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TURF BULLETIN

MASSACHUSETTS TURF AND LAWN GRASS COUNCIL INCORPORATED

WINTER 1970

BETTER TURF THROUGH RESEARCH AND EDUCATION

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The Massachusetts Turf and Lawn Grass Council Incorporated is chartered under the laws of the Commonwealth of Massachusetts as a non-profit corporation. The turf council seeks to foster "Better turf through research and education."

More detailed information on the subjects discussed here can be found in bulletins and circulars or may be had through correspondence with the editor.

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—Reprint from USGA Green Section Record, Sept., 1966

A view of a fairway sprinkler in operation.

A Closer Look at Watering

by Holman M. Griffin, Agronomist

The objective of watering turf is to maintain sufficient moisture in the soil for satisfactory growth and performance of the grass. In order to do this we must periodically replenish the moisture lost to drainage, plant use and evaporation, and maintain moisture in the full depth of the effective rooting of the grass. The big question to be answered before we can effectively cope with watering turf is:

"How much water does the turf need?"

If you can even come close to answering this question, then you truly have a green thumb as well as a keen grasp of turf problems. I hope that this review of some of the factors involved in the watering of turf will help your maintenance program and stimulate your thinking to aid you in making your decision of how much water the turf needs.

Just how water is absorbed and used by the plant is a science in itself and not all of the processes are clearly understood. However, we should be aware of the factors that influence these processes.

Water in a plant has many functions and composes 80 to 90 percent of the plant structure, so we must rightfully place great importance on the maintenance of adequate moisture for plant use.

Although this is true for all grasses, all grasses do not necessarily require the same amount of water. Considering only water requirements, we can group the grasses into three general categories: (1) Drought-tolerant, (2) Intermediate drought tolerance, and (3) Moisture-loving, with little or no drought tolerance. The more deep-rooted grasses such as Bermuda fall into the drought-tolerant class because their extensive root system is able to forage deeply for moisture. Fescue also falls into the drought-tolerant class because of its ability to curl its leaves and thereby reduce water loss from the stoma. Buffalo and bluegrass have rhizomes where some moisture is stored, which gives them moderate to good drought tolerance.

Most bluegrasses fall into the intermediate class while annual bluegrass, rough bluegrass, and creeping bent fall into the moisture-loving class because of shallow rooting or the inability to store or conserve absorbed moisture. Even though we understand these differences in drought tolerance of the grass, we must also consider such factors as soils, temperature, humidity, wind, and fertilization.

Soils greatly affect the watering program by their different capacities for moisture retention. Soils are classed roughly as clays, loams, and sands. This is the order of their ability to retain moisture. The permanent wilting percentage, or that point at which moisture is held by the soil with a force of approximately 15 atmospheres, is reached much sooner after an application of water to a sand than to a clay. Loam ranks between them.

The permanent wilting percentage of a soil is mentioned because this represents the maximum point of moisture stress to which the turf should be subjected. At this point, a plant will regain turgidity in most of its leaves when sufficient moisture is applied to the soil. Turf can survive and even absorb limited amounts of water at soil-water contents below the permanent wilting percentage. But if no water is added to the soil the turf will pass through the wilting range and quickly reach the ultimate wilting point. Then it dies.

Again considering the soils, the

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wilting range—from first signs of wilt to the ultimate wilting point—is narrower in coarse-textured soils than in fine-textured soils. Within this range, no plant growth occurs.

It might seem that since we should never allow the soil moisture content to reach the permanent wilting percentage that the answer to watering problems is to apply large amounts of moisture, or apply water frequently. However, this is not the case. Frequent or heavy applications of water exclude oxygen from the soil and thereby influence the rate at which moisture is absorbed by the plant. If drainage is excellent, some of the water loving types of grass, such as *Poa annua* and creeping bent, may survive on the oxygen in fresh water.

However, if drainage is poor and the water in which the oxygen has been depleted is unable to move down out of the root range to allow room for fresh water, oxygen soon becomes a limiting factor and the turf wilts.

In general though, water fills the available pore spaces in a soil and excludes oxygen in quantities sufficient for proper root functions. If insufficient oxygen is present in the root zone, this in itself causes the root cells to become less permeable to water and the moisture intake is greatly reduced. Thereby a plant may suffer from a lack of moisture even though the soil around it is saturated.

Since plants seem to absorb moisture best at or near field capacity, this is the level which we should strive to maintain. However, since water does not quickly reach equilibrium in most soils throughout even a 4-inch root zone, we are unable to maintain this level by simply watering frequently to replace the lost moisture. In the interest of good soil aeration, we should allow the soil moisture content to drop almost to the wilting range before more water is added and then the entire root zone should be recharged with fresh water. In this way the plants will always have adequate moisture and oxygen for proper growth while frequent watering would tend to exclude oxygen near the surface before the soil moisture could reach equilibrium in the root zone.

It is therefore important to observe the turf and note how long it takes the turf to begin wilting after a good watering. After observing the turf for a time and using a soil probe to check penetration and moisture depth, we well be because the rate of transpiration of the plant is exceeding the rate of water absorption. Cloud cover, temperature, humidity and wind all have an effect on transpiration of the grass plant. As a rule, lack of cloud cover, increased temperature, low humidity and wind movement all increase transpiration of the plant as well as evaporation of water from the soil. Therefore, we must consider the influence of these factors and make adjustments for them in our watering program.

Temperature is probably the climatic factor of greatest concern, since either extreme may cause a deficiency of moisture in the plant system. At high temperatures, the rate of water loss from the plant is increased and the supply in the soil must be adequate or the plant will wilt. Quite often, golf course superintendents syringe greens in hot weather to keep them from wilting. It should be emphasized that the purpose of syringing is not to add moisture (except when extremely shallow rooting exists) but, rather, to reduce the temperature of the grass and surrounding microclimate with as little water as possible.

On the other hand, a reduction in temperature slows down transpiration and less water loss occurs from the plant. Also the viscosity of the soil water is increased and the permeability of the absorbing cells is decreased, making it more difficult for the plant to obtain the moisture it needs from the soil. When the soil is frozen, virtually no water passes from the soil into the plant.

We can now see that climate has a definite influence on the watering program and that any factor or combination of factors mentioned may change the water use of the plant.

