EXPERIMENTAL CONTROL OF SNOW MOLD (TYPHULA SP.) ON TURF OF GOLF GREENS IN NORTHERN MICHIGAN

Thesis for the Degree of M. S.

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James C. Myers, Jr.

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This is to certify that the

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"Experimental Control of Snow Mold, *Typhula* sp. on Golf Green Turf in Northern Michigan"

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James C. Myers, Jr.

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William [signature]
Major professor

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EXPERIMENTAL CONTROL OF SNOW MOLD (*TYPHULA* SP.) ON TURF OF GOLF GREENS IN NORTHERN MICHIGAN

By

James C. Myers, Jr.

A THESIS

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VITA

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INTRODUCTION

The incidence of "winter-kill" and its obvious severity on the putting greens of approximately fifty golf courses in the upper peninsula of Michigan were noticed three years ago by the author. Upon inquiry, it was found that nothing was being done by the greenskeepers to combat the pathogen responsible for the destruction of the greens.

There are several diseases that attack the bent grasses grown on golf greens. Under certain conditions these diseases may be so severe as to produce extensive damage to, or even complete killing of, the turf. It is known that in some years the diseases may be very serious and cause extensive damage, while in other years there may be practically no damage. Such differences are usually associated with variations in the weather conditions from year to year. Temperature and moisture apparently play a major role in the incidence of the known turf diseases.

The purpose of this problem was to determine the identity of the pathogen responsible for the damage, and to assess the potential control, or inhibition, of the disease by a number of fungicides.

The preliminary work was started in the autumn of 1950, and the research program was carried on for the following three years in the belief that over such a period of time most of the materials used would show definite patterns of control in relation to the varying climatic conditions.

The Host

Bent grass putting greens are in use in nearly every section of the United States, and the bent grasses used for this purpose (varieties of Agrostis palustris Huds.[1]) are susceptible hosts to many turf diseases. South German Bent was one of the first varieties to be used for golf putting greens in this country. World conflict in 1914 made it impossible to secure adequate supplies of

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[1] The binomial here used for the creeping bent grass is the one accepted by Hitchcock and Chase (14) in Edition 2 of "The Manual of Grasses of the United States," published in 1951. Fernald (9), in Edition 8 of "Gray's Manual of Botany," published in 1950, subordinates the creeping bents as a variety under the redtop, and refers to them as Agrostis alba L., var. palustris (Huds.) Pers. Gleason (10), in "The New Britton and Brown Illustrated Flora . . .," published in 1952, obscures some of the creeping bents and the redtop as varieties of the European stoloniferous bent, and places the remaining creeping bents in a separate species; the creeping bents, therefore, are referred to by Gleason as Agrostis stolonifera L., var. compacta Hartm., and as A. tenuis Sibth.

the seed of this particular grass. Consequently, the Greens Section of the United States Golf Association fostered the selection and propagation of new strains of bent grass. Present-day plantings of selected creeping bents are the result of such research.

Almost all of the bent grasses now used on putting greens are susceptible to a number of turf diseases, although some of the most recent selections have proven to be more-or-less resistant to at least some of these diseases. The close-cropping of the greens and the resultant density of foliage, together with the usually abundant moisture and high temperatures of the greens' surface produces conditions ideal for infection and extensive spread of the causal pathogens.

The Diseases

Diseases commonly found on the golf greens of Michigan according to Howard (16), are: Brown Patch, Pellicularia filamentosa (Pat.) Rogers (Rhizoctonia solani, Kuhn); Dollar Spot, Sclerotinia homeocarpa F. T. Bennett; Melting-out, Curvularia geniculata (Tracy and Earl) Boldijn; and Snow Mold, Typhula itoana Imai. Isolations of all these diseases have been made from Michigan greens by Drs. John R. Vaughn and William Klomparens when at Michigan State

College. The identification of the organism considered in this thesis was confirmed by them.

Symptoms of Snow Mold Disease

The injury caused by Typhula occurs either under the snow or as the snow is melting. The visible damage begins as a blotchy circular area one-half inch to two inches in diameter. The fungus spreads radially as a band or ring of white, blue-gray, or sometimes almost black mycelium approximately one inch in width. The mycelial mat is often filled with small reddish-brown or dark-brown sclerotia.

Damage usually ceases when the area reaches a diameter of one or two feet because of the drying-out or warming-up of the turf surface. However, the patches of infection have been known to coalesce and cover an area twenty feet in diameter.

After the snow melts, the leaves of the host grasses die, and become grayish-white on drying. Finally, the leaves become matted together on the ground.

Economic Importance of Snow Mold

The losses from snow mold in Michigan are difficult to extimate. In some years there is little or no loss, while in other years the damage is extremely severe. For example, in the United States there are approximately six thousand golf courses occupying approximately 750,000 acres of land. The investment in land, buildings, machinery, playing equipment, and other necessities, and the labor required for maintenance of the courses makes golf a multimillion dollar sport. As it is quite obvious, this sport is all dependent upon grass.

The regulation golf course has eighteen holes, by tradition, but often many have only nine. These holes, of course, are located on the greens. Putting greens represent one of the most highly specialized uses of grass. Without an excellent turf on the greens to provide a keen putting surface, golf would not be the popular sport it is today.

It might be noted, here, that many golf courses have recently abandoned bent grass greens in favor of such substitutes as oiled sand greens because of the inability of the greenskeepers to cope with pathogenic problems. Even the high-score golfer is aware that such substitute greens are decidedly inferior to the traditional bent greens.

REVIEW OF LITERATURE

An investigation of the available literature with respect to snow mold on turf and other grasses showed that relatively little research and few papers had appeared on this subject. Imai (17), in 1936, reported and described a disease of grasses in Japan caused by an organism which he named and described as Typhula itoana Imai. Other reports and observations of this disease, as it affects various grasses, are by W. H. Davis (6) and Remsberg and Hungerford (22) in 1933, Vang (26) in 1937, Ekstrand (7, 8) in 1939, Remsberg (21) in 1940, Noer (20) in 1944, Blodgett (2), Brundza (4) and Vang (27) in 1946, Westcott (31) in 1950, Howard (16) in 1951, Meiners (18) and Sprague (23) in 1952, and Holton (15) in 1953. A number of these papers refer specifically to the presence or the effect of a snow mold organism (Typhula sp.) on the bent grasses used in the turf of golf greens.

Remsberg (21) decided that the pathogen she was studying was Typula itoana Imai, and states that it "occurred most frequently under deep and drifted snow, and in areas where the snow was slow and delayed in melting in the spring," although Vang (26) had earlier suggested that the damage occurred only at the time of snow melt.

During the year prior to Remsberg's report, Ekstrand (7, 8) had suggested that "infection probably takes place to a considerable degree through the soil." Remsberg and Hungerford (22) had previously reported that the snow mold organism (or organisms) reacted very differently to variations of temperature apparently associated with changes in depth of snow cover; they stated that optimum growth occured at 10° Centigrade and that growth appeared to cease at and above temperatures of 25° Centigrade.

In evaluation of the papers mentioned in the preceding two paragraphs, all that can be said honestly is that very little really is known about the etiology of the snow molds, of the conditions which infection occurs and in which subsequent epidemic development takes place.

A number of fungicides have been used, primarily in an experimental manner, in an attempt to control or inhibit the development of the snow molds and other turf diseases. The most important of these, on the basis of literature reports, seems to be cycloheximide (known in the trade as Acti-dione). Among those who have reported upon the effects of this particular fungicide are: Gottlieb, Hassan, and Linn (11) and S. H. Davis, Engel, and Silber (5) in 1950, Vaughn (28) and Nelson (19) in 1951, Meiners (18) and

Vaughn and Klomparens (29) in 1952, and Holton (15) in 1953. Other reasonably effective fungicides were discussed by Wernham and Kirby (3) in 1943. In some of the essentially preliminary reports on Acti-dione, it was intimated that this particular fungicide is very potent in its effects, but none of the authors mentioned above suggest any basis for such potency.

Recent work, on an essentially empirical basis, involving the effects of Acti-dione on cellular structure and organization and on nuclear response have been reported by Hawthorne (12) in 1951, Hawthorne and Wilson (13) and Thanos (25) in 1952, and Bowen (3) in 1953. In brief, these workers indicated that the effectiveness of Acti-dione as a fungicide may be due to intracellular effects such as mitotic irregularities, failure of cell-wall formation and resultant cessation of cell multiplication, and chromosome aberrations. Even in very low concentrations, Acti-dione causes cessation of both cell multiplication and cell expansion, with the resultant "death" of parts of organisms or entire organsims.

The relatively small number of papers discussed above, and included in the section on Literature Cited, may be explained by the comparatively short time that pathologists really have been interested in turf diseases. Also, the recent availability of Acti-dione and similar antibiotics and fungicides for experimental disease control is reflected in the same manner.

