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Contents

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Use of Sodium Chlorate and Other Chemicals in Controlling Turf Weeds

By Fred V. Grau

In the Bulletin for May, 1933 (page 47), a résumé was presented of observations made on the control of crabgrass and other turf weeds with certain chemicals in the first season's experiments in this problem, as conducted in 1932 simultaneously at the University of Maryland, College Park, Md., and the Arlington turf garden, near Washington, D. C. The continuation of this same experimental work during 1933 at these two stations supplemented by its expansion at a few additional stations, affords opportunity now to present further observations on the same subject. During this second season of our work the data accumulated have been considerably increased and their value in connection with golf course problems, it is hoped, accordingly enhanced. It is our purpose here to describe in greater detail the character of the experimental work thus conducted and to present the additional data that have accumulated.

The selective control of weeds in fine turf constitutes one of the most outstanding and important problems of turf research today. This control of turf weeds by the selective action of chemicals is a phase of the problem which has heretofore been only touched on, but with some encouraging results. Most of the experimental work conducted by the Green Section in 1932 was on crabgrass in fairway turf, using a few chemicals which, by preliminary experiments and through a review of the literature, had been selected from a great many and which showed the greatest promise for effective, cheap, selective control. This group of chemicals included the chlorates, arsenical compounds, ammonium thiocyanate, and the sulphates of iron and ammonia, each of which showed more or less specificity for certain types of weeds and attendant conditions. Of these sodium chlorate was reported as having given the best results on crabgrass and milk purslane, and gave promise for successfully controlling chickweeds. Ammonium thiocyanate compared favorably with sodium chlorate in some respects. The arsenical compounds failed to show satisfactory results on crabgrass but showed a great deal of promise for the control of legumes, plantains, chickweeds, ground ivy, knotweed and pennywort. Iron and ammonium sulphates gave little or no promise for crabgrass control.

During 1933 most of these same compounds, as well as others, were used in amplified and extended tests, which yielded information as to the times, rates and methods of application under different conditions of environment, soil type, moisture, and fertility.

Chemical weed control is not new, but its adaptation and application to turf, where freedom from weeds is above all desired, open up an entirely new field of investigation, which, at the outset, appears to be of tremendous importance. The benefits of such investigations will be shared by all who have occasion to enjoy fine lawns, golf courses, parks, polo fields, or other fine turf areas. A great deal has been written concerning the advantages of this and that fertilizer material or mixture for keeping turf free from weeds. Under many conditions some of these materials have been successful, but unfortunately they are not effective against certain weeds and under all soil and climatic conditions. Chemical weed control presents the possibility of attaining this result with a minimum of labor, materials, expenditure, and disturbance of the existing turf.

Let it be understood at the beginning that this article lays no claim that the ideal weedkiller for turf has been discovered, nor that by the use of the materials reported weed-free turf can be maintained with no other care. Reported here are the efforts of two years' work, which represent an endeavor to facilitate the removal of turf weeds which persist in spite of the best care that can be given. The importance of proper soil conditions, seed-bed preparation, fertilizer practices, clipping, and other factors is in no way to be underestimated. With this thought in mind the ensuing discussion of the experimental results should gain added significance.

The results obtained in 1932 indicated that certain rates of application of chemicals were more desirable than others at different seasons and at different stages of development of the turf and the weeds. The rates at which the various materials were used in the 1933 experiments are indicated in table 1. This series, in addition, yielded valuable information as to the time of year when a single application of any given material gave the most favorable results under the existing conditions.

TABLE 1.—CHEMICALS USED AND METHODS AND RATES OF APPLICATION, ACCORDING TO PLOT NUMBERS, IN EACH OF SIX SERIES TREATED IN 1933 AT THE ARLINGTON TURF GARDEN AND MARYLAND UNIVERSITY

Row	*Chemical used*	*Method of application*	*Rates of application in pounds to 1,000 sq. ft. on each of four 4-by-4-ft. plots within each 8-by-8-ft. plot*			
			No. 1	*No.* 2	*No.* 3	*No.* 4
A	Sodium chlorate	Spray	Check	½	1	2
B	Sodium chlorate	Sprinkle	1	Check	2	4
C	Sodium chlorate	Dry with fertilizer*	Check	1	2	4
D	Sodium chlorate	Dry with hydrated lime†	1	Check	2	4
E	Ammonium thiocyanate	Spray	Check	½	1	2
F	Ammonium thiocyanate	Sprinkle	1	Check	2	4
G	Arsenic pentoxide	Spray	Check	⅛	¼	½
H	Arsenic pentoxide	Dry with sand	½	Check	1	2
I	Arsenic pentoxide	Dry with fertilizer*	Check	½	1	2
J	Fertilizer (6-12-4 inorganic)	Dry	16⅔	Check	33⅓	66⅔
K	Fertilizer (6-12-4 organic)	Dry	Check	16⅔	33⅓	66⅔
L	Calcium cyanamid (powder)	Dry with soil‡	4⅔	Check	9⅓	18⅔
M	Lead arsenate	Dry with soil‡	5	Check	10	20

* The fertilizer used was 6-12-4 inorganic in amount equivalent to a rate of 16⅔ pounds, which yielded 1 pound of nitrogen in readily available form to each 1,000 square feet of area.

† Hydrated lime was mixed pound for pound with the chemical.

‡ Finely-sifted dry compost soil.

Experimental Conditions

The greater part of the 1933 work was conducted at the Arlington Turf Garden. Duplicate tests were conducted at the University of Maryland and supplementary tests were carried on in the Chicago District. Additional tests were made on some golf courses around Washington, in New Jersey, and at Indianapolis.

At the Arlington turf garden the natural soil is of the sassafras silt-loam type, light in color, has a pH of from 5.4 to 5.6, is generally low in phosphorus and potash and high in iron, but possesses a high potential fertility. When wet it puddles easily and when dry it becomes baked and cracked. In most respects the soil at Maryland University, where the tests were located, is identical with that at Arlington. The Chicago soils on which tests were made were generally of the black or dark brown silt-loam type, sometimes almost mucky in character, fertile and well-drained, and have a pH of about 6.5 to 7.0. The Indiana soils where the tests were located were of the clay-loam type, fine textured in nature, testing about pH 6.0 to 6.5, and rather deficient in phosphorus and potash. The New Jersey soils were generally sandy in character, well-drained but infertile, with a low organic matter content and possessed a rather high degree of acidity, about pH 5.0 to 5.2.

In these experiments the plot sizes ranged from 16 square feet to 1,000 square feet, depending upon the area available for tests and the character of the experiment, as well as the distribution of the vegetation. The amount of chemical applied, in no matter what manner, was calculated on the basis of pounds, or fractions of pounds, to 1,000 square feet. In the ensuing discussion, for the sake of uniformity and ease in interpreting results, the amount of chemical used on a given plot, regardless of area, will be expressed in pounds or ounces to 1,000 square feet (one pound to 1,000 square feet is roughly equivalent to 45 pounds to the acre).

The site selected at the Arlington turf garden was a portion of neglected, unfertilized lawn at the crest of a slight, well-drained slope exposed to the west. The rather fine-textured, infertile soil supported a profuse growth of crabgrass (*Digitaris sanguinalis*), a scanty growth of Kentucky bluegrass (*Poa pratensis*), great numbers of narrow-leaf plantain (*Plantago lanceolata*), a few major or broad-leaf plantain (*P. major*), considerable white clover (*Trifolium repens*), much field sorrel (*Rumex acetosella*), a goodly variety of chickweeds, largely the common or smooth chickweed (*Stellaria media*) with some mouse-ear chickweed (*Cerastium vulgatum*), and some milk purslane (*Euphorbia maculata*). Heal-all or carpenter weed (*Prunella vulgaris*) occurred in isolated patches, as did cinquefoil (*Pontentilla* spp.) and thyme-leaved speedwell (*Veronica serpyllifolia*). The poverty of the soil was indicated further by the presence of considerable wire grass (*Aristida* spp.). Yellow or wood sorrel (*Oxalis stricta*) was quite generally though thinly distributed, as was wild garlic (*Allium vineale*).

The ground cover at Maryland was quite similar to that at Arlington with a few exceptions. The site on the Maryland campus was not so well drained as that at Arlington. The slope was slightly to the east. A better stand of bluegrass was in evidence at all times, there was somewhat more white clover, no field sorrel, and few chickweeds. Wild garlic was quite profuse on all plots and there was more of the major plantain present. Fairy rings unequally distributed through the plots, which were not in evidence at the time the site was selected, introduced a considerable error in the turf readings by stimulating the turf as if fertilizer had been applied. Dandelions (*Taraxacum officinale*) were universally present, but accurate counts were not made due to the extreme difficulty in counting them.

In addition to the weeds named, observations were made at other places on goose grass (*Eleusine indica*), ladies-bedstraw (*Galium* sp.), annual bluegrass (*Poa annua*), and winter cress (*Barbarea* sp.).

Methods of Application

Apparent discrepancies have been observed among some of the previous investigators concerning the efficiency and applicability of the various methods of applying chemicals. It has been reported that for comparable results the dry application of sodium chlorate required five to six times as much material than when applied as a spray, cognizance being taken of the influence of the vegetation to be treated. In order to thoroughly test this point with respect to the treatment of turf with chemicals, over 600 4-by-4-foot plots were treated with a single application of materials during 1933 over a period of seven months by three methods, as shown in table 1: first, the dry method, in which the chemical is mixed with an inert carrier, such as soil, sand, lime, or superphosphate, and broadcast over the turf using only a sufficient amount of the carrier to insure uniform distribution; second, the spray method, where a quantity of stock solution of a chemical is diluted with water and delivered to the turf in the form of a fine, misty spray at the rate of 150 to 200 gallons to the acre or five gallons to 1,000 square feet, using a brass hand spray gun which delivers a continual spray, the spray being allowed to remain on the vegetation; third, the sprinkling method, whereby the chemical is dissolved in water and applied with a sprinkling can, barrel cart, or similar device, which delivers the solution to the turf as a coarse rain in large drops. In the sprinkling method the chemical is immediately brought into contact with the soil, sufficient water being used to insure this, with a minimum amount remaining on the leaves of the vegetation. The amount of water used in these experiments was at the rate of approximately 25 to 30 gallons to 1,000 square feet which, it was found, represented a minimum amount for obtaining uniform distribution in connection with the use of a garden sprinkling can.

Methods of Evaluating Results

Before treating any plot, the condition and adundance of the various components of the ground cover were determined by a technique developed during the preliminary experiments. Rosette weeds and those with upright stems (determinate) were counted. The relative abundance of the prostrate and spreading types (indeterminate) was estimated on the basis of 10 as a maximum, as was also the excellence of turf produced by the amount of turf grasses present. For example, a plot consisting of pure clover was given a rating of 10 for clover and 0 for all other components; one with a scattering of clover but with a fair turf of grasses would receive the rating "trace" for clover and 4 to 5 for turf, and so on. Obviously the method is inexact and lacks precision, but it is relative, and inasmuch as all plot readings, aside from actual counts, were made by a single observer, the inherent errors may, for the most part, be considered to be compensating. In the final check-up at the end of the season, duplicate readings were made at different times of the day and the results weighted. Most of the comparisons will be drawn from the late-season readings on a relative basis. Obviously the natural seasonal variation in vegetation would influence considerably any attempt to correlate the results of readings on spring-type vegetation and fall-type vegetation.