Last, we should consider fertiliza- can work out a pattern of watering which will supply the proper amount of moisture in the manner described previously. Although general rules about turf water requirements, such as one inch per week, are a good starting point for estimating quantities, the actual application should be more accurately determined.

Water should never be applied faster than the soil can absorb it. Otherwise we may lose a high percentage of the moisture applied through runoff and get very little penetration into the root zone of the turf.

After working out a good pattern of watering based on the characteristics of the soil we must then consider other factors, such as climate and fertilization. These will change the turf requirement.

With so many factors involved and interacting on each other, it is clear that water applications can never be reduced to a simple schedule. It must be based on the changeable needs of the grass plant to be effective.

We have often observed wilting of a green on a clear, hot, dry, or windy day. This may occur because moisture content of the soil is low. Or it may tion. Fertilization temporarily increases the need for water because of the action of osmotic pressures on the plant when the soil solution becomes more concentrated with solutes. Since osmotic pressures seek to equalize the concentration of solutions on both sides of a semi-permeable membrane, which is in this case the cell walls of the roots, and the movement of water is from the lower concentration to the higher one, then the addition of fertilizer may initially decrease the plant's absorption of water. It does this by increasing the concentration of solutes in the soil solution to a point greater than the concentration of solutes in the plant fluids or cell sap.

Provided the rate of fertilizer application is not too high, the plant usually adjusts to this situation very quickly and no permanent detrimental effects take place. Because of the process just explained, we should always water-in applications of fertilizer to help make it available to the plant as well as to make sure the soil solution does not become too concentrated.

Although I have just explained how fertilizer increases the need for water in plants, this effect is temporary. In the long run, proper fertilization will greatly aid the plant in its use of water. Experimental work has proven that plants which are properly supplied with nutrients actually require less water for growth and development. The mistaken belief that water can be substituted for fertilizer is altogether too common.

I have touched on the subject of watering and water use only lightly, but I hope that these facts will help to stimulate ideas, give a better idea of the principals involved and help someone to better answer the question: "How much water does the turf need?"

—*Reprint from The Sulphur Institute Journal, Summer, 1970*

SULPHUR
in Turfgrass Fertilization

J. D. BEATON

■ ADEQUATE SOIL FERTILITY is of great importance in the growth of turfgrass. Although the primary nutrients N, P and K have received most of the attention in turfgrass fertilization, lack of any one of the essential plant nutrients (N, P, K, Ca, Mg, S, Cl, Co, Cu, Fe, Mn, Mo and Zn) will result in unsatisfactory growth. Sulphur is an essential constituent of proteins, and an inadequate supply of this element will seriously retard the growth of all plants, including turfgrass.

Dr. J. D. Beaton is Director of Agricultural Research, The Sulphur Institute. This article is based on a paper delivered at the Eighth British Columbia Turfgrass Conference, Victoria, B.C., April 23-25, 1970.

Crop plants differ in their requirements for sulphur (4). Forage grasses, small grains and corn require much less sulphur than most other crops. Sulphur concentrations of about 0.2% appear to be adequate for forage grasses such as orchardgrass (3, 8, 20) and similiar levels are expected in turfgrass. Levels of S in three common turfgrasses grown in sand cultures are shown in Table 1. Concentrations between 0.04 and 0.08% were found in deficient plants while turfgrass receiving adequate nutrition contained from 0.12 to 0.19% (22).

Table 1 also shows that the sulphur requirement of each turfgrass is similar to its phosphorus and magnesium requirements. Similarities between sulphur and phosphorus levels are common in many agricultural crops (4, 20). The average nutrient concentrations in samples of Merion bluegrass taken near Madison, Wisconsin (27) are shown in Table 2. The similarity of P, Mg and S levels is evident.

Table 1
NUTRIENT CONTENT OF TURFGRASSES GROWN IN SAND CULTURES

	% Nutrient in Leaves					
Treatment	**N**	**P**	**K**	**Ca**	**Mg**	**S**
Seaside Bentgrass						
Complete	0.75	0.13	1.25	0.77	0.18	0.19
Deficient	0.40	0.06	0.31	0.27	0.08	0.08
Merion Bluegrass						
Complete	0.65	0.10	1.05	0.82	0.18	0.15
Deficient	0.38	0.04	0.19	0.05	0.05	0.06
Pennlawn Fescue						
Complete	0.78	0.09	1.23	0.65	0.14	0.12
Deficient	0.35	0.04	0.25	0.19	0.05	0.04

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Table 2 AVERAGE NUTRIENT CONTENT OF MERION BLUEGRASS SAMPLES COLLECTED NEAR MADISON, WISCONSIN					
%					
N	P	K	Ca	Mg	S
3.29	0.51	2.41	0.49	0.32	0.45

N:S relationships

Nitrogen and sulphur requirements are closely linked because both are required for protein synthesis. Plant protein contains about 17% nitrogen and 1% sulphur. The need for sulphur fertilization of agricultural crops often depends upon the supply of nitrogen and other nutrients. Fertilization at high rates, particularly with nitrogen, will greatly increase the need for sulphur and may induce a serious sulphur deficiency unless this nutrient is included in the fertilizer program.

Figure 1 demonstrates the close association between nitrogen and sulphur (25). It is apparent from this figure that sulphur deficiency restricted the crop response to nitrogen fertilization. Other studies (29) have shown that the magnitude of response to sulphur applications increased with the amount of nitrogen applied.

Diagnosis of sulphur deficiency

Visual symptoms may be used to detect sulphur deficiency. However, there are limitations in the usefulness of this approach because the signs of inadequate sulphur in turfgrass closely resemble nitrogen and potassium deficiency symptoms (22).

The initial symptoms of sulphur deficiency in Seaside bentgrass and Pennlawn fescue are a general paling of the leaves followed by the leaf blades taking on a pale yellow-green cast. Accompanying this is a faint scorching at the blade tip which advances toward the leaf base in a thin line along each margin. Gradually the border enlarges until finally the entire blade becomes fired and withered. In Merion bluegrass a chlorotic condition develops between the veins. The veins, especially the midvein, remain green giving the leaf a pale striped appearance (22). Eventually, all veins lose their color and the entire blade fires.

Hawkes (17) reported that sulphur deficiency in turfgrass shows up on the young growth as an interveinal chlorosis with the yellow color quite intense. The general appearance is somewhat between nitrogen and iron deficiency. In mild cases it is hard to distinguish from nitrogen deficiency.

