TURF CULTURE

Published by the United States Golf Association Green Section in the Interest of Better Turf for Golf Courses, Lawns, Parks, Recreation Fields and Cemeteries

CONTENTS

JANUARY, 1939

Volume I Number 1

TURF CULTURE

Published by
UNITED STATES GOLF ASSOCIATION GREEN SECTION

Office of the United States Golf Association Green Section

For regular mail—P. O. Box 73, Benjamin Franklin Station, Washington, D. C.
For telegraph, special delivery mail and parcels—Room 5632, South Building, Department of Agriculture, Washington, D. C.

SUBSCRIPTION . . . . . $4.00 PER ANNUM

TURF CULTURE

Volume I JANUARY, 1939 Number I

INTRODUCING "TURF CULTURE"

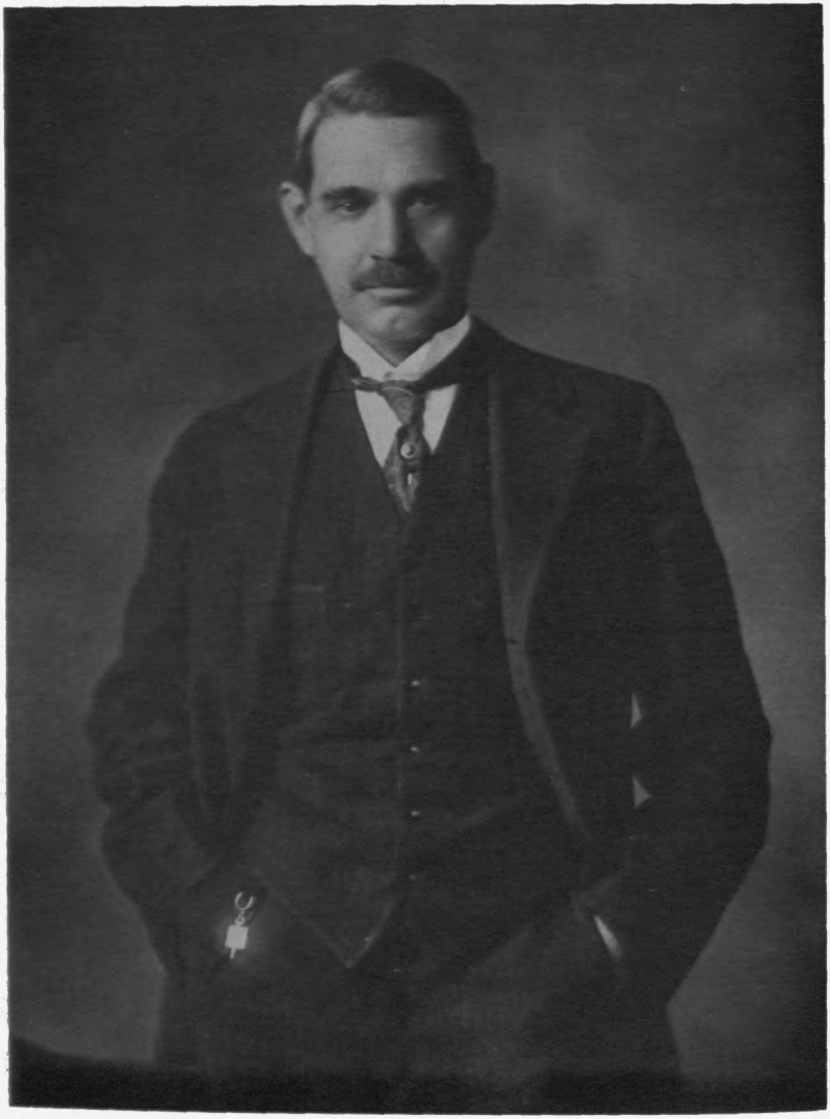
FRANK M. HARDT*

Apparently the first systematic study of grasses in this country for turf purposes was begun as early as 1885 by Mr. J. B. Olcott at South Manchester, Conn. Mr. Olcott traveled extensively and collected samples of promising grasses from various places in this country as well as in Europe, New Zealand, and Australia. These selections were made primarily from the standpoint of their lawn possibilities.

Later, as the interest in golf became more general and as golfers demanded better playing conditions, the men who were in charge of some of our principal golf courses were far-sighted enough to realize that ultimate improvements in turf could best be obtained by a scientific study of the various problems encountered in raising turf on golf courses under widely different soil and climatic conditions.

As a result, a cooperative agreement was drawn up between the United States Department of Agriculture and the United States Golf Association for a program for the study of turf grasses. This work was begun in 1920 under the direction of the late C. V. Piper, of the Bureau of Plant Industry, and has continued to date. During that interval extensive experimental work has been conducted in various parts of the country to determine the best grasses, the most effective fertilizers,

* Chairman, Green Section Committee.



Dr. C. V. Piper (1867-1926), under whose direction the Green Section investigations were inaugurated in the Bureau of Plant Industry in 1921 and whose dynamic influence was felt even after his death.

disease and insect remedies, and to develop cultural practices which will lead to the improvement of turf.

The results of these studies were made available to the public through the Bulletin of the Green Section of the United States Golf Association. The Bulletin was published from 1921 to 1933, inclusive. Since 1933 a few scattered mimeographed and printed pamphlets have been issued under the name of Turf Culture. The material published in those issues was of a different type from that intended for this new publication under the same name. The old series had a limited circulation and many numbers are already out of print. Any material of permanent value in them will be republished in the new series as opportunity is provided, so the old series may be ignored. Therefore, this issue is put out as Vol. I, No. 1, of a new series of TURF CULTURE, which is planned to be a permanent periodical devoted to the dissemination of information pertaining to the establishment and maintenance of turf.

The field covered by TURF CULTURE will be broader than that embraced by the old Bulletin. The new periodical will contain articles of interest to all workers concerned with the establishment and maintenance of turf on private lawns, parks, sports fields, cemeteries, airports, as well as golf courses.

Generally speaking, there will be three sections in each issue. In the first, original articles will give the results of scientific research or of large-scale practical applications of newly developed principles. In the second section summaries will be given of recent results of other workers on such subjects as may be of interest to those concerned with turf culture. Through the original papers and the reviews of published results of other workers, we thus will endeavor to keep our readers informed on the recent developments in the numerous fields

of scientific investigation which seem to contribute to turf improvement. In the third section, headed "Our Letter Box," readers will find correspondence which will be helpful not only to the original inquirer but also to many others who have similar problems.

Dr. R. A. Oakley (left), 1880-1931, of the Bureau of Plant Industry, and Dr. W. S. Harban (right), 1857-1938, were both active in the establishment and development of the Green Section. Dr. Harban was Vice President of the United States Golf Association when the Green Section was organized and served on the Green Section committee from 1921 until his death.

The plan is to group the articles wherever practical in such a way that the major papers in any one number will be centered around one particular subject. This arrangement will serve to focus the attention of our readers in turn on each of the numerous angles of turf culture, as well as to facilitate reference at some later date to material published in earlier numbers. Following this policy no attempt will be made to keep the issues a uniform number of pages.

It was natural perhaps that the golf enthusiasts should be among the first to be vitally concerned with improving the qualities of turf, since it contributes so much to their enjoyment of the sport. Many of the problems of raising turf having the especially fine quality required for putting greens are seldom encountered except on golf courses. However, by far the larger turfed areas of the golf course are the fairways, tees, and rough. The problems faced in improving the cultural practices on these large areas are essentially identical with those faced by anyone interested in the establishment and maintenance of superior turf on private lawns, parks, sports fields, cemeteries, road shoulders, airports, and other turfed areas. The results of our investigations of these problems should therefore be equally helpful to all those concerned with the raising of turf.

W. D. Vanderpool, as Secretary of the United States Golf Association, was influential in the organization of the Green Section and has been one of its staunchest supporters since its inception.

The United States Golf Association feels therefore that by the establishment of this publication, TURF CULTURE, it offers an authoritative organ created to serve the best interests of the golfing public, the professional greenkeepers, and that large group of individuals who are interested in improving turf for many purposes.

BUREAU OF PLANT INDUSTRY WELCOMES TURF CULTURE

M. A. McCALL*

The grasses make up the most important group of plants on this earth. The value of the grasses grown in the temperate zones lies in two essential uses—as food for men and animals and as a ground cover. Various members of the grass family have been cultivated for food purposes for centuries. In addition to those which are grown for grain, the cereals, there is the even larger group of grasses which provides the principal feed supply of our livestock. Grasses are used also to retain or improve the soil, but even when planted for that primary purpose they have usually been considered as well from the standpoint of providing feed for livestock.

Another most important use of grass, and the one we are interested in here, is as a ground cover in the many and varied situations where it is desired to have a low dense mat of foliage easily maintained throughout the season. Such a covering of turf is required on many areas such as lawns, parks, golf courses and other sports fields, cemeteries, airports, roadsides, and other places.

When grasses are grown for hay or pasturage, the objective is to produce maximum yields of herbage. On the other hand, when grasses are grown primarily for turf, the objective is to obtain a low dense coverage of foliage but with a minimum yield of herbage so that mowing and other maintenance costs can be kept at a minimum. Many of the grasses used for pasturage and hay are commonly used for the production of turf. Naturally, many of the fundamental principles involved in the

* Assistant Chief, Bureau of Plant Industry, and Member, Green Section Committee.

Airplane view of a small portion of the Bureau of Plant Industry Experimental Farm at Arlington, Va., showing the Turf Garden in the center.

cultivation of these grasses for pastures and hay apply when they are used for turf purposes. If, however, the same species of grass is to give best returns in the way of maximum yields of hay or forage on the one hand, and the best results in turf with a minimum of mowing costs on the other hand, the cultural practices must be modified in some manner to attain these entirely different end products. Different selected varieties of any species of grass may also in part help to attain these distinctly different objectives. Naturally, too, some species of grass that have little or no value for hay or pasturage offer considerable promise for development as turf-forming grasses.

The grasses that are grown for their grain have been studied and improved for hundreds of years. Our Federal and State

experiment stations have long conducted intensive work on these plants. It is only recently, however, that these agencies began intensive study of grasses for hay or pasture purposes, but there is still a minimum of research on grasses for turf purposes. This latter situation should be corrected as rapidly as facilities can be made available.

Part of the grass nursery at the Arlington Turf Garden.

The numerous letters received each year by the Department of Agriculture from one end of the country to the other indicate a widespread interest in turf for lawns, parks, various types of recreational fields, cemeteries, airports, road shoulders, and other areas where the public is interested in getting a maximum of coverage with a minimum of cost and effort. In answering these inquiries the Department of Agriculture makes frequent use of the results of the work conducted cooperatively with the United States Golf Association Green Section.

Federal research work on the culture of grasses is conducted by the Bureau of Plant Industry. Formal cooperation between

this Bureau and the United States Golf Association dates from 1920, though even earlier the Bureau was interested in the problems of turf. The Bureau appreciates the opportunity to cooperate with the United States Golf Association Green Section in any way possible to encourage research on turf, and it welcomes the appearance of TURF CULTURE as a medium through which the results of these studies may be made available to the public. This publication should be of interest not only to the golfing public but also to lovers of beautiful lawns and to those interested in the establishment and maintenance of turf for parks, various kinds of recreational fields, cemeteries, airports, road shoulders, and all other areas where it is desired to get a good coverage with no excessive production of foliage. May it grow and prosper!

Applying chemicals to plots on the Arlington Turf Garden.

ARSENICAL COMPOUNDS FOR THE CONTROL OF TURF WEEDS

JOHN MONTEITH, JR., and JOHN W. BENGTSON *

The control of weeds always has been and probably always will be an important factor in the maintenance of turf. The weeds which are most troublesome in turf vary in different districts. A list of perennial weeds which are pests over a wide range would include dandelions, broadleaf and buckhorn plantain, sheep sorrel, and white clover (which is not always considered a weed in turf). Such a list of annual weeds would include crabgrass, goosegrass and the chickweeds. Certain plants, such as the English daisy along our Northwest Coast, become the most menacing turf weeds in limited regions whereas in other parts of the country they are almost unknown.

Hand weeding was naturally the first resort for keeping lawns and putting greens free from weeds. Hand weeding is practical on small areas but rising labor costs are limiting its more general use. The increasing demand for weed-free turf over large areas has stimulated interest in more economical weed control than is offered by the hand weeding method. Many weeds such as crabgrass and plantain can be removed successfully by hand but the mat-forming weeds such as clover, with a network of rhizomes or stolons running through the turf, are extremely difficult to remove by hand. In any turf where there is a heavy infestation of weeds, hand weeding not only is expensive but it results usually in serious damage to the turf.

It is natural therefore, that those who have been interested in controlling weeds have been hopefully watching the study of chemicals for this purpose. It has long been known that vari-

* Director and Agronomist, respectively, of the United States Golf Association Green Section.

ous plants respond differently to treatments with certain poisons. Applying this principle it has been possible by means of a relatively inexpensive treatment with chemicals to destroy one group of plants in a mixed vegetation without killing another group.

The earliest work on chemical weed control in this country was done by Professor Bolley in North Dakota in 1896. He showed that certain weeds, especially mustard, could be controlled in grain fields by spraying with sulphate of iron. Later other chemicals were used by many workers.

A voluminous literature records experiences in controlling weeds with sulphate of iron, sodium chlorate, arsenicals, sulphuric acid, kerosene and other oils, as well as numerous other chemicals. Some of the compounds in the fertilizer group such as sulphate of ammonia, ammonium thiocyanate, calcium cyanamid and kainit, have been found useful as weed killers under certain conditions.

Some of these chemicals have been shown to have a specific effect on certain weeds, as is the case with sulphate of iron on mustard, and kerosene on dandelions. In other cases the selective effect appears to depend upon the fact that most of our troublesome weeds are broadleafed and present relatively large surfaces to the action of the chemical, while the grass blades are narrow and not readily wetted. Much of the chemical weed control work with crop weeds has been done with the objective of killing all vegetation in an area without permanently sterilizing the soil.

Various factors, such as the stage of growth of the plants when treated, soil moisture, temperature and others, influence the results with chemical weed killers. Probably for this reason results reported by workers in different countries vary widely.

For example, in South Africa sulphate of iron combined with sulphate of ammonia has been highly recommended for keeping lawns and putting greens weed-free. This method has also been found effective in England and elsewhere, but in many sections of the United States this combination has failed to give satisfaction. Sulphate of ammonia however universally has a good effect in promoting growth of grass and in that way helps the grass choke out the weeds.

The ideal killer for turf weeds is one that will destroy the greatest number of weeds with the lightest dose; that will cause the least amount of harm to the grass when applied at the dose required to kill weeds; that will be cheap, easy to apply and relatively safe to handle.

Chemical weed killers should not be considered as substitutes for good cultural practices for the production of a weed-free turf. They should be regarded as useful aids to supplement the best cultural methods. Good soil, drainage, suitable grasses, proper cutting and fertilizing, control of insects and diseases, and many other means no doubt will remain of utmost importance in keeping turf free from weeds, even when far better herbicides are developed than are available now. Unfortunately other plants thrive under the same cultural practices that are considered best for turf grasses, and they become troublesome weeds which must be controlled by other than cultural methods.

There are also many areas of turf where a maximum growth of grass is distinctly undesirable. In such areas weeds may develop since there is little competition from the grass. On areas where a heavy growth of grass is desirable an ample fertilizer program may result in a mat of grass heavy enough to smother out many weeds. On numerous lawns, fairways and other

turfed areas, it is definitely advantageous to fight weeds by this method. There are, however, large areas of turf, as for instance in parks and in the rough of golf courses, where such a fertilizer program not only is too expensive but also is definitely undesirable for the reason that it would add greatly to mowing costs. Weeds are often undesirable in such areas; furthermore, they may produce seed which may be spread to other areas where weeds are even more objectionable. In such cases as in many others chemical weed killers may serve a useful purpose.

Review of Previous Green Section Results

Experiments on the chemical control of weeds have been conducted by the Green Section for many years. Much of the work to date was summarized in the December, 1933, number of the Bulletin of the United States Golf Association Green Section. This summary included the following observations:

> Most of the common turf weeds may be selectively controlled by proper cultural treatments and, where these fail, by the judicious use of certain chemical compounds.
>
> Of the chemicals tested, the best results, in the order named, have been obtained with the following: sodium chlorate, arsenic pentoxide as representative of the arsenicals, ammonium thiocyanate, sulphate of iron, and sulphate of ammonia.
>
> With sodium chlorate, crabgrass has been best controlled by three successive applications at the 2-pound rate. Satisfactory control with lighter first and second applications has been indicated.
>
> Under the treatment as suggested for crabgrass, practically all other common turf weeds, such as plantains, field or sheep sorrel, chickweeds, milk purslane, ground ivy, heal-all, and speedwell, disappear within a single season. Dandelion and goosegrass are discouraged. Wild garlic is little affected.
>
> Potassium chlorate, calcium chlorate, and magnesium chlorate may be substituted for sodium chlorate.
>
> The dry method of applying chlorates has been found to be entirely

satisfactory, and the fire hazard, which is always present when chlorates are used in solution, is virtually eliminated with the dry method.

Compounds of arsenic, notably arsenic pentoxide, have been used most successfully on fairway, lawn, and putting green turf to selectively control clover, pennywort, ground ivy, *Galium* sp., knotweed, chickweeds, and heal-all.

Ammonium thiocyanate has yielded results inferior to those obtained by the use of chlorates. In these tests its use tended to encourage certain types of weeds, principally *Poa annua* and dandelion.

Sulphate of iron and sulphate of ammonia, alone or in combination, gave no indications of satisfactory crabgrass control but showed some promise on other weeds.