Comparison of Methods of Application

This comparison is based principally upon the efficiency of the chemicals applied by different methods, at equal rates of application, upon the reduction of lance-leaf plantain, with a single application of material. This permits of a rather accurate measurement, since the plantains were carefully counted in all plots on the first of November. The condition of the turf likewise serves as a means of evaluating any differences among the methods, although this is not so accurate a method, since the values for the condition of the turf are only relative and susceptible to the error of judgment. Since all notes were taken by one observer, in a single day, however, and taken in duplicate after a two-hour interval and averaged, this factor may be considered to be compensating among the different plots. The error due to initial unequal distribution of plants affects the results somewhat, so that small differences must not be considered too seriously.

TABLE 2.—PERCENTAGE REDUCTION OF PLANTAIN AND PERCENTAGE INCREASE OF TURF GRASSES, AVERAGED FOR OVER 600 PLOTS AT ARLINGTON TURF GARDEN AND MARYLAND UNIVERSITY TREATED WITH SINGLE APPLICATIONS ONLY, THROUGHOUT A SIX-MONTHS PERIOD IN 1933

Chemical	Rate (pounds to 1,000 sq. ft.)	Percentage reduction of plantain (first column) and percentage increase of grass (second column). Five methods of application.									
		Spray		*Sprinkle*		*Dry with 6-12-4 inorganic*		*Dry with lime*		*Dry with sand*	
		%	%	%	%	%	%	%	%	%	%
Sodium chlorate.	½	23	8								
Sodium chlorate.	1	35	7	41	5.5	77	6.5	53	5		
Sodium chlorate.	2	56	7.5	65	4.5	92	8.5	68	6.5		
Sodium chlorate.	4			95	8.5	95	6.5	90	9.5		
Ammonium thiocyanate.	½	0	1.5								
Ammonium thiocyanate.	1	7	2.5	8	0						
Ammonium thiocyanate.	2	8	3	20	4						
Ammonium thiocyanate.	4			55	0						
Arsenic pentoxide.	⅛	17	2.5								
Arsenic pentoxide.	¼	22	4								
Arsenic pentoxide.	½	30	3.5			60	9			56	3.5
Arsenic pentoxide.	1	[illegible]	[illegible]			80	13			60	11
Arsenic pentoxide.	2					90	15			70	12
6-12-4 inorganic.*	1									14	8
6-12-4 inorganic.*	2									60	10
6-12-4 inorganic.*	4									87	12
6-12-4 organic.*	1									20	5
6-12-4 organic.*	2									39	7.5
6-12-4 organic.*	4									84	9.5
Calcium cyanamid.*	1									17	3
Calcium cyanamid.*	2									34	1.5
Calcium cyanamid.*	4									48	4

* Rates for fertilizers represent pounds of nitrogen.

Table 2 presents the data on plantain reduction and turf increase with three chemicals and three fertilizer materials at different rates and methods of application. Some slight variances occurred in the results obtained at Maryland and at Arlington, but in general the figures represent the same order of magnitude at both places and have been averaged in table 2. Each figure in the table represents the average reduction or increase of plants in six plots, one from each of the six series. By a tabulation such as this any variations due to effect of season are smoothed out and become compensating.

In table 2 it is seen that the greatest reduction of plantain occurred in the use of sodium chlorate at the 4-pound rate, and that with sodium chlorate the greatest increase in turf grasses occurred when sprinkled at the 4-pound rate, and when applied dry at the 2-pound rate mixed with inorganic fertilizer; also that arsenic pentoxide was most effective when applied at rates of ½ pound or greater. This is to be expected when the reduction of plantain by fertilizer alone is studied. At the rate corresponding to 1 pound of nitrogen to 1,000 square feet, the 6-12-4 inorganic shows a 14-per-cent decrease of plantain, the 6-12-4 organic shows a 20-per-cent decrease, and calcium cyanamid, 17-per-cent. At the higher rates, the difference is in favor of the inorganic form.

Between spraying and sprinkling in the sodium chlorate treatments, there seems to be a slight difference in favor of the sprinkling method. This may well be due to the fact that in the spraying method a part of the material is lost on the bare ground and does not reach the plant in an effective form. The dry-lime method seems to be slightly better than either of the wet methods from the standpoint of plantain reduction. The single comparison between spray and dry applications with arsenic pentoxide shows the balance in favor of the dry methods. If the added effect of fertilizer is disregarded, the difference in turf increase is negligible.

The spray method depends principally upon leaf absorption and the destruction of the aerial organs. It is to this end that sprays are finely divided so as to enhance the possibility of the maximum amount of material being intercepted by the leaves of plants as it falls to the ground. In the four other methods the mode of absorption by the plant is principally by the roots from the soil solution. This is entirely true of the sprinkling method. With the three other methods, however, there is a dual effect of root absorption and destruction of aerial organs. As the material is broadcast, part of it is intercepted by, and rests upon, the broad-leaved plants such as plantain and dandelion. The chemical itself, as well as accompanying corrosive salts that are present in the fertilizer used, acts upon the leaves. The material which sifts through the leaves and reaches the soil soon goes into solution and enters the soil. The plants are thus attacked both above ground and below ground, which probably accounts for the higher value of plantain reduction for the methods where this dual point of attack obtains.

This evidence quite conclusively refutes the results of earlier experimental work which has pointed out that about five times the quantity of material, sodium chlorate in particular, was required for satisfactory weed kill when applied as a dry salt to the soil as against its application in the form of a finely divided spray. The weed species or the soil type and moisture may affect these results but hardly to such an extent. It is to be noticed that these findings in table 2 with all three chemicals bear out the validity of this statement. No research has been carried on up to this time to ascertain why this is true, yet it presents an interesting problem and one which may well engage the early attention of investigators in this particular phase of research.

Table 2 does not represent the true picture concerning the increase of turf, but only a general trend which in itself is sufficiently accurate. With any one treatment the condition of the plots of all six series was averaged. The best turf occurred in series 4, 5, and 6. Single applications, particularly of sodium chlorate, applied after June 1 notably increased the amount and vigor of the turf. Regrowth of crabgrass in all series prior to June 1, after the effectiveness of the chemical had been lost, smothered the grasses and presented nothing but a solid mat of crabgrass at the end of the season. Crabgrass which was able to germinate in the plots treated June 1, two to three weeks later, seemed unable to disturb the growth of the turf grasses which, by fall, had formed nearly a solid turf.

The effect of the lime, in conjunction with sodium chlorate, was apparently to somewhat increase the length of time the chlorate was effective, to retard its killing action, and to add vigor to the remaining turf grasses.

While the 4-pound rate of chlorate applied as a sprinkle and dry with lime shows an actual greater percentage kill of plantain, the increase in turf is to be regarded with caution, since at this rate a second application kills the turf completely. A single application causes heavy damage and, when the supply of soil moisture is insufficient, kills it entirely.

At equivalent rates the sodium chlorate has proved superior to ammonium thiocyanate, both in weed kill and in turf improvement, in spite of the high nitrogen content of the latter. A very significant feature of the thiocyanate-treated plots was the large attendant increase in the numbers of dandelion plants, which showed a decrease in vigor and numbers in the chlorate-treated plots.

A comparison between sodium chlorate and arsenic pentoxide, at the ½-pound rate and by the spray method of application, shows a slight increase in plantain kill in favor of the arsenic but a lower percentage increase in turf grasses. This situation is reversed, however, at the 1- and 2-pound rates applied dry with fertilizer. The comparison can not be made directly, since the effectiveness of the two compounds depends upon somewhat different conditions and again upon the specific nature of the materials involved.

Of the three fertilizer materials used, the 6-12-4 inorganic gave consistently the best results. Burns resulted from the two heavier applications but they were not so serious as to permanently impair the turf. The reduction in plantain is significant, indicating that by proper fertilizer practices at least a part of the weed population can be materially reduced. The crabgrass, however, responded entirely differently and, with the exception of the last two series of applications, flourished remarkably under the heavy feeding and virtually extinguished the existing turf grasses. The late-season applications, however, severely affected the crabgrass and encouraged the turf grasses, from which the major portion of the turf increases in table 2 are derived. This indicates that the time of application of fertilizers for most effective weed control and for the best results on turf is extremely important.

Calcium cyanamid applied on an equal nitrogen basis with the regular mixtures, yielded results far inferior, both in plantain decrease and in turf increase. The cyanamid was applied as a powder so that it would cling to the leaves of the vegetation. The recovery of the turf was notably slow for several weeks after application until the toxic decomposition products had disappeared.

Results of Successive Applications of Sodium Chlorate

Adjacent to the experiment outlined in table 1 a second experiment was conducted by which the effects of successive treatments of chlorate on different dates and at three rates might be determined. Plots 10 by 10 feet in size were so arranged that on any one date four successive plots were treated simultaneously at each of the three rates 1, 2, and 4 pounds to 1,000 square feet. Subsequent applications were made so that each time one previously untreated plot received a first application, whereas one of the previously treated plots received none. Applications were made on April 24, May 29, July 11, and August 29. By this plan a variety of combinations of rates and times of application were obtained. Half of the plots received 6-12-4 inorganic complete mixed fertilizer on June 21 and October 14 at the rate of 700 pounds to the acre. Natural conditions prevailed throughout the season, no artificial watering being resorted to.

Crabgrass began to germinate in this location about April 10. At the stage of growth represented on April 24, about the 2-leaf stage, a very satisfactory kill was obtained with the ½-pound application of chlorate. At this rate the grass was only slightly affected, whereas at the 2-pound rate there was considerable turf injury with a complete crabgrass kill and about a 75-per-cent kill of plantain. At the time of the second application on May 29 the 2-pound rate still showed some chlorate injury whereas the turf treated at the lower rates had completely recovered. At this date crabgrass was again repopulating all treated areas with newly germinated seedlings but to a somewhat less extent at the 2-pound rate.

On the basis of 100 per cent, as nearly as could be estimated, the maximum percentages of discoloration due to chlorate after the first application were, at rates of ½, 1, and 2 pounds, respectively about 40, 50, and 75.

In this experiment the best plot was that which received the 2-pound rate on April 24, May 29, and July 11. The fertilized portion was far superior to the unfertilized portion. Standing second was the plot receiving the 1-pound rate in 4 successive applications on August 29 in addition to the dates named for the 2-pound rate. Three applications at the 2-pound rate effected virtually complete eradication of crabgrass, plantain, and all other weeds except wild garlic. The decrease in numbers and vigor of dandelions was very marked. Coverage due to turf grasses increased from about 10 or 15 per cent in April to 95 per cent in October. There was less than 5 per cent increase in the control plots.

A duplicate of this experiment conducted at the University of Maryland yielded entirely comparable results. An examination of the root systems at the end of the season showed that the production of rhizomes in the plots receiving the heaviest treatment was superior to that in the control plots.