Plant analysis can also be used for the identification of sulphur deficiencies. Because of the difficulty in distinguishing between nitrogen, potassium, sulphur and iron deficiency symptoms it may be necessary to test for several of this group of nutrients.

Effects on turfgrass growth and quality

Information on the influence of sulphur on turfgrass is limited. However, the available evidence definitely indicates that sulphur is beneficial and that it has an important role in turfgrass management.

Studies conducted at Puyallup, Washington, have shown that sulphur is beneficial for cool season turfgrass (9, 11, 12, 13). Growth, color and density of turfgrass were enhanced by split applications of 50 to 150

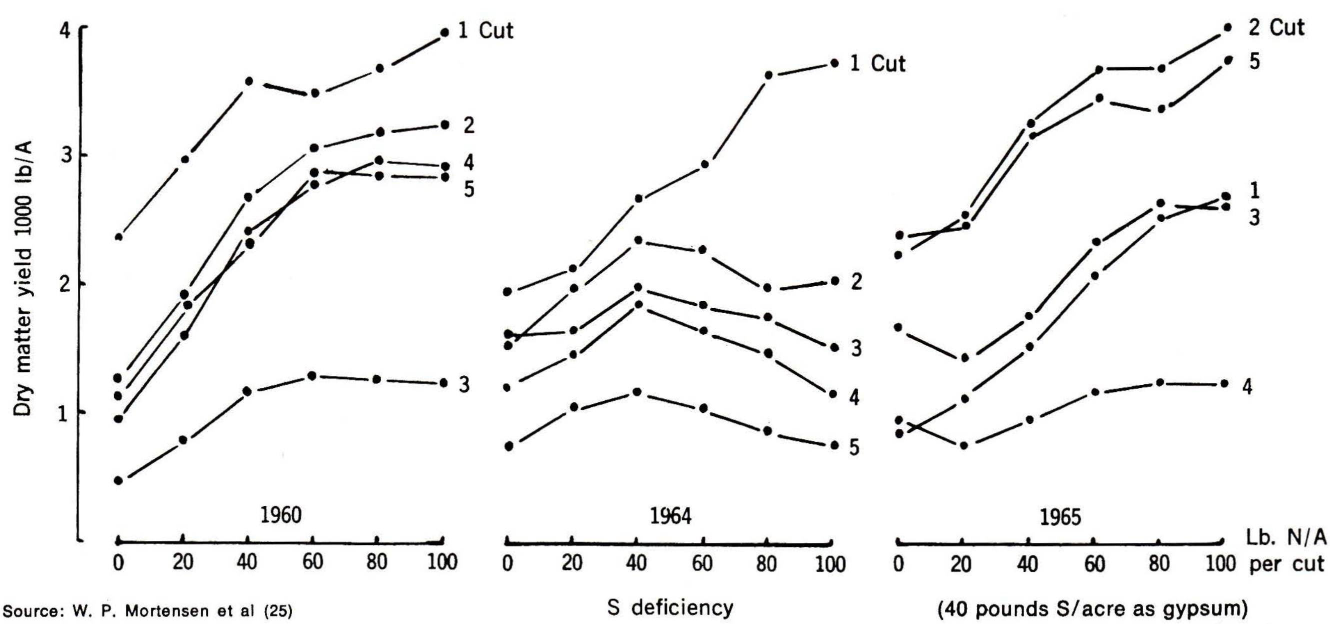

Fig. 1. The effect of sulphur on response of orchardgrass to nitrogen fertilization (25)

pounds of sulphur per acre per year (11, 12). The response to sulphur increased with the rate of nitrogen applied (9). The deeper green color resulting from the use of sulphur was most striking on plots receiving 20 pounds of nitrogen per 1000 square feet per season (12). A signficant response in color also occurred from dressings of sulphur on plots receiving 12 pounds of nitrogen. Only slight color improvement was obtained from sulphur used in combination with 6 pounds of nitrogen per 1000 square feet.

Growth of turfgrass on phosphorus deficient soil appeared to be improved by application of sulphur (12, 13).

In some springs, particularly under wet, cool conditions, turfgrasses in western Washington develop an unsightly yellow mottled appearance (13). Although this undesirable condition usually disappears as the season progresses, sulphur fertilization tended to reduce or eliminate the mottling.

Comparisons at the University of British Columbia on the effectiveness of urea, ammonium nitrate and ammonium sulphate, applied at rates equivalent to 200 pounds of N/acre, suggested that sulphur was beneficial for fescue, bentgrass and bluegrass (32). Ammonium sulphate dressings increased turf density, deepened the color of turf and lengthened the duration of response.

Growth of warm season turfgrasses in Florida has also been improved considerably by including sulphur in the fertilizer program (18, 19).

Disease control

Fusarium patch is the most serious disease problem in turfgrass in the State of Washington (13). Applications of 50 to 150 pounds of elemental sulphur per acre reduced the incidence of this disease by about 86% (12, 13).

Onset of *Fusarium* patch in turfgrasses is enhanced by soil pH's above 5.0 to 5.5 (31). Perhaps the beneficial effects of sulphur noted above are related to soil pH since severity of this disease was reduced by acid-forming fertilizers such as ammonium sulphate and ammonium phosphate (9, 31). However, sulphur fertilization is known to impart disease resistance to crops (6, 7). In addition, sulphur and its compounds possess fungicidal properties (6).

Ophiobolus patch, another major turfgrass disease in the Pacific Northwest, was reported by Gould (16) in 1966 to be best controlled with chlordane and ammonium sulphate. Ammonium sulphate alone reduced the disease markedly (15). Significant reductions in this disease also resulted from applications of elemental sulphur (9, 12, 13).

One of the characteristics of sulphur deficiency in Merion bluegrass is enhanced susceptibility to powdery mildew (22).

Sulphate-containing fertilizers reduced the incidence of dollarspot fungus in warm season grasses in Florida (19).