Calcium cyanamid did not give favorable results when applied as a dust at the rate of 780 pounds to the acre.

The perchlorates of ammonium and potassium proved unsatisfactory as weedkillers.

The turf was discolored by all the chemicals used, and the duration and intensity of the discoloration varied with the rate and time of application as well as with the attendant conditions of moisture and temperature.

Results with chemicals are affected to an undetermined extent by a number of factors, and for this reason more extensive investigations of the problem are deemed necessary.

Immediately after the results of this work were reported in 1933 it became necessary to curtail greatly the experiments with chemicals on turf. Some testing with sodium chlorate and the arsenicals, however, was continued. Although sodium chlorate continued to give favorable results, the various arsenicals appeared to have certain advantages which seemed to justify making a more thorough study of them.

Other promising chemicals also have been tested by the Green Section during the past several years of work at Arlington. The present report is concerned, however, almost entirely with the work on the various compounds of arsenic.

Several arsenical compounds are available commercially. These differ but slightly in name but greatly in their herbicidal properties. To the layman this variety of compounds may be somewhat confusing.

If one is not familiar with the terms it is an easy matter to purchase arsenious acid instead of arsenic acid or to obtain a sample of arsenic trioxide instead of arsenic pentoxide. Such substitutions would give unsatisfactory results and might naturally lead to the erroneous conclusion that arsenicals are not effective in controlling weeds.

Compounds of Arsenic

Arsenic occurs in two forms of compounds, the trivalent and the pentavalent. When arsenic in the trivalent form is combined with other elements it makes such compounds as arsenic trioxide, As_2O_3, (the common white arsenic sometimes referred to simply as arsenic), arsenious acid, and the various arsenites, of which sodium arsenite is the most common. Combined in the pentavalent form with other elements it occurs as arsenic pentoxide, As_2O_5, arsenic acid (which is formed when arsenic pentoxide is dissolved in water), and the various arsenates such as sodium arsenate, lead arsenate and calcium arsenate. A combination of copper arsenite and copper arsenate is in common use under the name of Paris green.

Soluble compounds of the trivalent form are reputed to be more toxic to plant life than those of the pentavalent form. In repeated trials at the light rates commonly used under field conditions, these soluble compounds, whether trivalent or pentavalent, applied at rates containing the same amounts of arsenic, showed little significant difference in toxicity. However, when heavy rates were used the trivalent form proved decidedly more toxic than the pentavalent.

Experiments have shown that the quickly soluble arsenicals are the most toxic to plant foliage and give the most rapid control of weeds. The comparatively insoluble compounds such as calcium arsenate, lead arsenate and arsenic trioxide, act slowly as weed killers and therefore seem to have less general value for weed control than the soluble forms.

Sodium arsenite, sodium arsenate, ammonium arsenate and arsenic pentoxide, being quickly soluble and very toxic to plant foliage, have all been tested rather extensively. Sodium arsenate and ammonium arsenate are more expensive than the other two compounds when based on the amount of arsenic they contain.

Two grades of sodium arsenite, a relatively crude and a more purified form, are available on the market in addition to the chemically pure material. Both are commonly used in large quantities. The crude product usually costs a little less than the purified form. Where the chemical is to be applied as a spray the purified grade may be preferable as it contains less insoluble material which might interfere with the spray equipment.

It should be remembered that all of these arsenic compounds are poisonous and that they should be handled with care. This danger need not check their careful use for they are no more dangerous to handle than the mercury compounds and other poisonous materials that have been in daily use on turf for many years.

Experimental Conditions

Some experimental work with different arsenical compounds has been conducted at the Arlington Turf Garden for a great many years but most of the work reported here was done over a five-year period (1934-1938). The amount of detailed information that has accumulated from the hundreds of experiments conducted during this period is so great that it must necessarily

be omitted. Only the general information covering the experiments is included in this report.

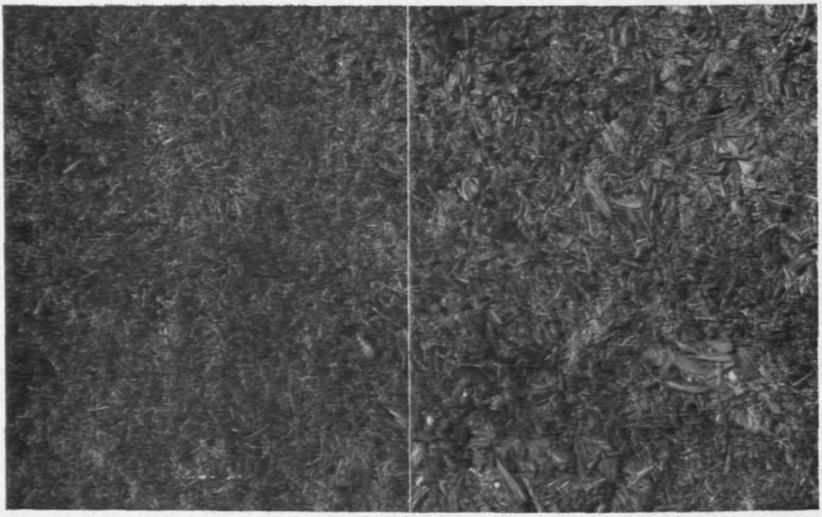
Most of the work has been carried on at the Arlington Experimental Farm. Conditions in the Washington district are especially favorable for crabgrass and some other weeds but are less so for bluegrass. Whenever a treatment showed considerable promise it was tested extensively on golf courses and other turfed areas in different sections of the country. Thus the treatments have been subjected to a wide variety of soil and climatic conditions.

While these treatments have been tested on different kinds of grasses the results reported, unless otherwise indicated, refer to Kentucky bluegrass turf. Most of the experiments at Arlington were conducted on a large neglected lawn. The crabgrass and chickweed tests were laid out on a nearly level, relatively fertile area, which is badly infested with these weeds every year. The experiments on other weeds were conducted on a well-drained, relatively infertile area. In all cases the turf was composed of Kentucky bluegrass and redtop, with patches of bent and *Poa trivialis*. This turf was badly infested with plantains, dandelion, chickweed, crabgrass, clover and many miscellaneous weeds.

Depending on the character of the tests and the distribution of the vegetation, the plot sizes in the experiments at Arlington ranged from 16 to 1,000 square feet. In the extensive experiments conducted in other places the areas treated varied from 16 square feet to entire fairways and football fields.

Method of Evaluating Results

Estimates of the percentage composition of the turf and actual plant counts were used in obtaining the data on percentage control. Plant counts were made more extensively at first but later only occasionally, as this method did not prove to be



Control of buckhorn plantain with a combination of equal parts of sodium chlorate and sodium arsenite applied in sand in September. Left, treated plot; right, untreated check plot. Picture taken the following May.

so applicable particularly in the cases of crabgrass, clover and chickweed. In many instances the remaining dandelions were so stunted from the treatments that they did not bloom and were very inconspicuous. In such a form they are not seriously objectionable in turf. Many small dandelion plants which do not bloom may make up a smaller proportion of the total composition of an area than a few large ones. This is especially true in a dense turf.

Judged by the estimate method a plot showing only 30 per cent dandelion control may have fewer dandelion plants than one showing 60 per cent control. By the actual count method the apparent results may be reversed. However, even though the number of plants may be greater, the figure showing 60 per cent control obtained by the estimate method gives the truest picture of the appearance and quality of the turf, and from this

point of view the control is better. Such differences in apparent results occurred in relatively few instances and only where a dense turf was present.

Records on the degree of control were taken several times following the treatment.

On acount of the variable composition of the turf it has been necessary to use frequent checks. Estimates of composition on the untreated areas which served as checks were made at the same time as the estimates on the treated areas. Unless the turf contained a relatively high percentage of a particular weed estimates were not used in recording control figures. Plant counts or merely observations were made but such observations were not used in figuring the percentage of control.

The grass injury as mentioned in the data refers to the actual discoloration of the turf grasses shortly after the treatment. Since the grass recovers rapidly, such discoloration usually represents only a temporary condition, depending somewhat on the degree of injury. When a small percentage of grass was present the browned appearance of all vegetation on the treated area may have been much worse than shown in the data.

In any weedy turf the soil is likely to be badly infested with weed seeds. When the crop of weeds growing in an area is killed the weeds are quickly replaced by new seedlings. For many types of weeds, therefore, repeated treatments are required. Obviously this reinfestation greatly complicates the matter of obtaining data on the degree of control secured. While a treatment may show control several weeks after its application, a few months later an entirely new crop of weeds may be growing in the area.

One treatment a year may kill the current growth of chickweed and crabgrass and prevent it from going to seed but several

years may be necessary to exhaust the supply of weed seed in the soil and completely clean up an area. A dense vigorous turf helps greatly in preventing this reinfestation by crowding out many new seedlings as they start growth.

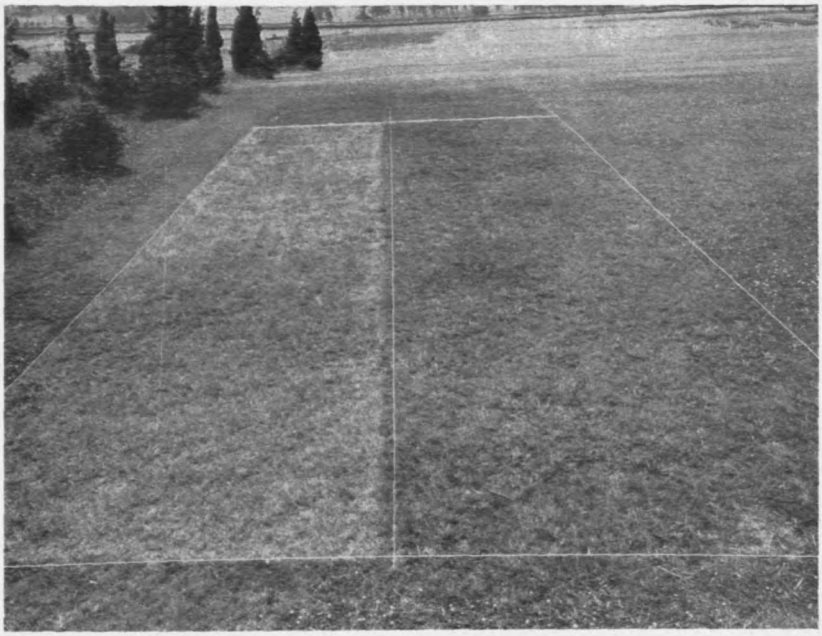
The chemicals used in controlling weeds may be applied dry or in solution depending on the type of chemical, the size and type of area to be treated, and various other factors.

Methods of Application

The dry method, in nearly all cases, consists of mixing the chemical with a carrier such as sand, soil, or fertilizer. A uniform mixture is best obtained by dissolving the required amount of chemical in a small quantity of water and mixing with the carrier. The dry chemical, however, can be mixed directly with the carrier provided care is taken to see that a uniform mixture is secured. The carrier containing the chemical is broadcast over the area to be treated. A sufficient amount of carrier must be used to insure uniform distribution. A convenient amount when spread by hand is from 8 to 16 quarts to 1,000 square feet.

The dry method offers many advantages. The chemical is deposited on the vegetation close to the ground and does not wet the foliage. Therefore some of the danger from poisoning is eliminated. There is always some danger in keeping supplies of poisonous chemicals on hand. When these are mixed with sand this danger is practically eliminated. The dry method is also safer to use around shrubbery and flowers. The treatments may be made by hand, so no expensive equipment is necessary. When an application of fertilizer is to be made the arsenic may be mixed with it and the two treatments applied in one operation, thereby reducing labor costs.

The chief disadvantages of the dry method are the greater cost of the larger quantity of chemical required, the cost of the



Greater injury to grass from spray treatments of arsenic acid than from dry treatments. Left, arsenic acid applied in spray at ½-pound rate; right, arsenic acid applied in sand at rate of 1½ pounds to 1,000 square feet.

material used as a carrier, and the extra time required to treat large areas.

In the wet method a solution of the chemical is applied either as a spray or by means of an ordinary garden sprinkling can. Different dilutions were tested and best control was obtained by dissolving the required amount of chemical in the least possible amount of water provided there was sufficient solution to thoroughly cover the foliage. On the small plots a compressed air hand sprayer which delivers a continuous fine spray has been used. Throughout these tests the rate of application has been 5 gallons of spray to 1,000 square feet. With the hand sprayer this rate of application could have been reduced

but it was used because it is comparable to that obtained with power sprayers.

Earlier work indicated that the dry method, while requiring a heavier rate of application than with a spray, gave about the same degree of control of most weeds but with less injury to the turf grasses. Continued experiments have substantiated this earlier work. However, where power sprayers with boom attachment are available the spray method is more economical and quicker. This is especially true where large areas are to be treated. Chickweed and crabgrass are usually more effectively controlled by the use of a spray.

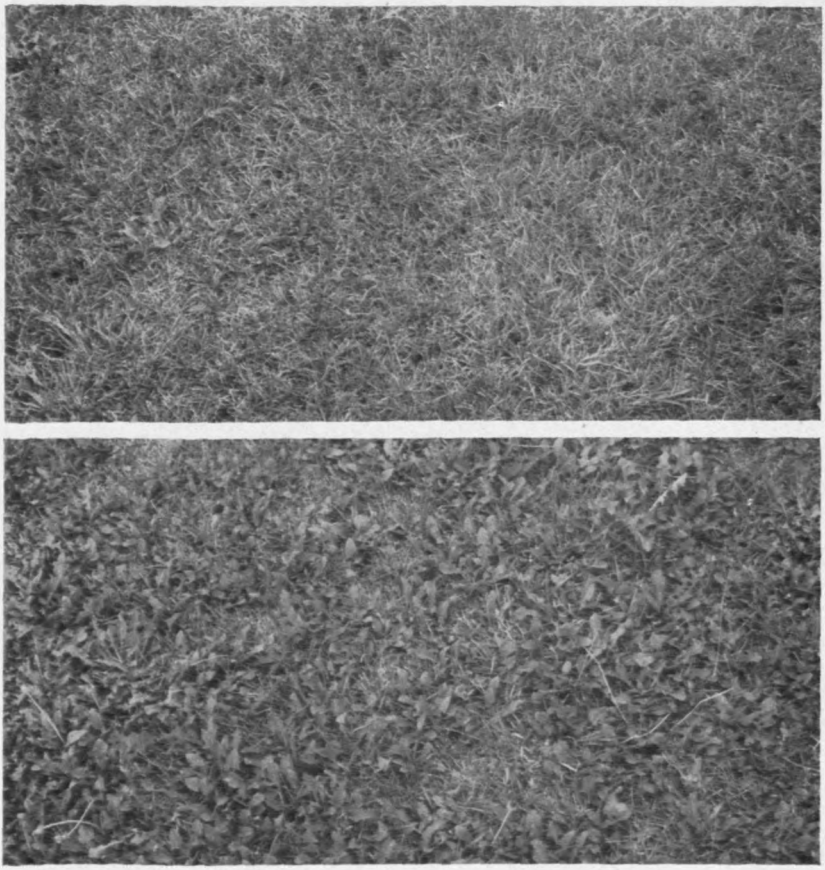
Another advantage of the spray is that in solution the chemical is more uniformly distributed than when mixed with a dry carrier. The spray also is usually more evenly distributed than the dry mixture.

A disadvantage of the spray method is that the expensive equipment necessary for large-scale operations may not be available. On the home lawn around shrubbery and flowers misty spray may drift onto the foliage even in calm weather and this may result in defoliation of these plants.

COMPARISON OF EFFECTIVENESS OF ONE APPLICATION OF SODIUM ARSENITE ON DIFFERENT WEEDS AT VARIOUS RATES. TREATMENTS MADE IN MARCH. OBSERVATIONS ON CONTROL MADE IN APRIL AND JUNE.

Method of Application	Rate in pounds	Per cent control of various weeds			Per cent burn to grass
		Plantain	Chickweed	Clover	
Spray	1/4	30	100	60	10
Spray	1/2	80	100	94	40
Spray	1	100	100	96	80
Dry (Sand)	3/8	14	100	67	15
Dry "	3/4	25	100	84	20
Dry "	1	50	100	99	30

The relative effectiveness of the spray and dry method is illustrated in the table above. Note that satisfactory control



Dandelion control with arsenicals in the Chicago District. Above, area on fairway sprayed with arsenic acid; below, typical weed-infested area on the same fairway.

can be secured with either method. The rate of application in the dry method, however, must be increased two or three times. One application at rates giving satisfactory control of the perennial weeds causes too great an injury to the grass. Repeated lighter treatments, however, give satisfactory control.

In the sprinkle method the chemical is dissolved in water and applied with a watering can. Much larger quantities of

water are used than by the spray method. Twenty-five to 30 gallons to 1,000 square feet are necessary to insure uniform distribution. The sprinkle method may be used where spray equipment is not available. It, however, requires larger quantities of the chemical to effect the same degree of control.

Comparison of Arsenicals

Both sodium arsenite and arsenic pentoxide are widely used as herbicides and have been employed in numerous tests at Arlington Farm. Arsenic pentoxide when dissolved in water forms orthoarsenic acid, in which form it functions as an herbicide. A crude form of arsenic acid (70 per cent) which, on the same arsenic content basis, is apparently equally effective, is sold commercially in this country at a much lower price than arsenic pentoxide. This crude arsenic acid has been used extensively in experimental work at Arlington Farm.