Development of Tolerance for Chlorate

Soon after the second application of chlorate on May 29 it became strikingly evident that the discoloration and turf injury was much less than it had been following the first application. This became evident again following the next successive treatment and was one of the outstanding features of interest. Apparently a development of the same tolerance was not shared by the weedy plants, particularly the crabgrass. Observations indicated that in the fertilized areas the turf grasses were less affected by the chlorate and that recovery was much more rapid.

From this experiment it becomes apparent that the addition of a fertilizer in conjunction with the chlorate treatment is advisable, particularly in badly run-down weedy turf. It seems that, inasmuch as the ½- and 1-pound rates efficiently eliminated the very young crabgrass at the beginning of the season, and since the bluegrass quite evidently acquires a toleranace to the action of chlorate, a gradual increase in the rate of successive applications might well be used. By doing this the rather severe injury resulting from the first application at the 2-pound rate may be greatly diminished, with the final results as good as those obtained with 3 successive full-rate applications.

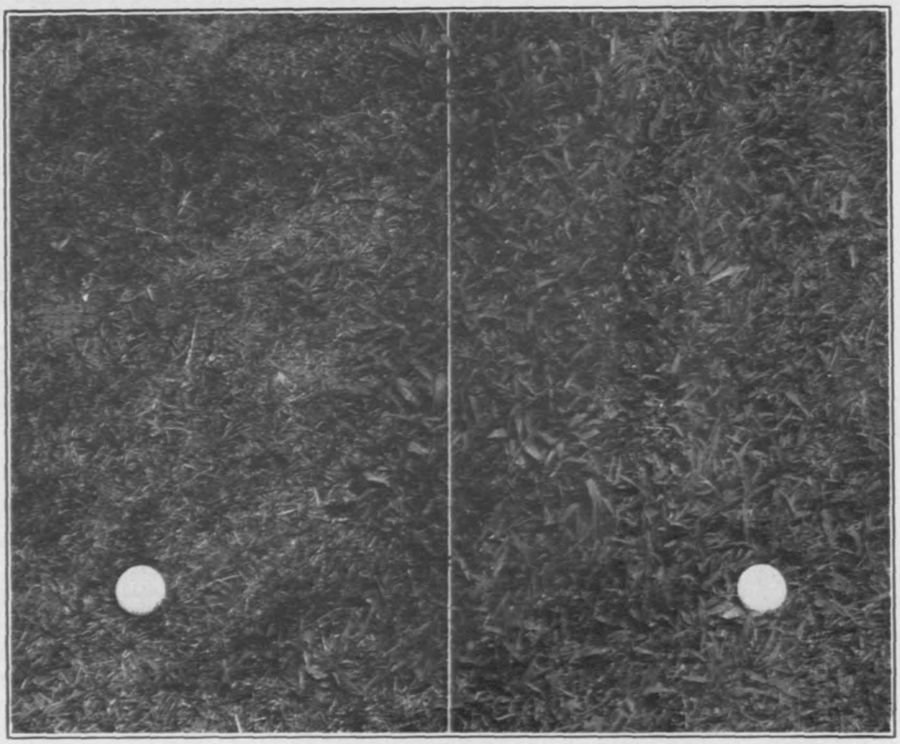


Figure 1.—Sodium chlorate treatment of Kentucky bluegrass infested with crabgrass. Treated plot on the left; check plot, untreated, on the right. Two 2-pound applications had been made to the treated plot, 6 weeks apart. Although the turf that remains in the treated plot is thin, it is in about the same condition as would have resulted from hand weeding.

Figure 1 shows how completely the crabgrass has been eliminated from the treated plot, which on July 1, when the picture was taken, had received two 2-pound treatments of chlorate.

Figure 2 shows the condition of the plot which received three 2-pound applications. At the top the normal condition is shown; at the bottom, the condition after the plots had been raked to raise the crabgrass. The fluffy appearance of the check plot on the left indicates a very heavy mat of crabgrass which virtually choked all the turf grasses. The almost complete absence of crabgrass in the treated plot is clearly indicated.

The results of a similar experiment on a different location with sodium chlorate yielded quite as striking results, as may be seen in figure 3. An 8-by-8-foot plot was quartered and 3 of the sections treated with chlorate at ½- 1- and 2-pound rates on May 12, June 16, July 11, and August 11. One section remained untreated as a check. Sulphate of ammonia at the rate of 2½ pounds to 1,000 square feet was applied simultaneously with the chlorate in solution and the mixture watered into the soil with a sprinkling can.

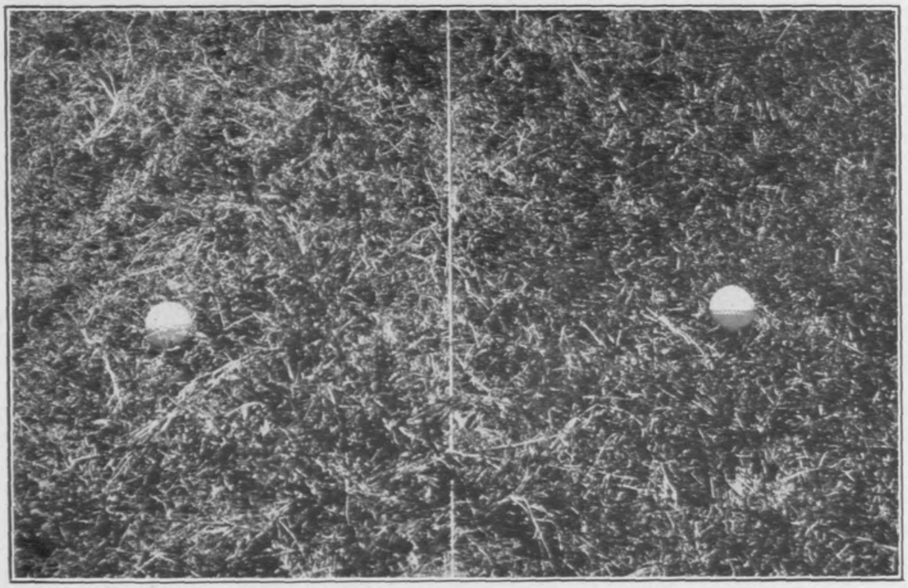


Figure 2.—Sodium chlorate treatment of Kentucky bluegrass infested with crabgrass. Treated plot on the right; check plot, untreated, on the left. Three 2-pound applications had been made to the treated plot, resulting in an almost complete elimination of the crabgrass. Both plots had been raked to lift the stolons of the crabgrass for photographing.

On October 7 pictures and color plates were made of this plot (figure 3) and at that time the final notes were taken. The ratio of turf-crabgrass at that time was 9, 30, 80, and 7 for the ½-, 1-, 2-pound rates and the check plot respectively, indicating practically complete freedom from crabgrass in the plot receiving 2 pounds at 4 successive times. The excellence of the turf in this plot as compared with that in the check plot was striking, both from the standpoint of density and color.

Effect of Continued Treatment With Chlorate and Thiocyanate

During 1932 two plots of 250 square feet each were treated twice for crabgrass control. On August 1 plot A received sodium chlorate and plot B received ammonium thiocyanate each at the 2-pound rate. On September 1 each received the 1-pound rate of the respective chemicals. No crabgrass seed matured in plot A but in plot B the control was much less marked.

Treatment was continued during 1933, and on June 21, July 15, and September 1 plot A received chlorate at the ½-, 1-, and 2-pound rates respectively. The rates of thiocyanate applied to plot B were 1, 2, and 2 on the respective dates. Nitrogen as sulphate of ammonia was added to plot A at each application in sufficient amount to equal the nitrogen applied to plot B in the thiocyanate. On October 10 one-half of plot A received 6-12-4 inorganic fertilizer at the rate of 700 pounds to the acre.

Figure 3.—Sodium chlorate treatment of 3 plots of Kentucky bluegrass infested with crabgrass, at 3 different rates of application with sulphate of ammonia added. Four applications had been made at ½-pound (lower right), 1-pound (upper right) and 2-pounds (lower left). The 2-pound rate showed almost complete control and excellent turf condition.

Later observations showed that the turf-crabgrass ratio in plot A was about 80 whereas the ratio in plot B was but 20. In plot A the turf consisted principally of Kentucky bluegrass, bents, and redtop. In plot B the turf was mainly annual bluegrass with scattering Kentucky bluegrass plants. Plantain and chickweed had virtually disappeared in plot A but were still plentiful in plot B.

One observation of note is that during late fall all chlorate-treated turf which had not received fertilizer showed bronzed leaf tips which persisted until the end of the growing season and in the early spring were evident as dead tips. Where fertilizer had been applied as a fall dressing no such tip-bronzing was apparent. No explanation has been attempted for this phenomenon, but it is possible that the residual chlorine in the plant sap has contributed toward this, and that by the addition of a complete fertilizer the subsequent growth has been sufficient to mask the effect of the chlorate.

The increase of annual bluegrass under the ammonium thiocyanate treatment and its decrease with sodium chlorate further show the specificity of these chemicals for certain types of plants. It indicates also that where annual bluegrass is desired it may be encouraged by small, frequent treatments with thiocyanate.

An examination of the soil in plots A and B at the end of the season showed pH values of 5.2 and 5.3 respectively with practically no differences in the amount of soluble constituents.

Additional Tests With Sodium Chlorate on Crabgrass

Crabgrass-infested turf on aprons, banks, and approaches of the putting greens at Bannockburn, and, in some cases, on the greens as well, was treated with potassium chlorate at two different times. The first treatment was made about June 20 and the second about the last of July. The results were gratifying. When observations were made on the first of September no crabgrass remained in the treated areas either on the greens or on the turf outside the greens. The turf grasses had begun to fill in the denuded areas and had a good, healthy appearance. On the greens the treatment was somewhat drastic but the bent grasses recovered from the shock and made good growth all the rest of the season.

Sodium Chlorate Tests at Indianapolis

The crabgrass-infested bluegrass and bent tees at the Highland Golf and Country Club at Indianapolis were treated with sodium chlorate shortly after the middle of August, 1933. The 2-pound rate was applied with a power sprayer and watered into the soil. Kentucky bluegrass and seaside creeping bent seed were sown at the time of treatment. Fertilizer was applied after September 1, watering being carried on as usual to keep the soil in good condition. At the time of treatment crabgrass had begun to develop seed heads where its normal development had not been retarded by cultural practices.

Later in the season it was reported that the treatment was highly successful. No crabgrass seed matured and the turf grasses filled in the area occupied by the crabgrass. The newly-seeded grasses developed normally and made good growth.

Experiments in the Chicago District

Tests were conducted at the Mid-West turf garden and on several golf courses in the Chicago District from July 22 until November 1. Treatments were made chiefly on fairway turf consisting principally of Kentucky bluegrass, bent, and fescue. The weed population consisted principally, in the order named, of dandelions, crabgrass, clover, major plantain, lance-leaf plantain, and chickweeds. Comparisons were made between the sodium and the potassium chlorates, arsenic pentoxide and potassium arsenate, and ammonium and potassium perchlorates, at rates ranging from 4 ounces to 4 pounds to 1,000 square feet for a single application. Subsequent applications were made as quickly as possible after the recovery of the turf grasses from the initial injury. Plots 4 feet square were used throughout.

