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A New Chemical Control for Clover in Turf

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In field screening tests for a number of chemicals for crabgrass control, Cornell University has discovered what may well be the long-awaited control for clover in turf. In the plots treated with disodium 3,6-endoxahexahydrophthalate (endothal) we observed that although crabgrass was not controlled, the clover had been entirely eliminated. To follow up this new discovery field experiments were laid out at Cornell beginning in September 1950. While many phases of the work need further investigation, the results of our preliminary tests are so striking that we wish to present them here as a matter of general interest.

What is White Clover?

White clover (Trifolium repens) is found in practically all regions of the United States where a good supply of moisture is available. There are, in general, three size classes of white clover. The large types, the most important of which is Ladino, are prominent pasture and forage legumes. The intermediate types include such southern strains as Louisiana white and New Zealand white. The small or low-growing types are more common to the closely grazed northern pastures. For some of these low strains the names of wild white, New York wild white, and Kent wild white have been publicized. Since the seed of the large, intermediate and small types cannot be separated by eye, the white clover found on permanent pastures, golf courses, lawns and turf areas in general may be a mixture of the intermediate and small types. This mixture has become known as white Dutch clover, a name without definite meaning in a botanical sense. For purposes of simplicity this common white clover will be referred to here simply as "white clover".

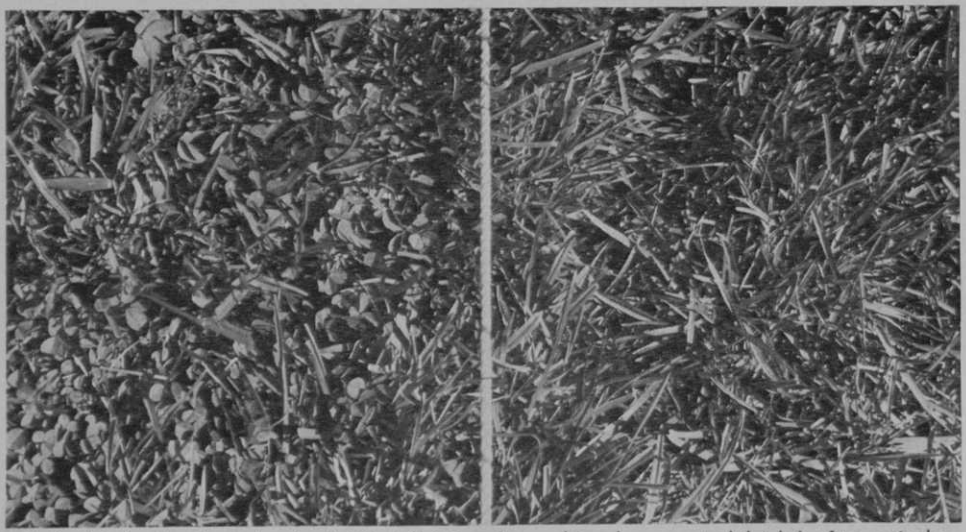
The Clover Problem

White clover is the foundation legume of most northern pastures because of its high-yielding, nutritious forage and because of its nitrogen-supplying capacity. With the growing trend toward grassland agriculture, more and more emphasis is being placed on white clover. In the production of turf, however, the picture is quite different. On golf courses, clover is definitely objectionable. Because of its coarse texture and horizontal habit of growth it does not support the ball adequately for making good fairway shots and during the flowering period its myriad of white blossoms camouflage golf balls lying on fairways and closely mown roughs. On greens it produces an uneven, slow putting surface. On athletic and play fields clover is slippery, does not withstand heavy play, and produces so-called grass stains on clothing. While home owners disagree as to the desirability of clover, enough have come to dislike it so that clover is often omitted from better lawn mixtures.

How Clover Grows

White clover is a rapid-growing perennial which develops in a manner similar to that of the strawberry plant. A relatively short tap root is produced under the crown but the plant spreads mainly by creeping stems which root at the nodes. Thus a single plant may extend over quite an area to produce the characteristic patchy appearance. Once established, this legume is very persistent. The white blossoms produce many seeds and these remain viable in the soil for long periods. This accounts for the frequent springing up or "volunteering" of clover where no seed has been sown. In most northern pastures it can be induced merely by suitable fertilization and grazing practices and it appears spontaneously under the maintenance practices of most golf courses and athletic fields.