Composition of turf

Annual bluegrass (*Poa annua*) is the predominant grass on most greens in the Pacific Northwest, although only bentgrass (*Agrostis spp.*) was originally planted (14). Annual bluegrass is also a major component of other types of turf in this region. Generally, turf will remain relatively free of this undersirable grass species for only a few years (13). *Poa annua* and other undesirable weeds tend to infest turf that has been weakened or destroyed by parasitic microorganisms such as the *Fusarium* and *Ophiobolus* fungi. Once annual bluegrass has invaded turf, the tendency toward complete domination accelerates in proportion to the number of plants (13).

Goss (12, 13) observed that applications of wettable sulphur at rates equivalent to between 50 and 150 pounds per acre prevented the infestation of bentgrass turf by annual bluegrass. It is not known if sulphur directly inhibits the growth of annual bluegrass or if the preventive effects are related to the control of parasitic fungi and perhaps other unidentified factors which make the turfgrass more susceptible to encroachment.

Occurrence of blue-green algae in turfgrass, usually considered undesirable, was significantly reduced by levels of 50 to 150 pounds of elemental sulphur per acre (12).

One of the important functions of sulphur in some plant species is to impart winter hardiness (21, 26), particularly in legume forage crops (5, 7). This favorable side effect of adequate sulphur nutrition may perhaps be equally important for turfgrasses.

Undesirable effects

The increased vigor of turfgrass receiving sulphur in combination with adequate levels of nitrogen resulted in 33% more clippings than when nitrogen only was used (12). Although faster growth may not be a desirable characteristic in some cases because of the need for more frequent mowing, it is nevertheless an obvious measure of plant vigor and health. Due to the faster growth rate and greater vigor of turf fertilized with sulphur, puffing and scalping were problems on some plots during periods of high heat stress (12).

Nutrient needs of turfgrass

Acceptable lawn turf is produced in the State of Washington with a fertilizer treatment of 8 pounds N, 4 pounds P_2O_5 and 4 pounds K_2O per 1000 square feet/season (9). On putting turf, the superior fertilizer program has consisted of 12 pounds N, 4 pounds P_2O_5 and 8 pounds K_2O per 1000 square feet/season (9, 10). However, the results discussed earlier in this paper suggest that sulphur will also improve the growth of these turfgrasses.

Because of the close relationship between nitrogen and sulphur in plant nutrition, the fertilizer sulphur requirements can be determined on the basis of the

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Table 3

NUTRIENTS REMOVED BY MERION KENTUCKY BLUEGRASS UNDER TWO LEVELS OF NITROGEN FERTILIZATION

Applied Nitrogen Pounds N/1000 square feet	Nutrients Removed—Pounds/1000 Square Feet/Season					
	N	P	K	Ca	Mg	S
2.5	3.5	0.57	2.8	0.51	0.31	0.46
5.0	4.7	0.76	3.5	0.64	0.43	0.61

amount of nitrogen fertilizer applied. If a ratio of 1 pound of sulphur for every 5 pounds of nitrogen is used, as is often done for agricultural crops grown on sulphur deficient soils (28), the amount of sulphur to be included in the above fertilizer programs would be 1.6 and 2.4 pounds for lawn and putting turf, respectively.

The amount of fertilizer sulphur required can also be estimated by equating the phosphorus (P) and sulphur requirements. In the above example, 4 pounds P_2O_5 would then indicate that 1.7 pounds S should be applied.

The sulphur requirements estimated by these two methods are reasonably similar to the 3.45 pounds of sulphur being recommended by Goss (13) for putting turf fertilized with 12 pounds of N, 4 pounds of P_2O_5 and 8 pounds of K_2O per 1000 square feet/season.

The reliability of determining sulphur needs by these procedures is supported by the figures for nutrient removal by Merion bluegrass as shown in Table 3 (23, 27).

A new lawn fertilizer formulated especially for alkaline soil conditions in Colorado contains 17% N, 4% Fe and 21% S (1). N:S ratios of approximately 1:1 may also be desirable for turfgrass grown on high pH soils of interior British Columbia.

Supplying sulphur

The most common dry sulphur-containing fertilizers are ammonium sulphate (21-0-0-24S), ammonium phosphate-sulphate (16-20-0-14S), normal superphosphate (0-20-0-12S), potassium sulphate (0-0-53-18S), potassium-magnesium sulphate (0-0-22-22S), elemental sulphur and gypsum (20% S). Some turf soil fertility specialists are recommending potassium sulphate or potassium-magnesium sulphate as potassium sources because of both the sulphur content and the absence of troublesome quantities of chloride (22).

A number of new sulphur-containing fertilizers have been developed recently, or are in the process of being developed. Most of these are based on adding elemental sulphur to high analysis materials like ammonium phosphates, triple superphosphate and urea. The development of a sulphur-coated urea by TVA (24, 30) is of particular interest in turfgrass management, since this material provides both controlled nitrogen release and plant nutrient sulphur.

Fluid fertilizers

The application of fertilizers through sprinkler systems is a practical and economical practice in turfgrass management. Some of the important advantages of this practice are: a) lower application costs resulting from less labor; b) split applications can be made readily; c) uniformity of distribution; d) micronutrients and other chemicals such as pesticides can be mixed uniformly; and e) more effective use of fertilizer materials.

Suitable sulphur sources for use in liquid fertilizers include ammonium thiosulphate (12-0-0-26S) and ammonium bisulphite (8.5-0-0-17S), both of which are available commercially in the liquid form. Ammonium sulphate may also be used in liquid fertilizers, but the relatively low solubility of this material limits the nutrient concentration possible.

Sulphur may be incorporated into suspension fertilizers either in the form of one or more of the salts of which it is a constituent or as finely divided elemental sulphur itself. Suspensions with grades such as 9-18-18-10S and 12-12-12-20S have been prepared by TVA by mixing finely ground sulphur with 12-40-0 base suspensions, urea-ammonium nitrate solution and potassium chloride (2). Stable N-S suspensions with sulphur contents up to 50% S have been prepared from a nitrogen solution, elemental sulphur and clay. A typical grade is 24-0-0-24 containing 2% attapulgite.

Sulphates of ammonium, potassium, potassium-magnesium and micronutrient elements are excellent sources of sulphur suitable for use in suspensions.

THOSE EXTRAS ON A GOLF COURSE

by Jack Fairhurst
Superintendent — Ashburn Golf Club
Halifax, Nova Scotia

Very little is ever mentioned about the extra beautification ideas on golf courses. With the addition of flowering trees and shrubs, hedges and flower beds, the beauty of a golf course can be greatly enhanced. Following are a few such ideas which can possibly make the difference between a satisfied membership or one that is not.