The varying moisture conditions prevailing over the various locations had a profound effect on the results. The soil type was fairly constant at all locations.

It is not to be expected that tests covering only a 4-month period or less should be regarded as conclusive. The information gathered, however, in connection with previous data, indicates what might be expected over a longer period of time as well as which chemicals appear to be the most effective under the conditions of the tests.

Sodium chlorate here, as elsewhere, has yielded results comparable to potassium chlorate when applied at rates yielding an equal amount by weight of chlorate (ClO_3). Arsenic pentoxide consistently yielded better results than potassium arsenate, at rates yielding an equivalent of equal quantities of the elemental arsenic.

The perchlorates (NH_4ClO_4, and $KClO_4$) proved to be undesirable and were alike in every respect. Their action on vegetation was rather unusual and merits some consideration. Since both salts are but slightly soluble they were mixed with soil and broadcast. At the ½-pound rate they were almost without effect. At the 1-pound rate, however, the results were striking. No apparent change in vegetation resulted for the first 2 weeks after application, at which time the crabgrass first began to show the effects. The fully developed blades assumed a coppery hue first on the edges and later all over, and apparently ceased development. All new shoots emerged as stunted, pale, tightly rolled, twisted, and deformed proliferated growths. Seed heads were unable to develop normally and practically no seed was produced even with a single application. Other vegetation appeared to be unharmed, but after 3 to 4 weeks the grass plants present began to show ill effects and gradually disappeared, simultaneously with an increased growth and population of dandelions, plantain, chickweeds, clover, and oxalis. This identical phenomenon had been observed at the Arlington turf garden on several plots earlier in the season. The high specificity of the perchlorates for crabgrass at first appeared to be of great value, but the later developments within 2 or 3 months unquestionably rule them out as desirable selective weedkilling agents.

Sodium chlorate at 1- and 2-pound rates effectively controlled chickweeds and plantain. Goose grass to some extent, and dandelions were in a large measure controlled by 3 successive applications. Here, as well as at the Arlington turf garden and at Bannockburn Golf Club, an interesting observation was made in connection with the treatment of goose grass with chlorate. Goose grass, as is well known, grows in flat bunches with the seed stalks lying flat, making it very difficult to cut the seed heads off with the ordinary mower. A few days after the initial treatment with chlorate the seed stalks raised up to a nearly vertical position, making it a simple matter to clip them off with a mowing machine. In this way seed production was almost entirely controlled even though the outright killing action was not marked.

During the progress of the experiments at Old Elm Club in the Chicago District there was noticed a weed growing on the bank of one of the greens which completely choked all the grass into which it was rapidly spreading. It closely resembled the common smooth chickweed in habits and appearance but the leaves were much finer and were whorled. It was identified as a species of Galium, and apparently was the late summer form of one of the perennial species.

Two plots were marked out where this weed had almost completely possessed the turf and were treated with potassium chlorate (plot 1) and with arsenic pentoxide (plot 2) both at the ½-pound rate in an effort to determine the effect of these chemicals on it. The first application was made August 8 by the sprinkle method. Four days later the weed was 95 per cent killed in plot 2 whereas no effects were noticeable in plot 1. The bent and bluegrass were entirely uninjured in both plots. On August 18 a second treatment was made on both plots at the initial rates. Ten days later the kill of the weed was virtually complete in plot 2 but still there was no apparent effect on plot 1. The grasses increased in plot 2 and none of the weed was again found although it grew vigorously in the untreated areas until frost.

Experiments on Sandy Soil in New Jersey

Chlorates of sodium, potassium, and calcium, as well as several of the arsenic compounds, were tested on three golf courses in New Jersey. The more extensive tests were conducted on fairway and putting turf at Pine Valley Golf Club, where one of the demonstration gardens has been located. Tests on tees and putting greens were conducted at Seaview Golf Club and at the Country Club of Atlantic City.

At Pine Valley the soil is largely pure white sand. It was found that the rates at which the chemicals could be safely applied on more finely textured soils caused such heavy injury to the turf on sand that they were impracticable. At the 1-pound rate the chlorates seriously injured the turf; above this rate the turf was largely killed. Wherever arsenic compounds at rates yielding the equivalent of ½ to ¾ pound of elemental arsenic to 1,000 square feet could be safely applied on fairway turf on finer soils, here less than half that amount represented the upper limit.

The best treatment on putting greens at the Country Club of Atlantic City for water pennywort in 1932 was arsenic pentoxide at the ½-pound rate. Two successive applications at this rate in July and August yielded 70 per cent control of pennywort and permitted normal development of velvet and other bent grasses.

Tests with arsenic compounds and sodium chlorate at the Seaview Golf Club have been inconclusive. Fairway tests on white clover with arsenic pentoxide are still in progress.

The inconclusiveness of the effects of chemicals on sandy soils indicates the necessity for further, more complete investigations. It is apparent that the rates and times, and perhaps the frequency of applications, require modifications from those applicable to the finer-textured types of soils.

Sodium Chlorate on Milk Purslane

Repeated tests have proved the efficacy of chlorates for selectively controlling milk purslane. Treatments on a large scale have yielded highly satisfactory results on coarse-textured, sandy soil in Florida as well as on the finer-textured loams and clay loams. Complete control has been effected by two applications made either by the dry method or the wet method. The ½-pound rate is sufficient for the first application made when the weed is just beginning to appear—usually around the middle of June at Washington, D. C. A second application three or four weeks later at the same rate and up to 1 pound has effected complete control. If the weed attains considerable size, however, it has been found better to treate initially at the 1-pound rate, followed by a second application at the same rate when regrowth occurs.

Effect of Sulphate of Ammonia and Sulphate of Iron Treatments

Several 8-by-8-foot plots uniform in vegetation were selected from an experimental area of a bluegrass-redtop-clover lawn and treated April 13. One plot which had been previously limed (No. 1) and an unlimed adjoining plot (No. 2) were treated four times during 1933 (April 13, May 27, June 21, and August 11), each time with sulphate of ammonia and sulphate of iron at the rate of 3 and 1.5 pounds to 1,000 square feet, respectively. The third adjoining unlimed plot (No. 3) received calcium cyanamid on the same dates at the rate of 2.8 pounds to 1,000 square feet. This rate yielded .6 pounds of nitrogen to 1,000 square feet, which was equivalent to that applied in the sulphate of ammonia on the first two plots.

The materials were broadcast as a dry mixture with compost and sand with no subsequent treatment. The mixture of sulphate of ammonia and sulphate of iron was prepared and applied after the methods employed in the British Isles. Notes were taken frequently throughout the season. The varied condition of the three plots at the end of the season was striking. Plot 1 had the best turf and color and showed no increase in the quantity of plantain. Plot 2 was the worst of the three; it had the thinnest turf, showed the highest increase in quantity of plantain, and the heaviest crabgrass. Plot 3 was intermediate.

An examination of the clay loam soil to a depth of 4 inches at the end of the season showed pH values of 7.0, 6.0, and 6.2, respectively, for plots 1, 2, and 3. The turf-crabgrass ratio calculated for October 1, 1933, varied as 40, 20, and 30, respectively, the variations closely corresponding to the variations in the pH values. While crabgrass on all three plots was greatly increased over similar adjacent untreated plots, the least increase occurred in plot 1, as shown by the ratio above.

While we attempt to draw no conclusions from this study, it is indicated that the treatment with sulphate of ammonia and sulphate of iron in eastern United States, particularly under the conditions surrounding Washington, D. C., becomes more successful under neutral to alkaline soil conditions. Much has been written concerning the advantages of the treatment with sulphate of ammonia and sulphate of iron for turf both here and abroad, particularly in the British Isles, and in South Africa where the practice originated and became general under the direction of Dr. Murray. (Bulletin reference December, 1927, pages 226 and 227.) Experiments have been made here from time to time, but the success of the treatment has been lacking. It is apparent that the subject merits consideration but that it requires further extensive testing.

Sulphate of Iron as a Spray

Spraying of sulphate of iron during 1932 as a control for crabgrass was reported in the Bulletin for May, 1933, as unsuccessful. Sulphate of iron, alone and in combination with sulphate of ammonia, had been sprayed at rates of 3.5 and 7 pounds to 1,000 square feet on July 13 and August 24. Greater damage occurred on the turf grasses than on crabgrass and other weeds, and at the end of the season there could be observed no improvement in turf nor a reduction in weeds. Crabgrass had increased. It was thought that the attendant conditions may have affected the results adversely.

During 1933 an 8-by-8-foot plot was quartered and three of the 4-by-4-foot plots sprayed with sulphate of iron at 1½-, 3-, and 6-pound rates on June 27, July 11, and August 29. On the latter date half of each plot was bruised with a heavy wooden instrument to ascertain if the effects corresponded with the claims made for this supplementary treatment.

This experiment in 1933 further substantiated the findings of the previous season, so that little need be said further concerning this treatment. The turf-crabgrass ratio for the three rates were, respectively, 15, 12, and 6, while that of the untreated plot was 26. It was further shown that bruising had little or no effect upon the results even at the heaviest rate, which corresponds to spraying 100 gallons of solution to one acre in which 230 pounds of sulphate of iron have been dissolved. All vegetation became blackened and injured, but eventually all recovered. From these experiments, then, it is indicated that a spray of sulphate of iron, either alone or in combination with sulphate of ammonia, has slight value as a selective eradicant for crabgrass or plantain.

Isolated tests in which the fused ground mixture, as reported in the Bulletin for December, 1927, was dusted on the leaves of clover, speedwell, oxalis, and heal-all show a great deal more promise than anything heretofore reported for sulphate of ammonia, sulphate of iron, or a combination of the two. Single applications made while the dew was still on the leaves gave quite satisfactory results, and were made on putting green turf of mixed bents and creeping bents with only slight injury to the grasses. Although further testing is necessary, it is indicated that the use of this mixture, or of a mechanical mixture made up of two parts of sulphate of iron and one part of sulphate of ammonia, will be more satisfactory for the control of clover and other weeds on putting greens than straight sulphate of ammonia.

Experiments with Compounds of Arsenic

Results of the preliminary experiments in 1932 indicated that arsenic had little or no value as a selective eradicant for crabgrass but that it showed promise for clover, chickweed, speedwell, and other low-growing weeds. The 1933 tests have shown that the time of application is an important factor, and that the failure to obtain favorable results in the 1932 tests may be traced in part to the time of year at which the applications were made.

Four plots of lawn turf treated with arsenic pentoxide in 1932 with amounts up to 4 pounds to 1,000 square feet in single and successive applications successfully discourage white clover and, to a large extent, narrow-leaved plantain. These plots, with no further treatment, are still clover-free, although plantain has reestablished itself to some extent. There has been no deterioration of the turf, and the response to fertilizer has been marked. Figure 4 shows this control of clover with arsenic pentoxide.