MATERIALS AND METHODS

Selection of Experimental Sites

Three golf courses were selected as being typical examples of the upper Michigan area. In 1950 the courses chosen were: (1) Portage Lake Golf Course, Houghton, Michigan; (2) Blaney Park Golf Course, Blaney Park, Michigan; and (3) Soo Country Club Course, Sault Ste. Marie, Michigan. These courses were approximately 300 miles apart from one extreme to the other, and with such a range of climate it was felt that any results determined would be acceptable as fairly accurate for this area. The following years of 1951 and 1952, the Les Cheneaux Club of Cedarville, Michigan, forty miles south of Sault Ste. Marie, was substituted for the Portage Lake Golf Course at Houghton because of the uncertainty of weather conditions in the autumn, when spraying of the greens was performed. While spraying the greens at Blaney Park in 1951, sudden heavy snows at Houghton made it impossible to continue the experimental work started there the previous year. As a matter of fact, the highways were blocked so that it was impossible to go to Houghton.

With the inclusion of the Cedarville golf course, a triangle of greens under observation was formed, with a forty-mile base from Sault Ste. Marie to Cedarville, and one hundred miles on the remaining sides from Blaney Park to each of the other locations. The map in Figure 1 indicates the location of the golf courses.

At each of these locations, one green was selected on the basis of its past history as the worst green, from the standpoint of "winter-kill," for the particular course. The greens so selected for the experimental work were:

(a) green number 3 at the Blaney Park Golf Course, Blaney Park;

(b) green number 3 at the Soo Country Club; Sault Ste. Marie;

(c) green number 3 at the Les Cheneaux Club; Cedarville;

(d) green number 9 at the Portage Lake Golf Course, Houghton.

On each of the greens, plots of approximately equal area were marked out, the number dependent upon the number of fungicides to be tested in a particular year; one of these was designated as the control plot, while the remaining ones were used for applications of the selected fungicides. Plot technique was essentially that recommended by Struble (24).

The greens selected for experiments at the three courses, as with standard greens in the area, were each approximately 6,000

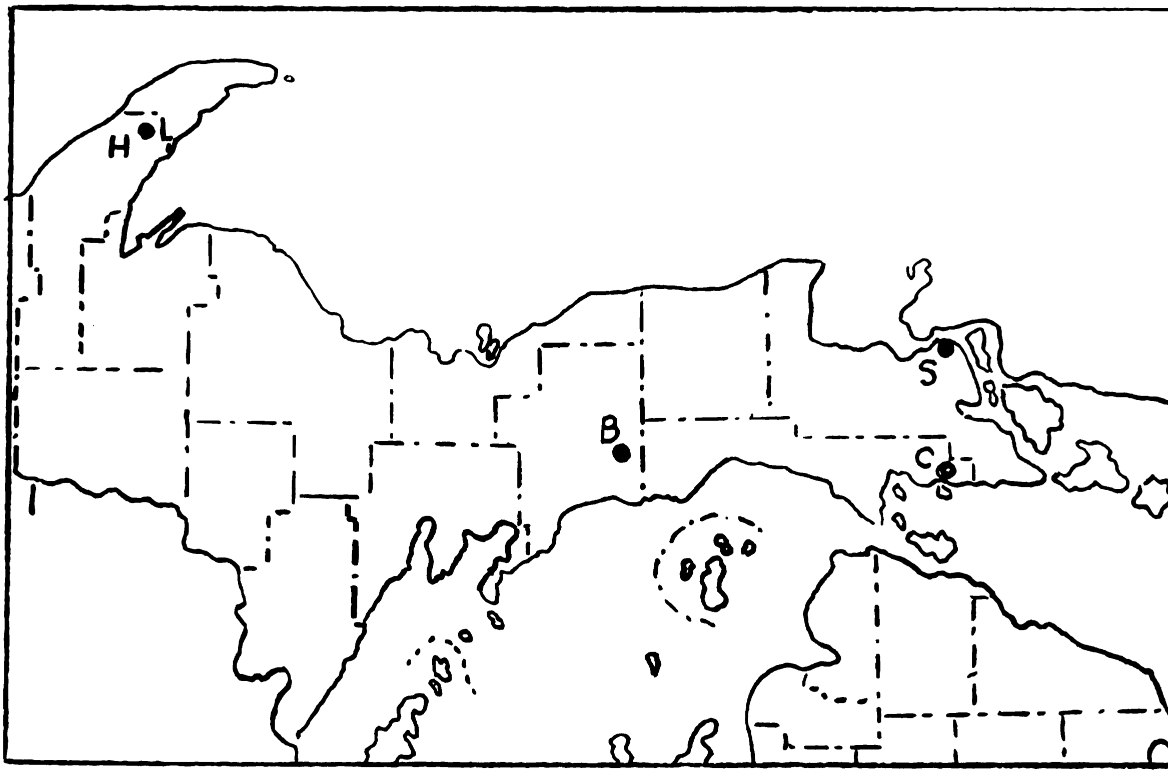


Figure 1. Diagram of the eastern upper peninsula of Michigan, showing experimental sites. B = Blaney Park; C = Cedarville; H = Houghton; S = Sault Ste. Marie.

square feet in area. The individual plots sprayed in 1950, when only three fungicides were tested, were approximately 1,500 square feet in area; in the other two years, when five fungicides were used, they were approximately 1,000 square feet in area. The greens under study were all of turf composed of creeping bent grass (*Agrostis palustris*), variety unknown, and was established turf at all locations.

Five fungicides were chosen for this experiment at the recommendation of Dr. John R. Vaughn; these were:

(1) Acti-dione (cycloheximide)

(2) Calo-clor (mixture of mercurous- and mercuric-chloride)

(3) C&C 1025 (mixture of copper- , zinc- , cadmium- and mercury-chloride)

(4) Cadminate (cadmium succinate)

(5) Tersan (tetramethyl thiuram disulphide)

In 1950, only the first three were used, but when the remaining two became available in 1951 they were added to the program for comparative purposes. The reason for the selection of the first of these fungicides was that an active program for study of Acti-dione was in progress both at Michigan State College, under the auspices of the Upjohn Company of Kalamazoo, and elsewhere in the United States. "Calo-clor" and "C&C 1025" and, subsequently, "Cadminate" and "Tersan" were chosen as representative examples of other available fungicides being marketed (or experimentally studied prior to commercial production) in competition with the Actidione. It seemed advisable to compare the effectiveness of these five compounds in controlling the snow mold disease through controlled experimental work.

The fungicides were applied to the plots with a standard Hudson hand-pump sprayer equipped with a mist-type nozzle. The same pump and nozzle were used throughout all experimental work.

In the experimental work carried out in the laboratory at Michigan State College during the summer of 1952, standard laboratory equipment for inoculation and studies of pathogen growth were utilized. Inoculum for these studies was obtained at the Sault Ste. Marie site in the spring of the same year. This was cultured at Michigan State College by Dr. John R. Vaughn and Mr. William Klomparens, who determined the organism as *Typhula* sp., probably closely related to, if not identical with, *T. itoana* Imai, the causal organism of snow mold disease in Japan. When the author returned to Michigan State College for the summer session of 1952, abundant material of the organism was available for the necessary experimental work. This consisted of observations on radial growth as discussed in the following section on Experimental Results.

No inoculum was obtained from the other sites, since macroscopic observation indicated that the same organism was present, and Dr. Vaughn did not believe it necessary to work with more than one sample of the parasite.

Field Study Methods

The greens selected at each site were chosen in conference with the greenskeepers on the basis of the past history as the worst green on each course. Each green was divided (as indicated in Figure 2) into equal plots, each approximately 1,500 square feet in area, in 1950, and approximately 1,000 square feet in area in each of the other two years, by means of marker stakes and boundary tapes. One plot was designated as the control plot and the other five were used for individual treatments. The position of each plot on a particular green was randomly determined for the first year. In subsequent years, a similar random designation of plots was made, but in no case was the same plot used for the identical treatment in more than one of the three years.