Comparison of Effectiveness of Sodium Arsenite and Arsenic Acid

Sand Treatments in October

Weed	Per cent control: Sodium arsenite 1 pound	Per cent control: Arsenic acid 2 pounds	Per cent burn to grass: Sodium arsenite 1 pound	Per cent burn to grass: Arsenic acid 2 pounds
Plantain	99	92	50	35
Dandelion	95	91	80	41
Chickweed	98	96	87	53
Clover	99	97	54	37

Spray Treatments in October

Weed	Per cent control: Sodium arsenite ½ pound	Per cent control: Arsenic acid 1 pound	Per cent burn to grass: Sodium arsenite ½ pound	Per cent burn to grass: Arsenic acid 1 pound
Plantain	91	95	60	50
Dandelion	24	28	60	54
Clover	98	97	60	50

Figured on the arsenic content basis, crude arsenic acid and sodium arsenite are about equal in price. These two compounds

have been compared in a large number of tests at Arlington. One pound of sodium arsenite, whether applied dry or in solution, is roughly equal to two pounds of crude arsenic acid in its toxicity to weeds. The arsenic acid, however, is less toxic to the grass, particularly at the heavier rates. The figures in the table on page 24 are an average of several experiments. They are typical of the results obtained in numerous tests from one application of these chemicals.

Rate of Application

The most desirable rate of application of any chemical for controlling weeds in turf is one which is heavy enough to kill the greatest possible number of weeds while at the same time causing the least possible injury to turf grasses. All plant tissues have certain fundamental likenesses, and any chemical which will destroy one plant is almost certain, if used in sufficient quantities, to cause some injury to all plants. No herbicide yet discovered is selective enough in its action to destroy one group of plants and cause no injury to another. The application recommended must necessarily be a compromise, since any rate that will effectively destroy weeds will cause some temporary injury to the grass.

The amount of chemical to apply depends upon the method and time of application, the type of weeds and grass in the turf, the soil and climatic conditions, and many other factors. No standard rate of application therefore can be recommended for all conditions. In some cases the fact that turf is badly discolored for two or three weeks may not be objectionable, and a heavy rate of application may be used in order to clean up the weeds in one operation. In other cases only slight and

temporary discoloration of turf is permissible and only the lighter rates of application may be used.

Since a definite recommendation covering rates of application to suit all conditions cannot be made, those contemplating the use of these chemicals should become acquainted with the factors affecting the results and should make small-scale tests before applying the chemical to large areas.

Generally speaking, the spray treatments of arsenicals at any given rate have proved to be more efficient in weed control than dry treatments of the same chemical made at the same rate. On the other hand, they are more injurious to turf grasses. To obtain equivalent control by the dry method, it is necessary to use two or three times the quantity of arsenical used in spray treatments.

The results of numerous treatments on weedy Kentucky bluegrass turf in the Washington district have shown that sodium arsenite or arsenic acid as a spray applied in early fall at 4 ounces to 1,000 square feet generally will give satisfactory weed control with the least amount of injury to the grass. Under different conditions of soil and climate, this amount has had to be decreased or increased. Also, if the turf consists largely of bent and fescue, application at this rate may be too heavy. By the dry method, sodium arsenite has given the best results when applied at the rate of ½ to 1 pound to 1,000 square feet.

The effectiveness of different rates of application is illustrated in the table on page 22. Note that one application of sodium arsenite at 4 ounces as a spray readily has killed chickweed but has given in this instance only 30 per cent control of plantain.

An application of sodium arsenite as a spray at ½ to 1 pound has given satisfactory control of plantain. The grass injury, however, has been increased to such a degree that some injury to the stand is likely to result. For this reason perennial weeds such as plantain and dandelions are best controlled by several repeated treatments at a rate causing only a light temporary injury to the grass. These figures are typical of numerous experiments where this chemical has been applied at various rates on different weeds.

Heavy rates of application have given 100 per cent control and thus have appeared superior to the lighter rates. They are not advocated for general use, however, as they cause too severe injury to turf, and leave it discolored over too long a period. These heavy rates have been used in the experimental work in order to obtain information on the correct rates of application.

One light treatment with arsenicals readily has destroyed the current crop of such weeds as chickweed and crabgrass. However, new seedlings usually reinfest the area. Either heavier applications or repeated treatments have been necessary for the control of perennial weeds such as plantains and dandelions. Experiments have shown that two or three repeated light treatments have successfully controlled perennial weeds with little injury to turf grasses. Any new seedlings that appeared also have been destroyed by the repeated treatments. Effective control of plantains and dandelions has been secured by three sprayings at the rate of 4 ounces of sodium arsenite to 1,000 square feet, or by three treatments of the dry material at the rate of ½ pound to 1,000 square feet, repeated at intervals of two to four weeks. These treatments also have destroyed the seedlings, and a high degree of control has been maintained for two years. Over a period of several years, satisfactory

control has been obtained with single fall treatments made in successive seasons.

Where rain or other factors apparently have decreased the effectiveness of a particular treatment, an additional treatment made within a few days has given good results. By this method the turf has been browned for only a normal period, while two treatments at longer intervals would have prolonged the period of browned turf. Tests have shown that when an application is repeated within a few days it is better to cut in half the rate for the second treatment. This does not hold true for a second treatment at an interval of two weeks or longer.

Where poor weedy turf is present and where a prolonged period of browned grass is not objectionable, it may be advisable to make a heavy treatment for a complete clean-up of all weeds present. Rates of application that will give complete control and not destroy the turf grasses will vary with local conditions. Kentucky bluegrass, although seriously injured, has recovered from three applications of arsenic acid applied as a sprinkle at the rate of 8 pounds to 1,000 square feet and followed by watering. The turf on these plots has been exceptionally vigorous and remarkably free from all weeds over a three-year period following the last treatment. Under different conditions, the more sensitive turf grasses or even Kentucky bluegrass might not recover from this heavy rate. These results show the large quantities of arsenic acid which Kentucky bluegrass has been able to tolerate.

Effect on Different Types of Weeds

It is generally recognized that certain types of weeds are easier to control by mowing, hand weeding or good cultural practices than others. Some weeds can also be controlled more

easily than others by the use of chemicals. This variation in the susceptibility of the different weeds to herbicides may be due to differences in size, shape and structure of the leaves, to kind and distribution of roots, and to growth and seeding habits.

Annual weeds and the low-growing, mat-forming type of weeds such as the chickweeds are generally more susceptible to arsenicals than deep-rooted perennials, such as dandelions. A single application of arsenicals at the suggested rates is often sufficient to control any particular infestation of mat weeds. The deep-rooted perennials, however, are more difficult to eradicate. This is probably due largely to the fact that they store sufficient reserve food in their long roots to enable them to send up new shoots even though their tops may have been killed to the crowns.

On account of differences in growth and seeding habits of the various types of weeds, some weeds are best controlled by early spring treatments, whereas others are more easily controlled by treatments in the fall. For instance, chickweed, which is a troublesome pest in turf in many districts, makes its principal growth in the late fall or early spring. It is easily controlled by spraying in the winter or early spring.

On the other hand, crabgrass, the most troublesome of all weeds in turf in the Washington district, does not become conspicuous until early summer and makes its best growth during midsummer. Under favorable conditions, this weed by early fall has nearly smothered out any bluegrass which may have been present in the turf. Early fall treatments may kill the existing crabgrass and prevent the weed from setting seed, but they are not made early enough to prevent it from choking out the turf grasses.

Invasion of crabgrass following severe turf injury resulting from heavy applications of arsenicals in July. The bleached remains of the crabgrass the following spring show how completely this weed covered the treated areas in late summer. The check plot, lower left, is covered with clover and other weeds which had continued to compete successfully with crabgrass.

Crabgrass seedlings in the two-and three-leaf stage are easily killed in late May or early June. However, even light treatments made at this time of the year have a temporary browning effect on the turf. This slight retarding effect on the growth of the turf grasses gives a distinct advantage to the succeeding crops of crabgrass which reoccur in many turfed areas until mid-August. For treatments of crabgrass at this season, sodium chlorate has given better results than the arsenicals.

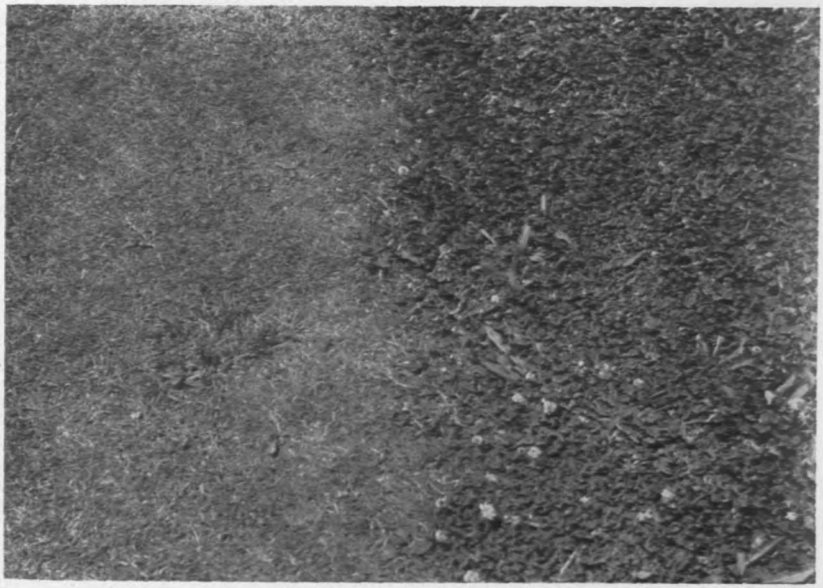
The best crabgrass control with arsenicals has resulted from late summer or early fall applications after the crabgrass seed is no longer germinating. Such treatments followed by a reseeding and fertilizing program have produced good stands of Kentucky bluegrass. The grass seed germinated rapidly and developed in the spots left bare by the killing of the crabgrass.

Dandelion control with arsenicals. The marked area includes four different plots treated with arsenic pentoxide or arsenic acid in succeeding falls. It is surrounded by untreated areas showing dandelions in bloom.

Removing the competition of the crabgrass has enabled the seedlings of the permanent grasses to become well established during the fall. Such a stand of grass helps to choke out the crabgrass seedlings when they begin to appear the following May or June.

Plantains and dandelions are difficult to eradicate on account of their deep roots. The plantains are greatly reduced by a single treatment of sodium arsenite or arsenic acid, particularly when such a treatment is made in early fall. Two or three treatments are usually necessary to give complete control.

Although dandelions are more difficult to kill than plantains, they have been satisfactorily controlled with arsenicals by a



Eradication of clover from bent turf with arsenic acid. Left, repeated light treatments in fall; right, untreated plot.

series of three or more treatments. Any remaining plants have been so stunted in growth that they did not produce seed and generally were not objectionable. Even when dandelions have been eradicated from an area, new plants may appear from seed which has blown in. It has been noted, however, in tests at the Arlington Turf Garden, at Chicago, and elsewhere, that in small plots or narrow strips from which dandelions have been removed by arsenicals, the reinfestation of dandelions was remarkably slow. Some of the treated areas have remained relatively free from dandelions for three or four years in spite of the heavy production of seed along the borders of the plots and in adjoining areas.

Clover, which is considered a weed in many turfs, is killed readily in the seedling stage by light sprays. Both clover seed-

lings and established patches of clover in turf have been more successfully eradicated by successive treatments in the fall than in other seasons.

The relative susceptibility of various weeds to arsenicals is illustrated in the table on page 22. Note that while chickweed has been killed readily with one spray application of sodium arsenite at the rate of ¼ pound to 1,000 square feet, plantain in these tests has been controlled only 30 per cent. Tests have also shown that other weeds show varying degrees of susceptibility.

A light treatment which causes little injury to the grass may give only a low degree of control of many weeds. For this reason repeated treatments may have to be made when light rates are used.

Effect on Different Grasses

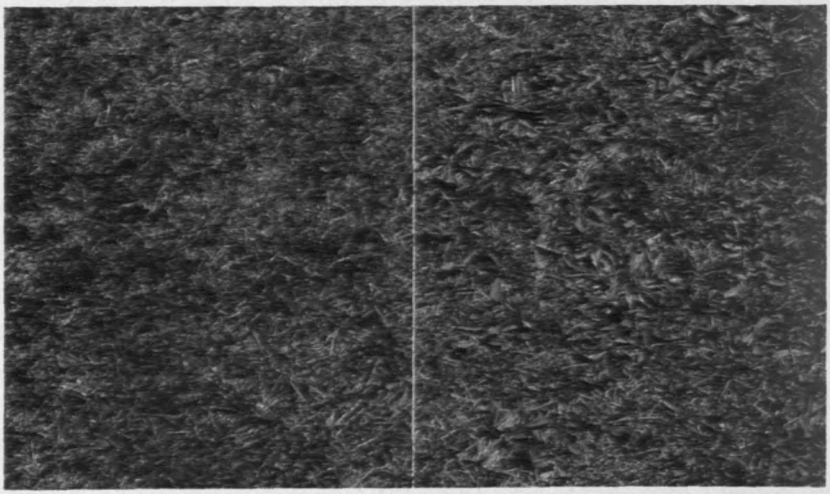
Grasses differ in their sensitiveness to arsenical treatments. Kentucky bluegrass and Bermuda grass seem to be the most resistant, being temporarily browned but recovering quickly from the treatment. *Poa annua,* the fescues, the bents, and *Poa trivialis* are increasingly sensitive in the order named. When the more sensitive grasses represent a large percentage of the turf, the rates of any particular treatment should be reduced.

Effect of Height of Cut on Injury to Kentucky Bluegrass by Spray Treatments of Arsenic Acid at ½ Pound Rate

Height in Inches	Percentage injury
3/16	40
1¼	30
2½	15

The amount of injury to turf grass resulting from applications of arsenicals varies with the height of mowing at the time

of application. The more closely the grass is clipped, the more sensitive it is to treatment. When grass is cut at the height used on putting greens, the injury has been shown to be greater than when it is cut at heights used on fairways or in the rough.



Plantain control with arsenic acid applied in sand in spring and again in September. Left, treated plot; right, untreated check plot. Picture was taken the following May.

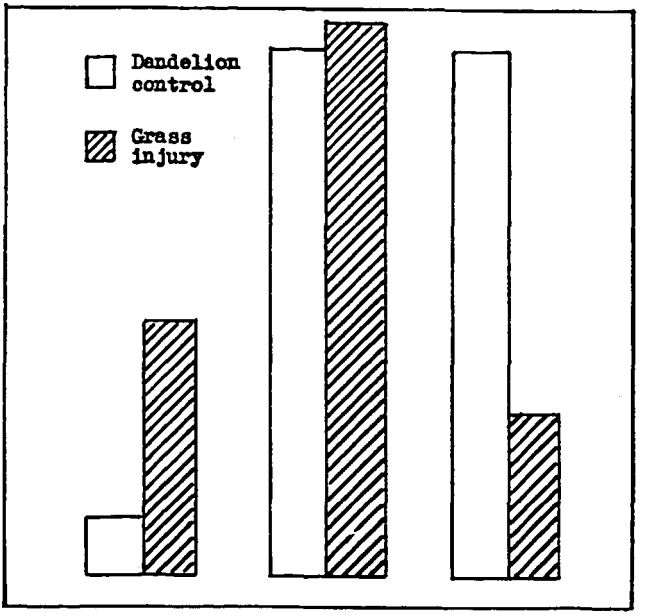
This is demonstrated in the table on page 33 showing temporary injury caused by the application of arsenic acid at ½ pound in spray treatments made in October.

Time of Application

Early spring and fall are the best seasons for the growth of Kentucky bluegrass. During the hot summer this grass makes little growth and consequently is at a distinct disadvantage in competing with crabgrass and many other weeds. Unless turf grasses enter the summer with the advantage of vigorous growth and maximum cover of the ground, crabgrass and other weeds are likely to take over the area. Experimental work on the control of weeds in farm crops has indicated that most weeds

are easiest to kill at the time when they have the least amount of reserve food stored in their roots.

This is usually sometime in late spring. In many districts it is not practical to take advantage of this weakened condition of certain weeds as the late spring treatments retard the turf



Percentages of dandelion control and grass injury with sodium arsenite at 1-pound rate at various times during growing season. Left, early spring; center, summer; right, early fall. Note that the early fall treatments give best control with least injury to the grass.

grasses, leave open areas where the weeds were killed, and make conditions favorable for the invasion of crabgrass, clover and other weeds. Treatments made in early fall leave the grass relatively free to cover the ground during the rest of the fall and spring so that crabgrass and other weeds have less chance to invade the area.

Tests have shown that high temperatures increase the effectiveness of arsenical treatments on weeds but also greatly increase the injury to the grass. This holds true whether the high temperature is confined to a several-day period in the fall or occurs in any of the summer months. Treatments during the summer months therefore should be made during cool, cloudy weather.

Generally speaking, the results with arsenicals are most satisfactory when applications are made in early fall, because at that time of the year the best weed control is effected with the least injury to the grass. The figure on page 35 has been made up from various experiments on dandelion control. Similar figures have been constructed for other weeds such as plantain, crabgrass, clover, etc. Although they differ in detail, in general they demonstrate the same relationship and justify our conclusion that early fall is the best time for application of arsenicals for control of most weeds.

EFFECT OF MOISTURE ON FOLIAGE AT TIME OF APPLICATION OF SODIUM ARSENITE AT 1 POUND RATE IN MARCH

	Foliage wet	Foliage dry
Plantain (percentage control)	70	50
Grass (percentage burn)	60	30

Experiments have shown that the amount of moisture on the foliage either before or after treatment, and the amount of moisture in the soil, influence the degree of control secured as well as the severity of injury to the grass.