Arsenic pentoxide has, in several tests, shown considerable value for the treatment of weeds in putting greens. The best results have been obtained with rates of application yielding the equivalent of ¼ to ½ pound of elemental arsenic, successive applications at the same or slightly lower rates following as soon as it is practicable. Probably the best method for applying it has been to dissolve it in water and use a sprinkling outfit. In this way it immediately becomes effective in the soil with a minimum of injury to the surface vegetation.

Of the arsenic compounds tested, the most effective at the lowest rates and the most toxic has been sodium arsenite. Its toxicity is such that, when applied at rates yielding ½ pound of elemental arsenic to 1,000 square feet, the entire treated area is denuded and rendered sterile for an indefinite period of time. Weedy species are more quickly reestablished in the bare areas than grass species. Chief among these has been species of Euphorbia. Potassium, sodium, and ammonium arsenates seem to be somewhat less effective than arsenic pentoxide, but are desirable in that they are dry crystalline salts which may be handled conveniently in a number of ways. At rates yielding ½ pound of arsenic to 1,000 square feet, all three salts have been successfully used on colonial bent. Three successive applications at this rate have not caused an undesirable condition, and clover has largely disappeared.

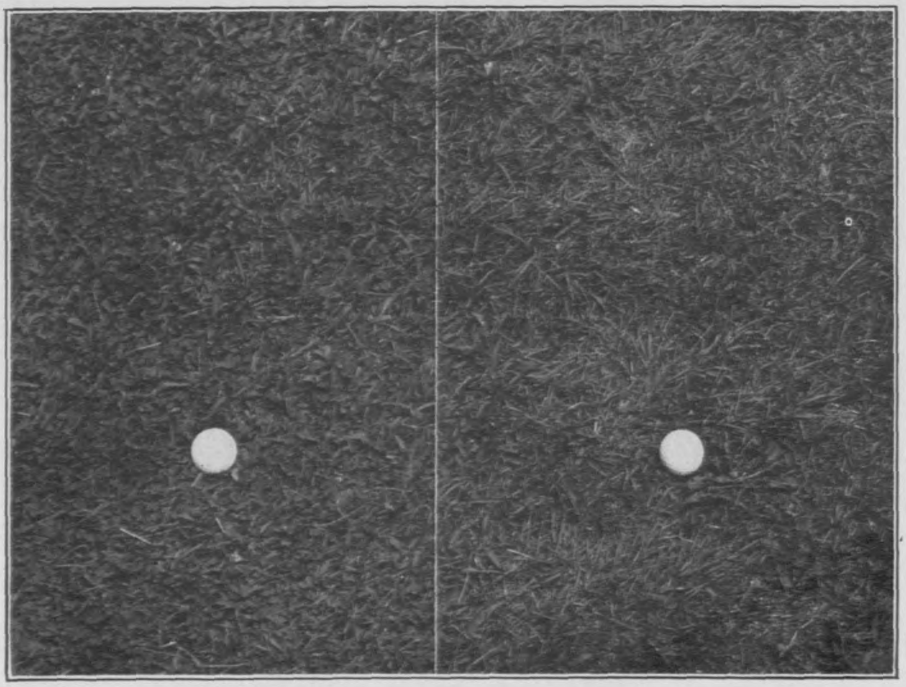


Figure 4.—Control of clover on a lawn at Arlington Farm, Va., with arsenic pentoxide. Both the untreated check plot on the left and the treated plot on the right were heavily infested with white clover. The treated plot received three applications of arsenic pentoxide in 1932, but no further treatment was given in 1933. The photograph was taken June 28, 1933, and shows the clover controlled in the treated plot.

Too heavy an initial application invariably is disastrous, but repeated small applications are apparently slightly beneficial to the turf. A tolerance is also apparently acquired by the turf grasses much as was observed with the use of successive treatments with sodium chlorate.

It has been reported by other investigators that any soluble compound of arsenic applied to the soil is quickly fixed in the surface in an insoluble form. This has been further substantiated by soluble-nutrient tests on arsenic-treated clay-loam soils. Sampled and tested at 1 inch, 2 to 3, 4 to 5, and at 6 inches, the only portion in which an increase in arsenic was detected was in the 1-inch surface layer. In this layer there was a general lower pH trend, up to as much as .3 of a pH, where a total of 5 pounds of arsenic pentoxide to 1,000 square feet had been applied in successive ¼-pound applications over a period of two years. This is but to be expected, since arsenic pentoxide in water solution is an acid corresponding in strength to phosphoric acid. There was no apparent difference in the solubility of other soil constituents tested for, indicating that, with certain restrictions, soluble arsenicals may be applied to soil without destroying its productive power. This may appear as a directly opposite view from the standpoint of the experience with decreased yields in connection with the use of calcium arsenate in the cotton belt. There, however, arsenic is applied in greater amount than indicated here and as an insoluble powder which is not at once "fixed" but gradually comes into solution through the action of processes within the soil. Once in solution, it is again fixed in a different form, but crop yields are reduced due to the action of the soluble stage, in which form it is absorbed by plant roots.

In New Zealand it is a regular practice to spray the banks and green surroundings with arsenic pentoxide in June, July, and August at the rate of 2 ounces to the gallon. Six gallons cover 1,000 square feet—a rate of ¾ pound. Similar treatments in the 1933 experiments here at the corresponding season have yielded comparable results. In our experiments the best results have been obtained through applying arsenic directly to the soil, either in solution as a coarse rain or mixed with dry compost or with fertilizer, broadcast, and watered in immediately. This procedure permits the shallow-rooted species to absorb the poison, whereas the deeper-rooted grasses are largely unaffected, due to the arsenic being held in the surface layers of the soil. This may be one of the influencing factors in the failure of arsenic compounds to successfully control crabgrass when applied after the crabgrass has become established. A further substantiation of the holding of arsenic in the surface is illustrated by the following experiment.

Plots were treated in January of 1933 with the following arsenical compounds, each at three rates yielding the equivalent of from ¼ to 1 pound of elemental arsenic and each as a dry mixture with compost: sodium arsenate, sodium arsenite, potassium arsenate, ammonium arsenate, arsenic acid, arsenious acid, and lead arsenate. The last was applied at 10-, 20-, and 40-pound rates. All vegetation except chickweeds was largely dormant at the time. No further treatment was made throughout the year.

Chickweeds were largely eliminated in all plots where more than ½ pound of arsenic in the soluble form was applied. This same observation was made on the 20- and 40-pound rates of lead arsenate.

The most striking observation of this early-season application of arsenic, however, was the fact that as crabgrass and other summer weeds began to appear in the check plots, there was no indication of establishment in the heavily treated plots. The bluegrass, redtop, and bents, however, flourished and largely occupied the otherwise sparsely covered soil. Later, however, as the effect of the arsenic had largely disappeared, encroachment of the more hardy seedlings occurred, and by mid-season these plots were again infested with crabgrass, but to a much less extent than the check plots (see figure 5). At all times the turf on these treated plots was superior to that in the check plots, and this effect is still apparent.

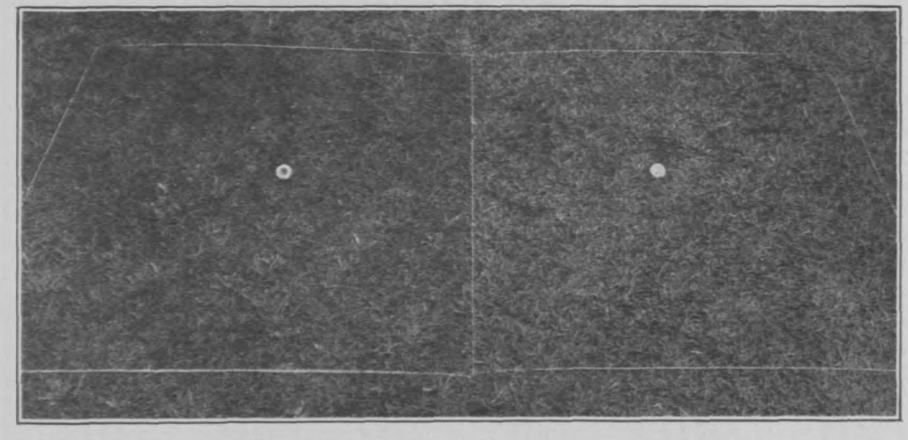


Figure 5.—Reduction of crabgrass and other summer weeds with lead arsenate in a lawn of bluegrass, redtop, and bent grass at Arlington Farm, Va. The check plot on the right received no treatment. The plot on the left had received one application of lead arsenate in dry mixture with compost at the rate of 40 pounds to 1,000 square feet March 21, 1933. Only a few weeds were present in the treated plot at the time this photograph was taken, June 28, 1933.

On the basis of this experiment and to further investigate reported control of crabgrass with lead arsenate, several test plots were treated. Lead arsenate was applied at 5-, 10-, 20-, and 40-pound rates in single and successive applications throughout the season. First applications were made on May 10 and subsequent applications at one-month intervals until September 10. Crabgrass had become established prior to the first treatment. At no time could there be detected any noticeable decrease in the amount of crabgrass present. This indicated that the presence of soluble arsenic in the soil at the time of germination either prevented germination or caused the young seedlings to die before they could push their roots beyond the zone of accumulated arsenic. It further throws light on the apparent specificity of arsenic for certain species, indicating that the depth of the effective feeding roots may have considerable influence on the resistance of plants to the poison.

In direct contrast to the results obtained by a January treatment of arsenic are results obtained on turf treated at that time with chlorate and thiocyanate. Treatment of turf with watery solutions of these chemicals as well as dry-compost mixtures gave no such desirable indications of toxic effects on germinating seeds of the summer weeds but, on the contrary, apparently stimulated germination. Chlorate at 1-pound rates and higher quite effectively controlled chickweeds, but crabgrass plants appeared first on the treated plots and most quickly covered the surface of the soil. Thiocyanate did not control chickweed at rates up to 2 pounds; above that rate both grass and weeds were killed. With thiocyanate there seemed to have been little further effect on germination except that annual bluegrass was more encouraged than in any other plots. In the chlorate and arsenic plots annual bluegrass made very poor growth.

Knotweed has been most effectively controlled with arsenic pentoxide when applied as a spray. The best results have been obtained when the first application was made shortly after the germination of the seeds and before much growth has been made. Two to three successive treatments at the ½-pound rate have largely controlled this weed, which heretofore has successfully resisted all attempts at eradication with chemicals.

Sodium Chlorate

Sodium chlorate ($NaClO_3$) is a dry granular crystalline salt very similar to coarse common table salt in color and appearance. It may be obtained in quantities with a purity as high as 99 per cent. Since it is a dry salt which may be reduced to any desired fineness it is admirably adapted to distribution in combination with any common dry inert carrier of an inorganic nature. Its high solubility in water also permits it to be applied in water solution as a spray with any type of sprinkler.