The fungicides were mixed with water on the basis of ratio of weight of fungicide to volume of water as indicated in Table I. Fungicide strengths used, as indicated, were at the recommended

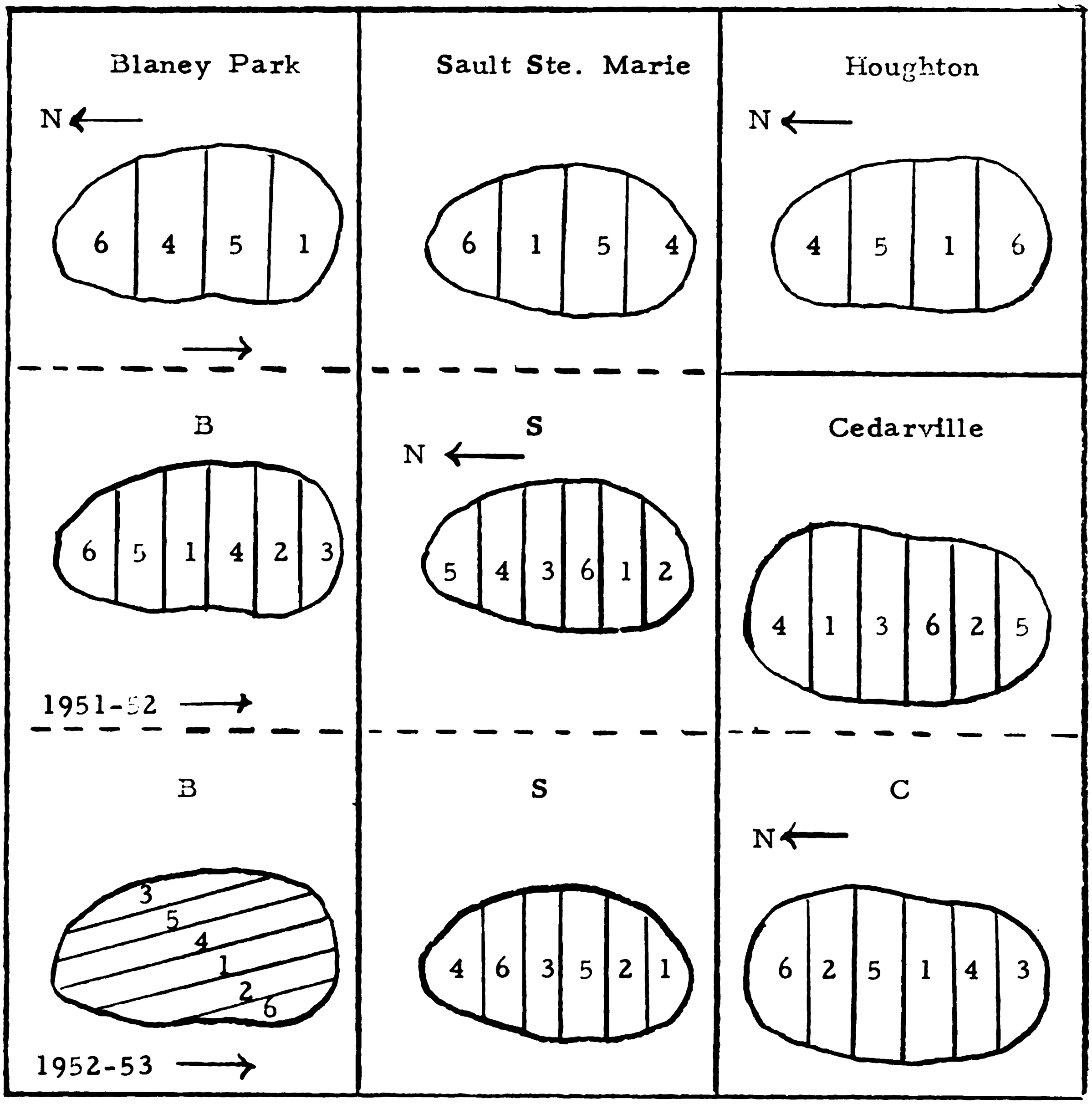


Figure 2. Diagrams of experimental plots at all sites for years 1950-1953, inclusive. N = north; 1 = Acti-dione; 2 = Cadminate; 3 = Tersan; 4 = C&C 1025; 5 = Calo-clor; 6 = Control plot; B = Blaney Park; C = Cedarville; S = Sault Ste. Marie.

TABLE I

STRENGTHS OF FUNGICIDE CONCENTRATIONS (WEIGHT OF FUNGICIDE/VOLUME OF WATER) UTILIZED IN FIELD EXPERIMENTS

Fungicide	Fungicide Weight (grams)	Water Volume (gallons)	Area Covered (sq. ft.)
Acti-dione	0.8	2	1,000
Cadminate	7.0	4	1,000
Tersan	42.48	4	1,000
C&C 1025	42.48	4	1,000
Calo-clor	29.4	4	1,000

dosage of the manufacturers, as suggested by Dr. Vaughn, in the belief that positive indications of effectiveness would be obtained.

Spraying was done in the late autumn as late as possible and just before the development of "permanent" winter snow cover. This time was selected because the damage to the grasses apparently occurs either during the winter under the snow cover or at the time of snow melt in the spring. The fungicides applied just before development of winter snow cover were thought to provide protection during the period that the ground was blanketed by the snow.

Immediately following snow melt in the spring, the greens were examined. Damage was visually estimated by the author and another unprejudiced individual. Estimates were made for each fungicide-sprayed plot in terms of the percentage of control (i.e., extent of undamaged area), in comparison to the percentage of undamaged area in the corresponding control plot. Dates of autumnal spraying and spring observations for each site in each year are indicated in Table II. As shown in a comparison of Table II with Table III, the variation in length of time between spraying and subsequent observation at the several sites is directly correlated with climatic conditions in each area.

No personal observations were made of the experimental sites between the time of a spring observation and the subsequent autumnal sprayings. Due to necessary duties of coaching and teaching during a part of these periods, and required resident attendance at summer sessions on the Michigan State College campus, such observations were both impractical and impossible. However, the respective greenskeepers, as indicated in the section on Acknowledgments, made and reported detailed observations during the spring, summer, and autumn months of each intervening season. From their reports it was possible to assess the residual effectiveness of each autumnal spraying.

TABLE II

SUMMARY OF DATES OF AUTUMNAL SPRAYING AND SPRING OBSERVATION, DURING COURSE OF FIELD EXPERIMENTS

Site	First Year		Second Year		Third Year	
	Autumnal Spraying	Spring Obser-vation	Autumnal Spraying	Spring Obser-vation	Autumnal Spraying	Spring Obser-vation
Blaney Park	N-5-50[a]	A-14-51	O-26-51	A-18-52	O-24-52	A-11-53
Cedar-ville			O-27-51	A-12-52	O-25-52	A-18-53
Sault Ste. Marie	N-10-50	A-13-51	N-10-51	A-5-52	O-23-52	A-2-53
Hough-ton	N-4-50	A-15-51				

[a] A = April; N = November; O = October.

Laboratory Study Methods

The studies carried out at Michigan State College in the summer of 1952 involved cultures developed from the inoculum collected at Sault Ste. Marie in the spring of the same year.

It was decided to determine the amount of radial growth of the fungus as grown in colonies in agar plates containing various amounts of the same fungicidal materials which had been used in the field experiments.

TABLE III

TOTAL SNOWFALL, AS RECORDED AT WEATHER STATION NEAREST EACH EXPERIMENTAL SITE, FOR THE YEARS 1950-1953, INCLUSIVE; INFORMATION FROM MONTHLY CIRCULARS ON MICHIGAN CLIMATIC DATA (1)

Locality and Dates	Snowfall in Inches per Month						
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Germfask, Mich.[a]							
1950-51	0.5	25.1	37.9	26.6	27.0	20.7	2.5
1951-52	Trace	22.6	46.7	29.5	9.5	19.6	7.3
1952-53	0.5	9.5	24.0	22.9	36.5	--[d]	--[d]
Sault Ste. Marie							
1950-51	2.0	19.6	30.6	15.1	22.2	17.5	4.5
1951-52	3.0	13.3	33.8	18.4	12.2	16.9	6.0
1952-53	2.1	14.4	12.7	32.1	23.0	16.8	9.9
Dunbar For. Exp. Sta.[b]							
1951-52	0.3	19.0	33.0	19.5	10.9	19.3	5.6
1952-53	1.7	11.6	14.4	38.2	25.3	10.6	5.9
Calumet, Mich.[c]							
1950-51	0.4	34.9	66.6	55.3	30.3	30.5	5.8

[a] Closest station to Blaney Park site.

[b] Closest station to Cedarville site.

[c] Closest station to Houghton site.

[d] Apparently no report available, since missing from official publication data.

The concentrations of fungicides used were 50, 100, 250, and 500 ppm., respectively. The medium used was a 2 per cent malt extract agar. The fungicides, which were not autoclaved, were added to the warm, liquid medium and then serially diluted. The resulting volumes were adequate to pour eighty-four plates, furnishing four plates for each concentration for all five of the fungicides used, including the control. A separate lot of malt extract was made for each series; thus the medium for testing the concentrations and the controls was from the same original source.

Each plate was seeded with a disk, approximately 5 mm. in diameter, taken from plate culture colonies seven days old. The disk was placed in the center of each plate and the plates were then stored in a refrigerator at a temperature of 10° Centigrade, as recommended by Remsberg (21). The plates were stored in darkness, as recommended by Vang (26), and radial-growth readings were recorded at 24-hour intervals for the 5 days following the first 48 hours from the initial seeding.

EXPERIMENTAL RESULTS

Results of Field Studies

A summation of all data obtained during field observations is presented in detail in Table IV (Appendix), and cumulative average data are graphically represented in Figures 3 to 6 inclusive.