When the foliage is wet at the time of application of arsenicals, there is generally a significant increase both in the control of weeds and in the burn produced on the grass. Take, for instance, the control of plantain with early spring dry treat-

ments with arsenicals. Although the plantain has been controlled 40 per cent better with the sodium arsenite applied to wet foliage than to dry, the grass has suffered 100 per cent greater burn.

If the material is to be applied when the vegetation is wet, allowance should be made for the greater injury to both the weeds and the grass in deciding on the rates to be used.

It has been recognized that showers coming shortly after application of the arsenicals reduce their effectiveness. Experiments have been set up therefore to determine the significance of this effect.

The arsenicals were applied in sand to bluegrass turf at several rates. Some of the plots were watered with 232 gallons of water to 1,000 square feet. Others received only 83 gallons to 1,000 square feet, and still others were not watered at all. The results on burn to the grass caused by the treatments with sodium arsenite are given in the table below.

EFFECT OF WATERING AFTER DRY (SAND) TREATMENT WITH SODIUM ARSENITE IN MAY

Rate of treatment in pounds	Percentage of burn to grass		
	Heavy watering (232 gallons to 1,000 square feet)	Light watering (83 gallons to 1,000 square feet)	No watering
1	8	15	60
2	20	50	80
4	80	85	95

From this table it can be seen readily that the burn to the grass resulting from these treatments has been progressively reduced with the addition of increasing amounts of water to the soil following treatment. This has been particularly striking at the lowest rate used in this test (1 pound to 1,000 square feet).

On the other hand, it should be remembered that this watering has a corresponding effect on weed control. Therefore, watering after the treatment decidedly reduces the effectiveness of the arsenicals as herbicides. Similar results may be expected from rainfall following an application of arsenicals, so treatments should be made when fair weather is predicted.

The higher rates would not be used in practice, but have been included for experimental purposes only.

As a rule, a high degree of soil moisture has decreased the effectiveness of a treatment when applied as a spray. If the soil is dry, the recovery of the grasses may be delayed.

Effect of Shade

Except for the tees, the shaded areas on golf courses are usually confined to the rough or to out-of-the-way places where the quality of the turf is not conspicuous. On the other hand, in parks and on home lawns, the shaded areas are the most frequented sections. Fortunately, crabgrass is usually not a pest in shade, but chickweed and other weeds may be abundant. Although proper fertilizer practices will do much to encourage an increase in the turf grasses and a decrease in the weed population, chemical treatments have been shown to hasten weed control and turf improvement in such areas.

In the experiments with chemicals, the same methods have been used in shady areas as in the exposed areas. The grass in the shady areas has been more severely burned than that in the open, the average burn having been estimated at 73 per cent in the shade and 23 per cent in the open. These results indicate that it may be necessary to use lighter rates for treating turf growing in the shade. Particularly is this true where the turf consists of the fescues and *Poa trivialis,* since these are among the grasses most sensitive to arsenical injury.

Arsenical compounds are fixed in the first few inches of soil so that, unless excessive rates are used, no damage should result to trees, which are normally deep rooted. Care should be taken, however, to avoid touching shrubbery or flowers with the spray.

Clearing Areas of Weeds for Reseeding

For satisfactory turf improvement in places where the weed infestation has become so severe as to seriously reduce the stand of turf grass, it is advisable to accompany the chemical treatment with an application of quickly available fertilizer and a reseeding program.

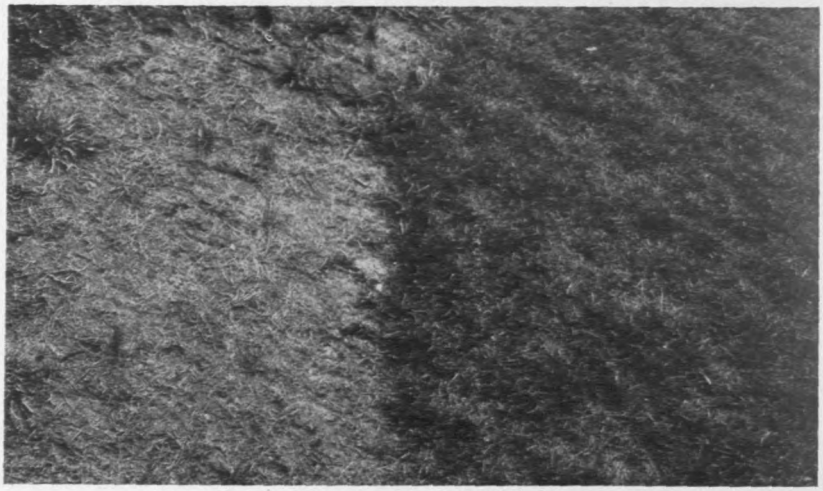
The varsity football field at the United States Naval Academy, Annapolis, presented such a problem in the summer of 1934. Crabgrass had taken almost complete possession of the turf, and it was recognized that this grass would last only a short time during the playing season. The Green Section cooperated in treating this field twice with sodium chlorate. The first application was made at the rate of 120 pounds to the acre on July 31. The second treatment of 80 pounds to the acre was put on eight days later.

A complete fertilizer was applied and seed planted with a disk seeder the middle of August. In spite of the retardation of the seedlings by the sodium chlorate residue in the soil, germination was excellent and a good stand of grass was obtained for the opening game. This treatment provided a good cover for the fall season without disturbing the surface by sodding or by cultivation for a new seed bed. The mat of dead roots and stubble of the crabgrass provided a satisfactory footing for the players while the new grass was becoming established.

Experiments conducted at Arlington simultaneously with the Annapolis treatment showed that as good a kill of crabgrass could be obtained with sodium arsenite and arsenic acid as with

sodium chlorate. Further, the arsenicals did not retard the growth of seedling grass as much as did the sodium chlorate. In other tests, grass seed planted only three and four days after the arsenicals were applied germinated successfully.

On several occasions at Arlington it has been necessary to delay seeding, due to prolonged fall rains starting within two



Crabgrass control with arsenicals. Entire plot was treated with sodium arsenite in early fall. Left, not seeded; right, seeded with Kentucky bluegrass at time of application of arsenicals. Picture was taken the following April.

or three days after the chemical treatments. Some areas, therefore, have been seeded immediately before the application of the arsenical. Germination has proved to be entirely satisfactory, and the seedlings have not been retarded seriously. By spiking in grass seed or putting it in with a disk seeder before applying the chemicals, the weeds are cut and bruised, and this may make them a little more sensitive to chemical injury.

The fact that the seed of the grass which is expected to replace the weeds is in the soil before the weeds are destroyed

is of even greater practical importance, since the period of discolored turf is reduced to a minimum. The rainy periods that may be expected in fall will hasten growth of the new grass rather than serve to delay its planting. This method makes it possible to do all the seeding, fertilizing and burning with chemicals during the same period of good weather and thereby avoid any long interval between the time the weeds are killed and the time when the new crop of grass begins to grow.

Experiments with this type of treatment on crabgrass-infested turf at Arlington have given remarkable results. The addition of fertilizers and reseeding following a September application of arsenical at the rate of 4 ounces to 1,000 square feet has resulted in an increase of the desirable turf grasses from 5 per cent in the fall of 1937 to 75 per cent in the fall of 1938.

For this particular type of treatment, rates of from 4 ounces to 1 pound of sodium arsenite have given satisfactory results. In turf where sufficient permanent grasses are present to justify some caution in preserving them, the lower rates should be used. However, where crabgrass and other weeds have taken over the area completely, the higher rates of application should be used. This increased rate will be more effective on perennial weeds and cause no harmful effects to the grass seedlings.

Several series of tests made at Arlington at weekly intervals during September have shown that the exact time of treatment of crabgrass-infested turf is not an important factor in this method of control. The treatment, however, must be made early enough to enable the seedling grasses to become established before winter sets in.

Additional experiments with this type of treatment are now under way.

Arsenic Residue in Soil

The ideal chemical to use for the control of turf weeds should leave no deleterious substances in the soil and should not have a prolonged toxic effect on the turf grasses. Since the quickly soluble compounds of arsenic are readily fixed by the soil, they appear to be remarkably free from either evil. None of the arsenical treatments have shown any residual toxic effect when used at the recommended rates.

Even a total of 24 pounds of crude arsenic acid to 1,000 square feet applied in three treatments and watered in following each treatment has not killed the bluegrass and has had no prolonged toxic effect on the grass. In fact the opposite has been true, as the treatment appears to have stimulated the Kentucky bluegrass and has resulted in a vigorous weed-free turf. This stimulating effect of arsenic has been observed in many of the experiments at Arlington, and also has been noted by other workers.

Experiments on the effect of heavy applications of the relatively insoluble arsenicals at rates as high as 40 pounds to 1,000 square feet have given variable results. Some of these heavy treatments appear to have had a retarding effect on the growth of Kentucky bluegrass. Other investigators also have observed this retarding effect.

Arsenicals in Combination with Fertilizers

A proper program of fertilization carried on over a period of years may control many turf weeds. When arsenicals are used in combination with a fertilizing program, the time needed to produce a good turf may be decreased and control

secured with less fertilizer and consequently at a lower cost. This combination has the further advantage of reduced mowing expense, since the grass is not stimulated to such rapid growth as when larger quantities of fertilizers alone are used to accomplish weed control.

On poor soils, turf grasses do not withstand the encroachment of the weeds, and under such conditions the use of some fertilizer is necessary if a satisfactory stand of grass is to be retained in the turf. On such soils, weeds, especially chickweed and clover, may be successfully controlled by the use of arsenicals, but unless the grass is encouraged the bare areas left vacant by the dead weeds are readily taken over by other weeds, the seeds of which are either present in the soil or are blown onto the area. When using the dry method, the arsenic may be mixed with the fertilizer and both of them applied at the same time. When using a spray, the fertilizer may be applied just before the chemical treatment.

Further reports on experiments at Arlington with arsenicals in combination with fertilizers will be published in a future issue of TURF CULTURE.

WARNING

Arsenic is a deadly poison. All arsenic compounds are dangerous.

Do not leave the powder or solution where children or animals can get it.

When applying the chemical see that the men do not inhale either dust or spray.

Exposed skin should be covered as far as possible. Poisoning may result from a deposit of arsenic on the skin.

Faces and hands should be washed as soon as the work is finished, especially before smoking, eating or handling any materials which are put into the mouth.

Do not permit grazing animals to eat plants that have been poisoned with arsenic.

LARGE SCALE WEED CONTROL WITH ARSENIC ACID

EVAN M. BEGG and H. C. PURDY*

For some years the weed problem on our golf course had become more and more serious. It finally reached the stage where members were talking about establishing a weeding fund and employing an army of boys or unemployed men to hand-weed all the fairways. About that time we heard of the Green Section's experiments with arsenicals and we were so intensely interested in the possibilities which these chemicals offered that we asked the Green Section if we might be allowed to join in the practical tests which it was making in various parts of the United States. In April, 1936, the material and instructions for conducting the tests were received.

The test plots were laid out as directed on a representative area of fairway which contained a fair stand of Chewings fescue, Kentucky bluegrass, *Poa annua,* and a small amount of bent. There was a high percentage of weeds in the plots—mostly knotweed and dandelion, with a fair sprinkling of clover, plantain, and chickweed. The soil on our course is a very poor fine sand. The sodium arsenite was applied in solution on some plots and dry on others. The wet applications were made at the rate of 1 ounce to 1,000 square feet on some plots and 4 ounces on others. For the dry applications the chemical was mixed with sand and was spread at the rate of 4 ounces of sodium arsenite to 1,000 square feet on some plots and 12 ounces on other plots.

* Chairman of the Green Committee and Course Superintendent, respectively, of the Toronto Golf Club, Toronto, Ontario, Canada.

Five applications were made at intervals of 2 to 4 weeks. Our conclusions were that the rates of application were too light for the type of soil we had but we could see considerable promise from the use of heavier applications. In order to test our theory, we laid out an area of some 30,000 square feet on one of our most heavily weed-infested fairways and treated it with a spray of 12 ounces of sodium arsenite to 1,000 square feet on September 3, 1936. There was much bent turf in this particular area which, although badly discolored by the treatment, was not killed. However, the one application of sodium arsenite at the 12-ounce rate resulted in practically 100 per cent kill of knotweed and about 50 per cent of dandelions and plantains. The area was seeded and fertilized and by the following spring was in splendid condition, with only a few scattered weeds visible.

Preliminary Treatments

Encouraged by this success, we decided in the spring of 1937 to treat large areas of fairways. We purchased a power sprayer having a tank of 240 gallons capacity and a 20-foot boom. The boom has 14 spray nozzles mounted 18 inches apart, center to center, and the orifices in the nozzles are 1/32-inch in diameter. The boom can be adjusted for height but we have found that best results are secured when the nozzles are 18 inches above the ground. The sprayer is lined with corrosion-resisting metal and is thoroughly washed out at the end of each day during which it is in use. We discovered that it was highly desirable to apply the solution as a fine mist. It was found that 150 pounds pressure in the sprayer gave the best results. Unfortunately, our sprayer has no motor on it and we therefore have been forced to use a tractor motor to operate the pump.

Spraying fairways on Toronto Golf Course. It was necessary to use an extra tractor to operate the pump, as there was no motor on the sprayer.

This necessitates the use of two tractors—one to pull the sprayer and one to operate the pump. This is an unsatisfactory arrangement, as it requires an extra man to operate the equipment. If we were doing it over again we would buy a sprayer with a built-in motor.

We were advised by the Green Section that arsenic acid was just as effective as sodium arsenite and might be purchased a little cheaper, so we endeavored to purchase a supply of it. To our surprise, we found that it was not available locally, but after shopping about we discovered that we could import arsenic pentoxide (As_2O_5) from Europe at a cost of 10 cents a pound, laid down in Toronto. This material, which comes as a white powder, is soluble in water and reacts with the water to form ortho-arsenic acid ($H_3AsO_4.\frac{1}{2}H_2O$). The arsenic

Sprayer showing 20-foot boom with 14 spray nozzles in action.

pentoxide is 84 per cent pure and therefore contains 54.77 per cent arsenic. Thirteen ounces of this material contains the equivalent in arsenic of 1 pound of the sodium arsenite we had been using. In order to figure our rates of application in terms of sodium arsenite, we made up a standard solution of 13 ounces of arsenic pentoxide in a pint of water and used this solution at the same rates as we would have used a solution of a pound of sodium arsenite to a pint of water. All rates given below are in sodium arsenite equivalents. Our standard solution was made up in batches of 30 gallons at a time by dissolving 195 pounds of arsenic pentoxide in 30 gallons of water and allowing it to stand for 24 hours. We used an oak barrel as a container and found that the solution ate right through it in one season. In loading the sprayer we used 17 pints of standard solution and added 230 gallons of water.

For our first test of large-scale operations, which commenced on May 11, 1937, we chose a fairway which contained about 80 per cent dandelions, plantain, and knotweed, and 20 per cent Kentucky bluegrass and *Poa annua*. Due to a mistake in our calculations in preparing the first batch of standard solution, we applied 12 ounces to 1,000 square feet, and needless to say the grasses were very badly discolored. However, we were agreeably surprised to find that practically no grass had been killed and in a few weeks' time it had completely regained its normal color. The Kentucky bluegrass actually seemed to have been stimulated by the treatment. Fully 75 per cent of the weeds were killed by the one application at this heavy rate and the fairway was left quite bare and muddy. No seeding was done but the area was well fertilized and kept thoroughly spiked and watered. By autumn of that year there was a good stand of Kentucky bluegrass and *Poa annua* and the weeds were few and far between.

That same spring we treated three other fairways but reduced our rate of application to 2 ounces to 1,000 square feet. Two of these fairways were treated once and the third fairway was treated twice with an interval of about 10 days between treatments. While the results on the fairways receiving only one treatment appeared to be good at the time, it was soon evident that practically all the weeds had recovered and there was no real benefit from the treatment. Good results were obtained, however, on the fairway which received two applications. With the lower rate of arsenic, there was no discoloration of the grasses.

As a result of our work up to that time, we felt confident that we were on the right track and that we could go ahead and attack our weed problem in a wholesale manner. We

decided to increase our rates of application in order to secure more effective control, and in the fall of 1937 we treated eight fairways. The first fall application was made at the rate of 4 ounces to 1,000 square feet, about September 20, and produced excellent results, with practically no discoloration of the turf. Knotweed was entirely killed by this application. The second fall application was made about October 14 at the rate of 6 ounces to 1,000 square feet and produced some discoloration of the grasses but not enough to be objectionable. The color was fully regained within 10 days. The weeds, however, including dandelions and plantains, turned completely black within three days after the second application. Chickweed and clover turned white and shriveled and the leaves of all weeds crackled when they were walked on. Within a week or 10 days we found the roots of most of the dandelions and plantains rotting and they eventually dried to a powder so that a pencil could be inserted into the hole where the dandelion tap root had been formerly. The clover, however, recovered to some extent but was somewhat thinner than previously. Some of the dandelions and plantains which were not entirely killed by these treatments were so weakened that they were killed by the frost during the winter.

Treating 12 Fairways

In the spring of 1938 we did a clean-up job on 12 fairways to kill the new seedlings before they gained a foothold. The first application was made about May 15, the second about June 1, and the third application was made on certain fairways on June 20. The rate of application in all these cases was 4 ounces to 1,000 square feet.

In the fall of 1938 we treated 14 fairways. The first application was made about September 14, the second about September 27, and certain localized areas received a third treatment on October 20. All applications were made at the rate of 6 ounces to 1,000 square feet.

Some idea of the area of turf we have treated may be gained from the following table.