For farm weeds in general, sodium chlorate has found wide application, and in comparison with a great many other chemicals it has been found to be most efficient and economical on a cost basis. This chemical has likewise been found to be the most efficient of a large number of chemical agents in the control of weeds of turf. So far as the investigations have been pursued it has been found applicable to the control of crabgrass, lance-leaf plantain, major plantain, milk purslane, goosegrass, chickweeds, speedwell, sour dock, and heal-all. Dandelions and clover have, to a large extent, been diminished and, with continued treatment, practically controlled with this chemical. Wild garlic, oxalis, knotweed, and some few other fairway and lawn weeds have not been found to be greatly affected by sodium chlorate according to the methods used.

Sodium chlorate has a temporary retarding effect upon the organic life in the soil which is concerned with transformations of nutritive elements. The extent and duration of this effect is dependent upon the rate and method of application, the soil type, the amount of effective rainfall whether natural or artificial, the temperature of the soil and of the surrounding air (i. e., the season of the year), and, to an undetermined extent, the reaction (pH value) of the soil.

The duration of the temporary retarding effect of equal amounts of sodium chlorate per unit area on soil is less prolonged when applied as a spray than when applied as a solution which enters the soil at once and becomes a part of the soil solution. This is due to the reducing effect of the organic matter on the surface of the soil, which quickly transforms the chemical from an active oxidizing and lethal agent to a less reactive and less harmful compound. The absorption of the chemical by surface vegetation likewise renders that part of it inoperative so far as soil organisms are concerned. Since the air temperatures during that part of the year when weeds are most troublesome, which is the time when the chemical is most used, are usually higher than the soil temperatures, it follows that the speed of the chemical reactions taking place will be increased.

When the chemical enters the soil it remains active over a longer period of time, due to the general lower temperatures and to the generally low percentage of reducing materials, since soil constituents are ordinarily in a more or less highly oxidized state. The distribution of organic matter in the soil, however, will affect this relation to some extent, so that soils high in organic matter will more quickly recover from the effects of an application of sodium chlorate.

Most of the experimental work to date has been conducted on soils of a fine-textured nature (clays, clay loams, and silt loams), which have in general a high absorptive capacity. A limited amount of work on soils of a coarser texture (sands and sandy loams) indicates that the temporary damaging effect of equal amounts of the chemical is greater on the coarser-textured soils. The duration of the effect on the lighter soils is less, however, due to the lower absorptive capacity and to the greater rapidity of percolation by means of which the chemical is carried out of the effective range. But, since the initial damage is greater, a longer time is required for regrowth of the remaining vegetation, due in part to the lower initial fertility of the coarse-textured soils. Hence it must be borne in mind that the recommendations given herewith are for soils belonging to the finer-textured types. They will be applicable to sandy soils only in part, and then with caution.

Sodium chlorate is soluble, and since it must be in solution in order that it may be readily absorbed by the plant roots, an optimum soil moisture content at the time of application is to be desired. This applies also to a large extent to spray applications, since the metabolic processes of the plant are greatest when the soil moisture is at an optimum, and since the chemical is readily absorbed by aerial organs and carried about in the transpiration stream it will be carried more effectively through the plant. Low soil moisture causes a more prolonged sterilization of the soil, greater injury to the desirable plants, and other undesirable results. Thus the selective treatment of turf weeds with sodium chlorate in sections which are subject to prolonged periods of drought where artificial watering is not available is liable to produce more or less unfavorable and undesirable results.

The duration of the effect of sodium chlorate on the soil, as evidenced particularly by the growth of grass, is, in addition to the factors named, dependent upon the rate of application. At the rate of ½-pound to 1,000 square feet, applied during the summer months, the effect on bluegrass under normal conditions entirely disappeared within 2 weeks. The 1-pound rate required approximately 3 weeks for normal grass growth to recur. At the 2-pound rate the time period increased to 4 or 5 weeks. These time-periods represent the relative duration of the effects under a given set of conditions approximating what might be called "normal" for moisture and temperature. Variations would occur, depending upon the difference in these and other influencing factors.

The first noticeable effect of sodium chlorate appears in 24 to 48 hours after application. It is evidenced by a grayish cast on the vegetation. Closer examination shows white streaks in the leaves parallel to the venation, indicating a disintegration of the chloroplasts. Later the entire plant takes on a whitish, sickly hue, and a little later still begins to turn brown and curl. Rather extensive discoloration may occur from applications at rates above 1 pound to 1,000 square feet.

In the event that sodium chlorate is distributed as a dry mixture with an inert inorganic carrier attention must be given to the nature of the carrier. Dry, finely screened soil may be used in any amount. The only effect of this carrier will be beneficial as a topdressing by smoothing irregularities in the surface. A mixture with limestone would be beneficial, not only from the standpoint of increasing the effectiveness of the chlorate, but also due to the desirable effects it has upon the production of sturdier plant growth and subsequent recuperation from the temporary undesirable effects. A mixture with a wholly inorganic fertilizer, such as the 6-12-4 used in these experiments which was made up of 3 ingredients, namely, sulphate of ammonia, superphosphate, and muriate of potash, may be used but with reservations. This fertilizer is physiologically acid and tends to increase the duration of the effects of the chlorate. This may be attributed in part to the additional corrosive effects of the fertilizer salts upon the vegetation with consequently a longer period of time elapsing before normal growth is resumed. This is greatly influenced by the rates of each used in the mixture, since at the 1-pound rate of chlorate the recovery of the turf was greatly enhanced due to the stimulating effects of the nutritive elements.

Certain precautions must always be observed in handling chlorates. Since they are active oxidizing agents they tend to promote combustion. For this reason a mixture of chlorate with organic materials such as clothing, wood, charcoal, dried vegetation and the like is highly inflammable. Clothing upon which chlorate spray has fallen and dried may be ignited by friction alone. Vegetation, sprayed with chlorate and dried, may ignite spontaneously under the action of the sun's rays. Matches and fires have strictly no place where chlorates are being used or stored. Metal containers should at all times be used and the material should be stored away from wooden buildings. The salt by itself or mixed with soil or sand is entirely harmless and noncombustible.

Potassium Chlorate

Everything that has been here written about sodium chlorate applies strictly to potassium chlorate ($KClO_3$) with only a few minor exceptions of detail. Potassium chlorate is slightly less effective, pound for pound, than the sodium salt. Likewise it is slightly more expensive. To offset these slight differences the potassium salt is to be preferred, especially in sections where potassium is deficient in the soil, since the beneficial effects based on cost comparisons offset the slightly lower effectiveness. The lower solubility of the potassium salt seems only to increase its effectiveness since it is not so readily leached from the soil. This characteristic of the potassium salt makes it especially adapted to dry mixtures with inorganic carriers, since it is yielded to the roots of plants more gradually and thus its effectiveness is increased by its being available over a longer period of time.

How Chlorates Kill

The killing action of chlorates has been discussed by other investigators from time to time. As oxidizing agents, the ClO_3 radicle being the active lethal ion, they are active in breaking down and destroying organic matter. Their chief effect within the plant has been shown by Latshaw and Zahnley, of Kansas, to be the disintegration and decomposition of starch granules as well as the chloroplasts and protoplasm generally. Without chloroplasts no food is manufactured; without starch there can be no production of soluble sugars. As a result the plant starves to death. Chlorates produce this same effect whether they are absorbed by the roots from the soil solution or absorbed by the aerial organs. Chlorates are not corrosive in any way and kill only upon being absorbed into the plant system.

Ammonium Thiocyanate

Ammonium thiocyanate (NH_4CNS) is a by-product of the coke-oven industry and, according to some investigators, has found considerable application in the destruction of certain weeds of agricultural lands. It has been tested upon turf and has elsewhere been reported to have yielded favorable results. During the present investigations it has been found to be less effective than sodium chlorate and more expensive.

In the pure form ammonium thiocyanate is a colorless salt, coarsely granular, which, upon exposure to the air, absorbs moisture so freely (deliquescent) that it soon becomes liquid. This characteristic limits its use solely to water solutions as a sprinkle or a spray. The commercial product is reddish-brown in color, coarsely crystalline, the color being due to certain coal-tar impurities. It contains approximately 35 per cent of nitrogen which becomes available to plants upon being applied to the soil.

The weeds upon which ammonium thiocyanate has yielded the best results are crabgrass and plantain. Dandelions have been little or not at all discouraged by its use and, in fact, have in some cases greatly increased where it has been used. In spite of the nitrogen contained in this chemical the growth of the turf grasses following its use has been discouraging to its further applications in extensive tests as compared with sodium chlorate.

As with the chlorates, this salt has a temporary retarding effect upon the soil organisms, which is largely due to the CNS radicle, particularly the CN part of it, which is quite poisonous. The effects at equal rates are somewhat more quickly dissipated than with the chlorates and are influenced in much the same ways by identical factors.

Ammonium thiocyanate is a noncorrosive material as applied to plants. Its killing action depends first upon its absorption into the plant system, where it retards the normal metabolic processes and brings about derangements which lead to the death of the plant. It is taken into the plant apparently equally well as a spray through the aerial organs or as a part of the soil solution through the roots. It is somewhat more effective by the root-absorption method, particularly at the lower rates.

When ammonium thiocyanate is applied to turf the first noticeable effects, which occur after about 10 or 12 hours, are a whitening of the tips of the grass blades, and a slight yellowing of the weedy grasses, followed by a pronounced bleaching effect over the entire treated area. The more resistant weeds become tinged slightly yellow, depending upon the rate of application, and at rates of more than 3 pounds the entire area is usually bleached completely to a whitish cast. This usually persists, at this rate, for about 3 or 4 weeks. The white-bleached grass blades turn a more pronounced yellow after a few days. Those weeds which have not been killed outright by the initial application of the material make a very rapid growth following recovery from the initial effects, due to the release of available nitrogen by the soil organisms. It has been very difficult in this respect to determine a satisfactory rate at which this chemical might be used, since a balance must be found between the amount necessary to kill the weeds and the amount which will permit the desired grass plants to successfully and most rapidly recover.

Few precautions need be observed in the handling of ammonium thiocyanate, except that the material should be kept in a tight container so as to preserve it from the deteriorating action of the air. The salty taste of the chemical seems to have a certain attraction for animals, particularly those that may have been deprived of salt. The effect on animals is not definitely known; so it is best to take the necessary precautions to prevent injury.

Arsenicals

Comparisons have been made among the several common easily obtainable compounds of arsenic. Most of the experimental results have been obtained, however, with the arsenic pentoxide, for several reasons. Although it is difficult to obtain and is high-priced at present, it represents the maximum content of the element arsenic obtainable. It adapts itself well to experimental procedure, is highly soluble, and, with care, may be used as a dry mixture. The other compounds of arsenic are applicable, but with some variations in procedure and rates of application.

Arsenic pentoxide (As_2O_5) is obtained as a white amorphous powder which easily takes up moisture from the air (deliquescent), so that as far as large-scale use is concerned it can not well be employed as a dry mixture. In combination with water, it forms the orthoarsenic acid, which is similar in practically every respect to the corresponding acid of phosphorus. Since it is extremely poisonous, as are all compounds of arsenic, it must be handled with extreme care, so that it may not be taken into the body or be allowed to come within the reach of children or animals.