Blaney Park experimental site. Figure 3 shows the percentage of control of the five individual fungicides used at Blaney Park for the three-year period on green number three. Cadminate and Tersan were used for two years only. As is readily noticed, Acti-dione gave the best control--92 per cent. C&C 1025 gave the next best control--87 per cent. Calo-clor ranked third with 85 per cent control. Fourth was Tersan, with 84 per cent control. Fifth was Cadminate, with 82 per cent control. The control plot at this site was 50 per cent damaged.

Cedarville experimental site. Figure 4 depicts the percentage of control of the five selected fungicides on green number three. At this site Calo-clor ranked first in controlling the pathogen by exhibiting control of 80 per cent. Acti-dione ranked second with 77

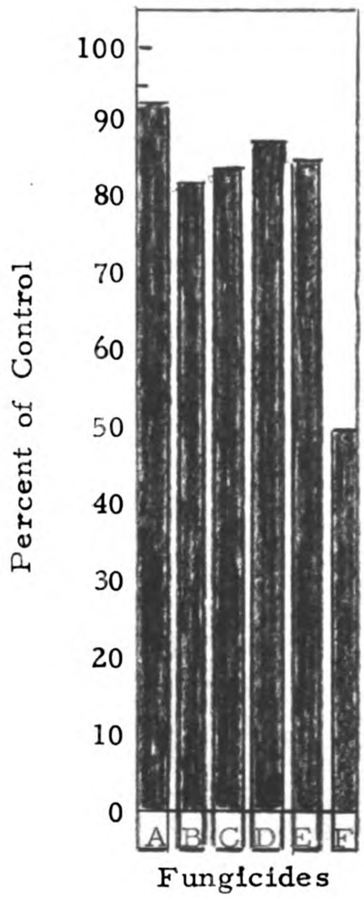


Figure 3

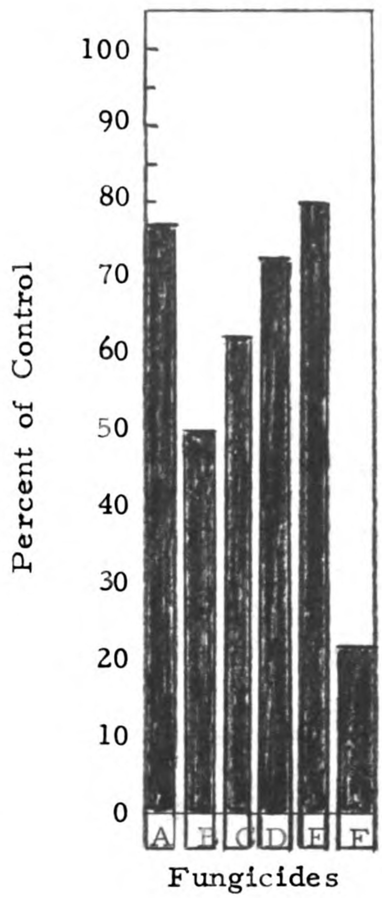


Figure 4

A - Acti-dione
B - Cadminate
C - Tersan
D - C&C 1025
E - Calo-clor
F - Control

Figure 3. Percentage of control at Blaney Park for green 3 (Cadminate and Tersan used for 2 years only).

Figure 4. Percentage of control at Les Cheneaux Club, Cedarville, Michigan, for 2 years, green 3.

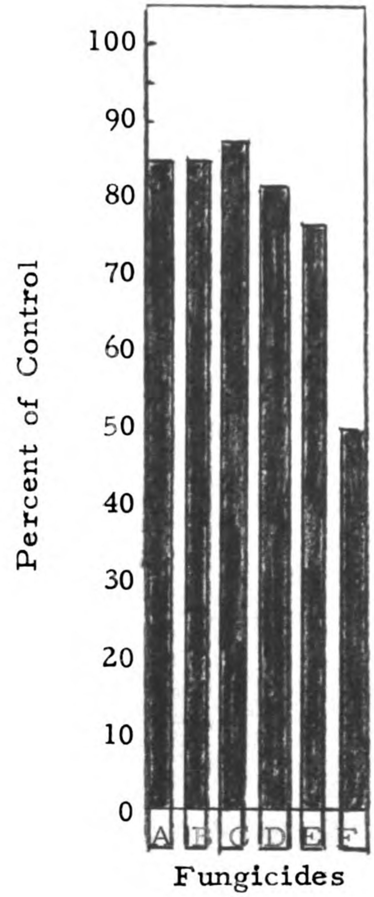


Figure 5

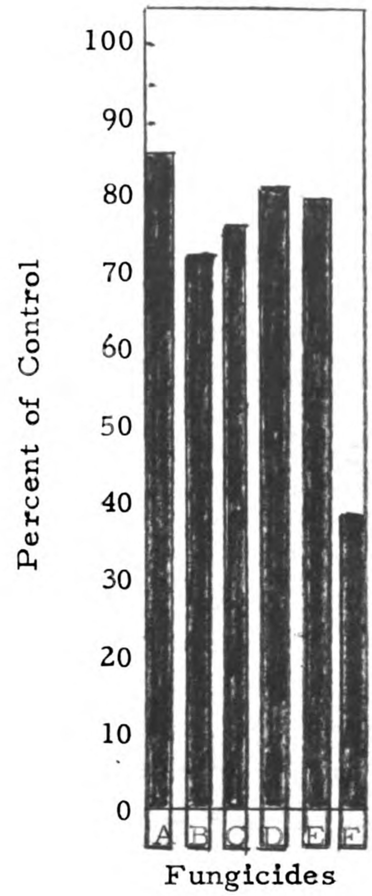


Figure 6

A - Acti-dione
B - Cadminate
C - Tersan
D - C&C 1025
E - Calo-clor
F - Control

Figure 5. Percentage of control at Soo Country Club, Sault Ste. Marie, Michigan, for 3 years, green 3 (Cadminate and Tersan used for 2 years only).

Figure 6. Percentage of control for all three greens for 3 years (exception: Cedarville was done for 2 years only).

per cent control. C&C 1025 was third with 72 per cent control; Tersan was fourth as a controlling compound by a limiting control of 62 per cent. Cadminate ranked fifth by exhibiting 50 per cent control. The control plot as this site was damaged 78 per cent.

Sault Ste. Marie experimental site. Figure 5 shows the percentage of control of the five selected fungicides on green three at this location. Tersan ranked first as a control by exhibiting 87 per cent control. Acti-dione and Cadminate ranked second, each giving 85 per cent control. Third was C&C 1025, with 82 per cent control, while last in effectiveness was Calo-clor, with 77 per cent control. The control plot at this site was damaged 50 per cent.

Results at the three locations. Figure 6 shows graphically, the average percentage of control for all five fungicides at all three sites for the three-year experimental period. Here it will be noted that Acti-dione ranks first, with 87.7 per cent control. C&C 1025 was second, with 82 per cent control. Third was Calo-clor, with 80 per cent control. Tersan was fourth, with 77 per cent control. Fifth, and last, was Cadminate, with 72 per cent control. The control plots on these greens showed an average of 62 per cent damage over the entire period.

Results of Laboratory Studies

The data obtained from the observations on radial growth in culture are presented in detail in Table V (Appendix) and represented graphically in Figures 7 to 10, inclusive. In these figures it will be noted that the average radial growth of the pathogen in the control plates was 33.75 mm.; maximum growth (in plates 1 and 3) was 37 mm., while a minimum growth of 25 mm. was noted for plate 2. The graphs are based upon growth attained at the conclusion of the experiment.

Figure 7 shows the average growth of Typhula sp. in Petri plates, each containing 50 ppm. of one of each of the five fungicides (see also Table IV). As is readily noticed, Acti-dione gave the best control by keeping radial growth of the pathogen static. Tersan ranked second best in controlling growth at this concentration by limiting average radial development to 5 mm. and maximum growth in any plate to 10 mm. Calo-clor was third, which, on an average, inhibited growth of the fungus to 21.50 mm.; followed by Cadminate, which restricted average growth to 22.75 mm.; and lastly, C&C 1025, which limited average growth to 33.75 mm.

Figure 8 depicts the average growth of the organism in Petri plates, each containing 100 ppm. of one of each of the five fungicides.