The first view a golfer gets is the entrance to the country club. Any entrance road can be beautified by lining both sides with flowering types of trees such as the mountain ash, flowering crabs, or dogwoods. The addition of hedges to break the vast parking area appearance or to line the approaches is very becoming to the members and guests.

Flowering plots around the clubhouse and surrounding areas can add to the general eye-appeal of the area. The trick to such beds is to have a variety of flowers so that at least one type will be in bloom from spring to fall.

On the course itself, flowering shrubs and small trees planted near the tees, but off to the side out of the way of play will provide beauty and possibly fragrance to the air while the golfers are waiting to tee up. A few such varieties would be: golden chain, lilac, smoke trees, forsythia, beauty bush, rose of sharon, and japanese quince. At the edges of landing areas, specimen and flowering trees such as white birch, lindens, pines, mountain ash and red maple planted in small groups will distinguish the hole and give it more perspective.

Around ponds and along streams add a majestic look to the area. It must be remembered that although plantings are appreciated by the golfers, they must be planted in areas that will not interfere with the flow of play.

It is advisable that those unsightly service roads receive some type of beautification program. Planting various trees to line the roadway will help hide the road and also provide beauty to the course. These trees also provide protection to the maintenance crew from stray golf balls, if placed in the right areas.

One final idea is concerning bridges on the golf course. A covered bridge can be a beautiful attraction and provide as a rain shelter at the same time.

These are only a few ways to add beauty to the golf course. I am sure that many other superintendents have more and different suggestions. The main objective, however, is to relax the golfer through a use of picturesque surroundings. I myself, have received many compliments for the few seemingly simple "extras" I have added to my course.

Turf Bulletin's Photo Quiz

CAN YOU IDENTIFY THIS PROBLEM?
Date: November
Area: Golf Green
Location: Northern Connecticut
Description: Numerous bare spots throughout green.

Answer on Page 15.

—Reprint from Plant Disease Reporter, August 1970

PROGRESS IN RESEARCH ON LIVE OAK DECLINE

E. P. Van Arsdel and Robert S. Halliwell[1]

Abstract

Live oak decline is a complex of diseases that affect other oaks as well as live oaks. A wilt disease (caused by Cephalosporium spp. = Phialophora obscura) is a major component of this disease complex. The fungous canker disease of Texas red oak (caused by Dothiorella quercina) has a morphologically identical Cephalosporium stage in culture, and the Dothiorella stage has been produced in post oak Cephalosporium cultures. Thus, Dothiorella quercina may be a part of the life cycle of the Cephalosporium wilt disease. Indications are that wilting symptoms are caused by mechanical interference with water flow, the presence of a toxin, or both. Hypoxylon atropunctatum (with a Hyalodendron imperfect stage) accounts for another portion of the live oak decline in Texas. It sometimes infects Cephalosporium-infected trees. Various mechanical wilts caused by earth moving result in similar symptoms.

INTRODUCTION

Live oak decline is a name that has been applied to a complex of diseases that affect other oaks as well as live oaks. Earth fill over roots or cuts nearby cause part of the problem. In Texas, a fungus, Cephalosporium spp., has been identified as a major component of this disease complex (4). It causes a vascular wilt that is apparently root graft-transmitted. Hypoxylon atropunctatum (with a Hyalodendron imperfect stage) accounts for another portion of the live oak decline in Texas. The Hypoxylon often is found as a secondary invader in Cephalosporium-wilted trees. In Maryland, the chestnut blight fungus, Endothia parasitica, has been designated as the cause of live oak decline (3). We have been unable to find Endothia parasitica on oaks in Texas, and Batson and Witcher (1) found that Endothia parasitica was not an aggressive parasite on live oak in South Carolina.

This paper summarizes progress in research up to the beginning of the 1969 field season.

A fungus originally identified as Cephalosporium spp. was consistently isolated from naturally infected live oaks (Quercus virginiana) (Fig. 1), water oak (Quercus nigra), Texas red oak (Quercus shumardii texana), and post oak (Quercus stellata) trees located throughout the State. The fungus appeared to be associated with the discolored heartwood and vascular tissue. It has not been isolated from dying terminals in live oak, but it has in post oak.

The fungus isolated from diseased live oak trees resembles Cephalosporium in the pointed appearance of the conidiophores, their occurrence for the most part as solitary structures, and the endogenous production of hyaline conidia which collect in slimy drops. The hyphal color and the frequent grouping of phialides on erect stalks, however, particularly in the older parts of a colony, are not typical of species in this genus. The pathogen has also been classified as Phialophora obscura after comparison with a type culture.

Dothiorella canker was observed on a Texas red oak (Q. shumardii texana) showing live oak decline symptoms in San Antonio in November 1968. The first samples were obtained by Robert S. Dewers and Allan Brooks. The isolated fungus at first produced a coarse, pigmented mycelium, but parts of it subsequently became hyaline. All secondary transfers produced hyaline cultures. The original dark-green pigmented cultures produced pycnidial-initial type structures. In addition the older hyphae produced isolated conidiophores with endogenous hyaline conidia collected in slimy drops. These were morphologically identical to Cephalosporium cultures made from infected live oak trees.

When using the Cephalosporium from cultures isolated from declining live oaks, typical symptoms developed in stem-inoculated cultivated trees after 2 to 8 months. Leaf-inoculated trees did not display symptoms after 1 year, and the fungus was not reisolated from the stems bearing inoculated leaves.

Root-inoculated trees developed symptoms and the pathogen was reisolated from the crown area. The pathogen was never isolated from roots of naturally infected trees.

The apparent absence of the pathogen in the dying terminals on live oaks would indicate that the symptoms were due to a mechanical interference with the passage of water, the pres-

[1]Associate Professors of Plant Pathology in the Department of Plant Sciences at Texas A&M University, College Station, Texas 77843.