Due to the rapid fixing of arsenic in the surface layer of soil, it is best adapted to the control of the shallow-rooted, low-growing forms of turf weeds, such as chickweeds, speedwell, white clover, and the like.

The killing action of arsenic depends upon its absorption into the circulatory system of the plant, where its toxic effect is particularly effective in preventing the formation of the products of photosynthesis. Its absorption into the plant depends upon a number of factors, chief among which are soil moisture and the moisture deficit within the plant. The value of the moisture deficit within the plant as an aid in the absorption of arsenic when applied as a spray is apparent as a result of the California investigations, where it was found that the best results were obtained by spraying in the early evening and up until midnight. This phase of the problem has not received consideration in these experiments.

There have been indications that the continued use of soluble arsenicals for weed control has a profound effect upon turf pests, such as worms, beetles, and grubs. The effects with small applications are scarcely noticeable, but actual counts of earthworm casts made on arsenic-treated plots after two years of light successive applications of arsenic pentoxide show a reduction of from 75 to 80 per cent in earthworm infestation. While this phase of the problem merits attention, it has received little consideration in this series of experiments aside from incidental observations. The opportunities of the problem are manifold, inasmuch as it reveals an opportunity for obtaining weed and grub control with a single chemical, thus reducing operating costs.

Summary

The data and observations obtained from two years of experimentation yield certain information which may be summarized as follows:

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 with three successive application at the 2-pound rate. Satisfactory control with lighter first and second applications has been indicated, and suggestions have been made as to rates and times of treatment.

Under the treatment as suggested for crabgrass, practically all other common turf weeds, such as plantain, field sorrel, chickweeds, milk purslane, ground ivy, heal-all, and speedwell, disappear within a single season. Dandelion and goose grass are discouraged. Wild garlic is little affected.

With any of the chemicals used there is a discoloration of the turf, the duration and intensity of which varies with the rate and time of application as well as with the attendant conditions of moisture and temperature.

Potassium chlorate, calcium chlorate, and magnesium chlorate may be substituted for sodium chlorate. The potassium salt has been mentioned as superior particularly where the soil is low in potassium.

The dry method of applying chlorates has been found to be entirely satisfactory. In addition, the fire hazard, which is always present when chlorates are used in solution, is virtually eliminated with the dry method.

Sodium chlorate has been tested on a large scale on golf courses as a result of these experiments and has been found satisfactory.

Ammonium thiocyanate has yielded results inferior to those obtained through the use of chlorates. In these tests its use tended to encourage certain types of weeds, principally annual bluegrass and dandelion.

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

Arsenic pentoxide apparently yields the best results when applied in successive treatments as a sprinkle at rates not to exceed ½ to ¾ pound to 1,000 square feet in successive treatments.

There have been indications that earthworms and grubs may be controlled through the use of soluble arsenicals for weed control.

Early-season treatments with arsenicals affect markedly the establishment of crabgrass but have little effect when applied after the plants have become established.

Over a period of two years, there apparently has been no permanently injurious effect on soil treated with any of the chemicals used.

With the judicious use of the chemicals, there may be expected an improvement in the turf over a period of time.

Certain precautions against poisoning and fire must be observed where any of the chemicals are used.

Sulphate of iron and sulphate of ammonia, alone or in combinations, gave no indications of satisfactory crabgrass control but proved applicable to the control of broad-leaved, low-growing weeds, particularly those in putting greens.

Calcium cyanamid yielded no 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 experiments have not been carried out to a sufficient extent on sandy soils to permit of definite conclusions. The greater part of the data has been gathered from results obtained on loams, silt loams, and clay loams.

Results with chemicals are affected by a number of factors to an undetermined extent, indicating the necessity for more extensive investigations of the problem.

Weeding Bermuda Grass Out of Creeping Bent Turf

By Thornton Conover,

Valley Club of Montecito, Santa Barbara, Calif.

The Valley Club of Montecito was opened for play in the fall of 1928. The putting greens had been sown with seaside creeping bent and the fairways with Bermuda grass. Both got a good start, and the season of 1929 opened auspiciously.

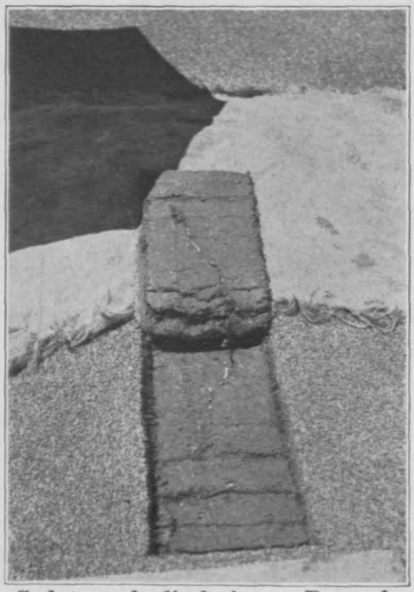
In the summer of 1930 the greens began to show a considerable amount of Bermuda grass. In spite of some surface weeding and patching, this grass continued to increase in the putting greens through this season and also in 1931. We then tried the method of turning back the sod and weeding the Bermuda from underneath. This method proved to be much more effective even though it was more costly than the other methods. Since the putting greens were so badly infested with the Bermuda grass, it was necessary to devote the entire services of one man to this work.

A careful workman was selected, and the first week he was assigned to the turf nursery to practice the technique. The second week he was moved to the croquet court, which was seldom used and not kept up as carefully as the putting greens. By then he had acquired proficiency and was ready to start on the regular greens. He worked five 8-hour days a week, turning back an average of 25 sods a day. From May to July it was a struggle to hold his own with new patches showing up constantly; but it was a cool summer and the Bermuda grass was a little late in sprouting. I decided to put on another man on July 1, and by the first of August we had it pretty well under control and one man finished the season. By the first of November the greens were practically free from Bermuda grass. How successfully the method worked out has been proved this season. Only a few scattered patches of Bermuda grass appeared in 1933. Of the many thousand sods turned back, only a small number had to be replaced. At no time during the season were any of the greens marred or their putting surfaces disturbed.

With the accompanying photographs, the method of weeding can be easily understood.

The first photograph shows the workman about to lift the sod after having cut three sides around the measuring board with a revolving-disc edger. We tried a number of different sized boards but finally decided on one 9 by 18 inches. Cutting larger sods might have saved a little time, but 9 by 18 inches was a size so handy to work with that we used it exclusively. On some soils it might be practical to use a somewhat larger measuring board. The workman,

Starting to lift the bent sod.



Sod turned, disclosing a Bermuda rhizome.

after cutting three sides of the sod, two long and one short, lifts the board and places it at the narrow, cut end. He uses it for leverage and to protect the turf by the edge of the measured turf when he lifts it with a spade. We tried different lifting tools but found an ordinary spade was the best. Lifting the turf is a very important part of the work. If it is cut an even thickness, there is much less danger of finding a hollow or bump after the turf is replaced. It takes continued care, but it is not difficult to cut it evenly after some practice.

It is hard to advise a definite thickness to cut the turf. That has to be gauged by the density of the Bermuda roots. It is best to cut it as thin as is practical; but if it is cut too thin, tearing out the roots would weaken the turf too much. On the other hand, if it is cut thicker than necessary it is difficult to find all of the Bermuda roots, and in taking them out so much soil is removed that it is hard to avoid soft spots when the turf is replaced. Soft spots will eventually become depressions. The larger proportion of sods are cut from 1½ to 1¾ inches in thickness.

The second photograph shows the sod turned back; a heavy Bermuda rhizome can be plainly seen. It will be noted that the sod is turned back in the shade of an umbrella. In the hot sun that is important. Before we began to use the umbrella we noticed that sods turned back in the hot sun were slightly brown after replacing even though we used plenty of water. After we began to use the umbrella we had no more trouble that way.

The workman first clears the soil beneath. For that work a small trowel is a handy tool. If the rhizomes run beyond the soil exposed it will be necessary to lift another piece of turf. Though Bermuda grass sometimes grows to prodigious depths it seldom goes down far under a green unless it is left to develop year after year. We had little trouble in clearing the exposed soil.

Extracting the rhizome. The work should be done under an umbrella to shade the sod.

Weeding the sod turned back is the most difficult part of the process. We found the handiest tool for that work was a 10-inch length of stiff wire with a loop in the middle for a grip and one or both ends turned back to make approximately a 1/8-inch hook. The wire must be stiff enough to stand substantial leverage, as some of the heavy rhizomes require it. Nothing but patience and care will achieve good results. It is most important to get out all of the rhizomes. Any left will mean further growth and labor wasted. When the rhizomes are all cleared from the bottom it is easy to pull out the surface growths from the top.

When the sod has been thoroughly weeded the low spots should be filled with moist soil. We found the best way to do this was to have the soil the consistency that would make a good mud pie, and handle it with a trowel the way a bricklayer would handle cement. Next to the actual weeding, this is the most difficult part of the process, as the soil must not only be spread evenly but the depressions must be filled so that when the sod is turned back it will lie smoothly and with a uniform consistency.

If the work is expertly done the marks of cutting will disappear within a few days. We have found it better to cut the sod at a slight angle so as to make it a shade wider at the top. When the sod is replaced the line of the cut should be hardly perceptible.

There are no especial precautions to advise except to keep the sod in the shade while it is turned back and to use plenty of water on hot days.

There will occasionally be a patch of Bermuda grass so thick that there is little soil left in the turf after weeding. In such a case it would be necessary to fit a new piece of sod. It is surprising though how few times that is necessary. We used not more than 20 to 25 new sods throughout the season; and our greens were certainly thick with Bermuda grass. On one green during the first thorough weeding we took out nearly 7 buckets of rhizomes and shoots from the sods lifted and from the soil beneath.

It might seem as if too much labor was involved in this process of weeding Bermuda grass from bent greens; but it must be borne in mind that our greens were so badly infested that with only surface weeding it would have meant a steady increase year after year and more and more labor required for weeding, with the highly unsatisfactory knowledge that we were losing ground and eventually would have to perform some major operation to the greens. By that time the rhizomes would have penetrated so deep that nothing but new construction would be practical. The winters here are not severe enough to kill Bermuda grass. It just lies dormant for a few months.

On golf courses which have Bermuda fairways and bent greens there will always be a problem of keeping the Bermuda grass out of the greens. A certain amount of surface weeding will be necessary every year. That is usually all that is done, but it is not enough. If the rhizomes are allowed to develop, it will certainly mean trouble in the future. The only sure methods of treatment are to patch if it can be done successfully or else to weed by turning back the sod as I have described. In either case it should be done as soon as the Bermuda grass appears. There is danger in neglecting to weed promptly and in allowing the rhizomes to develop.