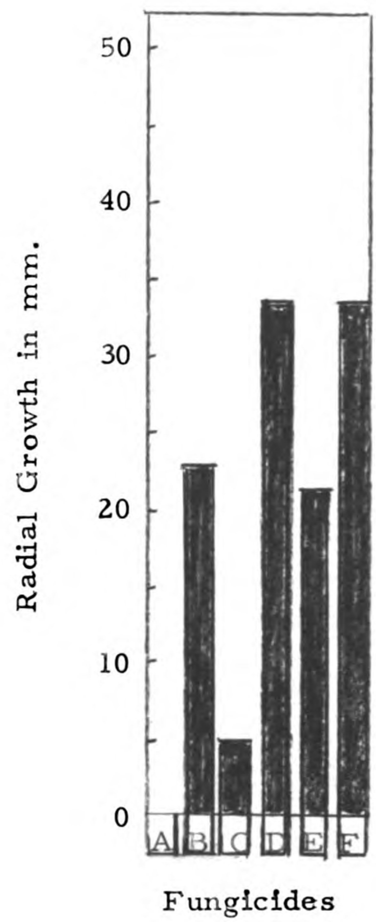


Figure 7

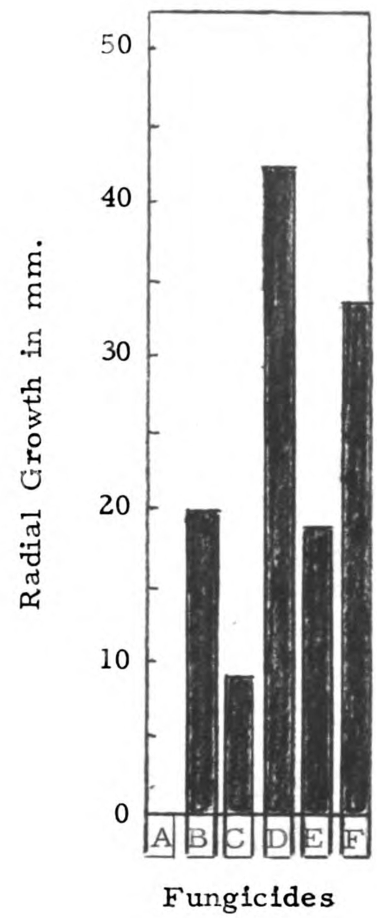


Figure 8

A - Acti-dione
B - Cadminate
C - Tersan
D - C&C 1025
E - Calo-clor
F - Control

Figure 7. Growth of *Typhula* sp. in medium containing 50 ppm. of all five fungicides.

Figure 8. Growth of *Typhula* sp. in medium containing 100 ppm. of all five fungicides.

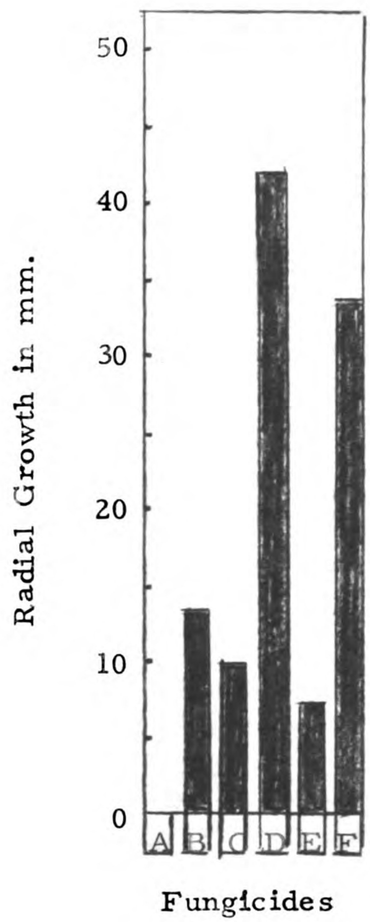


Figure 9

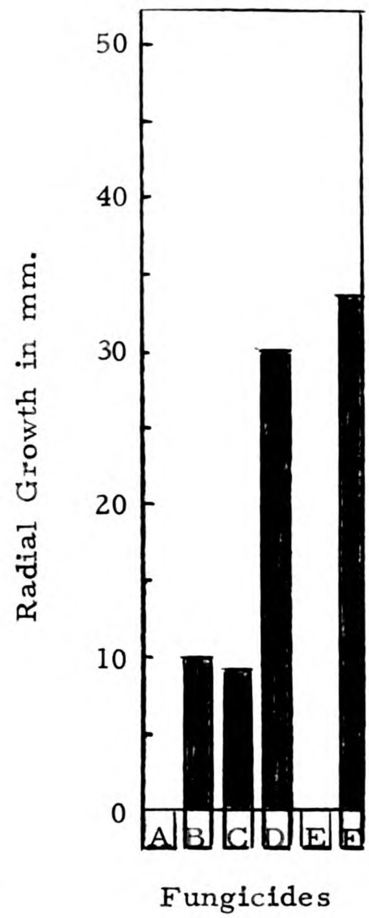


Figure 10

A - Acti-dione
B - Cadminate
C - Tersan
D - C&C 1025
E - Calo-clor
F - Control

Figure 9. Growth of <u>Typhula</u> sp. in medium containing 250 ppm. of all five fungicides.

Figure 10. Growth of <u>Typhula</u> sp. in medium containing 500 ppm. of all five fungicides.

Here, again, Acti-dione completely inhibited growth, while Tersan ranked second, limiting average radial growth to 9.75 mm. Ranking third was Calo-clor, with an average of 18.50 mm. of growth, followed by Cadminate, with an average growth of 19.75 mm., and C&C 1025, with 40.25 mm. of growth.

In Figure 9 the radial growth is shown in the medium containing 250 ppm. of one of each of the five fungicides. Acti-dione, again, completely inhibited growth, while the next-ranking fungicides were Calo-clor, with an average growth of 7.25 mm., and Tersan, with an average of 10.25 mm. Cadminate gave the fourth-best degree of control, limiting growth to an average of 13.75 mm., while C&C 1025 ranked a poor fifth, with radial growth controlled at 44.50 mm.

In the fourth concentration of fungicides, plates with 500 ppm. of each of the five fungicides were prepared. Acti-dione and Calo-clor both completely inhibited growth. Following these two was Tersan, which limited radial growth to 8.50 mm. Cadminate limited growth to an average of 9.25 mm., and C&C 1025 was once again a poor fifth, with growth at 30.00 mm. Figure 10 depicts the results at this 500 ppm. concentration.

The probably significance of these observed results will be discussed, together with the results obtained from the field studies, in the section of this paper which immediately follows.

DISCUSSION

The number 3 green at Blaney Park was selected because of its previous history as the green most severely attacked by snow mold on this course. It was approximately 6,000 square feet in size and was elevated at the south perimeter approximately two to three feet above the opposite side of the green. In addition, it had a slight depression bisecting it about midway from either side. In the average winter this green is covered with two feet or more of snow. These features all indicate that the locality should be favorable for snow mold attack, and it was rather evident this had, in fact, been severely attacked so consistently because of this location.

In the first year, Acti-dione, Calo-clor, and C&C 1025 were used. The following two years, Cadminate and Tersan were added for the remainder of the experiment. The elevated portion of the green seemed most consistently free from attack, whereas the depressed area seemed to be most frequently attacked. It was on this latter area that the melting ice and snow had lingered the longest. The fungicides used were rotated over these areas from year to year so that each was given the opportunity to cover a portion of these critical areas. As is noted in Figure 3, Acti-dione gave very good control on this green, with approximately 90 per cent effectiveness, while C&C 1025 ranked second, with 86 per cent control and was closely followed by Calo-clor and Tersan, with controls of 85 per cent and 84 per cent, respectively. Fifth was Cadminate, with 82 per cent control. By contrast, the unsprayed control area for this green exhibited 50 per cent infection.

Figure 11 shows the depressed area of Blaney Park green number 3 with typical mottling and coalescing spots of infection. Figures 12 and 13 are close-up views of the same area, showing more distinctly the mottling pattern of infection and typical coalescing of the mycelium. This same pattern of attack will be seen in subsequent photographs taken at the Soo Country Club at Sault Ste. Marie, Michigan, and the Les Cheneaux Club at Cedarville, Michigan (Figures 14 to 19, inclusive).

The mottled areas shown are principally the white, wool-like mycelium which was first observed soon after the snow had disappeared from the green. If now drying winds are obtained soon after, the plants begin to rot and die, and mat down. Some of these brown, dark matted areas are shown in Figure 13.

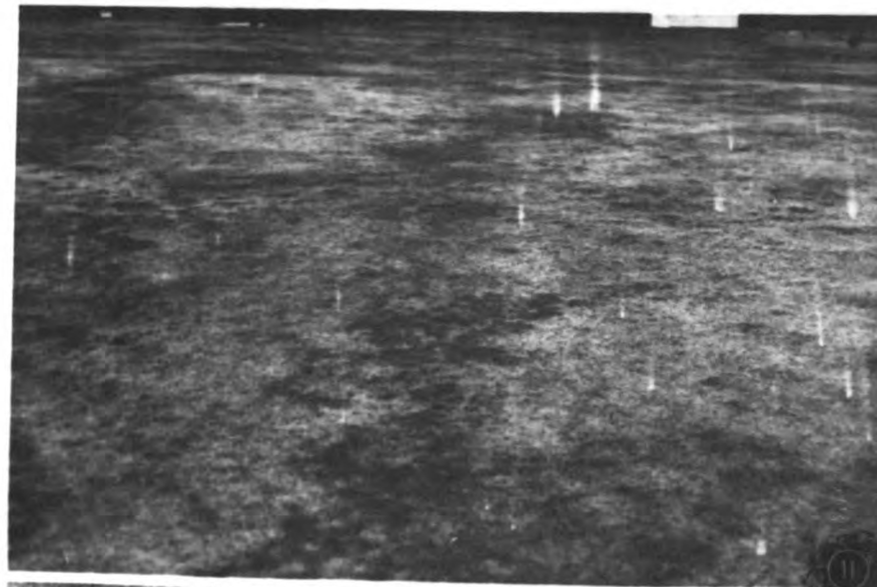
As previously mentioned, the Les Cheneaux Club at Cedarville, Michigan, was substituted for the Portage Lake Club at Houghton,

PHOTOGRAPHS OF GREEN NUMBER 3 AT BLANEY PARK GOLF COURSE, BLANEY PARK, MICHIGAN

Figure 11. Blaney Park green 3, showing depressed area with typical mottling and coalescing of infection spots.