White clover begins to grow in early spring and the plants remain green until late fall. Seeding plants will blossom by fall and will produce seed abundantly the second and third years. When closely cut



Turf plot showing typical untreated turf (left) and complete clover control (right) after a single endothal spray. Endothal was applied in October and photographs of treated and untreated areas were made on May 1st.

by mowing or grazing the plants may bloom all season. White clover is found under a great variety of conditions but grows best on moist, fertile, better drained soils. It is commonly found on heavier clay soils where drainage is fair, organic matter adequate, and acidity not excessive. Its growth is promoted by liberal use of phosphate fertilizer and lime. Seasonal conditions are of major importance in affecting its natural occurrence, fluctuation and distribution. White clover will tolerate limited drought but will disappear under natural conditions in excessively dry years, regardles of the management or fertility treatments. On the other hand it responds to irrigation but will not persist under continuous flooding. In general agriculture there are "clover" and "non-clover" years depending upon climatic conditions.

Intensive Management

Many of the natural environmental factors encouraging clover are amplified by management programs. High fertility levels promoted on golf courses, for example, tend to encourage clover infestation, particularly if fertilizers high in phosphate and potash are used. The frequent irrigation required on golf greens and some fairways improve the chance of clover survival. This is particularly true where bluegrass-fescue fairways are watered. Bluegrasses and fescues do not persist under frequent or excessive watering so that their reduced vigor opens the way for clover infestation. Even in unwatered lawns and fairways, close clipping weakens the permanent grasses and thus reduces the competition to clover. Aerification and other soil cultivation practices may bring new sources of seed to the surface. Disease or insect damage which thins out the turf also encourages the growth of this persistent legume.

Management Practices

Knowing that abundant lime, phosphate, and potash stimulate clover, the farmer increases the clover stand by providing these materials. The problem of clover control has been the subject of countless discussions among turf men. While various more extreme theories have had their proponents, a balanced judgment indicates that the only real ecological control measure available is to provide the grasses with the best possible situation for strong competition with the clover, i.e., reverse the practices of the dairy farmer. Thus the general practices of liming only when necessary for the grasses, relatively high nitrogen fertilization, moderately high mowing, and studied restraint in irrigation will tend to discourage clover. But the gains from such a program are only gradual and results are often confused by natural fluctuations in clover populations induced by seasonal conditions. There is a pressing need for assistance by the use of selective chemicals.

Chemical Control to 1950

In the past numerous chemical control measures have been employed, mostly with mediocre success. In recent years much hope was held for the 2,4-D materials so effective against plantain and dandelion. Unfortunately, 2,4-D has not been particularly effective and this hormone material now has few proponents for clover control. The older and more dangerous sodium arsenite remained as the chief chemical means for the control of clover. In the experienced hands of care-

ful workers sodium arsenite has been fairly effective even though it is far from an ideal material for the purpose. Sodium arsenite has a very small latitude of selectivity and there is constant danger that a slight error in application or judgment of weather conditions will produce serious injury to the turf grasses. Repeated applications are necessary, for while a single application will kill the clover leaves, there is prompt regrowth. Repeated leaf removal will gradually deplete food reserves until the clover plants die. Thus there is great need for a chemical that will eliminate clover by a single application without serious injury to the turf and without the danger that a small miscalculation will result in serious turf destruction. Endothal promises to fill this need.

Experiments with Endothal

The experiment that led to the discovery of endothal as a good clover control agent was conducted in Westchester County, New York, at the Willows Country Club in August and September 1950. One of ten materials included in the test, endothal, had failed in the role of a crabgrass herbicide. It was during a secondary observation designed to note the effect of the ten materials on the control of weeds other than crabgrass that this new clover control was first sighted. Experiments were designed to verify this discovery and to investigate intensively the use of endothal for clover control.

The first problem was to discover what rates of endothal would be most effective. The rates used in the crabgrass experiments had been arbitrarily selected at 8 and 16 pounds per acre because of lack of previous experience with the material. Since 8 pounds of endothal per acre had entirely eliminated clover, this rate was selected as the maximum for the new experiments. Considerable injury to the permanent grasses had resulted at this rate making it necessary to work toward lower concentrations. After two preliminary experiments it was found that rates as low as 4 pounds per acre eliminate all clover but still caused considerable discoloration and injury to the grasses. Two more tests at still lower rates were made to find a level where clover would be eradicated with a minimum of turf injury. The folowing data and discussion are the result of these latter two experiments.

