for disease development. Naturally, the control of brown patch should be "dove-tailed" into control programs aimed at preventing insect injury, weed infestation, plus other diseases such as Sclerotinia dollar spot, Fusarium blight, Helminthosporium leaf spots and "melting-out," rust, powdery-mildew, etc. Applications of certain fungicides (e.g., zineb, PCNB, Fore, Acti-dione), may control one disease or more, but increase the loss (injury) from another unless an additional fungicide is added to the spray mixture.
PYTHIUM BLIGHT OR GREASE SPOT

Symptoms - Pythium blight appears in northern states as round to irregular, reddish-brown spots up to about 4 inches in diameter; commonly with blackened, "greasy" borders. When the air is saturated with moisture, the white, cobwebby or cottony growth of the Pythium fungus may be evident on the grass blades. The blackened ring and cottony growth may soon disappear. Individual grass leaves are water-soaked and slimy in wet weather and commonly mat together. This is most evident in the "greasy" border when disease is active. As the weather dries, affected grass leaves turn light brown, shrivel, and often form a crust. Diseased areas now appear as bleached spots. In hot, muggy weather the spots may merge to blight rather large turf areas or form elongate yellowish streaks. The streaks tend to follow the moving patterns or flow of surface drainage water. Diseased turf generally recovers from light attacks of Pythium in 2 or 3 weeks. When disease attacks are prolonged (over 24 hours) and severe, entire stands of turf may be killed. Here it is necessary to resod or reseed. No other turf disease "moves" and kills as rapidly as Pythium blight.

Pythium is also an important cause of a seedling blight or damping-off, especially where new seedings are overwatered. Grass seedlings quickly discolor, wilt, collapse, and die in irregular patches - often in low, wet areas.

Grasses Attacked - Tests have shown that all grasses are susceptible during warm to hot (75°F to 100°F), moist weather. Bents and Poa annua are usually more severely attacked than bluegrasses, fescues, and ryegrasses. Dandelions, plantains, chickweed, knotweed, are also quite susceptible.

Cause - Pythium disease is caused by one or more species of Pythium (primarily P. ultimum and P. aphanidermatum or P. butleri). These are water molds with an active, swimming spore stage; hence the severity of disease in wet weather.

Like Rhizoctonia, Pythium fungi are very common in practically all fertile soils throughout the world. Both types of fungi also feed on decaying organic matter and attack a wide variety of living plants. One or more species of Pythium can infect the roots of practically all plants -- from trees to house plants.

Pythium may over-winter inside grass roots, crowns, rhizomes, or leaf sheaths as fungus threads (hyphae) from infections of the previous year. Over-wintering, or survival, may also occur as thick-walled spores (oospores) or as mycelium in organic matter. When temperature and moisture conditions are favorable, the long-dormant oospores germinate to produce a germ tube that soon produces a "sac" that gives rise to a number of much smaller, swimming-type spores (zoospores or swarm spores). Zoospores, germinating oospores, fungus mycelium in organic matter or in living grass plants, all may play a part in establishing Pythium blight quickly over rather large turf areas. Pythium spreads locally from grass plant to grass plant by "bridging" and growth of fungus threads as in Rhizoctonia brown patch, except the rate of growth and spread is much more rapid.

Disease Requirements - Pythium is favored by roughly the same requirements, as outlined above for Rhizoctonia. Little or no disease development
occurs at temperatures below 70° to 75°F. by the above-named species but other Pythium species kill grass at 40°F in wet spring and fall months.

Disease Development - Hot, wet weather "triggers off" the growth of Pythium mycelium within grass leaves, rhizomes, crowns, and roots. The fungi grow quickly throughout the grass leaf and progress to the tip. Spread to nearby leaf tips then occurs through drops of dew or guttated water as described for brown patch. This forms the active, spreading, outer dark ring of both diseases.

The Pythium fungi are easily spread by infected grass clippings, through mowing when the grass is wet, and by surface drainage water — hence the appearance of straight or "serpentine" streaks in golf greens or tees.

Well watered and succulent or "soft" turf is most susceptible to attacks of Pythium fungi. Keeping nitrogen on the low side and phosphorus and potassium relatively high, as mentioned for brown patch, may also help to keep Pythium blight in check. Calcium nutrition, however, affects Pythium much more than it does Rhizoctonia. Grass plants grown where available calcium is low are more susceptible to Pythium blight than where calcium supplies are adequate to high. This may explain, together with the "binding" effect of free water, why applications of hydrated lime frequently check active Pythium. Applications of lime are believed to check active brown patch because of its water-holding properties.

Control -
A. Cultural Practices -
1. Same as for Brown Patch above.
2. Keep the calcium level up, but the soil reaction (pH) slightly acid (below 7).

B. Chemicals -
1. Since attacks of Pythium occur erratically and occur very rapidly, it is difficult to conduct critical, replicated, and reproducible field tests for control of Pythium. Applications should be made when Pythium blight can be expected during hot and humid weather. Frequent applications (2 or 3 a week) may be necessary in continued hot, wet weather.

2. The outstanding fungicide for Pythium blight is Dexon. It is highly specific for the control of water molds. Dexon is available as a 35 or 70 per cent wettable powder, or in combination with Dyrene and PCNB. The yellow spray solution should be applied in the evening as it deteriorates when exposed to sunlight.

Chemical control of Pythium and brown patch is likely to be ineffective where one or more management practices (or the weather) creates a set of conditions favorable for the rapid growth and spread of Pythium and/or Rhizoctonia. Most harmful practices involve water and are "necessary" to maintain the growth of grass. Water becomes troublesome because of mis-application, poor internal and surface drainage, compaction, layering, thatch,
stagnant air, too much clay in the soil mixture, etc. The solution to this type of problem is not the promiscuous use of a more potent fungicide, but in properly rebuilding the trouble-making greens, tees, or other turf areas.

When using any fungicide, follow the recommendations of the manufacturer exactly. Read and follow all label instructions, including the precautionary statements.

SUMMARY

Rhizoctonia Brown Patch and Pythium Disease

Brown Patch and Pythium Blight are injurious to all fine turf and lawn grasses in hot, muggy weather. Bents are usually more severely attacked than bluegrasses, fescues, and other "coarse" grasses. Brown patch is most damaging from 70° to 95° F., while Pythium attacks usually occur at temperatures of 80° to 100° F. Control involves both cultural management practices and correct choice and proper application of turf fungicides. Even the most effective chemicals will do a poor job when: (a) turf is overwatered, (b) grass blades do not dry off properly, (c) turf is overfed (especially with nitrogen), (d) air is stagnant, (e) thatch is thick, and (f) soil drainage (both surface and subsurface) is poor.

Chemicals effective against brown patch include: mercury chlorides mixtures (Calo-clor, Calocure, Fungchex), Panogen Turf Spray, Tersan OM, Thimer, Dyrene, Difolatan (Folcid), Daconil 2786 (Forturf), mixture of mercury chlorides and thiram, Fore, Ortho Lawn and Turf Fungicide, and Stauffer Turf Fungicide.

Critical work on Pythium control has not been published, but the outstanding fungicide for Pythium is Dexon.

Always follow the manufacturer's instructions as printed on the package label.

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SCLEROTINIA DOLLAR SPOT AND "SNOW MOLD" 1

Noel Jackson 2

Sclerotinia dollar spot and "snow mold" are turf diseases frequently encountered in Rhode Island and most of New England. During the summer months the unsightly bleached patches typical of dollar spot are visible on a wide range of grass species comprising all types of turf. Similarly, as the snow melts each spring, "snow mold" is a common sight. The term "snow mold" is applied colloquially to any of several low temperature fungal parasites of turf, but the fungus commonly encountered in this area is Typhula incarnata causing Typhula blight.

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Dollar spot disease, caused by the fungus Sclerotinia homoeocarpa, is a widespread and damaging disease of turfgrass. In Australia and North America the disease occurs commonly on bentgrasses, fescues, and bluegrasses, but in Britain the disease is confined almost entirely to fescue turf, in particular creeping red fescue of sea marsh origin.

Though known prior to 1932 in the U.S., Monteith made the first recorded description of the disease in that year, replacing the name "Small brown patch" with the new familiar "dollar spot." He considered the causal fungus to be a species of Rhizoctonia, but five years later Bennett, after a detailed study of the dollar spot fungus in England, placed it in the genus Sclerotinia and adopted the specific epithet "homoeocarpa."

Symptoms. On turf, the disease is characterized by the development of injured areas that are at first brown, later becoming bleached or straw-colored and up to two inches in diameter. The affected regions frequently coalesce and involve large areas of turf.

Infected leaves show yellow-green lesions that become water-soaked and finally progress to a bleached or straw-colored tan. Often only the distal and proximal ends of leaves become bleached and shrunked with the intermediate portion remaining green or yellow-green. This banding of the leaves may be more obvious with the appearance of a definite narrow, black band which cuts off the bleached portions of the leaf from the still green portions. With dew present in the early morning a delicate, cobweb-like growth of mycelium may be seen suspended between the individual grass blades. More abundant production of mycelium may occur naturally with prolonged humid conditions, but mycelial growth can be promoted artificially by covering a diseased patch with a sheet of glass or a box. Early symptoms of Corticium pink patch on fine turf may be confused with Sclerotinia dollar spot, but examination of plants affected by Corticium fuciforme, even in the absence of red stromata, will reveal the pink-stranded mycelium of the fungus.