Figure 12. Blaney Park green 3, close-up view showing large infection area.

Figure 13. Blaney Park green 3, extreme close-up view of area attacked by *Typhula* sp.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Michigan, after the first year's tests. Hence, only two years' results of testing for this course are given in Figure 4.

However, this was a most interesting green to test experimentally, since it was flanked on the eastern side by a high snow fence. Consequently, the green was under a snow cover approximately 6 feet deep from early November until late April. It was also surrounded on three sides by heavy woods, which allowed poor air drainage over the green. These factors were considered by the author when he selected the number three green for this field testing program. Due to the abundance of snow on this green, and its slowness in melting clear, the spring visits for recording the results were made later than the spring visits to the Soo Country Club and Blaney Park.

However, it is felt that the results recorded are sufficiently significant to warrant inclusion here. At this later date, some small portions of this green were still covered with snow. On the whole, however, the major portions of each area were clear, and the proportionate areas recorded were typical control for the entire green.

Calo-clor rated number one as the controlling fungicide on this green, giving 80 per cent control. Acti-dione was second with

78 per cent control, followed by C&C 1025, with 73 per cent control. Tersan exhibited 62 per cent control, while Cadminate was 50 per cent effective. This green was quite hard hit by snow mold over the two-year period tested, averaging 78 per cent infection on the control plot.

Figure 15 is a photograph showing a close-up of the white, wool-like mycelium found on this green April 4, 1953. This flossy mycelium was found extensively on this green at this date. The area estimated to be covered was 80 per cent of the control area.

Figure 14 shows typical mottling and coalescing of the affected areas. The light spots are the matted, dead turf. Figure 16 is an extreme close-up view of a portion of the control area, showing, in greater detail, the irregular, mottled, blotched pattern.

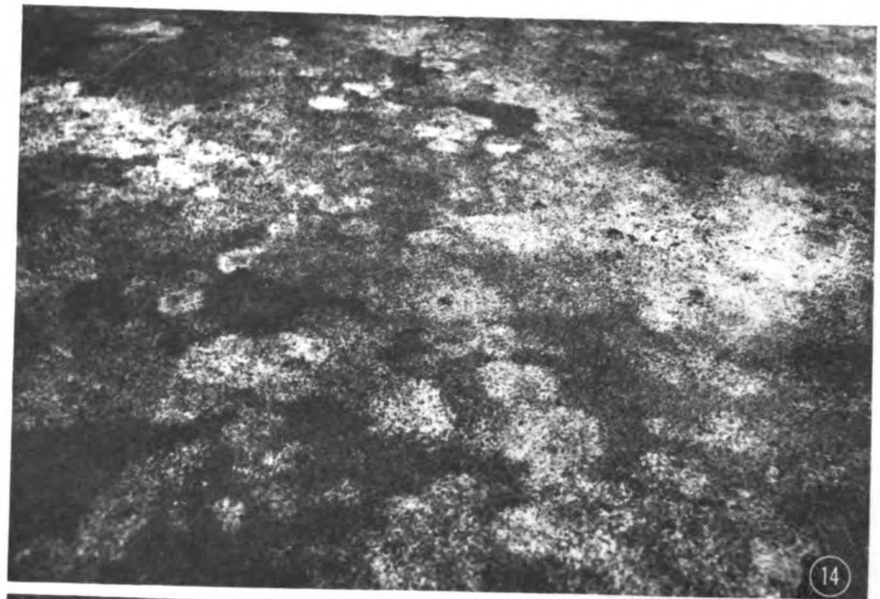
The infected areas seem to grow outwardly from the center, and under favorable temperature and humidity conditions continue to enlarge and unite with each other. It was here noted that, at a later date, these same infection spots showed evidence of beginning recovery in the very center. New blades of grass were in evidence, although very few in number. It was also noted that the new growth appeared much darker in color than the surrounding turf. The affected spots later, and after apparent recovery, also showed this

PHOTOGRAPHS OF GREEN NUMBER 3 AT LES CHENEAUX CLUB, CEDARVILLE, MICHIGAN

Figure 14. Les Cheneaux Club, Cedarville, Michigan, green 3; close-up showing typical coalescing of the infection areas.

Figure 15. Les Cheneaux Club, Cedarville, Michigan, green 3; close-up showing white, flossy, wool-like mycelium of *Typhula* sp.

Figure 16. Les Cheneaux Club, Cedarville, Michigan, green 3; close-up of control area showing clearly the infection pattern of *Typhula* sp.



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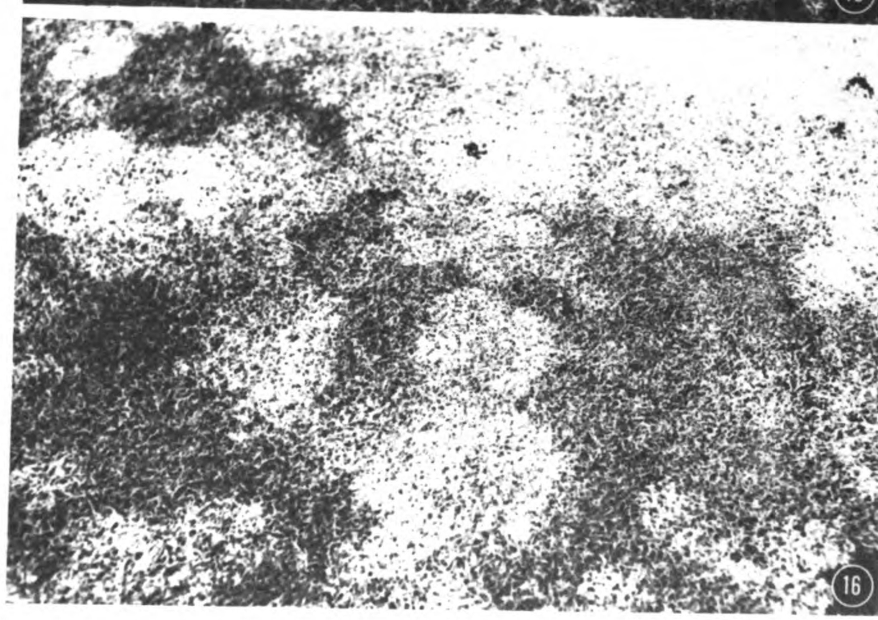

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characteristic smoky blue-green color. This condition also was in evidence at the other two courses studied. This condition gives the green an undesirable appearance, in that the turf coloring is not uniform.

The number 3 green at the Soo Country Club in Sault Ste. Marie was selected for testing on the basis of its past history for infection. It was readily accessible in the spring for early observations, so that a very close check was kept on the progress of snow mold development from the time the snow first began to melt until many weeks after its final disappearance. This green was comparatively high, windswept, and covered by no more than one foot of snow most of the winter. It usually did not become covered until late in November, and was relatively free from snow-cover early in the spring. These, in addition to its high incidence of attack by snow mold in previous years, were the determining factors in the selection of this green for study.

As shown in Figure 5, Tersan gave the best control of the five fungicides used on this green; control was 88 per cent. Following closely are Cadminate and Acti-dione, which gave 85 per cent control each. C&C 1025 ranked third, with a control of 83 per cent, and Calo-clor was last, with 77 per cent control efficiency. For the period studied, the control plot of this green was 50 per cent affected on the average.

Calo-clor has been used by the greenskeeper at the Soo Country Club for the past few years, late in the autumn, for snow mold control. However, he applied it in a dry state and without scientific preparation insofar as method of application and even-coverage were concerned. Furthermore, after application of Calo-clor, the greens were not watered down, as is the usual and recommended procedure for the mercury compounds.

It might be added that the over-all appearance of the greens at this country club was much better than that found at the other clubs under observation. Even so, all of the greens at this course showed evidence of having been attacked by snow mold at various times. Hence, it is doubtful in the author's mind just how valuable the autumnal application of dry Calo-clor on these greens has been.