FIGURE 1. Stages of live oak decline (Cephalosporium wilt in live oak): In the large trees, from left to right, the left tree is nearly dead; the middle tree has been defoliated and has had a characteristic resprouting from the main trunk and branches; and the right tree (distant) is apparently healthy. The stump of a dead tree is in the right foreground.

ence of a toxin, or both. Microscopic examination of fresh specimens taken from the margin of dying terminals did not reveal any invasion by fungi. Fungal hyphae were readily demonstrated in vessels and ray cells of discolored tissue. Vessels were frequently occluded with fungal hyphae, tyloses and a brown amorphous substance. Fungi were not observed beyond the margin of discolored tissue.

TAXONOMY OF PATHOGEN

There is some disparity in the identity of the pathogen; Dr. S. J. Hughes[2], Canadian Department of Agriculture, and Dr. H. L. Barnett[2], University of West Virginia, authorities on fungi of this group, agree that the pathogen is a somewhat atypical Cephalosporium species. It is morphologically identical to the Cephalosporium on elm (2). Dr. Walter Gams[2], Biologische Bundesanstalt, Kitzeberg, Germany, is preparing a monograph on the Cephalosporium species, and has examined the culture and reports that it compares favorably with the type culture of Phialophora obscura. The reason for the discrepancy, according to both Drs. Barnett and Gams, is that the Cephalosporium hyphae and conidiophores are not generally pigmented, and those of Phialophora generally are. Our cultures have both types of conidiophores.

Attempts have been made to induce sexual reproduction of the fungus by the use of different nutrient media (artificial and natural) and environmental stimuli, that is, dark, continuous light, UV light and temperature variations.

In one instance, while growing the fungus on Czapek's broth in shake culture, we observed a different vegetative growth. When the resulting culture was transferred to other media for development and observation, it resumed the normal growth habit. The atypical culture, when transferred to a sterile cellulose medium, produced apothecia-like structures. Asci or ascospores have not as yet been observed.

Comparisons of the Dothiorella cultures with the Cephalosporium structures offer a possibility that the Dothiorella has some of the functions of a sexual stage. An interesting possibility could be that the Dothiorella pycnidium is produced on a mycelium analogous to a dikaryotic Cephalosporium mycelium. Dothiorella stages have been produced in Cephalosporium cultures made from dead and dying declined post oaks. These results indicate a life cycle similar to that of the Dothiorella-Cephalosporium disease of elm (2).

[2] Personal correspondence.

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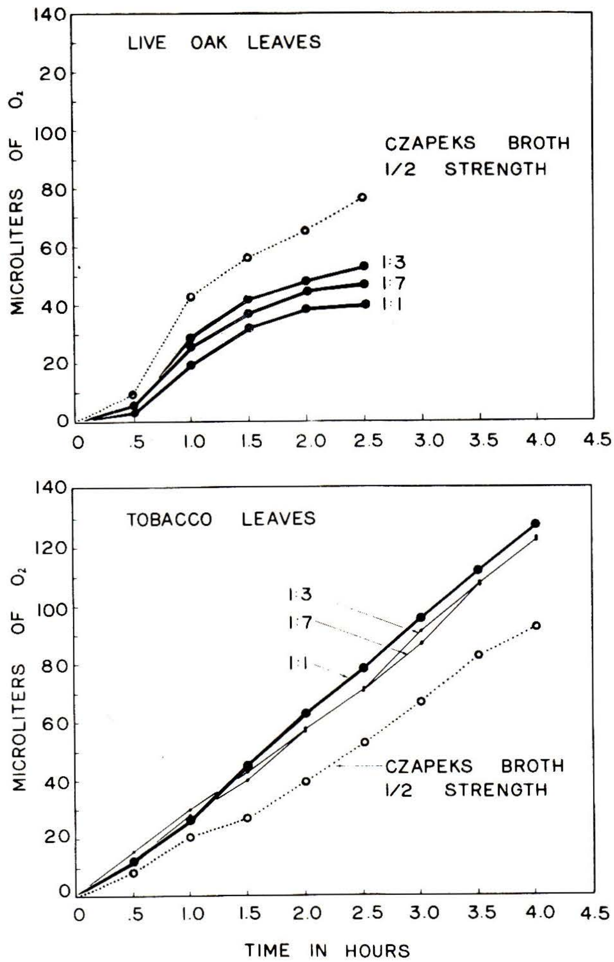

FIGURE 2. Effects of dilutions of live oak Cephalosporium on respiration of live oak and tobacco - representative data.

PATHOGEN DISSEMINATION

Experimentally inoculated hosts maintained in a greenhouse and shade house and naturally infected trees are periodically observed for signs of sporulation of the pathogen, in order to determine how and when the pathogen is disseminated. No sporulation has been observed.

The possibility of a Dothiorella stage in the life cycle offers some exciting possibilities. Since the Dothiorella has never been observed on live oak, but only on Texas red oak, it is possible that the fungus must spend part of its life cycle on other oaks for aerial (probably insect) dissemination.

The pattern of spread in this wilt-type decline in the Kerrville area indicates that root grafts could play a major role in the local spread of the disease.

PHYTOTOXIN

Since the wilt-type pathogen has never been isolated from or demonstrated in the dying terminals of infected trees, a phytotoxin has been sought.

The pathogen was grown in a shake culture in an inorganic medium (Czapek's broth). After 2 weeks a cell-free filtrate of medium containing exogenous metabolic products was obtained by filtration and centrifugation.

The filtrate was tested for toxicity on young oak cuttings and succulent plants by the following methods:

1) Plants and cuttings were placed in different concentrations of aerated test preparations. Culture media and water served as controls. In some cases oak cuttings with young succulent leaves immersed in the fungous filtrate wilted within 24 hours. The fungous extract did not affect the succulent plants tested.

2) The effects of the fungous extract on tissue respiration were determined. Oak leaf tissue placed in various dilutions of the fungous filtrate exhibited a decrease in respiration. The decrease was not proportional to concentration.

The succulent tobacco tissues tested responded conversely with an increase in respiratory activity, The effects on respiration have been highly reproducible, but significance of the effects on respiration have not been determined. Representative data are shown in Figure 2.

HISTOPATHOLOGICAL STUDIES

Wilted live oak leaves from naturally Cephalosporium-infected trees and leaves wilted after treating with the fungous filtrates were sectioned and examined with the light microscope. Drought-wilted leaves and normal succulent leaves were used as controls.

There was no apparent difference among the wilted leaves due to natural fungous infection, fungous filtrate or drought.

It would appear from this experiment and those previously mentioned that a phytotoxin is involved which affects, in addition to respiration, the osmotic properties of the affected cells.