Epidemiology. From the onset of primary symptoms in a turf area buildup of the disease may be rapid and, once established, it is most persistent. Activity of the fungus commences in late spring and declines during late autumn, but spots may persist throughout the winter and the disease resume activity on these sites the following spring. As yet, no spore stage or sclerotia have been recorded on turfgrasses in nature. It seems most likely that the disease persists as mycelium or mycelial aggregates in plant debris and that seasonal outbreaks occur as a result of favorable conditions for mycelial infection. Transport of infected plant parts on implements and feet serves to spread the disease from the primary infection sites.

In England optimum conditions for the development of the disease occur in warm (65-75°F), moist summers, but even in a dry summer the disease will persist and progress, dew providing sufficient moisture for active growth. Summer temperatures considerably in excess of those quoted above obtain in North America, but although Bennett (1937) showed the strains of S. homoeocarpa indigenous to this region to be tolerant of higher temperatures, in general the disease is more serious here in the cooler months of early summer and early fall -- conditions roughly comparable to the English summer!
Potash and phosphate fertilizer application have little effect in reducing dollar spot disease and soil pH does not appear to influence activity of the fungus. However, it is widely accepted in practical turf management that turf grown under adequate nitrogen fertilization, with consequent good plant vigor, is less susceptible to dollar spot.

Control. Though good cultural practices can do much to contain dollar spot disease, elimination of the symptoms calls for preventive fungicidal applications starting in early June. For the past 20 years fungicides based on cadmium have given excellent results. Cadmium-containing formulations show a high degree of selective toxic activity against S. homoeocarpa, requiring only 0.3 oz. of actual cadmium per 1000 sq. ft. of turf at monthly intervals to bring about control of the disease.

However, in 1964 disease symptoms indicative of dollar spot occurred on Penncross creeping bentgrass turf at the R.I. Agricultural Experiment Station. Repeated spring applications of cadmium-containing fungicides failed to prevent the spread of infection. The disease recurred in 1965, and again cadmium fungicides at up to 6 times the recommended application rate failed to inhibit the organism. Isolation from the diseased Penncross turf on several occasions over the 1965 season always yielded a fungus indistinguishable in culture from S. homoeocarpa, but which proved tolerant of dosages in excess of 200 ppm cadmium included in the growth medium. In contrast, growth of a nonresistant isolate of the dollar spot fungus was drastically inhibited by dosages as low as 12.5 ppm of cadmium. These observations and tests indicate that a race of the dollar spot fungus resistant to cadmium has come about. Reports from South Carolina, Missouri, Indiana, and Massachusetts suggest that this change in response to cadmium fungicides is not an isolated occurrence. Fortunately, Dyrene at 4 to 8 oz./1000 sq.ft. offers a very satisfactory alternative for the control of this cadmium-resistant dollar spot pathogen.

**TYPHULA BLIGHT**

Typhula blight, also known as sclerotium blight, gray snow mold, snow rot, snow scald, winter rot, frost rot, and frost injury, is a serious low-temperature disease of cereals and grasses. The disease occurs commonly in northern North America, northern Europe, and Japan, and is caused by the fungus *Typhula incarnata*.

**Symptoms.** The disease is first seen on turf as light fawn to yellow, "scalded," roughly circular areas 2 to 4 inches in diameter. As the disease progresses the invaded plants become covered with a dense, fluffy, grayish-white mycelium. By the time of the spring thaw when the injury is most readily apparent, affected areas may range up to 1 or 2 feet in diameter, but often patches coalesce to involve large areas of turfgrass. As temperatures rise, the mycelial growth of the fungus subsides and small, reddish-brown sclerotia up to 3/16" in diameter may be found embedded in the leaves and crowns of diseased plants.

**Epidemiology.** *Typhula incarnata* is pathogenic at temperatures between 32°F and 65°F but it is most damaging at the lower part of this temperature range where the fungus can take advantage of the dormant low vigor grass host. Invasion of turf may take place in late fall prior to snowfall if wet weather conditions with near zero temperatures prevail. More commonly the
fungus is active and damaging under deep and prolonged snow cover, especially if the turf surface remains unfrozen.

The sclerotia produced, as the activity of the mycelium subsides in early spring, are well adapted to survive high temperatures and desiccation, and serve to carry the fungus over the summer months. A period of desiccation, in fact, is necessary before the sclerotia will produce new growth.

In the autumn under suitable temperatures (optimum 50°F to 63°F) and conditions of high humidity, the sclerotia germinate either giving rise to one or more pink, club-shaped fruiting bodies or producing mycelium directly. During 1965 germination of sclerotia was first noticed at the Rhode Island Agricultural Experiment Station turf plots on October 1 but fruiting bodies were not abundant until November 3. These delicate-looking structures bearing the spores surprisingly can persist for several weeks and may resume more production even after desiccation. The small basidiospores are produced in large numbers and most probably are wind disseminated. Temperatures between 48°F and 68°F are favorable to their germination, but spores are able to survive temperatures as low as 5°F.

Probably the more important of the two means of renewing infection each year in turf is the germination of sclerotia to produce mycelium. Differences in susceptibility to the disease, both between grass species and between varieties of the same species, are apparent but the condition of the host plant and the duration of the snow cover have an important bearing on this factor. Weakened or injured plants of most turfgrass species will succumb if the snow cover is deep and persistent.

Control. Preventive fungicide application in late autumn prior to snowfall offers the most effective means of avoiding damage by Typhula blight. Several fungicides have proved effective in this respect, those based on organic or inorganic mercury compounds probably being the most widely used. Cadmium-based fungicides are also gaining favor here whilst in Europe quintozene is commonly used in agricultural practice for control of this disease.

Development of granular formulations for "snow mold" control have greatly facilitated the late fall/winter application of fungicides and one timely application of a suitable material is usually sufficient to protect the turf throughout the winter. Emphasis is placed on preventive fungicide treatment prior to snowfall, since midwinter application of fungicides to existing infections may have no noticeable effect on reducing injury or on the rate recovery of the diseased turf.

FUSARIUM BLIGHT - DISEASE OF TURF GRASSES

George A. Bean
University of Maryland

Merion Kentucky bluegrass (Poa pratensis L.) is a widely used turf grass in the United States. Under proper management, Merion forms a beautiful vigorous dense turf that is both weed resistant and drought resistant. It is relatively resistant to leaf spot (Helminthosporium spp.) but susceptible
to stem rust (Puccinia graminis F. sp. agrostis Eriks.), stripe smut (Ustilago striiformis (West) Niessl) and mildew (Erysiphe graminis DC.).

In 1962, a crown rot disease was observed in some Merion lawns in the Washington, D. C. area. The disease rapidly invaded a lawn and produced numerous irregular patches of dead turf. In 1959, Couch had made similar observations in Pennsylvania and in 1964 reported that Fusarium roseum (lk.) amend, S. & H. was the causal organism (2).

Symptoms. Fusarium blight is characterized by a crown rot plus leaf spot phase. The most characteristic symptom is the crown rot phase which as irregular areas of dead sod which are tan in color and 1-3 inches in diameter. At this stage it resembles dollar spot infection, Sclerotinia homeocarpa F. T. Bennett. If favorable conditions persist, however, the Fusarium blight areas increase in size and finally coalesce. In a Merion, common Kentucky or bentgrass lawn infected with dollar spot, the infected areas normally remain relatively small and rarely coalesce. Fusarium blight can develop very rapidly and areas of sod have been completely destroyed within 10-14 days after symptoms first appeared. As a blighted area increases in size, the grass around the edge is usually wilted and mycelium of F. roseum may be found in the crown area. Occasionally a small amount of healthy sod persists in the center of a blighted area and this "frog eye" effect some consider the characteristic symptom of Fusarium blight although it is rarely observed in the Washington, D. C. area.

Leaf lesions occasionally occur in sod showing crown rot symptoms; however, lesions can also be found in sod with no evidence of crown rot. One to many lesions can occur on a single leaf. They are characterized by having white centers surrounded by light brown margin of infected tissue similar to lesions resulting from dollar spot infection. The lesions eventually extend across the width of the leaf which then causes a yellowing of the leaf tips. When heavily infected, the sod will usually have a yellowish discoloration because of the damage to leaf tips. Fusarium lesions can readily be distinguished from Helminthosporium lesions in that the latter are much darker in color and the lesions are more elongate and rarely extend across the entire width of the leaf.

Time of Occurrence. In the Washington, D. C. area, Fusarium blight was first recognized as such on July 18, 1963, although turf workers have observed similar symptoms in this area as early as 1952. The fungus remained active through August in 1963; however, by September as daily temperatures decrease, the disease was no longer spreading. In the lightly infected areas, healthy sod grew back into the dead areas. In 1964 and 1965 the disease appeared much earlier, June 26 and June 23, respectively, and it remained active through August and September. Most of the infected areas had to be either re-seeded or re-sodded in 1964 and 1965. The build-up of inoculum may have accounted for the earlier appearance of Fusarium blight in 1964 and 1965 but there was less rainfall from June through September in 1964 and 1965 which may be just as important as inoculum build-up. The total rainfall from June-September in 1963, 1964, and 1965 was 19.4, 7.6 and 11.4 inches respectively. Furthermore the severity of infection was much less in 1964 than 1965 which could also be related to the amount of rainfall.

Locations of Infection. Since 1963, 16 turf areas in the Washington, D. C. area have been under observation. The damage to turf from Fusarium
Fusarium blight has ranged from very severe to no disease. In the most severely infected areas, more than 50 percent of the sod has been destroyed necessitating re-seeding or re-sodding. The disease has appeared more prevalent and severe within Washington, D. C. than outlying suburban areas. This may be the result of generally higher temperatures that prevail in the center of a city. Woollum (3) reports that such a condition does exist in the Washington, D. C. area.