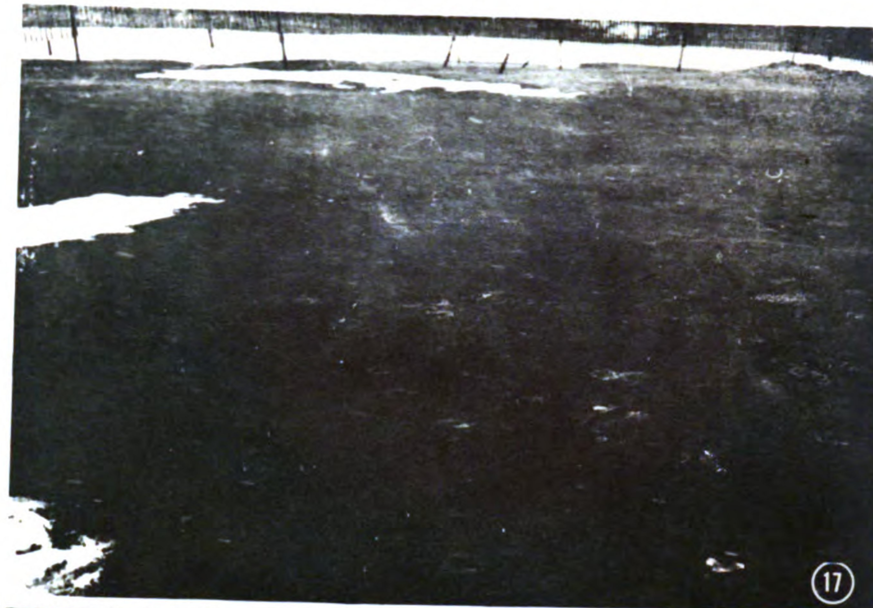
Figure 17 is a photograph showing the very early stages of infection on the untreated green number 8 at the Soo Country Club. Large irregular blotches can be detected on the surface of the turf in this view. These are the white and brownish-white mycelial mats formed at the areas of infection. Figure 18 is a close-up view of one of these mycelial mats; this particular view is of the control

PHOTOGRAPHS OF GREENS 8 AND 3 AT SOO COUNTRY CLUB, SAULT STE. MARIE, MICHIGAN

Figure 17. Soo Country Club, Sault Ste. Marie, Michigan, green 8; early stages of infection of *Typhula* sp.; this green was untreated.

Figure 18. Soo Country Club, Sault Ste. Marie, Michigan, green 3; close-up of mycelium mat on the control area, rather gummy in appearance at this stage.

Figure 19. Soo Country Club, Sault Ste. Marie, Michigan, green 3; control area showing large dried blotches of infectious material on surface of green.



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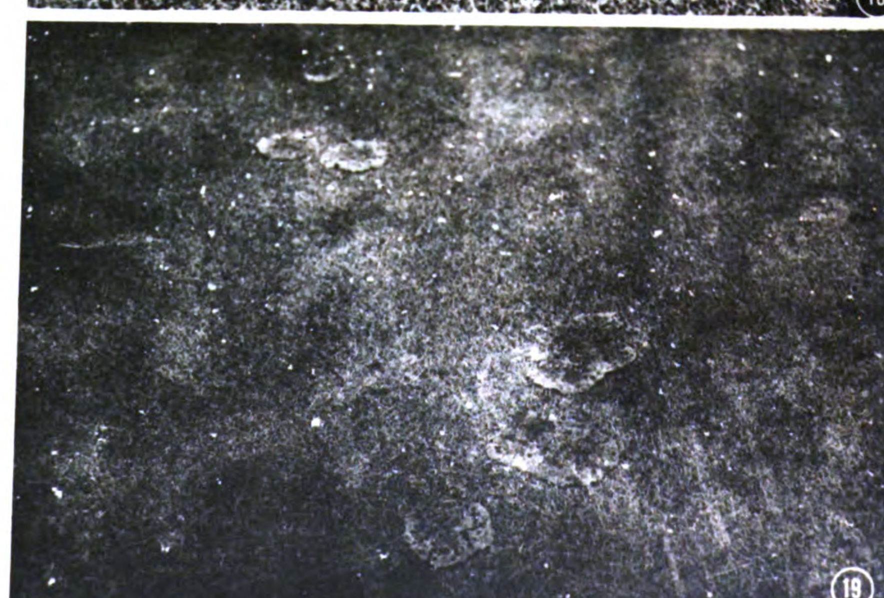

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area of green 3, the green under observation. One will readily notice the flossy-white and somewhat gummy appearance of this spot of infectious material. This is typical of the organism in its earlier stages. Scrapings were taken for laboratory culture from this area in the spring of 1952. It was from this culture that the laboratory correlation work was performed.

Figure 19 is another close-up view showing the irregular blotches of mycelium in early stages on green 3. These measured approximately 4 to 6 inches across at the time they were photographed, and later coalesced to such a degree that they covered many square feet of the control area of the green. At this stage the green was decidedly unsightly, and as the infection increased in quantity and intensity, the turf became less and less pleasing in its appearance. It has been noted at this location that the turf has recovered very slowly each year from the damage incurred by this pathogen. However, it required most of the summer months for such recovery, and all the while the greens have not presented eye-appeal to the golfer. Green number 3, which has been under testing for these three years, has brought favorable comment from numerous individuals in regard to its appearance and state of healthfulness. Many of the persons who made these comments were unaware of the testing program and the author's work on same. They were purely unsolicited remarks of a complimentary nature concerning the aforementioned green.

The graph in Figure 6 summarized results for all three areas under observation for the entire three-year period the program was carried on. The detailed data which form the basis for this figure are given in Table IV.

In the laboratory correlation work, it is of interest to note that the radial growth of the pathogen on the plates of C&C 1025 exceeded the growth on the control plates (Figures 8, 9). It is therefore interpreted that, at the concentrations of 100 ppm. and 250 ppm., C&C 1025 apparently was stimulating to the organism. Moreover, at 50 ppm., average radial growth was exactly equivalent to that of the control, while at 500 ppm., slight inhibition was shown. It is difficult to explain the effectiveness of C&C 1025 in the field when, in the laboratory, at least in certain concentrations, it appeared to stimulate growth of the pathogen. The mode of application, time of application, stage of development of the pathogen, or some unknown factors such as the effects of competing soil organisms, must have been decisive in bringing about its effectiveness in the field. Except for this one exception, there is comparatively good correlation between the laboratory and field results. Acti-dione, then, ranked first in the field and first in the laboratory. The other three compounds of Calo-clor, Tersan, and Cadminate rated 2-2, 3-3, 4-4, respectively.

The five fungicides used were selected for a representative sampling of the many types of available fungicides. Since this was the first time an experiment of this type was known to have been attempted in the State of Michigan, it was felt that representatives of various classes or types of fungicidal agents should be tested. Represented in this sampling are an antibiotic (Cycloheximide = Acti-dione), and organic cadmium (Cadminate), and organic sulphur (Tersan), an inorganic mercury compound (Calo-clor), and C&C 1025, which contains chromium and mercury as active ingredients. No consideration was given to the cost or economy of any of the fungicides used in these trials, since the major endeavor was to determine the most efficient fungicide for inhibition or control.

Based upon the aforementioned facts, it is evident that fungicides differ in efficiency from green to green and from year to year. Factors influencing the results may be position and topography of the green, environment, and geographical location. All of these, plus local soil factors, could easily influence the numbers of soil-borne organisms present at any one time in any given area. On the other hand, some consistency was noted, since Calo-clor was rated first at Cedarville green number 3 for two consecutive years. This particular green, with its extremely heavy snow cover, could not be analyzed for disease incidence until later than the other sites. There is a possibility that Calo-clor has better residual action than the other four fungicides, and was thus able to be effective over this longer period of time.

Some challenging questions brought out in this particular investigation, and which may be of interest for future experimentation, concern the following: (1) bent grass varieties; (2) time of spray application; (3) specific action of the fungicides; (4) residual action of the fungicides. It is not known what would occur if the same fungicide were applied to the same plot for a given number of years. Cumulative residual action may affect to a large degree the control attained in subsequent years. There is also the possibility that one or more of the fungicides tested could be detrimental to the natural soil-borne antagonists which may aid in disease control. This could be brought out by a testing method such as that just described.

It also would be interesting to test all available strains of bent grass for varietal resistance; this is known to occur in relation to the other diseases of fine turf. Work of this type would be done by artificial inoculation, not only with *Typhula* spp., but also with *Fusarium* spp., which are also known to cause snow mold. Still another approach is to test for varietally resistant strains among the pathogens.

Another aspect that could be tested would be applications of various fungicides to the plots at varying times, beginning several weeks before "permanent" snowfall is expected, or at intervals during the gradual establishment of the snow cover. There is the possibility that the snow mold organisms may begin to grow actively with the advent of cold weather; thus the mycelium would be much more susceptible to fungicidal action than would dormant sclerotia. Precise timing may allow considerable eradication without reducing the amount of fungicide left available for residual preventative action in the spring. In contrast, fungicidal applications to melting snow could be expected to be efficient if rapidly growing mycelium was present at such a time. A limiting factor in spring applications would be the depth of snow cover resulting in possible excessive dilutions of the fungicide.