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Editorial

DO YOURSELF A FAVOR

Many superintendents and other employers are experiencing difficulty in hiring good, reliable labor. However, there is a segment of the labor market that many have not considered although it has great potential. This is the handicapped.

By hiring the handicapped you can relieve the frustrations of potentially productive people while at the same time gain faithful, conscienctious employees.

Suppose you were in the position to hire a handicapped person? Would you go a little out of your way to hire this person or would you take the easy way out by not considering him? There are many success stories of handicapped people who have been given chances and proceeded to contribute greatly to their employers and companies. For instance, I know of a superintendent of a well-known country club who has nothing but praise for a deaf young man who works on his course. This person never misses a day and can perform all of the maintenance operations on the course as well as anyone else.

On the other hand, there are many cases of such people who have not been able to find jobs. While many of us help in supporting individuals who are unable to support themselves, too few are aware of the less expensive alternatives. It has been proven that for every one tax dollar spent in hiring and rehabilitating the handicapped, ten dollars is repaid by this person in taxes alone — not to mention that he is no longer dependent on public support.

If you've never given a handicapped person a chance, I urge you to give it a try. You'll find that everyone concerned will profit by the decision. Remember — every disabled person has certain abilities which may be the ones you require in your establishment. Hire the handicapped — it is good business.

Fred Cheney

Turf Bulletin's Photo Quiz

Answer to Photo Quiz — Greens were heavily infested with crabgrass during season. When the crabgrass went out in October, the bare patches resulted.

The Performance Characteristics of Kentucky Bluegrass Mixtures

F. V. Juska and A. A. Hanson[1]

It has been suggested that two or more Kentucky bluegrass varieties should be blended to reduce the incidence of disease and insect damage, and to produce, on the average, a higher quality turf than that obtained from a single variety planted alone. Very little information is available to support this theory or to show shifts in botanical composition that may or may not occur when blends are planted. Hanson et al. (1) compared the forage yield of five apomictic lines of Kentucky bluegrass when grown alone and in all combinations of 2, 3, 4, and 5 lines. In this study, apomictic lines that produced high yields when grown alone appeared to give the best response in mixtures with other types. This suggests that vigorous selections may become the dominant type in mixtures, but no attempt was made to record changes in botanical composition.

It is possible that a blend of two or more bluegrasses may reduce the incidence of disease and disease damage, provided the varieties differ in disease reaction and a reasonable balance of the varietal components is maintained in the resulting turf. Thus a mixture of

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Merion and common Kentucky bluegrass would combine the *Helminthosporium* leaf spot resistance of Merion with the higher tolerance of common Kentucky bluegrass to stripe smut (*Ustilago striiformis*). The severity of leaf spot and stripe smut may be reduced in the mixture, and, hopefully, the recovery of the turf would be improved if one variety was damaged by disease. In addition, the persistence of individual Kentucky bluegrass varieties grown in mixtures will be influenced by environmental conditions and management variables, including temperature, water, soil type, pH, soil fertility, and mowing height and frequency. It is entirely possible, therefore, that a single aggressive bluegrass variety, well adapted to local environmental conditions or to the management practices that are applied, may dominate blends in a comparatively short period, possibly in the first growing season.

Changes can be anticipated in the composition of complex Kentucky bluegrass blends, but these changes are difficult to identify in solid seedings. Conversely, simple blends consisting of two varieties that have contrasting characteristics (color, growth habit, leaf width, disease reaction, etc.) offer promise in following trends in botanical composition.

An experiment planted at Beltsville in September 1964 was designed, in part, to provide information on the interaction of six Kentucky bluegrass entries, planted alone and in selected two-entry combinations. Each component was seeded at the rate of approximately 1 pound per thousand square feet in 4- by 10-foot plots. The experiment was arranged in a randomized block design with three replications. All plots received 3 pounds of nitrogen as ammonium nitrate each year with phosphorus and potassium maintained at optimum levels. Plots were mowed at a height of 2 inches at weekly intervals, with clippings removed when growth was excessive. During the first 2 years very little change was

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observed in the relative contribution of the individual components within blends. The contribution of individual components was estimated on the basis of percentage ground cover on April 25, 1966, and again on December 2, 1968. Stand estimates obtained in 1966 reflect differences in rate of establishment that may be associated with seed quality of the various bluegrass entries. The 1968 estimates show changes that resulted from differential spread and survival under the management conditions of this experiment.

Table I shows the relative botanical composition of the mixtures in 1966 and 1968. The table also gives the average incidence of leaf spot and turf quality recorded in 1966 and 1968. The balance in the Belturf-Beltsville 117 mixture was excellent in 1966, with the varieties contributing 52% and 48%, respectively, to estimated ground cover. In 1968, Belturf occupied 87% of the plot area and Beltsville 117 had been reduced to 13%. The increase in Belturf can be explained on the basis of greater vigor, although management and some stripe smut damage on Beltsville 117 may have contributed to the overall shift in composition. A similar change is seen in the combination of Pennstar and Beltsville 117.

Pennstar, Belturf, and Merion proved to be the most vigorous bluegrasses used in the mixtures, with a trend toward either increased ground cover, or at least no major reduction in stand, in 1968. However, the relative contribution of Belturf declined when grown in association with Pennstar and Merion. This shift was appreciable with Pennstar and comparatively minor with Merion. The Kentucky blend, which consisted of selected lines from Kentucky, and common Kentucky bluegrass were the poorest performers in this group of bluegrasses. The Kentucky blend was more aggressive than common in 1966, and it held much of this advantage over common in 1968.

In general, leaf spot scores improved from 1966 to 1968 as the contribution of leaf spot resistant bluegrasses increased in most combinations. Quality scores are not directly comparable, since the 1966 results were obtained in the fall when all plots had recovered from leaf spot damage. The 1968 quality ratings reflect leaf spot damage, vigor, and overall desirability. They show that with few exceptions an increase in the relative proportion of aggressive varieties was associated with acceptable turf quality. The lowest quality mixture consisted of the Kentucky blend in association with common Kentucky bluegrass.