Susceptibility of Turf Grasses. Couch (2) found that under greenhouse conditions, Highland bent grass (Agrostis tenuis Sibth.) was most susceptible to F. roseum with Merion bluegrass and Pennlawn red fescue (Festuca rubra L.) ranking next in order to susceptibility. I have observed the following turf grasses, either in pure stand or mixture: Kentucky bluegrass (Common, Merion and Windsor), creeping red fescue (F. rubra L.) bermuda grass (Cynodon dactylon L.), bent grass (A. tenuis Sibth.) and Meyer zoysia (Zoysia japonica Steud.). Characteristic symptoms of Fusarium blight have been observed on the following grasses: pure stands of Merion, Windsor, Common Kentucky and a mixture of Common bluegrass and creeping red fescue. Infected pure stands of creeping red fescue, bermuda, bent grass and Zoysia have not been observed. In one location a putting green of Pennlawn bent grass remained disease free although the surrounding Merion sod was destroyed by the disease. Caloclor (60% mercurous chloride, 30% mercuric chloride) applied every 7-10 days to prevent dollar spot infection may have prevented the occurrence of Fusarium blight.

Influence of Environment. The first area of a lawn to be infected is usually on sloping land that is close to a driveway or walkway. In addition, sod on south facing slopes is usually more severely infected than sod on north slopes. The severity of infection is directly proportional to intensity and duration of sunlight. The most severely infected sod receives full sun during the warmest part of the day from 12 noon to 4 P.M. Often, only a small opening in a dense tree canopy will result in the turf below it becoming infected.

Control.

Chemical: Successful control of Fusarium blight was reported applying Dithane M-45 at the rate of 4-6 oz. per 1,000 sq.ft. (2). In 1964 this chemical was applied throughout the summer but it failed to control the disease. In 1965 it was applied at the 8 oz. rate and compared with 3 other turf fungicides, Difolatan, Dyrene and Tersan OM (1). In addition one-half of each plot received an application of hydrated lime at 25 pounds per 1,000 sq.ft. on May 11. The chemicals were first applied May 7 and weekly thereafter. Fusarium blight did not appear until July 11. Notes were taken on the percent diseased area at weekly intervals. This information is summarized in Table I. Tersan OM was applied at 6 oz. and the rest at 8 oz. per 1,000 sq.ft.

The plots which received Tersan OM had only trace amounts of disease throughout the summer. There was little difference among the 3 other fungicides although they had less disease than the unsprayed check treatment. Regardless of the fungicide applied, the application of hydrated lime reduced disease severity by about 50 percent. It was also noted that as the season progressed the effectiveness of lime decreased.
Table I. The effect of hydrated lime and fungicides on Fusarium blight of Merion Kentucky bluegrass.

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<th>Average</th>
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<td>Tr</td>
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<tr>
<td><strong>Average</strong></td>
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Cultural: Replacing infected sod with healthy sod may not be practical especially if the lawn is severely infected. In the fall of 1963, severely infected areas of Merion sod were replaced with 1 year old disease free sod. During the following summer, disease symptoms first appeared in the original sod; however, within 1 week the newly laid sod became infected. Within 2 weeks replaced sod was as heavily infected as the original sod.

Where trace amounts of disease are present in a lawn, it is possible to control Fusarium blight by cutting out the infection centers and replacing with healthy sod. Care should be taken, however, to remove enough of the sod around each dead area to eliminate the mycelium in the crown area. At least 3 inches beyond the circle of dead sod should be removed. Unless this is done, the mycelium can continue to spread outward and infect the original sod.

The level of thatch in a lawn has little effect on disease severity nor does collecting the grass clippings each time a lawn is cut. I was also unable to correlate disease severity with nitrogen or calcium levels in the soil as had been reported (2).

Conclusions. Fusarium blight disease is a serious problem only in certain areas even though the causal fungus has widespread distribution. The disease is active only during the warmest part of the summer and the first part of a lawn to be infected is usually the warmest location indicating that light, temperature, moisture or a combination of these factors may be predisposing the turf to infection. Although the promising results using Tersan OM are still preliminary, it does indicate that control by fungicide application is possible. The importance of a good turf management program should not be overlooked however, since Fusarium blight appears to be a disease of weakened grass so that providing adequate moisture, fertilizer and aeration may reduce if not prevent infection.

Literature Cited.
PHOTOGRAPH I

Fusarium infected Merion bluegrass showing the irregular areas of infected sod.
OBSERVING THE WEATHER - OLD AND NEW TECHNIQUES
Robert C. Copeland
Meteorologist, Westinghouse Broadcasting Company

Since the atmosphere is the medium in which we all live and breathe, work and play, man since his origin has been vitally interested in knowing about this medium, its effects on him, and hopefully, in knowing how its present state may change in the future.

Probably even among primitive man there was the awareness that certain types of clouds approaching meant that quickly finding shelter was the smartest thing to do. Other than cloud-watching, which still is a pretty good system for local short range forecasting, the first orderly quantitative way of observing the atmosphere can be credited to Torricelli who invented the mercurial barometer in 1643. Since that time much effort has gone into a steady increase in the quantity and quality of equipment which measures, indicates and records the many variables of our atmosphere, such as temperature, pressure, humidity, wind speed and direction, sunshine, rainfall, snowfall and other phenomena much more obscure.

While many of these weather variables are recorded periodically or continuously at thousands of points around the world or reported and intra-communicated at predetermined intervals for the preparation of weather maps, it should be remembered that the "map" which results does not tell the whole story. Since the atmosphere is after all a continuous medium, describing the wind, weather and temperature at any number of points does not account for everything that might be going on and is not a completely adequate or satisfactory way of representing much a continuous medium.

What we are implying here is that essentially we are losing much of the three-dimensional information about the atmosphere that really exists, and some of which is indeed more adequately represented by our old view of the clouds from below. In fact, one observational technique for observation of a sizeable chunk of the atmosphere utilizes a camera mounted above a hemispherical mirror, periodically photographing a 360 degree, horizon-to-horizon picture of the cloud distribution. But of course, the magnitude of our observation decreases rapidly as the height of the clouds decreases, and we are completely limited by darkness, fog and precipitation.

The use of tracking balloons which ascend at a fixed and known rate is a step toward overcoming the limitations of fixed point observations because the winds above the surface can be computed from the tracking information. However, this gives us information on roughly a vertical line above a point on the surface and still doesn't tell us much about any large three-dimensional segment of the atmosphere. The more elaborate radiosondes which utilizes radar tracking plus a transmitter which radios back to earth continuous soundings of pressure, temperature and humidity as the balloon ascends, never-the-less suffers from the same line-in-space affliction. On the other hand, without radiosondes observations of the upper atmosphere, we would not even be close to where we are today in forecasting the motion and development of highs and lows and weather in general.
During World War II, a device known as radar (which means radio detection and ranging) was developed and greatly assisted in the war effort in the detection and tracking of enemy aircraft and ships. However, it was also observed that strange echoes appeared on the radar screens at times which when intercepted turned out to be only rain showers. On the other hand, it was found that at times, widespread rain areas masked the approach of enemy planes or ships.

The unique ability of radar to continuously scan one hundred or more miles in all directions, night and day, for rain or snow in the atmosphere has been developed and expanded since the war to include a nationwide weather radar observation network run through the cooperation of the Weather Bureau, the military services and some universities. In addition to the distinct advantage of being able to present a limited three-dimensional view of extensive portions of the atmosphere, to track individual storms from thunderstorms to hurricanes, and to fill in the gaps between conventional weather observation stations, radar has also permitted us to investigate many of the inner workings of storms, fostering a much better understanding of the processes by which nature produces rain, snow, sleet, hail and even thunderstorms.

The most recent addition to the meteorologist's arsenal of weather observational tools is the weather satellite. For several years after the war, scientists experimenting with captured V-2 rockets and some of our own subsequent boosters, were very impressed with the pictures of wide areas of the surface of the earth and its cloud cover taken from many miles above the surface by cameras designed primarily to observe performance of the rocket. It was obvious that this resulting birds-eye view of atmospheric phenomena (almost all of the clouds and weather occurs within the first ten miles above the surface) could tell us much about the tremendous "organization" of the cloud systems in the atmosphere. It was further obvious that a satellite with picture-taking capabilities could give us nearly continuous coverage of the changing cloud patterns over most of the earth, provide much information over otherwise data-sparse areas such as the oceans, deserts and polar regions, and even perhaps aid in forecasting, especially with regard to large-scale, slow moving weather systems.

The TIROS weather satellites, first sent aloft in April 1, 1960, relay cloud photos back to earth via a miniature television station on board and have the capability of storing on board pictures recorded over remote parts of the earth for later relay to United States ground stations.

The TIROS series has been especially valuable in first spotting and then tracking many of the hurricanes which are prevalent in the late summer and autumn over the relatively unobserved expanses of the Caribbean Sea and the Atlantic and Pacific Oceans.

During February (1966) the satellite program moved from the experimental stages to an operational global observation system with the addition to the weather satellite family of ESSA I and II (ESSA -formerly TIROS but changed to correspond to the initials of the agency now in charge of the U.S. Weather Bureau....... The Environmental Science Services Administration).