Rates of Application

This experiment was conducted on a bluegrass-ryegrass turf on the grounds of Cornell University. Rates chosen included 0, ½, 1, 2, 4 and 8 pounds per acre of endothal in 100 gallons of water per acre. The experiment was devised in a 6 by 6 latin square, with six replicates of each treatment. The plots were 6.5 feet square. A single application was made on October 4, 1950. In less than one week the clover leaves had turned brown and dropped from the plants in all plots except the check. The clover plants soon withered and disappeared. The final analysis of these plots was postponed until the following spring. On April 21, 1951 injury ratings were made on this experiment, followed by a clover analysis on May 1. The data from these findings were analyzed statistically and the results are presented in Table 1. The clover analysis was made by estimating the percent of area covered with clover. Square foot quadrats were used and two samples were taken from each plot. This analysis was essentially only a formality for it was quite obvious that there was no clover present on any plots except the checks. This is borne out in Table 1 below.

The turf injury ratings tell a different story. Injury to the grasses increased progressively from the lower to the higher rates of chemical. At the two lower rates (½ and 1 lb./A) injury was not greatly different from the check plots, which also registered some discoloration due to drift from adjacent treated plots. The ratings were based on an injury scale progressing from 0 to 5, with 0 indicating no injury or discoloration, and 5 indicating very severe to complete kill of the turf. The injury figures given in Table 1 are the sums of the injury ratings for all replicates of the same treatment. For example, if all six check plots have been given a ranging of 1, the figure which would have appeared in the volume headed "Turf Injury" would have been 6.0 instead of 6.75. Similarly, if all six replicates of

TABLE 1
CLOVER CONTROL IN TURF WITH ENDOTHAL

Clover control and turf injury resulting from various rates of endothal in 100 gallons of water per acre

Endothal pounds per acre	Clover remaining	Turf Injury	Rank of Significance 1% level
½	0	9.75	*
1	0	12.50	*
2	0	13.50	**
4	0	20.50	***
8	0	23.25	***
Check	58%	6.75	
LSD_{05}		4.40	
LSD_{01}		6.00	

Application date October 4, 1950
Turf injury analysis April 21, 1950
Clover analysis April 21, 1950
Turf injury scale:
0.0 = no injury
30.0 = severe to complete kill

the 8 lb./A treatment had been given the maximum rating of 5, the corresponding injury figure in this table would have been 30 instead of 23.25.

It was quite obvious that the lower rates of endothal would effectively eradicate clover with only moderate injury to the grasses. A further aspect to be studied, however, was that of gallonage. What effect, if any, would different gallonages have on the results of any given rate of chemical per acre? Would the material be effective at low volume or would it be necessary to use less desirable high gallonages? The next experiment was designed to investigate these points.

Volumes of Spray Material

For this phase of the study, rates of 0, 1, 2, 4 and 8 pounds per acre of endothal were chosen, each to be applied in 10, 50, 100 and 200 gallons of water per acre. The design was a randomized replicated block with plots 6.5 by 15 feet. Each treatment-gallonage combination was repeated three times. A single application was made on October 11. Injury ratings and clover estimates were made on May 1 in the same manner as in the previous experiment and again the data was analyzed statistically. Results in Table 2.

Table 2 shows quite clearly that gallonage did play a very important part in the results. A definite rate-gallonage relationship existed. From table 2 it can be seen that there was little difference in discoloration or turf injury at any of the tested rates when endothal was applied in 10 gallons of water per acre. Discoloration was significantly greater than on the untreated plot but not serious (as indicated by a single star). Further it can be noted that the 1 pound per acre rate of endothal gave practically the same degree of turf injury regardless of the amount of water applied. The 2 pounds per acre rate showed a similar trend at the two lower gallonages, but injury was progresively more serious at the 100 and 200 gallons per acre volumes. At rates above 2 pounds per acre of endothal, turf injury became increasingly more serious as gallonage increased. Eight pounds of endothal in 200 gallons of water per acre caused the greatest injury in the test.

Clover analysis figures in Table 2 indicate that some clover remained in three out of four treatments at the 10 gallons per acre volume. The amount is relatively insignificant based upon amounts remaining in the untreated plots, but it is apparent that while high gallonage increases turf injury, adequate coverage is necessary for complete clover eradication.