Average leaf spot and quality scores for the six Kentucky bluegrasses seeded alone are given in Table II. Pennstar and Beltsville 117 had the lowest leaf spot scores, 1.9 and 2.2, respectively. In spite of the high level of leaf spot tolerance exhibited by Beltsville 117, both Belturf and Pennstar suppressed 117 in mixtures. In this experiment Pennstar and Merion appeared to be about equally aggressive.

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The best overall quality scores were assigned to Belturf, Merion, and Beltsville 117.

These data indicate that aggressive bluegrasses tend to dominate mixtures in which they are included, but that aggressiveness will vary with the characteristics of other Kentucky bluegrass varieties included in the mixture. In general, the growth characteristics and relative vigor and aggressiveness of varieties must be somewhat comparable if suitable mixtures are to be maintained for a reasonable period of time. Thus, the development of satisfactory bluegrass blends will require information on relative vigor, aggressiveness, and disease reaction of individual varieties when these varieties are evaluated under different cutting heights, levels of soil fertility, and soil-water regimes. Blends formulated on the basis of inadequate information may revert to essentially pure stands in a relatively short time.

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Table I. Percent stand, average leaf spot, and average turf quality scores for Kentucky bluegrass blends (1966-1968)

Bluegrass Blends[1]	Percent Stand		Average Leaf spot 1-10 most		Average Quality 1-10 best	
	1966	1968	1966	1968	1966 (Fall)	1968 (Spring)
Beltsville 117	48	13				
Belturf	52	87	3.0	4.3	8.3	6.3
Beltsville 117	71	12				
Pennstar	29	88	1.7	1.7	8.0	4.7
Belturf	53	33				
Pennstar	47	67	2.7	2.7	7.5	5.8
Belturf	72	63				
Merion	28	37	3.3	3.3	8.0	6.7
Belturf	37	60				
Common	63	40	6.0	4.3	8.2	6.3
Belturf	60	52				
Ky. blend	40	48	6.7	6.0	8.1	5.9
Pennstar	65	77				
Merion	35	23	2.7	2.3	7.2	5.0
Pennstar	8	60				
Common	92	40	3.3	2.0	7.2	4.3
Pennstar	42	77				
Ky. blend	58	23	4.3	2.7	8.3	4.3
Ky. blend	40	23				
Merion	60	77	5.0	4.0	8.1	5.7
Ky. blend	82	70				
Common	18	30	8.0	7.3	7.6	4.0
Merion	57	77				
Common	43	23	5.0	4.0	7.8	6.0

[1] 50-50 blends by seed weight.

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Table II. Leaf spot and quality scores of Kentucky bluegrass entries seeded alone. Scores are averages for the period 1964 to 1969.

Source	Average Leaf Spot 1-10 most	Average Quality 1-10 best
Beltsville 117	2.2	6.2
Belturf	4.4	6.9
Pennstar	1.9	5.5
Ky. blend	6.8	4.8
Merion	2.7	6.9
Common	6.7	4.5
Average	4.1	5.8

—Reprinted from Sports Turf Bulletin, No. 71, 1965.

MOSS

Mosses belong to a group of plants known as the "Bryophyta" and, by their structure and way of life, come somewhere between the algae and the ferns. The moss plant in turf competes directly with the turf grasses for space, light and soil nutrients. Mowing, by injuring the leaves of the grasses of the turf, increases the competition ratio between moss and grass in favour of the moss plant. Although there are 600 species of mosses in the British Isles only a few are of common occurrence in sports turf. Perhaps the most common mosses of turf are "Bryum," Hypnum," "Ceratodon" and "Polytrichum." General recognition of these mosses is possible because "Ceratodon" is found as velvet-green cushions; "Bryum" and "Hypnum" have a fern-like appearance; and "Polytrichum" appears in shape to be minute Xmas trees.

Mosses thrive under a wide range of conditions and their presence in turf cannot be attributed to any one factor. Generalizations can be misleading but observation has suggested that "Bryum" and "Hypnum" thrive best when excessive surface moisture is present, whereas the cushion-type "Ceratodon" prefers acid conditions and infertile sandy soils. "Polytrichum" thrives on shallow soils which dry out and also on poverty stricken soils. "Bryum" and "Ceratodon" will infest turf in the industrial areas because they are tolerant of pollution by industrial dusts and smoke.

Causes of Moss Infestation

The items listed below are associated with one or more species of moss in turf grass areas:—

(1) Poor drainage.
(2) Excessive shade.
(3) High fibre content of the turf (causing moisture retention).
(4) Poor soil.
(5) Shallow soil.
(6) Over-acid soil.
(7) Inadequate level of fertilization.
(8) Too close cutting.
(9) General neglect of the turf.

Control

(1) Detect and remove the prime cause of moss infestation.

(2) Raking and Renovation: The raking out of living moss may cause the spread of the moss infection but it would allow the vigourously growing grass to invade the moss areas. For preference, the moss should be killed and then raked out, indeed the velvet-green cushions of "Ceratodon" must be raked out because they die into a hard mass, which would prevent any effective renovation.

Gentle scarification will tease out "Bryum, Hypnum" and "Polytrichum" from the sward, and this alone may encourage the grass to increase its density of growth. Only with "Ceratodon" is a bare patch left after destruction of the moss; this bare scar may be seeded with a fescue/bent mixture for renovation.

(3) Chemicals: Various chemicals have been tried throughout the years but sulphate of iron has been found to be most useful. Sulphate of iron and sulphate of ammonia mixed with sand form the commonly known and useful "lawn sand." There may be some doubt whether it is effective against the moss spores resting on the ground; it is quite effective against the moss plant. Whether or not it is effective against the moss spores the cause of moss infestation must be removed, or re-infestation is most likely to occur.

Calomel powder in an inert carrier can be used any time for moss control. This dressing should be applied to the areas of turf which show the moss patches; the rate of application is 1 oz. per square yard when using the 4% Calomel powder. This substance is toxic if misused so do "read the label."

A marked improvement in the control of moss came about when calomel was added to an ordinary lawn sand. The amount of calomel added should be sufficient so as to give a dosage rate of 1-2 grams of calomel per square yard. This mixture is the well known "mercurised lawn sand" which may be purchased ready mixed throughout the country. The effectiveness of calomel in a lawn sand is due to its toxicity not only to the moss plant but to the resting spores.

It has been found that the addition of superphosphate to a mercurised lawn sand enhances the growth of grass after the destruction of the moss.

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