AREAS OF FAIRWAYS ON TORONTO GOLF COURSE TREATED WITH ARSENICALS

Hole No.	Length (Yards)	% of Fairway Treated	Hole No.	Length (Yards)	% of Fairway Treated
1	366	25	10	353	100
2	393	100	11	390	100
3	488	100	12	368	100
4	189	None	13	524	100
5	465	None	14	156	None
6	394	90	15	407	100
7	180	100	16	500	90
8	420	100	17	222	75
9	456	100	18	342	None

It is impossible to estimate the percentage of weeds that were killed but undoubtedly the percentage was very high. One of the best evidences of this was in the reaction of the players. During 1937 they complained bitterly about the damage we were doing to the fairways but during the whole of 1938 we did not hear a single complaint. On the contrary, the members were commenting on the lack of weeds this year and could not understand what had happened to them. Visitors to our course also commented on our freedom from weeds and went home and advocated the same treatment at their own courses.

It should be emphasized that our soil is very sandy and the rates which we have used might need to be varied for a different type of soil. It should also be pointed out that fescue and bent are more susceptible to injury than are Kentucky bluegrass and *Poa annua*. One interesting thing we noticed was that the young *Poa annua* seedlings just appearing above the ground were not affected in the slightest degree by the treatments.

Cost of Treatments

For all the treatments made during the years 1937 and 1938 we have used 1,425 pounds of arsenic pentoxide at a total cost of $142.50. Using it at the 4-ounce rate (i.e., the equivalent of 4 ounces of sodium arsenite), the material cost per application is 2.03 cents for 1,000 square feet. At the 6-ounce rate, the cost is 3.05 cents.

Our total labor cost for these treatments for the years 1937 and 1938 was $196.15. Breaking this figure down and figuring the labor cost separately for each application, we find that it varies from a minimum of 3.49 cents to a maximum of 3.52 cents for 1,000 square feet. This is for three men running the equipment. If the sprayer had a motor mounted on it two men would be sufficient and the above figures could be reduced by one-third.

The total cost for labor and material at the 4-ounce rate has been about 5.53 cents for 1,000 square feet an application, or about $2.41 an acre. At the 6-ounce rate, the total cost for labor and material has been about 6.55 cents for 1,000 square feet an application, or about $2.85 an acre.

In our opinion, at least two applications are necessary at intervals of 10 days to two weeks. All the weeds cannot be eradicated in one season but over a period of several years effec-

tive control can be secured. Fall applications appear to be more effective than spring ones, particularly on the older established weeds. The spring application, however, is useful as a clean-up job to kill the small new weed seedlings before they become established.

Factors to be Considered

There should be plenty of moisture in the soil before the applications are made but better results are obtained if no rainfall follows the treatments for at least 48 hours. No mowing or watering should be done for at least 48 hours after treating. Applications made after 4 p. m. seem to be better than those made earlier in the day. We observed that severe burning occurred when treatments were made with the air temperature over 75 degrees.

Great care should be taken to keep the sprayer moving uniformly, and it is necessary to watch that its speed is not reduced on a hillside. To prevent severe burn due to the application of an excessive amount of the chemical, the nozzles should be shut off the minute the sprayer stops moving. No applications should be made on a windy day, as the spray will drift and cause streaking.

Physicians advise us that the men operating the equipment should wear gauze masks covering their mouths and noses and that they should wash their hands thoroughly after each application to avoid any possibility of arsenic poisoning.

Needless to say, we are very enthusiastic about large-scale weed control with arsenic acid and we intend to continue treatments spring and fall for another year or so, by which time we hope to have completely conquered our weed problem.

CHEMICAL WEED CONTROL ON LAWNS AND SPORTS FIELDS

FRED V. GRAU *

A few years ago when the news of a cheap, effective, reasonably safe method of controlling weeds in turf with chemicals began to spread, there were many who harbored the illusion that this was the final answer. There would be no more weeds! Simply sprinkle a magic powder over the lawn and presto!—a perfect lawn with no work involved! This idea, more than any other, has retarded the cause of chemical weed control by producing disappointing results. Some illusions are dispelled quickly, others gradually; this one takes no time at all. The first trial convinces anyone that chemical weed control is but one step in the production of beautiful turf.

After the weeds are killed, the grasses must be properly fed to encourage them to crowd into the bare spots left by the death of the weeds. The weeds prefer the same environment as grass and, like grass, they are encouraged by a lack of competition. It is therefore important to accompany the application of chemicals for weed control with a good fertilizing program in order to establish a turf so thick and sturdy that competition with the grass discourages the weeds.

Whereas various methods of application may be used, experience with controlling weeds in lawns and in sports turf in Pennsylvania has taught us several things.

Dry treatments are safest from the fire hazard standpoint when using sodium chlorate. They are uniformly distributed only with great difficulty either by hand or by machine. Few people can broadcast uniformly by hand. Operators of most

* Extension Agronomist, Pennsylvania State College.

Hand spotting rosette weeds with arsenicals by means of a spoon.

machines are quite likely to miss on some strips and overlap on others. This doubling of the rate of application on the overlap may be disastrous to grass.

Chemicals can be distributed most uniformly when in solution, but in the case of sodium chlorate a greater fire hazard to operators is presented unless proper precautions are observed. It is possible, however, to miss or to overlap with any type of sprayer, dependent upon the operator.

It may be interesting to consider a few case histories of demonstrations of successful chemical weed control in Pennsylvania. These demonstrations taken from our files illustrate

the importance of combining chemical control with a good fertilizing program.

A Home Lawn

The turf on this home lawn consisted of Kentucky bluegrass, Chewings fescue and white clover, but this was thin due to close clipping and starvation. It was overrun with speedwell, knotweed, chickweed, self-heal and sorrel. Hand weeding had proved ineffective.

On August 17, 1936, a mixture of 12 quarts of dry sand and 4 ounces of sodium arsenite to 1,000 square feet was uniformly broadcast by hand. The soil was moist, weather mild, and the poison was not watered in. The turf was slightly browned but recovered in a few days. Weeds, except dandelions, were killed 90-95 per cent. All dandelions, except the very young plants, recovered.

On September 25, 75 pounds of limestone and 30 pounds of complete fertilizer were applied and the mower set to 1½ inches. By September, 1937, the turf was vigorous and weeds negligible. Another treatment in the spring would have been desirable but the one treatment was satisfactory.

A School Lawn

A school lawn on well drained shale soil consisted of Kentucky bluegrass, with some Chewings fescue, bent and *Poa trivialis.* Close cutting and lack of fertilizer had resulted in a thin turf overrun with ground ivy, speedwell, buckhorn plantain, yarrow, self-heal, sorrel, mouse-ear chickweed, common chickweed, dandelion and crabgrass. Due to the severity of infestation and the lack of help, hand weeding was out of the question.

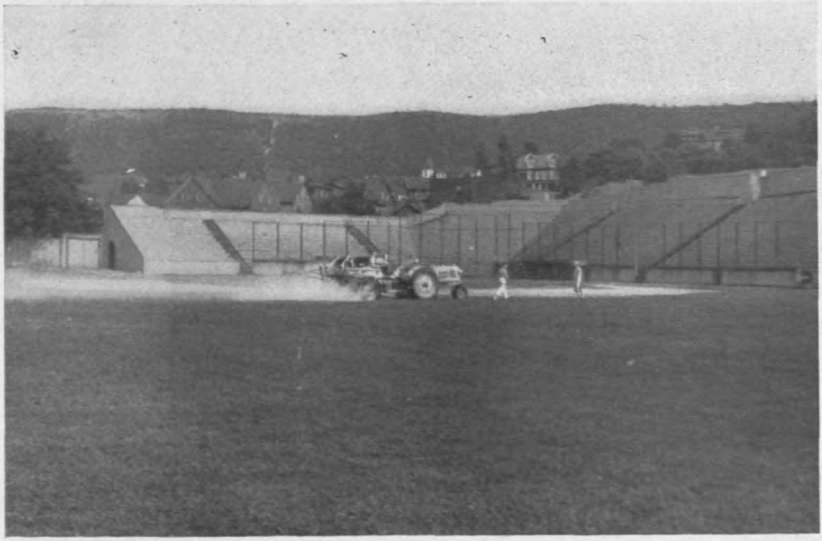
In April, 1937, 50 pounds of ground limestone and 25 pounds of 4-12-4 fertilizer were applied to each 1,000 square feet and the mower set to 1½ inches. On September 7, 1937, during a soft drizzling rain the area was sprayed with a solution of 12 ounces of sodium chlorate and 4 ounces of sodium arsenite in 3 gallons of water to 1,000 square feet. This was applied as a fine mist through a knapsack sprayer. The soil was moist and growth vigorous.

The grass was browned but soon recovered and after an application of 25 pounds of 4-12-4 fertilizer to 1,000 square feet in late September made a vigorous growth. Ground ivy was 98 per cent killed; buckhorn plantain, 95 per cent; and chickweeds, 100 per cent. In September, 1938, the turf was in fine condition, with only a few weeds. The untreated strip had poor, thin turf with 60 per cent weeds, mostly ground ivy.

A Sports Field

A college soccer field was on level ground with heavy clay soil and not well drained. The field was scarred from heavy play. The turf was almost entirely Kentucky bluegrass with some *Poa trivialis* in wet places but was infested with plantain, some buckhorn plantain, knotweed and a little crabgrass. Cultural control had been ineffective over a period of two to three years. Hand weeding was too expensive.

On August 18 the area was sprayed at the rate of 4 ounces of sodium arsenite to 1,000 square feet. The work was done with a calibrated tractor pulled power sprayer with a 10-foot boom and with 6 nozzles set 20 inches from the ground. The pressure gauge was set at 200 pounds. The tractor ran in low gear at 3½ miles an hour. Spraying was done between 2 and 4 p. m., with the soil moist and vegetation vigorous. The grass



Eight-row potato sprayer with 20-foot boom spraying an athletic field to control weeds.

had been clipped at 3 inches, two days previously. The entire field became brown but 10 days later the bluegrass had almost completely recovered and 99 per cent of the plantain was killed. *Poa trivialis* recovered more slowly. Three hundred pounds of 8-24-8 fertilizer and 1 ton of limestone were applied to the acre. Within a month after the application of the arsenite the grass was growing vigorously and the field was green and being used for play.

All sports fields and many areas of lawn on that campus are now sprayed regularly for the control of plantain, buckhorn plantain, crabgrass and knotweed, using mixtures of chlorate and arsenite adjusted to the weeds and grasses present.

Another Lawn

On a home lawn with south and west slope the bluegrass was almost completely choked out with crabgrass and some buckhorn plantain, all other weeds having been choked out by

Weed canes for treating scattered weeds. By this method small quantities of chemicals can be applied to individual plants in a clean-up job.

crabgrass. This lawn had been spring seeded with a mixture consisting mostly of Kentucky bluegrass, but only straggling plants were left. Hand weeding was impracticable and weed control by cultural methods alone was too slow. The lawn might have been plowed and reseeded but this might have entailed loss of soil and seed from washing rains.

On August 15, 1936, when the soil was moist and the crabgrass vigorous and just starting to bloom, this lawn was sprayed with a solution of 2½ pounds of sodium chlorate in 3 gallons of water to 1,000 square feet. The material was applied with a knapsack sprayer and not watered in.

While the lawn was at first brown the Kentucky bluegrass resumed vigorous growth in 10 days while the crabgrass and

buckhorn plantain were dead. At this time 50 pounds of ground limestone, 15 pounds of 4-12-4, and 15 pounds of cottonseed meal were applied to each 1,000 square feet, and lightly raked in. On August 27 the area was reseeded with a good mixture lightly raked in and topdressed. On October 1 the new grass was vigorous and ready for clipping.

The owner had a green lawn throughout the fall, winter and spring for the first time in years. The following fall the lawn was in excellent condition. Only a few scattered crabgrass plants appeared in the new vigorous turf and they were removed by hand before the seed matured.

Results Vary with Conditions

The records above are only four out of many records of successful treatment on lawns, sports turf, cemeteries, parks, etc. There are also records of failures. These failures can mostly be traced to the "personal factor" making for lack of uniformity in the application of the poison. Another important factor is the weather. Treatments during extremely dry weather may result in a high mortality of the grass. In this case water should be applied. Treatments on dry parched turf and dry soil are likely to fail.

Spring and fall appear to be the most favorable seasons for the application of sodium arsenite. The perennials and biennials such as dandelions, buckhorn plantain and most rosette and mat-forming weeds are in most active growth at these seasons and the grass is most vigorous. In summer arsenicals are more harmful to grass and less selective. The contrary is true of chlorate. This is most effective during hot weather.

Heavy frost following an application of arsenite will greatly increase its effectiveness. Excess moisture in the soil will reduce

the effectiveness of both chlorate and arsenite. On light sandy soils rates of application must be reduced to about half.

As shown by the records, most weeds can be killed by applications not stronger than the grass can endure. It may be temporarily browned, but recovers. Dandelions, however, can seldom be eradicated with one application without killing all vegetation. Young plants are killed and the old plants weakened, but to effect complete control periodic applications must be made at a rate that will gradually weaken the dandelions but permit the grass to recover before the next application.

Applying arsenate of lead for control of grubs. These men were careless. Their faces and hands were white with arsenic dust. This is dangerous. Skin poisoning may result.

THE CONTROL OF CRABGRASS IN A CEMETERY

C. R. RUNYAN*

In the cemetery of Spring Grove, crabgrass is the most troublesome weed. Others, such as broadleaf plantain, chickweed, and dandelion, are a nuisance but not as serious as crabgrass.

A few years ago, during a visit to the Arlington Turf Garden, we were shown some of the results of weed control treatments with sodium arsenite. Many of these treatments were so successful that we decided to make some similar tests under our conditions in Cincinnati. Our preliminary trials in 1936 showed that while both dry and spray treatments were effective, the spray treatment was more practical for our purposes. Although 1936 was a bad year for trials because of the drought, it was noted in the fall that there were decidedly fewer weeds on the test plots than on the untreated areas.

The great flood of January, 1937, deposited about an inch of silt over the test area and brought with it seeds of many weeds not present before. During that year we treated extensively for both chickweed and crabgrass. In late August and early September, before the crabgrass had gone to seed, we treated with sodium arsenite, applying 2 ounces of dry material or 4 ounces of a 50 per cent solution to 1,000 square feet. After treatment, bluegrass was seeded without disturbing the soil to any extent. The result has been a good stand of bluegrass and the almost complete elimination of crabgrass. The few plants of the latter that did appear were easily removed by hand.

During the past season, the treatments have been repeated on a larger scale. We have also treated areas of *Muhlenbergia*

* Superintendent, Cemetery of Spring Grove, Cincinnati, Ohio.

schreberi, which is often a serious pest here. What the result will be cannot yet be stated. At any rate, the treatment of the *Muhlenbergia* made it easier to sow bluegrass seed, which is difficult unless the mat of *Muhlenbergia* is removed in some way.

We found that 2 ounces of sodium arsenite to 1,000 square feet so crippled the crabgrass that it did not recover in time to produce seed. There was less discoloration of the bluegrass than when the heavier rates were applied. As little as ½ ounce of sodium arsenite to 1,000 square feet is often enough to control chickweed but 1 ounce is more certain to produce results. When applied during winter or in early spring, this gives better control than any other method that we have tested.

We are thoroughly convinced that chemical control of crabgrass is practical and economical when combined with good lawn maintenance practices. Whether sodium arsenite will be the chemical most suited to our needs or whether some other material will be used, is something that only experimental work will determine. Up to the present time sodium arsenite appears to be the most successful and economical. For cemetery use, it has a distinct advantage over such chemicals as iron sulphate, as it does not discolor granite or other stone.

During the 1939 season we shall make even more extensive trials on areas badly infested with crabgrass and *Muhlenbergia.* We shall conduct also a series of tests looking toward the control of buckhorn plantain, the next worst pest with which we have to deal.

The best time to remove stones from turf is early spring. Heaving brings stones to the surface and if these are removed just as the frost leaves the ground and before the grass starts to grow, the fairways can be rolled to settle the sod.

KILLING WEED SEEDS IN SOIL WITH CHLOROPICRIN (Tear Gas)

JOHN MONTEITH, JR., and A. E. RABBITT*

A supply of soil comparatively free from weed seed is desirable not only for topdressing turf but also for the establishment of new seed beds. While well prepared compost is relatively free from weed seed the fact is that much of the compost used on golf courses is not well prepared. The illustration on page 64 shows that such compost may be full of weed seed. The use of soils, as for instance woods earth, which contain few seed of important turf weeds, is advisable, but such soils often are difficult to obtain. The destruction of seed by composting soil is a slow process which is not always practical.

Heat has been used to destroy weed seed in soil. Both the steaming and the baking processes have been employed for this purpose. Although these methods are effective they frequently damage the physical properties of soil and are somewhat expensive.

Agricultural workers have tested many promising chemicals in the hope of reducing costs of the partial sterlization of soil. Although good results have been obtained with some of them they generally have been unsatisfactory because of the excessive cost or due to the fact that they have remained too long in the soil and thereby have limited the growth of the plants for which this soil had been used.

In recent years chloropicrin (one of the tear gases) has been used successfully for partial sterilization of soil, chiefly for the control of nematodes. Although it had not been tested for the

* Director, United States Golf Association Green Section, and Greenkeeper, National Capital Parks, respectively.