ESSA I is an advanced version of the early TIROS satellites, which could only relay pictures to two major receiving stations on the earth at irregular
times and of different places each day. ESSA I provides dependable once-a-day coverage of the entire sunlit part of the globe, and these pictures are relayed to all weather stations on the national Weather Facsimile Network. As with the earlier TIROS series, pictures over remote portions of the earth are recorded on tape within the satellite for later readout when the "bird" approaches the ground station.

ESSA II in a polar sun synchronous orbit (which means it is over the same spot on earth at roughly the same time each day ...about 9:00 A.M. in New England) automatically transmits pictures on every sunlit portion of its pass. These pictures are snapped and transmitted once every six minutes, providing overlapping cloud pictures about two thousand miles on a side (almost four million square miles each) and can be received daily at the same time covering a wide area around any given point by anyone with the right kind of equipment. Many first-line Weather Bureau stations are so equipped ... so are many foreign and Russian stations ... even you can have your own satellite-cloud photos daily with about $15,000 worth of equipment.

Certainly these weather satellites are not the whole answer nor are they going to result in any rapid or drastic improvement in weather forecasting... but they do finally provide us with a continuous birds-eye-view of the overall cloud distribution in the atmosphere, which in turn tells us much about the weather occurring over a large part of the earth's surface.

Satellite observations when combined with all of our conventional weather observations permits us to fairly accurately depict current weather conditions over much of the globe, and certainly an adequate knowledge of what's going on now is one prerequisite to anticipating what's going to happen tomorrow.

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WATER SUPPLY

Allan Grieve, Jr.
Principal Civil Engineer
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Water Division

Indispensable to life itself, water like the air we breathe has always been with us. It is casually accepted as God's greatest gift to mankind.

Ancient Hebrew scholars wrote in the very first words in the Bible of the creation of the earth - Genesis 1 - "In the beginning God created the heavens and the earth. And the earth was waste and void; and darkness was upon the face of the deep and the Spirit of God moved upon the face of the waters."

One theory of modern scientists, or geo-physicists, is not unlike that of those ancient scholars. This theory envisions the beginning of the planet, Earth as originally a spinning gaseous mass being transformed gradually into a sphere with a rugged outer layer named the crust. Inside this crust, water, more or less in the form of steam, was trapped under great pressure and was hidden in great underground pools and streams. This water was forced upwards to the surface by various eruptions eventually to form the great
oceans and a portion was drawn further upward by the action of the sun to form the atmosphere around the earth.

The water in the world of today is to all intents and purposes the same water as that which existed millions of years ago. It is the one natural resource which apparently is inexhaustible. The total amount is constant, but the relative amounts in the oceans, lakes, and streams, under the ground and in the air are in a constant state of change and variation. The oceans remain the great reservoir of all waters which furnish life on this planet.

A repeating cycle exists whereby water rises, salt free, from the oceans, to be borne by the winds across the face of the land and to return to the sea again through various and devious ways. The source of energy for this cycle is the sun which distills from the ocean brine, pure water vapor to be picked up by the winds.

When precipitation hits the earth, it runs off to form surface water which either flows down the streams to the sea or evaporates to the atmosphere, or it percolates into the earth to form ground water, which is stored or moves slowly to the sea; or it is used by plants and vegetation from which the water transpires to the atmosphere. This unending movement of water from the oceans back to the oceans through the various channels is called the "Hydrologic Cycle."

In a recent journal of the American Water Works Association, James A. Shear wrote with regards to this cycle "that the total water in the earth's system is estimated at about 1,000 trillion acre-feet, a staggering and reassuring quantity. About 97 per cent of this total is in the oceans and not in condition for immediate use except in a very limited way. The oceans dominate the hydrologic cycle. Outside of the 97 per cent of ocean saline water, some 3 per cent of the total is in fresh form. Of this 3 per cent, 2.25 per cent is tied up in ice with about 6,000,000 cubic miles of ice in the Antarctic ice cap alone. Of the remaining 0.75 per cent, more than half is within the earth's crust at a depth greater than 2,500 feet and in forms that make it essentially unavailable. About 0.3 per cent is in the first 2,500 feet of the earth's crust, 0.01 per cent in the earth's atmosphere, 0.003 per cent in soil moisture, and only 0.0001 per cent in streamflow."

In spite of periods when we are aware of its near absence in droughts and dry spells, it is surprisingly abundant - so much so that if all the earth's mountains and ocean depths were levelled off, the entire earth's surface would be covered to a depth of approximately two miles.

From remote antiquity, the highest value has been set upon an abundant and potable water supply. Centers of population sprang up in ancient times around those regions where it was readily available and great expenditures of time and labor were spent to convey it to places where it was not naturally plentiful.

The peoples of Assyria, Babylon, Egypt, Israel, Persia, Greece, Rome, India and China built many water supply facilities long before the Christian era. Ancient reservoirs of large size, canals and irrigation works have been discovered in southern Arizona, Central and South America. Five thousand
years ago, the civilization of the Indus Valley in India enjoyed the benefits of well designed water systems. Excavated ruins of that period have revealed a surprising variety of waterworks, including tanks and canals for irrigation. Many of the larger undertakings connected with water supply throughout history were those built more or less in connection with general systems of irrigation. About 950 B.C. Solomon directed the construction of sizeable aqueducts to provide for the needs of man, beast and field. Among the early Greeks, Hippocrates, Father of Medicine, recognized the danger to health of polluted drinking water and recommended that the water be filtered and boiled. Most of the permanent settlements in the arid regions, today as in ancient times, have concentrated along river valleys. Even along seacoasts, dwelling places grouped around or near the convenient source of fresh water.

There have been droughts in all ages and in all countries. The seven years of drought and famine in Egypt recorded in Genesis, began in the year 1708 B.C. In the year 310 A.D. hardly a drop of water fell in England and 40,000 people died of famine. In 951, a drought began in Europe that lasted four years. The summers were intensely hot and famine again prevailed everywhere; 3,000,000 died of hunger. For many centuries devastating droughts have occurred in India and China where untold millions have perished as a result. In the United States, the drought of 1930 has been one of the worst of any on record, causing the great dust bowls of the mid-west. During the year 1930, forty out of the forty-eight states had less than normal rainfall. Precipitation and runoff records indicate that droughts of major proportion, both in severity and in extent, have occurred at intervals of 15 to 20 years.

Governor Volpe, in his recent annual message to the State Legislature in January stated, "The vital importance of water to our lives and to our state's economy has been brought home with unusual force due to the drought of the last four years - the longest continuous drought in Bay State history."

The 1965 drought has been bad news for all of us in the Northeast but it has also been a lesson to us. We have discovered the inadequacy of appraisals of yield of our supply sources.

We have discovered that our factor of safety which we had allowed for runoff was inadequate. We knew that stream and surface supplies would be the first to be affected, and that ground water sources would ultimately suffer. Only now are the statistics beginning to be available.

Future planning for the many uses of water must be based on a thorough realization of the fact that a drought is not an isolated freak of the weather, but as a menace which unquestionably is certain to recur.

GROUND WATER

The intelligent use of ground water supplies by means of wells properly located and constructed, can do much to lessen the severity of droughts and should be made a part of the overall plans of communities, commercial interests and industries which now either have ignored this potential, or regard it with little interest.

There are many opportunities throughout the region for developing additional sizeable ground water supplies. Ground water is the accumulation of water in the pores and crevices below the surface of the ground. Its primary source is rainfall which enters by percolation through the surface.
material. The upper limit of water in the ground is termed the "water table." All water entering the ground and not taken up by vegetation must after a certain penetration, (a) escape laterally to some ultimate outlet at a lower elevation in a stream, spring, lake or ocean or (b) add to the storage in the ground and raise the water table. Free lateral flow takes place only through deposits or strata of relatively permeable materials such as sand, gravel or decomposed rock.

In Massachusetts, the most favorable water-bearing material consists of the deposits of glacial sand and gravel that cover the bedrock surface. The largest ground-water supplies are obtained from the outwash that lies in the pre-glacial bedrock valleys. Some of the buried valleys in Massachusetts contain over 200 feet of this outwash material, but the valley filling in most places is relatively thin - commonly less than 100 feet. The position and trend of some of these valleys is not readily apparent and their extent must be determined if the ground water resources are to be effectively utilized.

The development of underground water is a highly specialized art, which demands the services of geologists, engineers and contractors qualified by practical experience. Only if the contractor and engineer have such training does the client receive the service he has the right to expect. Although the proper choice of personnel is not an absolute insurance against trouble, it will limit the difficulties to those which are unavoidable because of the nature of the task and will definitely assure the owner of fair treatment and minimum expense.

In 1965, according to the records of the Massachusetts State Department of Public Health, 301 water supply systems in 274 municipalities of the 351 cities and towns of the state were served by public water supplies. The public water supplies for about 210 of these communities were obtained wholly or in part from underground sources, such as wells or springs.

New England is a region that is rich in its water resources. But it is also a densely populated industrialized region which is demanding larger quantities of fresh water each year.

The trend in water usage is ever upward. Less than fifty years ago, the amount of water used per day per person was governed largely by the basic requirements of health and cleanliness. Today the average consumption per person must also satisfy many other needs.

As science provides new methods, new devices for better living, they are frequently accompanied by increased water consumption. As typical examples may be cited, air conditioning units, automatic washers, garbage disposals, lawn sprinklers and many more. In addition, modern factories use tremendous quantities of water and on an ever increasing scale.

Not only is there a continuing demand for more water, but water of better quality is also demanded.