TABLE II
CLOVER CONTROL IN TURF WITH ENDOTHAL
Effects of gallonage-rate combinations on clover control and turf injury

Endothal pounds per acre	Gallons per acre	Clover percentage	Turf Injury	Rank of significance 1% level
1	10	1.1	4.5	*
2	10	0.3	5.0	*
4	10	0.3	4.5	*
8	10	0.0	4.5	*
1	50	0.0	4.5	*
2	50	0.0	2.5	*
4	50	0.0	10.0	**
8	50	0.0	9.0	**
1	100	0.0	2.5	*
2	100	0.0	5.5	**
4	100	0.0	10.0	**
8	100	0.0	12.0	***
1	200	0.0	3.5	*
2	200	0.0	6.5	**
4	200	0.0	11.5	***
8	200	0.0	14.0	***
Check	0	39.0	0.0	
LSD_{05}			3.99	
LSD_{01}			5.42	

Application date — October 11, 1950
Turf injury analysis — May 1, 1951
Clover analysis — May 1, 1951
Turf injury scale:
0.0=no injury
15.0=severe to complete kill

The figures in Tables 1 and 2 indicate that at rates of 4 and 8 pounds of endothal in 100 or 200 gallons of water per acre there was a marked thinning out of the turf. In making field observations it was noted that what turf remained in these plots was dark blue-green while that in the untreated plots and plots receiving lighter applications was a brighter and definitely more yellow-green. All ryegrass had been eliminated from the turf. The elimination of ryegrass from a bluegrass turf has promising practical aspects. Also, this suggests that had our plots contained more bluegrass the injury ratings for some plots would have been much lower. Further observations on the selective effect of endothal on various grass species are being undertaken.

Practical Aspects

Based on work to date it appears that clover can be eradicated from mixed fairway, park or lawn turf by a single autumn application of endothal at rates as little as 50 gallons of water per acre. Lower rates may be satisfactory, but their effects are yet to be investigated.

Endothal has two faults that prevent it from being an ideal material. It is a toxic material, approximately as poisonous as sodium arsenite, so it must not be handled carelessely. Also, at the rates and gallonages used in these experiments the turf was temporarily browned by the applications even at the lower rates. This browning may be much less at the minimum effective rates, a problem requiring further testing. Even if the burning effect cannot be reduced, the fact that effective applications can be made in the autumn, when turf use is lessened and when grass growth is most vigorous, makes temporary discoloration of less importance. With these two exceptions endothal seems an almost ideal material for clover control. It is readily soluble, it seems to be adapted to the convenient low volume-low pressure apparatus used for 2,4-D work, and a single application of a small amount of the chemical appears to be adequate for clover eradication. The cost of the material*, while not yet fixed, will probably be low enough to be appropriate for inclusion in the most modest turf budget.

Problems Ahead

While considerable information has been gained about the use of endothal for clover control by experiments to date, much work is yet to be done before complete recommendations can be made. Obviously we have not yet determined the minimum rates of application necessary nor do we yet know the minimum gallonage (apparently between 10 and 50) needed for adequate coverage.

While results of the present fall treatments seem conclusive, verification is needed. We need to know for how long the endothal will be effective—how long it will be before clover reappears. This will require periodic clover counts, a follow-up of the present experiments, as well as additional tests. In addition to fall treatments, information is needed and experiments are under way to determine the effects of spring and summer applications. While fall would seem to be an ideal time to treat clover, conceivably there would be situations where spring or summer applications might be necessary. There is also need for comparisons between spring, summer, and fall treatments as to clover control and turf injury.

Information will also be needed on compatabilities with other chemicals. While it is known that endothal and chlorates are not compatible, it is conceivable that both endothal and 2,4-D can be applied at the same time in the fall or early spring. Since both materials are adapted to low-volume applications, and since fall applications are effective with both, time and labor would be saved by combined applications. Perhaps other materials, such as fungicides for snowmold prevention, might be compatible with endothal. Thus experimentation is needed to explore these avenues.

Last, but by no means least, we expect to gather information on the use of endothal on bentgrass turf. Will it be suitable for watered bent fairways where clover is commonly such a pest? Can it possibly be used on putting green turf?

It seems to us that the importance of this discovery and the amount of information gathered to date demands further immediate research. For the coming year much of our time and efforts will be directed along these lines. Obviously we can not at this time make general recommendations for the use of endothal for selective clover control in turf, but there is reason to hope that sufficient information will be uncovered during this season to make recommendations possible.

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