Nine samples of compost collected from golf courses showed remarkable differences in weed infestation when placed in flats and subjected to growing conditions and offer an explanation of the greater abundance of weeds in the greens of some courses as compared with others. Some of the flats are almost weed free. Tests of this kind have demonstrated that it is not unusual to plant 70,000 weed seed on a putting green in a single topdressing.

control of weed seed in soil, certain results obtained with it seemed to indicate some possibilities of useful application in turf maintenance work. Therefore numerous tests with chloropicrin were conducted at the Arlington Turf Garden. The results of some of these tests will be outlined in the pages that follow.

Chloropicrin (Trichloronitromethane—CCl_3NO_2) is an organic compound made up of carbon, chlorine, nitrogen and oxygen. It is a colorless liquid about one and three-fourths as heavy as water. It is practically non-inflammable. Although almost insoluble in water it dissolves readily in gasoline and almost all other organic solvents. It vaporizes to form a very pungent tear gas which has great penetrating power.

Chloropicrin has a pronounced odor. It is a respiratory and

lachrymatory (tear producing) irritant and, as such, was used in the World War. Prolonged exposure to relatively high concentrations of the gas causes serious detrimental effects on the respiratory system. Chloropicrin is not dangerous to work with, however, as a person can not willingly withstand even a small fraction of the concentration that would be dangerous to human life. Although it has a corrosive action on the skin there is no irritation if the liquid momentarily comes in contact with the skin.

Numerous research workers since 1907 have experimented with chloropicrin for fumigating grain and plants and for the killing of fungi. It is now extensively used as a fumigant and as an insecticide in warehouses and grain elevators. Applied at the rate of 150 pounds to the acre it has given 83 per cent control of nematodes and 52 per cent increase in the yield of pineapples. As a fumigant it has the advantage of high toxicity, practically complete freedom from fire and explosion hazards, relative non-reactivity to metals, and ability to penetrate bulk commodities. Another advantage over other common fumigants is the pronounced warning which its odor and lachrymatory effects give, even when it is present in minute quantities.

The first tests made with chloropicrin at Arlington in the spring of 1937 were concerned with the sterlization of small lots of compost in wooden boxes. The promising results which were obtained led to more extensive tests.

The clay-loam soil used for conducting the experiments described was from the surface of an area heavily infested with weeds. In some instances additional weed seed were added to the soil two or three weeks before it was treated. Supplementary tests were made on the regular compost material used at Arlington.

For most of the tests galvanized iron garbage cans of 1 cubic-foot capacity were used. When tightly covered these cans provided relatively gas tight containers. The soil to be treated was in all cases screened before it was used. Three-fourths of a cubic foot of soil was put into each of the cans and the required amount of chemical was placed in a hole in the center of the soil mass. The rates are given in terms of actual weight of the liquid rather than in fluid ounces. The soil in these cans was left covered for several days and then placed in regular greenhouse flats, watered as needed and placed in the greenhouse or out-of-doors wherever conditions were most favorable for the germination of weed seed. Counts of the various weeds were made when new seedlings ceased to appear. Usually this was from four to six weeks after the soil was placed in the flats.

Several methods were tested for treating field plots both in turf and in cultivated soil. These consisted of sprinkling the liquid directly over the surface or in applying it in holes or narrow furrows. Various depths and spacing of holes and furrows were tested. After treatment the holes and furrows were filled with soil and the treated area immediately covered to prevent escape of the gas.

Various covers were tried, including canvas, kraft glue-coated paper, concrete water-proof paper and a layer of wet soil. The best results were obtained by using the kraft glue-coated paper. A shallow trench was dug around the plot to be treated and the edges of the paper laid in the trench and covered with soil. Four days after treatment the cover was removed and any gas remaining in the soil was permitted to escape into the air. Tests on the time necessary to keep the soil covered after treatment have indicated that no further killing is accomplished

Method of application of the liquid chloropicrin into the soil. The waterproof paper in the background was to be placed over the plot and sealed with sterilized soil as soon as the application was completed.

after four days. A shorter period than this has given reduced effectiveness.

Piles of soil were treated in several ways. Two of the methods tried seemed to be more satisfactory than the others. The most satisfactory of these consisted of building up a pile of screened soil in 6-inch layers, with the first layer somewhat less than 6 inches thick. Chloropicrin was sprinkled over each layer as the pile was built up to the desired size. A more uniform distribution of the chloropicrin was secured by first emulsifying it in water so as to obtain a larger quantity of liquid to sprinkle over the soil.

The other method consisted of building up a pile of compost and making holes to the bottom of the pile at distances of from 6 to 8 inches apart. Chloropicrin was poured into each hole, which was then filled in with compost to a depth of from 6 to 8 inches, another application made, and so on until the hole was entirely filled.

Effect of moisture on partial sterilization of compost with chloropicrin at rate of 20 ounces to a cubic yard. Left, untreated; left center, soil dry; right center, soil medium wet; right, soil saturated during treatment. Weeds are chiefly crabgrass and goosegrass.

The piles of compost were covered with kraft glue-coated paper, several widths of this paper being glued together for this purpose. When treating soil in boxes this paper was used as a cover by gluing it to the edges of the box. Other waterproof paper and even canvas which is kept moistened gave satisfactory results.

Observations at Arlington indicated that the variable results secured with chloropicrin were due probably to variations in soil moisture, temperature and species of weeds present. The effect of each of these factors was separately tested and the results are summarized in this article.

Effect of definite percentages of moisture on partial sterilization of compost with chloropicrin. Chloropicrin applied at 15 ounces to a cubic yard at soil temperature of 77° F. Back row, left to right, 40 per cent and 50 per cent moisture and untreated soil; front row, left to right, 10 per cent, 20 per cent, and 30 per cent moisture present in compost at time of application. Note most effective sterilization when soil contained 20 and 30 per cent moisture at time of application.

Influence of Soil Moisture

The effect of varying amounts of moisture in the soil at the time of the application of chloropicrin on the percentage of weed seed killed has been studied. Varying quantities of water were added to air-dried soil, ¾-cubic foot of soil was placed in each iron garbage can, chloropicrin was added at rates varying from 10 to 30 ounces to a cubic yard, and the cans were immediately covered. After four days the lids were removed and the different lots of soil placed in flats to permit germination of the viable weed seed.

Results from numerous such experiments showed that the best kill of weed seed was obtained when the soil was medium wet. As the soil became more nearly saturated with water the

rate of kill fell off rapidly. In the case of all weeds except crabgrass there was not as much kill in the extremely dry soil as in the medium wet soil.

In the experiment for which the data are given in the following table chloropicrin was applied at the rate of 20 ounces to a cubic yard with the soil temperature at 77° F. Approximately 90 per cent of the plants that developed in the untreated area were crabgrass. The figures show that about the same percentage of crabgrass seed was killed in the dry as in the medium wet soil but that when the soil was very wet the percentage of kill was less. For other weeds the percentage of kill was better in the medium wet than in the dry or the wet soil.

EFFECT OF SOIL MOISTURE ON PERCENTAGE KILL OF WEED SEED BY CHLOROPICRIN AT THE 20-OUNCE RATE AT 77° F.

Moisture content of soil	Percentage kill of seed	
	Crabgrass	All weeds
Air-dry (0-10 per cent)	97	74
Medium-wet (20-30 per cent)	97	91
Very wet (40-50 per cent)	25	26

Other series of tests made with soil containing different proportions of moisture consistently indicated that best results may be expected when chloropicrin is applied to this type of soil when it contains from 20 to 30 per cent of moisture.

EFFECT OF TEMPERATURE

Experiments on the effect of temperature on the power of chloropicrin to kill weed seed were set up in a manner similar to those used in the investigations on the effect of moisture. Rates varying from 5 to 20 ounces to a cubic yard were applied to ¾-cubic-foot lots of soil at temperatures ranging from 32° F. to 104° F. After four days the covers were removed and the

Effect of temperature on killing of weed seeds in compost with chloropicrin at various rates. Temperatures from left to right, 32°, 50°, 68°, 86°, and 104° F. Rate of treatment from front to back, untreated, 5, 10, 15, and 20 ounces to a cubic yard. Note stimulation of crabgrass in soil treated at 5-ounce rate and also at the 10- and 15-ounce rates at 32° F. Note also the most complete sterilization at highest temperatures and highest rates.

soil was placed in flats to allow the germination of remaining viable weed seed. At the same time equal volumes of untreated soil were held at similar temperatures for the same period of time and then placed in flats.

The number of seedlings appearing in treated soil at each temperature was compared with the number in the untreated soil at the same temperature. The untreated lots of soil held at different temperatures were also used to ascertain whether the short exposure to these different temperatures might in any way affect germination of the seed.

The following table shows that, with a few minor exceptions, percentages of crabgrass seed and of weed seed as a whole killed with applications of chloropicrin at rates of 10, 15 and 20 ounces to the cubic yard increased as the temperature rose from 32° F. to 104° F. At the highest temperatures with the heavier rates there was practically a complete kill of the weed seed.

At the 5-ounce rate with temperatures of 32°, 50°, 68° and 86° F., and at the 10-ounce rate at 32° F. there was actually an increase in the number of crabgrass plants. An increase of all weeds will also be noted in the table in the 5-ounce series at 32°, 50° and 68° F. The numbers of most weeds, however, were not increased. The increase in number of all weeds reported is due to the large proportion of crabgrass.

The results showed that weed seed are most easily killed when treatments are made at high temperatures. This fact probably accounts for the greater effectiveness of chloropicrin in compost or turf in mid-summer than in fall. In June and July 98 per cent of the weed seed was killed by the treatments when made out-doors. In late September and in October under similar conditions except for the temperature the kill was 76 per cent.

PERCENTAGE CONTROL OF WEED SEED AS INFLUENCED BY TEMPERATURE

Temperature	Number in check	Percentage control 5-oz.	10-oz.	15-oz.	20-oz.
Crabgrass					
32° F.	203	+ 76	+ 30	23	71
50° F.	183	+ 93	47	52	95
68° F.	134	+ 188	25	86	93
86° F.	151	+ 29	89	97	95
104° F.	148	63	90	99	100
All Weeds					
32° F.	360	+ 42	1	24	45
50° F.	304	+ 30	44	45	43
68° F.	261	+ 29	14	81	58
86° F.	300	30	74	83	87
104° F.	333	50	69	98	99

The + indicates the percentage of increase in weeds.

EFFECT ON DIFFERENT WEEDS

The seed of different turf weeds vary in their susceptibility to chloropicrin. The percentages of weed seed killed at a 20-

ounce rate at both favorable temperatures and soil moisture have been taken from numerous experiments. These weeds have been listed here in the order of the decreasing susceptibility of the seed to chloropicrin in the soil.

Seed of chickweed, witchgrass, quackgrass and sedge have proved to be easily killed. Clover seed was generally resistant to chloropicrin, although the results were somewhat inconsistent. Other tests indicate that the seed of plantain, *Poa annua,* foxtail, Jimson-weed and *Muhlenbergia* also are easily killed.

The percentage of goosegrass seed killed by a treatment at the 20-ounce rate varied under similar environmental conditions. In some instances 50 per cent of the seed was killed while in others the chloropicrin appeared actually to stimulate germination so that there were 95 per cent more goosegrass seedlings in the treated than in the untreated soil. In this case, however, the soil temperature during germination was too low for the normal germination of goosegrass seed.

AVERAGE PERCENTAGE KILL OF SEED OF VARIOUS WEEDS BY CHLOROPICRIN AT 20-25 OUNCE RATE

Weed	Percentage kill
Chickweed	100
Witchgrass	100
Quackgrass	98
Sedge	95
Crabgrass	83
Clover	23

CHLOROPICRIN IN COMPOST PILES

Excellent results have been secured by treating 5 cubic yards of compost at a time at the rate of 30 ounces to the cubic yard. In this experiment a pro-rated quantity of chloropicrin was sprinkled over each 6-inch layer of compost as the pile was

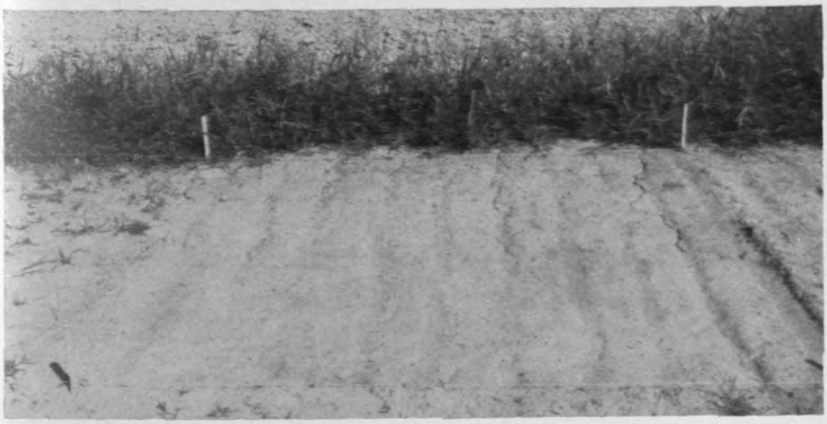
built up. The pile was then sealed with kraft glue-coated paper. Several flats of the untreated compost taken before treatment and flats of compost taken after treatment were placed in a favorable place for the germination of any viable weed seed. After two months counts were made of the seedlings in both sets of flats. Apparently the crabgrass, chickweed and *Poa annua* seed had been killed 100 per cent. On the other hand the resulting stand of clover was reduced only 15 per cent and that of goosegrass was increased 40 per cent. This experiment was set up in October, but similar results were obtained from like experiments conducted in June, July and August.

Results in Turf and Cultivated Areas

Chloropicrin has also been used on a turf badly infested with weeds in order to destroy weed seed in the soil and avoid removing the upper layers of soil before reseeding. In September, 1937, chloropicrin at the rate of 8 pounds to 1,000 square feet was applied to turf in furrows 2 inches deep. The treated areas were covered with canvas. Ten days later the treated and untreated areas were seeded to Kentucky bluegrass and two months after treatment there was a better stand of grass on the treated than on the untreated plots. The weeds were completely controlled. The color of the grass was also better and the favorable result of the treatment was clearly evident nearly a year later.

In recent experiments on turfed areas it has been shown that the application of chloropicrin at the rate of 14 pounds to 1,000 square feet applied to a depth of 3 inches will destroy weed seed in the surface soil. In several series of experiments chloropicrin was applied to 4 by 4 foot plots of turf at rates of 12, 14, 27.5 and 55 pounds to 1,000 square feet, and the areas covered with kraft glue-coated paper.

A week following the application of the chloropicrin a 2 by 2 foot section in each of the experimental plots treated at 27.5 and 55-pound rates was scraped to remove the dead vegetation. These sections as well as untreated plots were then seeded to redtop.



Sterilization of soil in the field with one application of chloropicrin to a depth of 2 inches at the rate of 4.6 pints (8 pounds) to the 1,000 square feet. Check untreated strip in the background.

After 10 days the redtop had come up to good stands on the untreated areas and on the plots treated at the 27.5-pound rate but to an irregular stand on the plot treated at the 55-pound rate. After six weeks the stand of grass on the plots treated at the 27.5-pound rate was twice as high and twice as dense as that on the untreated plots.

These results indicated a decided stimulation of the grass with the chloropicrin when applied to a depth of 3 inches at the rate of 27.5 pounds to 1,000 square feet. A toxic effect on the grass seedlings was evident only when chloropicrin was used at the high rate of 55 pounds to 1,000 square feet. Allow-

ing a longer period of time for aeration of the soil between treating and seeding probably would have eliminated this toxic effect.

These experiments were conducted on both Kentucky bluegrass and Bermuda grass turf. All vegetation, even the tough, resistant rhizomes of Bermuda grass and the bulbs of wild garlic which are usually difficult to destroy, was killed at the 14-pound rate. On the plots treated at the 12-pound rate, *Poa annua* began to appear after one month, and other weeds came in at the edge of the plots two weeks afterwards.

Soil from the treated and the untreated plots was placed in flats and taken into the greenhouse to check the germination of the weed seed under more favorable conditions. In the soil treated at the 14-pound rate there were 75 per cent fewer crabgrass seedlings and 87 per cent fewer weed seedlings of all kinds than in the untreated soil.

PERCENTAGE KILL OF WEED SEED IN TURF WITH CHLOROPICRIN APPLIED BY SEVERAL METHODS AT THE 14-POUND RATE

	Crabgrass	*Poa annua*	All weeds
Applied in holes	76	28	46
Applied in furrows	75	100	87
Applied by sprinkling can	+7	21	+7

The + indicates the percentage increase over the check.

Experiments were set up to compare the efficiency of the several methods of application. In a series of experiments chloropicrin was applied to 4 by 4 foot plots at rates of 12, 14, 27.5 and 55 pounds to 1,000 square feet. In one set it was put into narrow furrows 3 inches deep and spaced 8 inches apart; in another, in holes made 3 inches deep and 8 inches apart; and in a third set surface applications at the three heaviest rates were made with a sprinkling can. In all cases

the treated areas were promptly covered with glue-coated kraft paper. All vegetation apparently was killed by all three of the methods. However on plots treated by the sprinkling can method a medium stand of weeds was reestablished within a month and a half, even when treated at the 27.5-pound rate. On the other hand, no vegetation appeared two months later on plots on which the chloropicrin was applied either in furrows or in holes to a depth of 3 inches at the 14, 27.5 or 55-pound rates.

Soil from each treated plot and from untreated plots was taken into the greenhouse to obtain the germination of viable weed seed. The following data taken from the record of plots treated at the 14-pound rate shows that the best kill of weed seed follows when chloropicrin is put into furrows.