WATER LAW

The basic right to use the resource of flowing water in New England comes from the English common law doctrine of Riparian Right. The law on
water courses governs non-tidal natural streams, large or small, usually flowing, which have bed and banks, a definite direction and a permanent source. Streams may periodically dry up, flood or even abruptly change course, but their essential identity is never lost. Simply stated the Riparian Right is the right of an owner of property on a stream to receive the natural flow of the stream unimpaired in quantity and quality subject to reasonable use of the flowing water by riparian owners upstream. Under his right the owner may take water from the stream for use to develop power or for other purposes. He must return it to the stream in substantially the same condition and quantity as he took it, else he violates the right of each owner downstream. His right does not entitle an owner to take and use water for irrigation. Irrigation use consumes a large proportion of the water employed. In numerous cases the Courts have protected riparian owners from diminution of the quantity of flow. Their right to receive the stream flow unimpaired in quality is much less possible to maintain and in some streams probably has been lost by default.

The power of eminent domain is the one way in which the possessor of riparian rights can be deprived of them for the public good. It is the power which is given to municipalities or to water supply companies to take water for public use. Every act of the Legislature which gives that authority must of course contain a provision for the payment of damages; otherwise, such legislation would be unconstitutional and void. With this power, the doctrine of riparian rights has been no barrier to intense developments, as some of our water supply projects here in the Northeast demonstrate.

"An interstate stream offers especial complications in condemnation." Many of these complications have been cleared away by two decisions of the U. S. Supreme Court, Connecticut vs. Massachusetts, decided February 24, 1931, and New Jersey vs. the State and City of New York, the Commonwealth of Pennsylvania, Intervenor, decided May 4, 1931. These two cases, which were almost exact parallels, were decided by the court, not on the basis of a strict interpretation of the riparian doctrine, but on what the court termed in the former case "equality of right" and in the latter case "equitable apportionment." The decisions approve the appropriation of the waters of an interstate stream by an upper proprietor within the limits of "equality of right" or "equitable apportionment", and at the same time they guarantee to the lower state immunity from the injury of any substantial interest by the appropriation above of undue amounts of water.

In both cases, the Complainants had pleaded for a strict interpretation of the law of riparian rights which would have entitled them to the flow of water in the river undiminished in quantity and uncontaminated as to quality. With such an interpretation of the doctrine affirmed, diversion could not have been permitted.

The decision granted the diversion, but at the same time it recognized rights of the lower states in both cases and the decrees provided for a substantial regulated release of water from the storage developments which are part of the diversion project. This release will amount to an increase in the flow of the receiving stream at times of low water.

The decisions forwarded the cause of stream regulation under a new doctrine of equality of right, assuring to an upper state full benefits from waters within its borders and to a lower state immunity from material damage and a better river in extreme dry weather.
Very briefly, a few of the outstanding quotations from the opinions of the Court, as delivered respectively by Mr. Justice Butler on February 24, 1931 and by Mr. Justice Holmes on May 4, 1931 are as follows:

"Drinking and other domestic purposes are the highest uses of water. An ample supply of wholesome water is essential."

"A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it."

"The different traditions and practices in different parts of the country may lead to varying results, but the effort always is to secure an equitable apportionment without quibbling over formulas."

"The removal of water to a different watershed obviously must be allowed at times unless states are to be deprived of the most beneficial use on formal grounds."

In a few states, special legislation is necessary in each case to authorize the taking of water for a public water supply. Such legislation is required in Massachusetts to take water from any source, surface or underground, and by either a municipality or a water company. In Massachusetts, plans for a water supply development must be submitted to the State Department of Public Health before petitioning the General Court for a charter or authority to take water from any source, and the Department's advice and recommendation thereon must accompany such petition. The Department is required to consider the existing and future needs of other municipalities and persons which may be affected by the project. The legislature has for many years adopted the Department's recommendations and provided, in each case, that the source of supply and the location of all dams, reservoirs, wells, etc., as well as the taking of any land for the protection of the water supply shall be subject to the approval of the Department. Thus, while the Legislature retains complete control, by utilizing the technical services of the Department of Public Health, a studied allocation is obtained.

DESALINIZATION

Other sections of the country and the world are not as fortunate as this section. A widely circulated Associated Press story, for example, quoted a government official as saying the nation may be short as much as $5 billion of gallons of water a day within 20 years. Other stories described possible solutions to this alarming prospect.

The proposed solution drawing most attention is Desalinization. Conversion of sea water, or brackish water into potable water is, of course, already a reality. Brackish water is a term used to differentiate certain inland waters from ocean or sea water. It usually contains salt in a moderate degree as water in a saline soil; hence it is distasteful, nauseous, bitter and salty. It is apt to be found in certain desert areas.

Today the problem is to determine which of the numerous conversion methods is the most efficient and the most economical. Actually the chief obstacle is one of cost. Costs in plants now operating are running from $0.50 to $2.00 per 1,000 gallons. When work was started in this field, about ten years ago, the cost of desalting was about $5.00 per thousand gallons. Rates of the Metropolitan District of Boston are $0.12 per thousand gallons.
The use of nuclear energy in this field is receiving active consideration by the Atomic Energy Commission. In very large quantities, over 100 million gallons per day, some scientists believe the cost could be brought down below $0.35 per thousand gallons.

It is reasonably apparent that work along conventional lines in this region should not be held in abeyance in expectation of more economical desalinization methods.

Frank C. DiLuzio, the new Director of the Office of Saline Water readily acknowledged that desalinization had been oversold, that the desalting of the sea is only a minor part of a great national and international problem, that "we'd be a lot better off utilizing existing fresh water supplies properly," and that some basic scientific breakthroughs are necessary before desalting will generally be an economically attractive way of getting fresh water.

**SUPPLY OF METROPOLITAN BOSTON**

In 1890, there were several cities and towns in the Metropolitan Boston area, whose sources of supply were either inadequate in quantity or of unsatisfactory quality. An Act of Legislature in 1895 established the Metropolitan Water District. The Board created under the Act was given broad powers to construct, maintain and operate a system of water works.

The Water Board acquired the Cochituate and Sudbury water supply reservoirs and pumping stations owned by the City of Boston; Spot Pond Reservoir and Pumping Station, which were the property of the cities of Malden and Medford and the Town of Melrose; also the Mystic Lakes and the pumping station. The Mystic Lakes were abandoned in 1898 as a source of supply because of the unsatisfactory quality of the water.

For a main storage and supply reservoir, the decision was made to go westward to the South Branch of the Nashua River and construct the Wachusett Reservoir - Capacity - 65 Billion Gallons. It was pointed out that a reservoir at Clinton would fit very effectively into the future development of the Ware and Swift Rivers further to the West and the ultimate development of the water system by the taking of additional supplies from contiguous watersheds such as that of the Miller's River.

**Quabbin**

Quabbin Reservoir, the latest extension to the District's supply is located in the valley of the Swift River, a tributary of the mighty Connecticut - the largest river in New England. It was started in 1926 - completed in 1938 and as far as we know it is the largest reservoir in the world constructed solely for municipal water supply.

The reservoir, created by two large earth dams, is 18 miles long and has an area of 39 square miles with a storage volume of 412 billion gallons. Each upper foot holds about 8 billion gallons. It has a shore line of about 150 miles with many rocky and hilly islands. The depth of water at the dam is 150 feet; 8 miles above the dam 90 feet; and the average depth over the entire reservoir is 50 feet.
The Area of the watershed directly tributary to the reservoir is 186 square miles. Storage is provided also for the flood flows from the Ware River with a gross watershed area of 97 additional square miles.

Studies are being made at the present time concerning the diversion of flood waters from the Miller's River to the North.

The construction of Quabbin necessitated the relocation of the boundaries of six towns and three (3) counties and eliminated from corporate existence the Towns of Enfield, Dana, Greenwich and Prescott. About 2,500 people living in 650 houses in the area were required to find other homes in the surrounding towns. Most of these homesteads had been established within these towns for many years and some of them for centuries.

The reservoir derives its name from the Indian word "Quabbin" meaning many waters. There also was an old Indian Chief Quabbin whose tribe was known as the Nip Mucks. They fished and hunted this valley for untold generations before the coming of the first white settlers.

We have been fortunate here in Metropolitan Boston that the topography of the State of Massachusetts is such that we can collect and deliver tremendous quantities of water by the use of gravity, eliminating to a great extent the high cost of treatment and pumping. Water from the western upland storage basins flows more or less downhill through the aqueduct systems to the points of demand near the coast.

Today, some thirty-one (31) communities, with a combined population of nearly 2 million thirsty customers, make up the Metropolitan Water District. Ten (10) other communities satisfy all or part of their water needs from connections with the metropolitan system without being official members of the District.

When additions to the transmission and distribution systems are complete, the District will be the proud possessor of pure supplies with a safe yield of 330 M.G.D. - equivalent to about 40% of the state's presently developed public water supply sources.

The Distribution Section has as its responsibility the operation and maintenance of some 250 miles of large diameter supply pipe lines in addition to the 16 distribution reservoirs and standpipes which supply the local communities with their supply of water. There are twelve (12) pumping stations that serve the higher elevations in the district.

Just a short time ago we were saying that the problem of providing ample sources of water had been solved; but there still remained the complicated problem of distribution within the present Water District. For the past 70 years we have been tackling this problem of distribution - extending the large diameter pipe line system to take care of both old and new members.