Since it is not known whether the fungus was completely killed, or only severely inhibited, in the Petri plates used in the laboratory experiments, a testing program could be set up to determine the extent and rapidity of such fungicidal action. This would be accomplished by transplanting disks of seemingly inhibited mycelium to pure nutrient agar. If this were set up as a time study, the exact number of hours for complete killing to take place could be determined.

SUMMARY

The effects of "winter-kill" on bent grass golf greens on many golf courses in the upper peninsula of Michigan were observed during the summer and early autumn of 1950. This condition was suspected to be pathogenic in origin.

Three representative sites were selected for study, and the worst green, on the basis of past history, was chosen at each of the three golf courses. These courses were located in the vicinity of Blaney Park, Sault Ste. Marie, and Houghton. Because of extreme climatic conditions, a course near Cedarville was substituted for the one at Houghton after the first year of experimental work.

Three, and later five, commercial fungicides were selected for study of experimental control of the "winter-kill," which was determined to be equivalent to Snow Mold disease in which one pathogen is a species of <u>Typhula</u>. The principal fungicide under consideration was Acti-dione, on which considerable experimentation was underway; the other fungicides were chosen for comparative studies of relative effectiveness of control of the disease. These other fungicides were Cadminate, Tersan, C&C 1025, and Calo-clor.

The selected greens were divided into 6 equal plots each of approximately 1,000 square feet area; one of these was assigned as a control plot and each of the other plots was sprayed with a double-strength solution of a particular fungicide. Spraying was done in the late autumn just prior to development of "permanent" winter snow cover. Observations on effectiveness of control were made early in the following spring at snow-melt time; these observations were in the form of percentage of control (i.e., percentage of uninfected or undamaged green area), in comparison to that of the control plot at each site. Spraying and subsequent observations were made over a three-year period including the seasons 1950-1951, 1951-1952, and 1952-1953.

Laboratory studies were made during the summer of 1952 with cultures developed from inoculum from the Sault Ste. Marie site. These studies consisted of five-day observations of radial growth on seeded plates with the observations beginning 48 hours after seeding. The plates were prepared from 2 per cent malt extract agar to which the individual fungicides were added; four serial dilutions of 50, 100, 250, and 500 ppm. were used in this phase of the study. Radial growth was determined in millimeters of mycelial expansion from the focal center of seeding.

CONCLUSIONS

1. The relative ranking of the five fungicides, in order of decreasing effectiveness of control in the field experiments is as follows: (1) Acti-dione; (2) C&C 1025; (3) Calo-clor; (4) Tersan; (5) Cadminate.

2. In the laboratory experiments the ranking, in order of decreasing effectiveness is: (1) Acti-dione; (2) Calo-clor; (3) Tersan; (4) Cadminate; (5) C&C 1025.

3. In the laboratory experiments the C&C 1025 appeared to act as a stimulant to growth, rather than a retardant, at concentrations of 100 and 250 ppm. At a concentration of 500 ppm there was inhibition of fungal growth, but at a concentration of 50 ppm. the growth was equal to that of the control.

4. On the basis of the experimental work the recommendations for control of snow mold disease, with respect to the five fungicides, are as follows:

(a) Acti-dione is the most effective of the five, and, if available, should be used in preference to the others;

(b) All five of the fungicides, since they gave 74 per cent or better control of the disease, can be effectively used in protecting bent grass golf greens in the area studies;

(c) Further experimental work, utilizing time of fungicide application and increased dosages (beyond the double-strength used in these experiments) should be carried out;

(d) Further experimental work should be undertaken to determine the nature of infection and the longevity of the organism in soil surface.

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APPENDIX

The two tables which follow contain all of the "raw" measurement and observation-estimate data obtained during the experimental work on this problem. These data are here included for reference in future work, either by the author or some other person, on this problem.

TABLE IV

SUMMATION OF ALL DATA OBTAINED BY FIELD OBSERVATIONS ON THE EFFECT OF FIVE FUNGICIDES IN CONTROL OF SNOW MOLD DISEASE AT FOUR LOCALITIES IN MICHIGAN
(see text for exact locations of experimental sites)

Localities, Dates, and Averages	Per Cent of Control (undamaged area) by Fungicides					Pct. of Undam-aged Area in Control Plots
	Acti-dione	Cad-minate	Tersan	C&C 1025	Calo-clor	
Blaney Park						
1950	95.0	--[a]	--[a]	90.0	90.0	66.7
1951	95.0	99.0	99.0	95.0	85.0	85.0
1952	95.0	65.0	70.0	75.0	80.0	0.0
3-year avg. . . .	88.3	82.0[b]	84.5[b]	86.7	85.0	50.7
Cedarville						
1951	80.0	60.0	60.0	75.0	75.0	35.0
1952	75.0	40.0	50.0	70.0	85.0	10.0
2-year avg. . . .	77.5[b]	50.0[b]	62.5[b]	72.5[b]	80.0[b]	22.5[b]
Sault Ste. Marie						
1950	60.0	--[a]	--[a]	80.0	80.0	25.0
1951	90.0	90.0	95.0	95.0	65.0	50.0
1952	95.0	80.0	80.0	75.0	85.0	25.0
3-year avg. . . .	81.7	85.0[b]	87.5[b]	83.3	76.7	33.3
Houghton						
1950[d]	95.0[c]	--[a]	--[a]	85.0[c]	85.0[c]	65.0[c]
Fungicide avg. .	85.7	74.0[b]	78.0[b]	82.3	81.0	39.7

[a] Not used (see text).

[b] 2 years only.

[c] 1 year only.

[d] "Average."

TABLE V

SUMMATION OF ALL DATA OBTAINED BY LABORATORY OBSERVATIONS ON THE INHIBITION OF RADIAL GROWTH OF THE SNOW MOLD PATHOGEN BY THE FIVE FUNGICIDES

Concentration	Time	Acti-dione				Cadminate			
		1[a]	2	3	4	1	2	3	4
50 ppm.	48 hours	0	0	0	0	0	0	0	0
	72 hours	0	0	0	0	14	12	15	15
	96 hours	0	0	0	0	18	19	20	20
	120 hours	0	0	0	0	19	20	25	24
	144 hours	0	0	0	0	21	22	28	25
	4-plate average		0.00				22.75		
100 ppm.	48 hours	0	0	0	0	0	0	0	0
	72 hours	0	0	0	0	14	13	14	14
	96 hours	0	0	0	0	18	18	18	16
	120 hours	0	0	0	0	19	19	19	17
	144 hours	0	0	0	0	21	19	20	19
	4-plate average		0.00				19.75		
250 ppm.	48 hours	0	0	0	0	0	0	0	0
	72 hours	0	0	0	0	10	11	10	9
	96 hours	0	0	0	0	11	14	11	10
	120 hours	0	0	0	0	14	15	13	11
	144 hours	0	0	0	0	16	15	13	11
	4-plate average		0.00				13.75		
500 ppm.	48 hours	0	0	0	0	0	0	0	0
	72 hours	0	0	0	0	5	8	5	5
	96 hours	0	0	0	0	8	10	7	7
	120 hours	0	0	0	0	9	10	7	7
	144 hours	0	0	0	0	10	11	8	8
	4-plate average		0.00				9.25		

Fungicides Used: Acti-dione, Cadminate

[a] Numbers 1, 2, 3, and 4 are plate numbers.

TABLE V (Continued)

Fungicides Used												Control			
Tersan				C&C 1025				Calo-clor							
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	20	19	18	18	12	14	17	14	20	15	21	23
0	0	7	7	28	28	29	29	16	18	21	17	28	20	30	30
0	0	9	9	32	29	32	32	17	22	24	17	32	22	35	34
0	0	10	10	38	29	33	35	18	23	26	19	37	25	37	36
		5.00			33.75				21.50				33.75		
0	0	0	0	0	0	0	0	0	0	0	0				
0	0	0	5	19	19	18	24	12	12	14	10				
0	7	7	7	25	27	28	30	17	14	18	14				
7	10	9	7	33	33	35	38	19	17	20	15				
10	12	10	7	37	40	39	45	20	17	21	16				
	9.75				40.25				18.50						
0	0	0	0	0	0	0	0	0	0	0	0				
0	0	0	0	18	19	18	17	0	0	0	0				
3	4	4	4	27	27	26	23	0	6	6	5				
6	7	9	9	35	36	36	32	0	9	8	8				
10	9	10	12	43	41	44	38	0	10	10	9				
	10.25				44.50				7.25						
0	0	0	0	0	0	0	0	0	0	0	0				
0	0	0	0	15	15	13	14	0	0	0	0				
0	0	0	0	23	22	18	20	0	0	0	0				
6	7	10	6	30	28	22	25	0	0	0	0				
6	11	11	6	35	31	26	28	0	0	0	0				
	8.50				30.00				0.00						