Control of Microorganisms

As the experiments on the killing of weed seed by chloropicrin were in progress numerous samples of the treated and untreated lots of soil were used by Nathan R. Smith, of the Bureau of Plant Industry, United States Department of Agriculture, to determine the power of chloropicrin to kill fungi, bacteria and protozoa. The results of these tests, together with others conducted by Mr. Smith, will be published soon in Soil Science Society of America, Proceedings, Vol. 3.

Mr. Smith reports that the effect of chloropicrin on the microorganisms of the soil varies in much the same manner as it does on weed seed. Temperature was found to have a definite influence on the efficiency of chloropicrin. At 32° and 50° F. the killing was not as great as at temperatures of 68°, 86° and 104° F. At the high temperature of 104° with the 15 and 20-ounce rates "the number of fungi

was reduced from 130,000 per gram to 5 per gram; actinomycetes from 28,000,000 to 6,000 and 8,000, respectively; and the total viable organisms from 180,000,000 to around 3,000,000 per gram."

Growth of grass in compost treated with chloropicrin. Red top seed was sown in a 4-inch strip of each flat eight days after the application of chloropicrin. Flats in back row contained untreated soil. Coming forward, the rates used were 5, 10, 15, and 20 ounces to a cubic yard. Temperatures at time of treatment from left to right were 104°, 86°, 68°, 50°, and 32° F. There was no retardation in germination of red top seed even in the soil receiving the heaviest rate. On the contrary, growth was stimulated in the treated flats.

Soil moisture was also found to have a decided influence on the efficiency of chloropicrin in destroying microorganisms. The fungi and actinomycetes were killed best when the soil contained from 10 to 15 per cent moisture. The bacteria and protozoa were killed at the same moisture content and also when the soil contained more moisture. The conclusion reached was that from the standpoint of controlling soil microorganisms "a temperature above 20° C. (68° F.) and a soil moisture content of 10 to 15 per cent are optimum conditions for treatment with chloropicrin and that these conditions seem as important as the rate of application."

Tests were also made to determine the effect of the treatment on the later development of soil organisms. At the lower concentrations of chloropicrin fungi and bacteria were found

to develop rapidly within 10 days. In the following 10 days the soil that had received the higher applications also showed some increase in microorganisms. Nitrates decreased slightly and ammonia increased slightly in the treated soil within 20 days after treatment.

Some Advantages and Disadvantages of Chloropicrin

Advantages

The chloropicrin method of partially sterilizing soil has certain advantages over the common methods now in use. It requires no expensive equipment, which may be a distinct advantage in treating small lots of soil. Unlike the heat process of sterilization, chloropicrin has no harmful effect on the physical properties of the soil. The soil can be used soon after it has been treated with chloropicrin as then it will not be toxic but actually may be stimulating to grass. In one case when weeds were controlled completely grass seed germinated satisfactorily when planted only two days after the chemical was applied. Soil can be treated successfully with chloropicrin in piles or in turf without incurring the cost of moving the soil in and out of containers for treatments.

Disadvantages

It requires careful covering of the treated soil to prevent escape of gas. As its effectiveness is decidedly reduced at low temperatures, it can not be used to advantage at all seasons. Heavy rates must be used to accomplish complete control of some of the most troublesome turf weeds. Where seed of the more resistant weeds are abundant in soil the cost of the treatment is high.

WHAT OTHERS WRITE ON TURF

In this department will be given the substance of research in the various fields of scientific investigation which seems to have a definite bearing on turf improvement. The articles will summarize results of recent investigations made in various parts of the world. They are not published here as recommendations but simply as information for our readers and as suggestions which may have practical applications in many situations. Where the Green Section's tests or the information it has obtained from other reliable sources in this country substantiates or contradicts the results obtained by other investigators, comments to that effect may be included as a guide for our readers. In all other cases the reader will receive in brief the results and conclusions as given in the original papers.

Control of Dandelions in Lawns

Dandelions are perennial pests on lawns, fairways, and other turf. Cutting them out may be feasible on a small area but even then the exposed soil makes a place for new dandelion seedlings or other weeds to get a start. Iron sulphate has been used with some measure of success, especially when at the same time the grass was heavily fertilized to stimulate growth.

Loomis and his associates in Iowa have shown that a certain grade of kerosene can be used effectively to kill dandelions. They studied the food reserves in the plant and the influence of different temperature, moisture, and sunlight conditions upon the killing effect of the kerosene and the damage done to grass. While sunlight appeared to have no direct effect, the high temperatures usually experienced on a sunny summer day decreased the effectiveness of kerosene on dandelions but increased its injury to grass. The best results "were obtained at temperatures up to 72° F. by spraying in the evening or on cloudy days."

In articles in Science and in the Journal of Agricultural Research they recommended spraying at the rate of 5 gallons to 1,000 square feet during cool, cloudy weather. Their best results were obtained from early fall treatments made six to eight weeks before the first grass-killing freezes or heavy snows. They also advised heavy applications of ammonium sulphate and ferrous sulphate spray for a year preceding the kerosene treatment. This was to encourage the growth of grass among the dandelions so that when they were killed the vacant spaces would

be quickly filled with grass rather than with weeds. The kerosene spray had no effect on other lawn weeds.

The grade of kerosene used apparently determines in a large measure the success of the treatment. The use of impure distillates showing a yellow coloration resulted in a complete kill of bluegrass and white clover sod. Consequently, only the clear or so-called water white products can be used and even among these some appear to be more toxic to bluegrass and less harmful to weeds than others.

These workers found that the per cent of unsaturated hydrocarbons determines the toxicity of the product to bluegrass and its efficacy in weed control. They consider that for the best weed control with the least injury to grass the product should contain 2.5 to 4 per cent of unsaturated hydrocarbons and should have a boiling point of 180° to 250° C. (356° to 482° F.).

Experiments conducted by the Green Section with kerosenes from several sources so far have given inconsistent results. In some cases good control of dandelions was effected. However, this was accompanied by an increase in the amount of crabgrass. In other cases, although very little control of dandelions was secured, the amount of crabgrass was still greatly increased.

Lead Arsenate Not Injurious to Grass Seed

In connection with the use of arsenic compounds as described in this issue, and especially with reference to the work of Welton and Carrol as reported here, it is of interest to note from the Journal of the Board of Greenkeeping Research that Dawson and Ferguson at Bingley, England, found that lead arsenate applied with the seed did not prevent germination. They mixed 2 ounces of the chemical to the square yard with the surface 1-inch of soil and seeded fescues, bents, Poas, perennial ryegrass, and crested dogtail. This rate equals 14 pounds to 1,000 square feet. No significant differences were noted between the germination of seed in the control pots and that of seed in the treated pots. With the exception of crested dogtail, there was no material effect on the subsequent growth of the grass.

The rate of application was lower than the rate used by Welton and Carrol (20 to 25 pounds to 1,000 square feet). The germination of the seed was complete in 30 days after the application of the arsenate, while in the Ohio work several weeks or months elapsed between the appli-

cation of the arsenate and the time when crabgrass seed usually germinates. This may have given time for the arsenate to become soluble. In a few Green Section tests at the Arlington Turf Garden and elsewhere, some retardation of germination has been noted in areas receiving as little as 5 pounds of arsenate of lead to 1,000 square feet, but in most cases the results have been in accord with the Bingley observations.

A Distinctive Color for Arsenates

The Paris green with which we used to kill potato beetles had a distinctive color and could not be mistaken for flour or sugar. Lead and calcium arsenate, however, look too much like flour or sugar to make them safe to have about the house. In fact, many cases of poisoning have been reported because of error in the use of the arsenate. Three states, Louisiana, South Carolina, and Tennessee, have legislation requiring that poisons which resemble foodstuffs or any ingredient of foodstuffs, shall be stained. Through the voluntary action of the manufacturing chemists' association such coloring will be made general, as the association has announced that both lead and calcium arsenate will be colored pink. This action is to be commended, as it will help to decrease deaths due to mistakes in the identity of the poison. The color will not interfere with the effectiveness of the poison.

Sodium Arsenite and Sodium Chlorate Render Soils Sterile

Perhaps there is no part of the United States in which there has been more interest in chemical weed killers than in the West. Chemicals are used extensively on the Pacific Coast to kill weeds in cultivated fields but the problem of sterilizing soil so completely that vegetation may be excluded from tennis courts, drives, walks, and waste places is of special interest. Crafts in California made a study of the relative toxicity of sodium arsenite and sodium chlorate in four different California soils. The reports on this work appeared in Hilgardia. The soils varied from a heavy clay loam and adobe loam to a sandy loam and a fine sandy loam, and the results varied considerably in the different soils.

Varying proportions of arsenite were added to the soils and oats were planted to indicate the degree of sterility. Taking a growth of one gram in weight for 10 oat plants in 30 days as indication that the soil was practically sterile, it was found that the quantity of arsenite required

to produce this result varied from 500 parts per million in Yolo clay loam to only 60 parts per million in Fresno sandy loam. Stockton adobe clay needed only 100 parts per million while Columbia fine sandy loam took 240 parts per million.

This great variation shows how impossible it is to give broad advice that will apply to all soil types. It may also explain many anomalies in the results of field work. The power of these soils to fix arsenic, the depth of penetration of the arsenic, and the rapidity of leaching, also varied with the different soils. Expressed in terms of practice, the information seemed to show that 7 pounds of sodium arsenite to 1,000 square feet were as effective on Fresno sandy loam as 28 pounds on Yolo clay loam. The depth of penetration of the arsenic varied with the soil and this fact influences the value of the treatment for deep-rooted plants. An application of 14 pounds to 1,000 square feet on Fresno sandy loam penetrated 12 inches, with a total rainfall of 5 inches, while in the Yolo soil, under similar conditions, the penetration was only 2 inches. Loss of toxicity with time also varied, being greatest in Yolo soil and least in the Fresno sandy loam.

The toxicity of sodium chlorate also varied with the soil, but not in the same order as the arsenite. It was highest in the Stockton adobe clay and lowest in the Yolo clay loam. Toxicity was higher when the chlorate was mixed with moist soil than with dry soil. The chlorate could be completely washed out of sterile soil by a liberal use of irrigation water.

In later work by Crafts and Cleary combinations of various chemicals were used and it was found that some neutralized each other in one soil while in another the combination had greater killing power than either alone. Thus arsenic and borax were antagonistic in Yolo clay, while in Fresno loam the effect of one was added to that of the other. Arsenic and chlorate mixed were additive in effect in all soils and form a very useful mixture. Although borax and sodium chlorate are antagonistic, this antagonism could be reduced and the advantages of the combination retained by using the lowest effective dosage of chlorate and adding enough borax to complete the destruction of the vegetation. This combination is practically non-poisonous and the borax reduces the fire hazard, which is always present where chlorate is used. The borax also has a residual effect and decreases the chance of reinfestation by seedlings.

Mercurated-ethyl-stearate in Kerosene for Killing Weeds

Ralston, Christenson, and Josh published a paper in the periodical Oil and Soap in which they gave the results of their investigations on the effect of mercurated-ethyl-stearate on weeds. They found it to be specific in its attack on weeds having latex-containing roots, such as dandelions, sunflowers, and milkweeds.

Following this work, Hanley and Weinard in Illinois studied the effect of a solution of this chemical in kerosene on turf weeds. In the Proceedings of the American Horticultural Society they published their results, which indicate that they obtained better control of weeds with the kerosene solution of the mercurated-ethyl-stearate than with kerosene alone. According to the authors, this chemical is a complex organic compound of which only small amounts are necessary to kill not only dandelions but also broadleaf plantain, buckhorn, crabgrass, sheep sorrel, milk purslane, and dock.

In their experiments, test plots were treated with .1, .2, .3, .5, and 1.0 per cent solution of mercurated-ethyl-stearate in kerosene. The resulting weed control was compared with that obtained on plots treated with kerosene alone, iron sulphate, copper nitrate, and Ammo-phos. They obtained the best coverage with 1 liter of the kerosene solution for each 50 square feet (the equivalent of 5¼ gallons to 1,000 square feet). Best control was obtained with .2 to .5 per cent solutions (2/3 fluid ounce in 5 gallons makes a .1 per cent solution).

With the kerosene solution, the tips of the bluegrass were burned, but this injury was temporary. The dandelions were said to be killed easily. The plantains were also controlled if the spraying was done not later than July 15. With reference to crabgrass, they state that it "can be effectively controlled if the spraying is done in late June or July."

Penetration is best during dry weather, so mid-June to late July is the best time to spray. Late afternoon and evening sprayings were most effective. The writers conclude that the action is not wholly due to the stearate "but rather to the combined effect of the kerosene plus the mercury compound."

They recommend for the average lawn the use of 3 cubic centimeters to 1 liter of solution. This figures out to about 2/5 fluid ounce to each gallon of kerosene or a .3 per cent solution. Best results were obtained with the use of 5¼ gallons to 1,000 square feet.

It will be noted that the amount of kerosene recommended by these investigators is slightly greater than that used by Loomis in Iowa when using kerosene alone for dandelion control. The addition of the mercurated-ethyl-stearate materially increased the cost of the treatment. However, the solution has been recommended for the control of various weeds, whereas the kerosene is said to be specific for dandelions.

Preliminary experiments with this substance at the Arlington Turf Garden have not given any too promising results. However, further work will be necessary before definite conclusions can be drawn. Our tests have shown that while it controls the dandelions somewhat more effectively than does kerosene alone, it causes a marked increase in the injury to the turf grasses with a resultant increase in crabgrass later in the season.

Control of Turf Weeds in Great Britain

At a symposium on the chemical control of weeds held in Great Britain the past season most of the papers dealt with the control of weeds in cultivated fields. R. B. Dawson, Director of the St. Ives Research Station, however described the English method of controlling weeds in lawns and fine turf. This and the other papers given at the symposium were published in the Annals of Applied Biology. Apparently in England they continue to get good results from a combination of three parts of sulphate of ammonia and one part of calcined sulphate of iron. The calcined sulphate of iron is our copperas or green vitriol with the water of crystallization driven off. These substances are mixed with 20 parts of soil, compost or other carrier, and applied six times a year at the rate of 4 ounces to the square yard (28 pounds to 1,000 square feet) for the more easily controlled weeds. This is similar to the remedy for turf weeds that has been used in South Africa for many years under climatic conditions widely different from those in England.

For weeds such as dandelion, plantain and cat's ear that are harder to control, a stronger preparation of three parts of sulphate of ammonia to two parts of calcined sulphate of iron is mixed with five parts of carrier and applied at the rate of 3 to 4 ounces to the square yard (21 to 28 pounds to 1,000 square feet).

Sulphate of iron alone or mixed with ammonium sulphate has been used in the United States for a great many years. Under certain conditions it gives satisfactory control of

weeds, but under other conditions it is not effective. At the Arlington Turf Garden combinations of sulphate of iron and ammonium sulphate, particularly when applied during the summer months, have invariably given discouraging results.

Crabgrass Control with Lead Arsenate and Calcium Arsenate

Arsenic compounds are rather widely used as weed killers, and any information showing that the use of these compounds can control crabgrass, the worst turf pest in many regions, is welcome. Welton and Carroll in Ohio conducted experiments in which they used lead arsenate and calcium arsenate applied in late fall, early spring, or summer. A report on this work appeared in the Journal of the American Society of Agronomy. The crabgrass plants on the treated areas were counted in October after the applications were made and checked against those on an area which was not treated. While there was some variation in effectiveness, the date of application was not an important feature. Rates of application less than 20 pounds to 1,000 square feet were not as effective as higher rates, whereas rates higher than 25 pounds were but little more effective than the 20 to 25-pound rates and were more injurious to the bluegrass. The best rates, therefore, were 20 and 25 pounds to 1,000 square feet. In 1933, 20 pounds of lead arsenate were applied to 1,000 square feet on various dates, and in October, 1934, and again in October, 1935, counts were made of the number of crabgrass plants on the treated areas. In 1934 the treated plots contained only 4 per cent as many crabgrass plants as the untreated areas. In 1935 the number on the treated plots had increased to 14 per cent of that on the untreated plots. Even at the 20-pound rate of application there was some injury to the grass, but this did not appear until a year or more after the application and was overcome by a liberal use of fertilizers high in nitrogen.

Calcium arsenate was, pound for pound, more effective than lead arsenate. Fifteen pounds of calcium arsenate did as good a job as 25 pounds of lead arsenate. When used at rates in excess of 15 pounds to 1,000 square feet, calcium arsenate was hard on turf, in fact it killed some of the grass.

As was pointed out by the authors, the reports on the use of arsenate of lead for the control of weeds in the different districts have been variable.

The first observations on the control of turf weeds by this chemical were published by the Green Section. Later tests showed that under many conditions the treatment was ineffective. It undoubtedly is a valuable remedy where conditions are favorable for its operation. On the other hand, it is an expensive method for one to use on a large scale only to find that his particular conditions are unsuitable for this remedy. It is therefore advisable to test this method in a small way before making general applications.

Arsenic Interferes with Phosphorus Tests

As a help in determining the fertilizer requirements of turf, a series of rapid chemical tests is used to show the amounts of the more important food elements which the plants may obtain from the soil. There are different methods for making these rapid tests but those that are commonly used for phosphorus all depend on the fact that a solution of phosphorus turns blue on the addition of stannous chloride. Chemists have shown that a solution of arsenic gives the same color reaction. Anderson and Bengtson in a recent number of the Journal of the American Society of Agronomy have reported on some tests made of samples obtained from the Arlington Turf Garden. They found that when arsenic compounds have been used on turf the blue color of this test may be due to the presence of arsenic rather than to phosphorus. Therefore, where medium or heavy applications of arsenic compounds have been made as insecticides or as weed killers, other procedures will have to be used when it is desired to determine the phosphorus requirements of soils.