The City Tunnel, the latest major artery of the system has been extended 7 miles from Brighton, northerly to Somerville and Malden. The surface connections between the tunnel and the existing pipe line network have been completed and proved to be of great value during the recent dry spell. A new tunnel, a vital link for the future, is being constructed from the Wachusett Reservoir in Clinton to connect with the aqueduct system in Marlboro. Preliminary studies are under way for the construction of another tunnel southerly from Brighton under Brookline to Milton.

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WATER QUALITY STANDARDS

The development of water quality standards has come about almost entirely in the last half century. The Water Division has gone a long way toward the ideal of furnishing a drinking water that is clean, pure and low in color.

Drinking water averages approximately one per cent of a public supply—even if there be included the water drawn to obtain a cool drink and that allowed to flow in rinsing the glass. While the amount involved is about a gallon per day per capita, sanitary standards as well as those of color and clarity are based on what we believe to be either necessary or desirable to secure a proper drinking water. The Water Division of the Metropolitan District Commission maintains 3 laboratories located at Boston, Framingham and Belchertown where Sanitary Engineers and Bacteriologists are continually analyzing samples of water taken from various watershed streams, reservoirs, aqueducts and water supply mains in order that we may be assured that the water furnished consumers complies with all Public Health Standards.

The quality of the water furnished to the Metropolitan District has already been greatly improved by the abandonment of objectionable sources and by the work accomplished for the protection and purification of the supply. The superior quality of the water is owing not only to the dry, gravelly soil and other natural conditions applicable to the sources from which waters flow, but also in a considerable measure to the absence of the polluting influence of a large resident population.

A greater means for the purification of waters for domestic use is afforded by the construction and use of large storage reservoirs. It is an accepted and proven theory that the purity of any water is more than all dependent upon long-term storage. In this respect, the opportunities afforded by the Metropolitan Boston System, not only for the present but for the distant future, are unexcelled by those of any other major water works in the world.

RECREATION AT QUABBIN RESERVOIR

Since 1952, rules and regulations have been adopted relative to the recreational use of the lands and waters at Quabbin Reservoir for fishing and boating. In cooperation with the Water Division, the Department of Natural Resources has carried out an extensive fish stocking program with very successful results. Excellent catches of fish have been reported during the various seasons. The boat mooring areas open on the first day of each fishing season, about April 18, and remain open until October 15, weather permitting. Private boating is allowed. However, Rule 9 states "Only substantial rowboats of a minimum length of twelve feet and of a type considered safe by the Commission representative in charge shall be used. No sailboats or inboard motor boats, canoes, collapsible boats or other similar craft will be permitted in the waters designated." The Commission also has available for rental, 115 boats and 50 outboard motors. Rental is on the basis of first come, first served; there are no reservations. Almost 50,000 people used the areas during the past season. There are several large parking areas, fine picnic facilities and public rest rooms available. There is a fire and observation tower on the summit of Quabbin Hill where there is a truly magnificent view of the reservoir and valley.

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On a clear day the mountains of New Hampshire can be clearly seen. The tower and rest rooms are usually open from April to November.

Quabbin Reservoir now forms a notable geographical feature of central Massachusetts. The new superhighways make it possible to visit Quabbin quite readily in quick driving time from the Metropolitan area. About 85 miles west of Boston, a journey to the large reservoir, with its many miles of shore fishing area plus its boat and renting facilities, its fine picnic areas, affords plenty of room for those who want to get away and visit this peaceful valley. A fast trip to the large reservoir can be made by way of the Massachusetts Turnpike to Exit 8, then Route 32 to the Town of Ware, then Route 9 to Belchertown. For those who like to go fishing or boating, they may take Route 202 on the west side of the reservoir or Route 32 on the easterly side.

WATER RESOURCES PLANNING ACT

I was talking to Malcolm Graf - Director of the Water Resources Commission and he was telling me of a most important piece of legislation that was drafted and passed by the 89th Congress on July 22, 1965 - Public Law 89-80. This Act may be cited as the "Water Resources Planning Act." The statement of policy is - "In order to meet the rapidly expanding demands for water throughout the Nation, it is hereby declared to be the policy of the Congress to encourage the conservation, development and utilization of water and related land resources of the United States on a comprehensive and coordinated basis by the Federal Government, States, localities and private enterprise with the cooperation of all affected Federal agencies, States, local governments, individuals, corporations, business enterprises, and others concerned. Title I establishes a Water Resources Council - Title II creates River Basin Commissions - Title III provides financial assistance to the States for comprehensive planning grant authorizations.

SUMMARY

"In a State where the rainfall is as plentiful as it is in Massachusetts, most water shortages can be prevented by the adoption of a local improvement program or becoming a member of a regional water system. Four steps should be taken to prevent water shortages. Briefly, these include adequate planning by the municipalities, establishing realistic water rates with water revenues being used for improvements and the replacement of worn out equipment; making basic studies of the water resources at the state level; and developing good water management programs throughout the State with integration of the programs with the adjoining New England States."

As the American Water Works Association points out, there is more than enough water to meet all our future demands - providing that we arrange far enough in advance for adequate storage, processing and delivery of the water, where and when it's needed. Our greatest problem is not a shortage of water, but rather the need for intelligent maximum use of all our water resources, and the correction of the present pattern of waste and contamination which dissipates them.

Drought has occurred in Massachusetts before, and presumably can be expected again, perhaps in even greater intensity.

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Expansion: This covers most of the problems we have at the University of Massachusetts including turf. Increased enrollment means more of everything: buildings, utilities, facilities, faculty, staff, and above all and probably most important, students.

The face of the campus is constantly changing and it is here that I feel our fight begins. When a new building is planned, both the plans and specifications must be carefully reviewed to make sure that what we want is spelled out in detail to make certain that is what we get. Limit of work lines are set to fix the bounds of the contract. Within this area any portion of the site that will be under buildings, pavings or is to be subject to grade change must have the loam stripped from it in a suitable manner to conserve this precious natural resource.

Then the grading operations take place to the finished subgrade which is true and parallel to the proposed finish grade. Loam to the specified depth is placed and prepared as a seedbed. Fertilizers, agents, soil conditioners and necessary products are added and worked into the seedbed. Then the specified seed mixture is applied. Depending on site conditions, the use of mulch may be used. Maintenance and guarantee are inserted and may be variables. However, the main concern is that the turf produced fits the requirements as set forth in our specifications for turf. During the entire construction process constant inspection is carried out to ensure a satisfactory product.

This leads to an important question. Exactly what are we looking for in turf and why?

Turf for campus must be capable of taking abuse. Yet, it must always look good. Our major landscape effect is actually that versatile ground cover, turf.

As to the cultural aspect of turf maintenance, it is our belief that we can, by proper methods, produce desirable turf. During the mowing season we strive to mow as high as most of our units will adjust for cut. Our seven-gang unit is set for a three and one-quarter inch mowing height. This we feel gives us several advantages, some of which are:

1. The Amherst area has heavy morning dew which, in combination with tall grass, tends to discourage walking on the turf. Those who do walk on the grass have very wet feet as a reminder.
2. The heavy carpet resulting acts as a wear surface to offset the pedestrian traffic.
3. Increased height helps shade the soil surface, resulting in cooler earth temperatures, less transpiration loss, less chance of chasing the bluegrass into dormancy, less chance of encroachment by warmth-loving crabgrass and better competition against weeds.
4. Less breakdown time to repair equipment damaged by contact with cans and bottles. The units now pass over these objects.
Our fertilizer program is now set up for two applications per year. We have selected a 10-6-4 granular because more companies will bid on 10-6-4 than on 8-6-4, and we desire competitive bidding to gain price advantage. In the spring we apply 15 pounds per 1000 square feet and in the fall 10 pounds per 1000 square feet. Our fertilizers must contain at least 50 percent of the nitrogen from organic sources with not over one-half of the nitrogen water soluble. By doing this we attempt to make our nutrients available over a longer period of time.

As to the species of grasses we are trying to encourage, we desire the bluegrasses, both Kentucky and Merion, and the fescues, both Illahee and Pennlawn.

Last year based on the acreage of turf being maintained with the desired amounts of fertilizer on two hundred and thirty acres, we needed one hundred and forty tons of fertilizer.

Some areas of campus, because of abuse, have large tracts of crabgrass flourishing. To fight this, some of the fertilizer is mixed as a carrier for dacthal and applied, saving a labor operation and secures a control.

For insect-larva or grub control in turf, some of our fertilizer is the carrier for insecticides such as dieldrin, aldrin or heptachlor. There is not much sense in carrying out any turf program that allows grubs to feed away on the grass roots, -roots that provide nutrition to the plant. This is the same as sitting someone at a banquet table, tying their hands behind them and saying "eat and enjoy yourself."

Another factor is pH. I have always preferred to see ground dolomitic limestone applied more often in smaller doses than in huge amounts periodically. During periods of normal rain fall, it is quite possible to apply in alternate years thirty pounds of limestone per 1000 square feet. Testing of the soil should be a must. Too often the tendency is to forget or put off this aspect and turf decline of desirable species is the result.

Broad leaved weed control is a program that will be followed in earnest this spring. In this area dandelion and plantain flourish, trespassing unrestricted from adjoining pastures and fields. Our intent is to apply a spray application of 2,4-D to the campus before the dandelion's flower forms seed. This way we will catch as many plants both young and old as had been growing as of the date of the spray, without the mature plants having set seed. Since this program is new, we will repeat a spray in early fall to catch the many new plants resulting from dormant and translocated seeds. Gradually, the program will concern itself with a single yearly application as necessary to keep the weeds out and the grasses in, thus allowing maximum expansion of desirable turf.

During the entire growing season, we have aerators working, both tractor drawn and self-propelled. Their task is to pull thousands of plugs from the ground. Compaction has been a serious problem and the grass roots have had to struggle to maintain their plants. After aerating, we can see the upswing in plant vigor due to the chance for root development. Another factor of aeration is an important one to us.

Last summer Amherst had what was considered normal total rainfall. However, this rain was delivered to us by three storms which averaged two and
one-half to three inches each. The fingerlike projections into the earth caused by aeration acted as reservoirs to trap the water and allow it to percolate rapidly. The result was that we had little run-off and the water was stored in our soils. The most favorable result of last year's endeavor was that despite the drought, campus turf was spared the brown palor of surrounding areas. Our turf stayed green.

This is extremely desirable because we now operate three semesters a year and students are here all summer. Therefore overall year round aesthetics are important.

On new construction we strive for a minimum turf slope of two per cent to allow ample drainage of the surface especially at this time of the year when grasses are stimulated into activity and such growth, if drainage is poor, only helps drown the plants that are literally floating in water. Water doesn't drain because someone considered that grade was unimportant.

In our review of plans, we stress proper grading and drainage. We don't want water flowing across our side walks, especially for winter ice control. We don't want people cutting corners at walk intersections and tramping out all the turf. Therefore, although it is not a factor of turf, walk design is important to how good our turf looks.

One of the methods used to control traffic on our grass lands is by constructing walks in the areas of sufficient width to carry the numbers using them. This has resulted in walks twenty feet wide which, during class changes, are full to capacity. If a walk is too narrow, people overflow the edges and the walk has worn lanes parallel to its length. At points of walk intersection, unless radius points are installed, the corners have no grass. We therefore call for fifteen foot radii on all corners. This also accommodates the proper turn radius for service vehicles using the walks. Our recommendation is that no walk on campus be less than ten feet wide.

Most of our walks are of bituminous concrete. This material is prone to broken edges, especially if improperly supported, and encroachment by turf. Therefore, we now stipulate the use of steel curb one-quarter inch by five inch wherever bituminous concrete walks abut turf or bed areas. The turf grade is kept one inch lower than the walk which allows water to run off the walk, over the edge, and away, because the grade pitches positively away from the walk. If the grades are kept this way, when snow is plowed off walks, the melting is not across the walks, but is away from them. Also, plows are less apt to plow out turf strips as so often happens now.

The use of the steel curb gives us neat and well delineated walk lines—lines that we can maintain with a minimum of mowing and trimming. Also, the one inch drop along the edge means that this turf along the walks is deeper, has more wearing surface and doesn't get scalped. This helps eliminate the browned-out look usually evident along walk ways.

For areas that are in prominent places, especially court yards, terraces and the like, we find that periodic de-thatching is a great help in maintaining vigor.

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Fall brings on added problems, namely leaves. Leaves and turf are poor mixers. We must remove all leaves from turf before winter sets in, lest they smother out our lawns. Most of this operation is mechanized and the leaves are removed in force and are dispatched to our nursery where they are composted.

Prior to snows I like to see the last mowing done at a low cut. Depending on the type of area the cut varies but should be between one and one-half inches. This prevents matting and the threat of winter problems of fungus, such as snow mold.

Because of the areas involved, it is imperative that our operation be mechanized wherever possible. Therefore for mowing operations we use our new Jacobsen seven gang frontcut reel mower. This is our work horse and takes care of the larger areas. Supplementing this we have a small fleet of Locke reels with sulky riders. For the rougher areas we have small rider tractors equipped with rotary or flail mowers. We also have for our large tractor units three-point hitch rotary units as well as sickle-bars. Following the Lockes we have an army of trimmers for which we use Bunton's. As expansion continues, we increase acreage and the need for more units.

For fertilizing we now rely on a large Lely rotary-broadcast spreader mounted on its own dolly so any rig can pull it. For lesser areas we use the smaller canister rotary-broadcast units that have become increasingly popular of late. We prefer broadcast application of fertilizers because of the even distribution, less chance for human error causing burned areas, and if areas are missed, they appear as faded areas rather than as distinct misses.

For aeration we use a tractor drawn spoon aerator for the large areas and a smaller self-propelled unit for inaccessible areas.

For weed control we have a trailer mounted spray unit with high-low pressure control with swing out booms that allow a swath over twenty feet wide. This does large tracts beautifully. For confined areas we will rely on a small unit using a wheel impeller power source for spray pressure.

For leaf control and sweepings we have a tractor drawn unit that will hold five cubic yards of picked up substance. It is quite versatile and beer cans and bottles fall easy prey to its fingers. Another advantage is its easy dumping process for fast unloading. For smaller areas we have power driven lawn sweeper units.

For de-thatching we have a heavy self-propelled unit that has proven highly satisfactory both from efficiency and effectiveness.

Our operations cover the entire campus with all its aspects, so, the equipment listed is just that portion whose major task is maintaining our turf. We attempt to be a flexible unit, therefore a given piece of equipment might on occasion find itself in strange company.

Because of the tremendous human population on campus we must at times take measures to keep people off of the turf. Short cuts, many of which prove to be longer distances than the walkways, are discouraged by plantings at key points which act as obstacles to such trespassings. It is sometimes
amazing to see what determination is shown by individuals who insist on forging new pathways across campus. Some cry out, why don't you put walks where we walk? Observation has shown that if we paved where people walk, the entire campus would be paved. Granted, more and better walks are needed. In the meantime, and even after, we intend to maintain our turf in a manner that it will withstand all onslaughts against it. Today we have over twelve thousand students, by 1975 we can expect double that number.

Our program is new. Its infancy was last year. This will be the first year it will hit full swing. To ensure that everything is done the way we prescribe, we intend to put tight controls on manpower and supervision. On a campus this large, it is very easy to miss an area or to double treat an area. To help in this regard, we will post in our shops small maps of campus. These maps will be made up from masters as blue line prints. At the end of each day, a man's foreman will mark the map covering the operation. Each type of operation will have its own map which will be color-coded. The portion of campus completed that day will be shaded in with the proper colored pencil and the date will be marked within the shading with the operators initials. Then when a supervisor checks the maps, he can tell at a glance what areas have received what treatments, and when and by whom they were applied. This will also be valuable in determining effectiveness of application as to timing and weather.

It was not so long ago that the area around the pond was mowed twice a year for hay. It is now maintained turf. Our turf varies greatly as to its use. We have areas of prime turf. These are the intensive care areas usually associated with main campus. Secondary turf would be areas such as turfed parking areas at the stadium. These areas can be rough cut most of the time except when actual usage of the area is necessary. Lastly, rough turf includes drainage swales in areas such as the stadium, outlying and margin areas and certain orchard and minimum use areas. These areas never usually service people. They have varying functions and must be maintained for drainage, fire protection, site preservation and general appearance. Each type area has a diversity of use as well as diversity as to degree of maintenance required.

Construction on campus is starting to develop at a tremendous rate. Fine buildings by famous architects are being planned. Landscape effects will be created to embellish all these projects. However, the thing that will act as the tie-in between all these elements, whether they be boulevards, malls, twenty-two story dormitories, a twenty-eight story library, a fine arts center almost seven hundred feet long, any one of the many new structures we will have, that thing is turf. It will be our job to make sure that this turf fills the need and the requirements as set forth. As the numbers increase, more eyes will be watching, commenting, criticizing and we hope praising our endeavors.

The function of turf on campus will increase its need to making the whole picture fit together. We hope this picture will be a good one, not only to the untrained eye, but also to the professional. It is our desire that it be said that not only is fine turf taught at the University, but that the University practices what it preaches.
ATHLETIC FIELD MANAGEMENT

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Management of any athletic field or fields complex must start where the field started .... the beginning. In this case the proper specifications must be established on paper. By proper, I mean they must be clear, complete and cover soil preparation and seeding in entirety so there will be no doubts in the mind of the contractor, clerk of the works or other interested parties. This will also provide a definite and uniform basis on which bids can be submitted.

Specifications will vary widely with individual jobs for as we all know, each seeding, soil type present, facility, location, drainage situation and other related factors vary with each job. Certain things will, however, be common to all. These include a preliminary statement as to what is to be done, areas involved, materials to be used, rates and methods of application. A blank specification can be found in the publication Athletic Fields (design, specifications, construction and maintenance) from Penn. State University, College of Agriculture Ext. Service, University Park, Pennsylvania.

Also at the time the field is built, water problems and supply should be considered. In this category falls proper drainage both surface and internal. Surface water drainage problems can be virtually eliminated to start with on baseball and football fields if proper grading is accomplished. Internal drainage is more expensive initially but well worth the outlay of tile lines installed at necessary locations on the field. In the case of football fields, these lines will be parallel to the sidelines, baseball fields need it placed outside the skin portion of the infield (on the outfield grass) and down each foul line and outside the circle marking the homeplate area. They will dump into a catch basin.

Once conditions to promote drainage have been established, a method of applying water during periods of drought should be considered. Irrigation systems can be elaborate with underground plumbing carrying water to pop up heads, of if funds are limited (and they usually are), a temporary system can be fabricated with plastic pipe and heads or as traveling sprinklers on hose lines. The only requirement of a good system is that it distribute enough water to meet maximum turf needs. The amount of water needed on a turf during droughty conditions is about 2 acre inches per week.

The layout of the athletic field should be so the long or main axis of the field runs north-south. This helps prevent sun problems that bother the players.