Periodical coring of greens by means of tubular tines or other devices is considered important in New Zealand. The Grass Research Station there says: "If you want to get over all your surface difficulties, it is necessary to core your greens from time to time." Some greens cored every year for the past three years are said to go through the season with less trouble than those that have not been cored.

Professor Stapledon stated at the Fourth International Grassland Congress that "grass is greener and more variedly and more vitally green than anything in the whole wide world, and green is the vital color."

Does Weed Seed Mature in Cut Flower Heads?

This question is often raised in connection with the mowing of flower heads of such weeds as dandelions or thistles in an attempt to prevent maturity and distribution of seed. The question was answered for the case of the dandelion by LaRue at the University of Michigan in 1935. As reported in Science he found that viable seed is not formed in cut heads unless they are cut after the petals have fallen and the white pappus has begun to extend beyond the green tips of the bracts.

Last year Gill in Great Britain conducted a comprehensive series of experiments in order to answer the same question for sixteen weeds. The results of Gill's study were published in Annals of Applied Biology. Although some of the weeds studied are not common turf weeds, all of Gill's results are summarized in the two accompanying tables because of their general interest. In each case he obtained the percentage of germination of the dead-ripe seed as a control, taking into account the dormant period where that was necessary. The immature material was allowed to dry on the cut plant so that the seed might have some chance to mature.

These data were taken at harvest. The dead-ripe seed of Datura failed to germinate after one month unless the seed coats were cracked, whereas the milk-ripe seed germinated 100 percent all winter. This was likewise true of other weeds. The explanation is that the seed coats of dead-ripe seed became impermeable to water whereas the milk-ripe seed did not.

So far as dandelions are concerned the results secured by Gill agree with those of LaRue. Roberts in Winni-

Comparison of Germination of Seed from Plants Harvested When Mature, in Flower and in Bud

WEED	Percentage of germination dead-ripe seed	Percentage of germination cut in flower	Percentage of germination cut in bud
Ragwort (*Senecio Jacobaea L.*)	73	80	0
Sow thistle (*Sonchus oleraceus L.*)	100	100	0
Groundsel (*Senecio vulgaris L.*)	90	35	0
Sea aster (*Aster Tripolium L.*)	90	86	0
Dandelion (*Taraxacum vulgare* Schrank)	91	0	0
Cats ear (*Hypochaeris radicata L.*)	90	0	0
Creeping thistle (*Canada thistle*) (*Cirsium arvense* Scop.)	38	0	0

PERCENTAGE OF GERMINATION OF SEED AT TWO STAGES OF MATURITY

WEED	Percentage of germination dead-ripe seed	Percentage of germination milk-ripe seed*
Meadow barley grass (*Hordeum nodosum L.*)	94	90
Soft brome grass (*Bromus mollis L.*)	96	81
Curled dock (*Rumex crispus L.*)	84	88
Broad dock (*Rumex obtusifolius L.*)	84	88
Thorn apple (*Datura stramonium L.*)	100	67
Shepherd's Purse (*Capsella bursa-pastoris* Med.)	viable	viable
Corn speedwell (*Veronica agrestis L.*)	viable	viable
Chickweed (*Stellaria media* Vill.)	viable	viable
Poppy (*Papaver dubium L.*)	0	46
Nettle (*Urtica dioica L.*)	77	70

*By milk-ripe seed the author refers to seed in green capsules.

peg, Manitoba, as reported in Scientific Agriculture, found that when dandelion heads were clipped in mowing a lawn thirteen percent of the seed produced were ripe enough to germinate.

How Many Seed Do Dandelions Produce?

It is easy to see that dandelions produce plenty of seed but Roberts in Winnipeg, Manitoba, made a study and reported the results in Scientific Agriculture, showing that in a thick stand of dandelions in sod between 240 and 270 million seed may be produced to the acre. That is seed enough to infest new land at the rate of 100 seed to the square yard on 500 to 580 acres.

He counted the plants in 50 small areas and found that the field contained an average of 137 plants per square yard; these plants had a total of 265 seed bearing heads and, on the average, each head produced 192 seed. This figures out to 50,880 seed per square yard. These plants were crowded in sod and did not produce the maximum number of heads or of seed. Plants on the margin of this field where they had room had an average of 93 heads per plant and the heads contained an average of 252 seed. The highest number of heads per plant produced by these uncrowded dandelions was 146 and the highest number of seed per head 412. This makes a possible seed production of 60,152 seed per plant.

OUR LETTER BOX

The Green Section receives numerous inquiries concerning local turf problems and is always glad to reply to them. With the hope that some of these questions and answers may be helpful to others besides the original correspondent, a few of them will be published. While most of the answers will have a general application, it should be remembered that each recommendation is intended for the locality designated at the end of the question.

Best fertilizer for turf.—We would appreciate your recommendation as to what is generally considered to be the best turf fertilizer. We know that this is difficult to make without a soil analysis for the specific soil in question. I might say that we have a clay loam soil with an underlie of limestone. The turf is 10 years old, and consists of a mixture of Kentucky bluegrass and redtop. (Wisconsin.)

ANSWER.—For turf fertilizing we generally find that best results are obtained by using a fertilizer such as a 12-6-4, 10-5-3 or similar combination containing twice as much nitrogen as phosphorus, and a still smaller amount of potash. The best fertilizer is one which will provide the most plant food in approximately the proportions mentioned above for a given expenditure. Sometimes there are decided variations in soils which make it necessary to resort to certain modifications of the preceding recommendation.

Bagasse cinder in topdressing.—At a 9-hole golf course here they use ground bagasse cinder for topdressing greens, particularly during the rainy season. The cinder results from the burning of cane refuse (bagasse) in the sugar mills. It is cheap and plentiful. They have Bermuda grass greens and only a few players. However, the cinders seem to have given them good results over several years. I am sending you a sample and should appreciate your comment on it as a material for topdressing. Might it be substituted in part for the peat which we lack? (Cuba.)

ANSWER.—From the standpoint of soil improvement, this material should be entirely satisfactory as a substitute for part of the sand and humus. There is a danger that there may be too much soluble salt in bagasse cinder to warrant repeated large-scale use. However, tests of your sample show that it has been effectively leached of practically all

such harmful material. Therefore, we think you can use this material safely as the heavy rains in your section will undoubtedly take care of any excess of soluble salt. It might be well to set aside a pile somewhere to leach for at least one rainy season before it is used on your turf. The small pieces of charcoal in the bagasse cinder should be effective in improving your soil texture, and we think you could safely use it to the extent of at least one-third of the compost mixture.

* * *

Rates and time of application of lead arsenate for earthworm control. At present I am assisting The Panama Canal employes in the construction of a 9-hole golf course at Gamboa. The ground is badly infested with worms. I should like to know how much arsenate of lead to use for each 1,000 square feet of top surface. Should the first application be 1 or 2 feet below the surface? (Canal Zone.)

ANSWER.—When applying arsenate of lead, we have found that it is not necessary to put it deep into the soil. Earthworms, like grubs, feed most heavily near the surface, and therefore the poison should be at the surface. You can apply the arsenate of lead before you seed, by lightly raking it into the soil during the last raking process before sowing the seed. On the other hand, it may be applied after the seed has germinated. Usually the before-seeding method is preferable, although there is a likelihood that it may slightly retard the germination of the grass seed. This retarding effect, however, can be overcome by adding an application of sulphate of ammonia, about 5 pounds to 1,000 square feet.

The amount of arsenate of lead needed to control worms varies with different soils and with different species of earthworms. Some tropical and semi-tropical species are hard to poison. The heavier soils generally require more arsenic than do the light, sandy soils. We ordinarily recommend that arsenate of lead be applied at the rate of 5 pounds to 1,000 square feet. If this rate is not sufficient for your soil, repeat the treatment until you build up enough poison to get control. From the standpoint of economy, we feel that it is wiser to try the lighter dosage and be prepared to add more until you get the desired effect rather than to go to the expense of immediately applying the heavy treatment.

It may take three or four weeks for the arsenic to show much of an effect on earthworms. Therefore do not be in a hurry to pass judgment on the effectiveness of the treatment.

Arsenic acid in weed control.—We have been applying arsenic acid (75 per cent) with the power sprayer at the rate of ½ pint in 50 gallons of water to cover 1,000 square feet of turf to control chickweed. It has burned the clover out and injured dandelions and broadleaf plantain. There has been considerable burning of the turf however. Has our rate of application been too heavy? (Massachusetts.)

ANSWER.—Arsenic acid is a heavy liquid and therefore 1 pint of it weighs almost 2 pounds. You can roughly figure it on a 2-pound basis. Therefore, you were applying the material at the rate of 1 pound to 1,000 square feet. This is a very heavy application as a spray and would be expected to cause some injury to the grass. It has been our experience that the best results are obtained when arsenic acid is applied in the form of a spray at the rate of ¼ to ½ pound to 1,000 square feet. The ¼-pound rate is usually ample to give fairly good control and does not cause a great deal of damage to grass. In the case of the bent grasses, the rates have been reduced to 1 or 2 ounces to 1,000 square feet. However, when these light rates are used, it is necessary to repeat the treatment at least two or three times to get a reasonably good control of the weeds. Even though you have considerable burning of the grass, you no doubt will find that most of it will recover. The amount of water which you used is much more than we ordinarily find necessary for complete coverage.

* * *

Sulphuric acid in weed control.—It is my understanding that many thousands of acres of wheat fields were sprayed with sulphuric acid to kill the weeds. Is this method of weed control applicable to weeds in turf? (Michigan.)

ANSWER.—We have tested sulphuric acid for the control of weeds in turf, but our results have not been as promising as those obtained from the use of arsenic acid. In addition, sulphuric acid is a difficult material to handle unless one has proper equipment and experience.

* * *

Earthworm control in lawns.—We have several lawns which are badly infested with earthworms. These Bermuda grass lawns are now almost dormant, and we shall not put in winter ryegrass until about the first of November. Therefore it seems as though there should be little danger of burning by using chemicals during this season. Will you please recommend the best and most eco-

nomical measures to rid the grass of these pests? (Georgia.)

ANSWER.—You no doubt would find that arsenate of lead would be the most effective chemical to use for the control of earthworms under your conditions. It should serve also to protect the sod against certain insects, including white grubs and mole crickets. For ordinary purposes we recommend 5 pounds of arsenate of lead to 1,000 square feet for the first application. On sandy soils the 3-pound rate is often sufficient, but on heavier soils it is sometimes necessary to increase the dosage to 10 or even 15 pounds before an effective control of earthworms is accomplished. We suggest, therefore, that you try using it on your lawns at the rate of 3 to 5 pounds to 1,000 square feet. If this is not sufficient you can repeat the dosage. However, you should allow at least two or three weeks for the arsenate of lead to control the worms before making the second treatment. Frequently the earthworms do not appear to be affected by the lighter applications for several days after the treatment.

* * *

A good fairway mixture.—Will you kindly inform us what proportion of Kentucky bluegrass, redtop and bent would be best for our fairways? (Delaware.)

ANSWER.—For your fairways, we think a good mixture would consist of 80 per cent Kentucky bluegrass, 15 per cent redtop, and 5 per cent colonial bent.

* * *

Improving sand fairways.—We have an 18-hole golf course, the fairways of which are of Bermuda grass. The last three years our fairways have been getting poorer and poorer. We are anxious to obtain the best information available on the subject of growing and maintaining over the years a satisfactory grass surface in the sand. Our practice in past years has been to rely largely, if not entirely, on fertilizer. Now our committee is wondering if we should not perhaps add clay or humus to the sand, or perhaps grow and plow in a cover crop of clover or cowpeas. (Florida.)

ANSWER.—If your soil is primarily sand, you no doubt would find it beneficial to work a little clay into the top few inches. This would help to retain both the fertilizer and the moisture and thereby increase grass growth. I doubt that a cover crop would be practical, since it would necessitate putting the course out of play for a considerable period. No doubt the addition of clay plus fertilizer would be the most effective procedure.

Improving turf on athletic fields. We have been having considerable difficulty in maintaining a stand of grass on our high school athletic field. I am forwarding under separate cover a sample of the soil on the field. We should like to know whether the soil is in proper condition to grow grass or whether it should be cut with sand. Also, I suppose you can let us know by testing the soil what types of fertilizer would be required to get the best catch of grass. As you can imagine, the turf is abused chiefly during the two seasons which are best for growing grass. I should like to know at what time of year we could do a reseeding job, if that is what you recommend. (New York.)

ANSWER.—You may find that an ample feeding program may enable you to thicken up your grass satisfactorily without seed. Tests made on the sample which you sent indicate that the soil contained a good supply of phosphoric acid. Undoubtedly a liberal application of fertilizer containing a high percentage of nitrogen should be effective in increasing the growth of grass. We therefore suggest that in early spring you apply sulphate of ammonia at the rate of about 200 pounds to the acre. This should be applied when the grass is dry.

If the turf is very thin and obviously needs some seed, you probably can get best results by seeding in the spring during the period of late freezing and thawing. At that time some of the grass may be able to germinate and become established before the ground is sufficiently dry to be suitable for play. If neither of these programs gives you satisfactory results, it would be well during late August next year to cut in a little sand and seed and keep the field out of play as long as possible in September to enable the seedlings to become established.

* * *

Horse-tails as a lawn pest.—I have a colonial bent lawn that is infested with a weed, a sample of which is enclosed. I think it might be one of the sedge family, and I wonder if you have any control methods for this particular type of weed? (Ohio.)

ANSWER.—The specimen of weed you sent to us is one of the common horse-tails. These plants are common in poor soil but are seldom serious pests in turf. They can ordinarily be controlled simply by the liberal use of fertilizers such as sulphate of ammonia, to give a quick growth of grass and force a rank growth of horse-tails which will be injured by the mowers.

"Turfing Daisy" as a substitute for grass.—We have had inquiries concerning the use of the "Turfing Daisy" as a grass substitute. This apparently is a low-growing plant which only needs to be cut once or twice during the growing season. As we have no knowledge of its identity, I would be glad if you could furnish me with any information you have on the subject. (Ontario.)

ANSWER.—The plant referred to is *Matricaria tchihatchewi*. It is one of several plants that may be useful for lawn purposes under favorable conditions. However, it does not overwinter any too well and requires excessive moisture. Although under very limited conditions it may produce good turf, it can in no way be considered as a satisfactory substitute for grass.

* * *

Effect of height of cut of grass on incidence of weeds.—The grass on our fairways has been cut to 1¼ inches, which is ⅜ inch longer than in previous years. The question arose as to the likelihood of an increase in weeds because of this practice. Your opinion on this question is requested. (New York.)

ANSWER.—According to tests that we have conducted in different districts, clover and other turf weeds are likely to be less troublesome in grass that is cut to 1¼ inches than they are in grass that is cut very short.

* * *

Yellow hawkweed as a lawn pest. During the past three years we have noticed a weed in our lawn which we have been told is yellow hawkweed. It has a deep root and seems to choke out the grass, but it has not spread to any extent. What is the best method of getting rid of this weed? (Pennsylvania.)

ANSWER.—Weeds of this type can often be controlled in small areas by scattering a little sulphate of ammonia on them and burning the crowns. This operation usually has to be repeated two or three times as the plants recover. Sulphate of ammonia not only burns the weed, but also stimulates the grass around it, tends to force a rank growth and crowd up the leaves of the hawkweed so that they are cut by the mower.

Various weed killers may be used with success, but as this is a deep-rooted weed, repeated applications of most of these chemicals may be required. Sodium chlorate or sodium arsenite may be used to advantage, but we think that sulphate of ammonia should serve the purpose, since you say the weed is limited to a small lawn area.

Powdery mildew on bluegrass.—I am sending you a small piece of Kentucky bluegrass sod which appears to have a mildew which gives off a fine dust when the grass is perfectly dry. I should appreciate your advising me what is affecting the bluegrass, if there is any danger from it, and, if so, how it can be treated. (Virginia.)

ANSWER.—The sample you sent was affected by powdery mildew. This commonly occurs on Kentucky bluegrass in the spring, but we have never seen it do any serious harm. This fungus can be controlled by dusting it with finely powdered sulphur. This is the treatment we use in the greenhouse, where the disease is troublesome in propagating stock material. We do not know of any place where the disease has been troublesome enough to justify treatment out-of-doors.

* * *

Effect of arsenate of lead on grass. Is there any grass so fine in texture that it will not survive arsenate of lead treatment? Would arsenate of lead that is applied to greens have any effect on the grass? (New York.)

ANSWER.—Under some circumstances arsenate of lead, when used in excess, may retard the germination of grass seedlings and may check the growth of some of the more delicate grasses. However, when applied at normal rates, it is perfectly safe to use it on any of the common turf grasses—even the delicate bent grasses used on putting greens.

* * *

Tobacco as a fertilizer for bluegrass.—We are in the midst of the tobacco section, and it frequently happens that we can get damaged tobacco at a small cost to put on our bluegrass. I have the opinion that tobacco affords too much potash and would therefore not be desirable for turfs. Have you had any experience with tobacco as a fertilizer on bluegrass? (Kentucky.)

ANSWER.—Tobacco analyzes from 1 to 5 per cent nitrogen and from .5 to 10 per cent potash. Therefore, its value for the fertilizing of bluegrass is variable, depending entirely on the analysis. If your particular lot happens to be one which runs low in nitrogen and high in potash, it should not be so good for grass fertilizing. On the other hand, if it is the reverse, being high in nitrogen and low in potash, it should be entirely satisfactory.


UNITED STATES GOLF ASSOCIATION
ORGANIZED 1894