General soil preparation should be considered too, for a short time ago, last year in fact, I was called on to recommend weed control materials to combat knotweed on a football field. In finding out past history of the construction of the field and actually what type of sub-surface material existed, the weed problem became quite clear. Beneath the loam 6-8 inches deep that was carefully brought in, spread, fertilized, seeded and all other necessary steps carried out to establish a turf, lay a rock ledge which allowed
no sub-surface drainage and formed the other side of the squeezing action
the surface soil was subjected to by the ever present cleats and heavy
traffic. Of course, the soil would be compacted and no amount of manage-
ment using any or all machines at the maintenance departments disposal is
going to solve the problem.

Maybe I have dwelled too long on the initial phases of planning and
building a facility but to me, careful planning and good common sense at
this stage can save many woes and make a good manager of that piece of
turf at a later date when a grass cover has been established.

I would point out that having a good set of specifications set forth
is not going to guarantee a top quality playing field. The kind and quality
of materials and the manner in which the work is done as to how and when
they are applied are just as important. This phase also requires the
manager to follow the work being done to be sure it is being carried out
properly and in accord with the specifications.

Let's assume the site has been prepared and the rough and finish grading
has been accomplished and the seedbed has been prepared using lime and
fertilizer based on soil tests, seeding has been accomplished with moisture
being carefully controlled during the seed germination period and first
mowing has been accomplished. It is at this point that you as the manager
of this expanse of turf takes over and are totally responsible for the
condition thereafter.

It is up to you to establish general requirements and make the turf
live up to them. First and foremost is a maintenance program whose essential
goals are:

1. Produce tough grass with a maximum wear resistance.
2. Keep it thick to prevent weed and undesirable grass invasion.
3. Deep root systems promoted to provide firm anchorage for the
glass and firm footing for the players.
4. Adjust mowing height to meet grass and playing demands.
5. Apply food and irrigation so as to provide steady growth and
    high quality.
6. Schedule field use in line with endurance limits of the grass.
7. Injury and wear spots should be taken care of immediately.

After digesting this set of requirements which is not difficult to state but
certainly not easy to live up to or implement, these operations are the primary
ones you will end up doing to meet the general requirements I have just
mentioned.

First, mowing which can be accomplished with many different machines.
The time to mow a field will vary with the machines cutting width in use.
If a 24 inch machine is used, it will take approximately 2 1/2 hours at 2 1/2
miles per hour rate to cut a football field turf. Use of a sharp reel type
mower on fine turf is most desirable with a cutting height of 1 1/2 -2 inches
maintained and cutting about 3/4 inches of grass off the top during each
mowing. In other words when grass height reaches 2 1/2 - 3 inches it's
time to cut.
Next .... Watering: Normally, and that doesn't mean the last 2 years, in any week the weather bureau indicates 2 inches of rainfall have occurred you can be fairly sure your fields are receiving enough water. To check on this a moisture probe can be purchased to check how far the water has penetrated into the top 6 inches of soil. If it has moistened this portion then no more need be applied that week. If not, irrigation must be accomplished. First, apply only as much as the ground will absorb. Any more than this is wasted. To check on how much you are putting on the surface of an area over a given time, the use of straight sided cans placed under the falling moisture and easily measured once the time has elapsed. Best time to apply water is early in the morning because there is no evaporation loss then as there would be during the sunlit hours and it is less of a peak period on city water supplies too!

The next operation to be discussed that of aeration can be a valuable tool to the athletic field manager because one of his biggest problems is compaction. This compaction problem is one common to all athletic fields from the little league fields to the varsity play fields of high schools and colleges. Compaction is the pressing of soil particles tight enough together so no air, water, grass roots or nutrient can penetrate and grass either fails to grow or grows sparsely. This condition is aggravated most during the seasons of the year when the soil is saturated with water. The same condition can be brought on at that time by heavy equipment used to mow, roll or otherwise treat this piece of turf. Fortunately many tools have been devised to break through this compacted soil mechanically and remove a core or tube of soil to permit vertical drainage. I would recommend against the use of these tooth disc mounted aerators or other types that do not remove some type of plug as a method, because I feel it does no good and may possibly increase compaction. When this piece of metal plunges into the soil, there is nowhere for the soil to go except into other soil. The net result is a few holes in the turf but compacted soil surrounding these holes. The core removing type has either hollow tines or spoons and usually penetrates the soil to a 3 inch depth. The diameter of the holes in athletic field turf should be 3/4 - 1 inch in diameter and should cause no problem with cleats catching and injury resulting. Fields should be aerated systematically in spring and again in the fall after the season closes. When these aeration operations are done, this is an ideal time to apply limestone and fertilizer if in spring so they will be introduced to a portion of the sub-surface area of the soil as well as the top. The two times are only a minimum recommendation, for a turf manager should check at least once a month if the field is in constant use for soil compaction indications. Sparseness of growth and influx of knotweed can be danger signs.

When the operation of aeration is accomplished, the machine should be run not once, or twice, but 3 times, once crossways, once lengthwise, and once diagonally. The cores should be screened to put back some topsoil in a loosened condition with the remainder of particles that do not break up being raked off.

Grass grows best at a pH of 6.0 so this reading is the one you should maintain. It is not difficult once it is established and soil tests should be made every 3rd year as a check. When the pH has dropped off some, ground limestone should be applied and this is done in late fall following
aeration. Actually the limestone can be applied anytime as it does not react with fertilizer as hydrated lime can. Another asset limestone has, is it's cheap! You can even spread it in the winter on frozen turf if you didn't get it on in time in the fall.

Fertilizer applications can usually be made in the spring of the year or in early fall (Sept. 1st.). To cut down repetitive smaller applications I think your best bet is to choose a fertilizer designed specifically for turf such as 10-6-4, 8-6-2, 20-10,5, etc., where 50% or more of the total nitrogen is in slowly available form and apply only twice a year, at a rate of 2 pounds nitrogen (actual) per 1,000 square feet each time. This figures to be 800 pounds per acre of 10-6-4; 1,000 pounds per acre 8-6-2 or 400 pounds per acre of 20-10-5. If inorganic quickly available short lasting materials such as 5-10-5, 5-10-10, etc. are used, lesser but more repeated applications are needed with irrigation used to prevent burning.

If the turf is composed of predominantly Merion Kentucky Bluegrass, a strong growing strain, you will have to increase the total nitrogen applied from 4 pounds per 1,000 square feet (actual) to 6 pounds per 1,000 square feet (actual) per year.

I should say a word or two about grass species to be used on athletic fields.

1. On game fields where traffic will not be as heavy as practice fields:
a mix of 50% Merion Kentucky Bluegrass and 50% Fine-leaved fescue - Pennlawn, creeping red or 100% pure Merion Kentucky Bluegrass. The mix at 4 pounds per 1,000 square feet; the pure at 3 pounds per 1,000 square feet.

2. On practice fields that are torn up virtually every year and have to be reseeded:
100% Kentucky 31 Fescue or even perennial ryegrass can be used. The coarse leaved fescue is drought resistant and takes quite a bit of abuse but is not considered a good looking turf for spectator or for game fields.

Diseases and insects may be a problem but there is no recommended yearly maintenance program to prevent them. If you think you have troubles, get in touch with your county agent and he can recommend a specific control. Make sure you know what you are treating before you go out and buy the chemical.

Weeds can be controlled with today's chemicals but, as I mentioned before, good cultural practices and attention to construction details can prevent most of them. Again, for a specific weed problem, your county agent can help you identify the weed. If it is a broad leaved one, such as dandelion or plantain, you know what to do, apply 2,4-D or one of the combinations. If it is crabgrass, one of the pre-emergence controls in the spring will handle it.

I cannot over emphasize this point. Use discipline in regulating traffic on your turf as much as possible. You and I both know that even the best turf cannot stand constant traffic without injury. This point must be stressed to athletic directors, superintendents, recreation commissions and others in authority, who can back up your regulations. Tell them if the turf is injured,
it is going to cost money and more important, time, to repair damage.

1. Be sure minimum use of fields is scheduled for wet season.

2. Rotate areas for play as much as possible. If your town does not have these alternate fields now, they either must get them or pay a fancy repair bill for the present fields or forget about having decent athletic fields on which to play.

3. Keep the band off for practice marching unless absolutely necessary. Sunday morning golfers should be chased also and the local police can be alerted about this problem.

4. Do not allow use of new seedings until a mature turf has developed.

5. Keep off the field until completely thawed out and the grass has come out of winter dormancy and started to grow.

You may say these rules cannot be followed. I firmly believe unless you do follow them, you will have no turf to manage.

There are two ways to repair turf. Seeding which takes a 4-6 month growing program to mature, and Sodding. This sodding method, although more expensive, is the answer to maintaining an adequate turf grass cover on heavily and continuously used fields. It is most expensive when purchased from a commercial sod nursery at 20-30¢ per ft. or less if purchased in quantity. The other possible source may be in your own back yard. Recently I was at a football field site that was under heavy use and the park commissioner and his crew were unable to maintain a grass cover by the seeding method. They couldn't afford to buy 15,000 square feet of turf. They mentioned having turf on a playground that could be used. It is hoped they will move it this spring. It takes only 4-6 weeks to knit to the point it can be walked on and in 4-5 months it will take heavy play. I will estimate a sod nursery of 5,000 - 6,000 square feet will maintain a football field, or other play field once a good turf is established.

In summing up, good management will prevent costly repairs, maintain playable turf and in time reduce overall maintenance costs. You will enjoy life more too!