It has been estimated that American agriculture suffers annual losses reaching hundreds of millions of dollars from ground squirrels, prairie dogs, jack rabbits, pocket gophers, woodchucks, bobcats, stray domestic cats, moles, porcupines, mice, and rats. That golf courses share to some extent in these losses is evident to anyone who has observed turf uprooted or killed from tunneling or who has seen half-eaten carcasses of birds strewn on a fairway or in the rough. Though it is true that certain of the rodent pests destroy quantities of grubs working beneath the surface, it is considered that on the whole they are more of a detriment than a benefit to a golf course. No general program can be outlined for the control of pests of this kind. Some can be controlled only by poisoning, others by trapping. Each case must be handled individually. In one year over 100,000 farmers took advantage of opportunities offered them to wage cooperative warfare on these pests under trained leadership.

Don't place any faith in rain-making devices. As long ago as 1880 Daniel Ruggles obtained a patent on a rain-making device consisting of balloons equipped with explosive cartridges and torpedoes to be set off by an electric wire trailing on the ground. In 1891 Louis Gathmann obtained a patent on a device for spraying liquid carbon dioxide gas high up in the air, the evaporation of which was to cool the air sufficiently to cause rain. Since then other rain-making devices have been patented. The science of meteorology is still, however, in its infancy, and the growers of plants are as much at the mercy of the elements for their rain as were their ancestors thousands of years ago. Numerous devices are still being offered to farmers by professional rain-makers. Fortunately most golf courses are not so extensive but that they can equip themselves with reliable means of watering fairways and therefore offer little appeal to rain fakers.

Fertilization of Fairways: Some Experimental Results

By Kenneth Welton

The most common cause of poor fairway turf is undoubtedly starvation, although turf may become poor due to a variety of other causes. Grass plants require an abundance of nitrogen for the production of their highly prized leaves or foliage; but it happens that this element is not available in most soils in amounts required for good fairway turf. Grass plants also require a number of minerals, such as phosphorus, potash, and calcium, and the lack of sufficient quantities of any one of these may prevent grass from making adequate turf. If the soil is sufficiently fertile and the other requirements are supplied, turf grasses are capable of providing a solid, dense, and pure turf year after year.

Starved turf gradually becomes thin and bunchy, and with starvation comes a gradual decrease in depth and size of root system, which allows fine-textured soils to pack and makes it difficult for roots to forage for food. Foreign grasses and weeds, including clover, which can better adapt themselves to such conditions, soon appear and crowd the grass. Thin turf, weedy turf, or a combination of the two does not come up to the requirements of good golf clubs; and if this condition exists for long, clubs often find their members seeking better fairways. Clubs can not afford to lose members these days, and, if for no other reason, should be interested in any means by which poor fairways may be improved.

Not so many years have passed since the popular method of thickening turf, particularly fairway turf, was by sowing seed. The more seed sown the thicker the resulting turf was supposed to be. This procedure was costly, not only because of the actual outlay for seed, but also because of the time and effort lost, since seldom, if ever, did the mere act of reseeding effect any permanent improvement. Seed is often sown on the theory that the plants have died of old age and must be replaced by new plants from seed. This theory is not founded on fact however, since most desirable fairway grasses, such as Kentucky bluegrass, fescue, bent, Bermuda, and carpet grass, are perennials and are capable of producing solid pure turf almost endlessly without being allowed to seed, or without seed being supplied. It is not intended to argue that there are no instances where reseeding will bring a marked improvement in old fairways. There are cases where the introduction of a new species of grass may solve the problems, and it is often necessary to introduce new plants into areas that have become so patchy that they can not be thickened in a reasonable time by the spread of old plants. Except for special cases, such as the sowing of seed on southern fairways for temporary improvement and coloring of winter turf, it has been shown frequently that it is extremely unlikely that a good catch will be procured on old turf unless a seed bed be prepared by raking, spiking, straight-discing, topdressing, or other methods.

Old grass plants are able to increase and spread by root division and from buds formed on rootstocks. The young plants coming from the roots of the old plants are planted already in the soil and are protected by the old plants, so that plants so produced have a much better chance of surviving than plants produced from seed. Considering the above, it is evident that one should not expect seedling plants to produce good turf where old plants have failed. It is unreasonable to expect tender seedlings to grow and spread in an area where old plants with established root systems have failed to make any increase or have died. This has been proved time and time again on the golf courses of the country, and greenkeepers now recognize that it is useless to sow seed where turf has failed, unless the conditions which have caused the poor turf are first corrected; and it has been found frequently that where there is a reasonable number of old plants, an improvement in the conditions has enabled the old plants to develop new plants, to fill in the area, and to form a dense turf without the aid of any reseeding.

Responsibility for the poor quality of the turf on some fairways is often laid to lack of water. Water is necessary for plant growth, but perennial grasses can survive long periods of drought and then make remarkable growth if the soil is fertile. Without plant food, however, no amount of moisture will make grass grow. Poor fairways are sometimes blamed also upon poor soil. If lack of plant food is meant, fertilizing will solve the problem. Poor soil structure may be a factor, inasmuch as it limits root growth; but poor structure under turf is more often the result of than the cause of poor turf. Many fine fairways have been produced on packed, hard soils and have been maintained in excellent condition by adequate fertilizing. Such heavy turf eventually greatly improved the structure of the soil by increasing its humus content. Sometimes also poor turf is supposed to be due to poisons in the soil, but this condition is rare and is usually found only in arid or semi-arid areas. There are cases, such as in poorly drained areas, where grass will not grow even if abundantly fertilized, but in most cases on golf courses the real factor in fairway maintenance is fertility, and the problem is hence one of how much and what kind of fertilizers to use and the best time to apply them.

An experiment was planned and carried out by the Green Section to learn how much fertilizer is needed to produce a dense Kentucky bluegrass turf on a poor bluegrass fairway. Complete mixed fertilizers were used in order that there would be no deficiency in any of the three elements most needed by fine turf. The fertilizers were made up in both the inorganic and organic forms in order that a comparison could be made between the effects of the two forms. It was recognized that information on several phases of fairway culture could be gained through such an experiment, and data on the following points were also procured: whether the development and spread of turf could be gained in proportion to the amount of fertilizer applied; the quantities of fertilizer which under these conditions would injure the turf; the effect of heavy fertilizing on certain weeds; the difference in availability to the plant of inorganic and organic fertilizers; the improvement of the soil as measured by the increase in amount of organic matter and certain minerals; and whether the use of organic fertilizer makes an appreciable increase in soil organic matter over the use of inorganic fertilizer.

Kinds of Fertilizers Used in the Experiment

A 6-12-4 fertilizer was made up in both the inorganic and organic forms. In other words, the fertilizers contained 6 per cent of nitrogen, 12 per cent of available phosphoric acid, and 4 per cent of potash. This formula was chosen since there are several popular fairway fertilizers on the market which contain approximately 6 per cent of nitrogen. Nitrogen is the element most needed by grass plants for turf production, and fertilizers for this purpose should be compared on a nitrogen basis. Hence the rates used in these experiments may be easily compared with fertilizers commonly used. The soil upon which the tests were made was found to be deficient in available phosphorus. Ample phosphorus is necessary in increasing growth of the stiffer plant structures, such as roots, rootstocks, and stems; and as it is necessary to increase the growth of these parts in thickening turf, a fairly high percentage of phosphorus was used in the fertilizer mixtures. Few soils show potash deficiencies in turf culture, but since it was expected that a very heavy growth would be produced by the heavier fertilizer rates it was thought that 4 per cent of potash in the fertilizer would more than supply any demand made by the plants for this element.

General view of the fairway fertilizer experiment at the Bannockburn Golf Club, Glen Echo, Md. The four dark areas are the four pairs of fertilized plots; the light areas between and at the end are the unfertilized check plots. Each of the four pairs of fertilized plots is divided equally into an area fertilized with inorganic fertilizer and an area fertilized with organic fertilizer. Reading from left to right, the four fertilized plots represent the 700-pound rate up to the 5,600-pound rate at the right. The dark color of the fertilized plots is caused by a heavy growth of Kentucky bluegrass.

The composition of the 6-12-4 inorganic fertilizer was 30 pounds of sulphate of ammonia, 62 pounds of 20-per-cent superphosphate, and 8 pounds of muriate of potash. The composition of the 6-12-4 organic fertilizer was 45 pounds of sewage sludge, 44 pounds of 3.6-per-cent-nitrogen steamed bone meal, 3 pounds of urea, and 8 pounds of muriate of potash. Muriate of potash is not an organic material, but it was necessary to use a small amount of this material in the organic fertilizer to bring up the potash content to 4 per cent.

The plots were laid out running across the No. 16 fairway of the

Bannockburn Golf Course at Glen Echo, Md. The area chosen was high, well drained, fairly flat, and had a gentle slope in one direction. It was particularly suitable for such a test, as it was of uniform topography, soil, and turf. The soil was a poor reddish clay loam of the Louisa series. The dark layer of topsoil was from 1 to 2 inches in depth. This area of fairway had been in play for 12 years and had received no fertilizer during that time. It had been given one application of ground limestone at the rate of one ton to the acre a year before the experiment was started, with no apparent effect on the turf. The soil was about neutral in reaction. This area was

	Check.
Plot No. 1	Inorganic fertilizer at rate of 700 pounds per acre.
" " 2	Organic " " " " " " " "
" " 3	Check.
" " 4	Inorganic fertilizer at rate of 1400 pounds per acre.
" " 5	Organic " " " " " " " "
" " 6	Check.
" " 7	Inorganic fertilizer at rate of 2800 pounds per acre.
" " 8	Organic " " " " " " " "
" " 9	Check.
" " 10	Inorganic fertilizer at rate of 5600 pounds per acre.
" " 11	Organic " " " " " " " "
	Check.

Plan of the fairway fertilizer experiment. Each plot is 10 by 100 feet in size

chosen also for its uniformly poor turf made up of a sparse but even distribution of Kentucky bluegrass, a thin scattering of white or Dutch clover, chickweeds, plantains, and dandelion. During the summer common crabgrass (Digitaria sp.) became more or less plentiful. There was no provision for watering the fairways on this course, and the experimental area received no artificial watering.

Rates and Methods of Application

The method in which the plots were arranged is shown in the accompanying diagram. Each fertilizer or check strip was 10 feet wide and 100 feet long. The check plots, Nos. 3, 6 and 9, and the area surrounding the experimental area, were left unfertilized. In plots Nos. 1 and 2, 43.5 pounds of nitrogen to the acre was applied. This amounts to about 700 pounds of 6-12-4, and is about the normal rate for fairway fertilizing with fertilizers of that formula. Plots Nos. 4 and 5 received twice this much, or 1,400 pounds of fertilizer to the acre. Plots Nos. 7 and 8 received four times the normal, or 2,800 pounds to the acre, and plots Nos. 10 and 11 received eight times the normal, or 5,600 pounds to the acre.

The fertilizers were broadcast without mixing with any inert material and were not watered, brushed, spiked, or raked into the soil. The first application was made somewhat late in the season, on October 21, 1931. At that time 700 pounds to the acre were applied to plots Nos. 1 and 2, and 1,400 pounds to the acre to plots Nos. 4, 5, 7, 8, 10, and 11. There was a 2/3-inch of rainfall on October 27, and a second application of fertilizer, of 1,400 pounds to the acre, was made on October 29 to plots Nos. 7, 8, 10, and 11. After another rain an application of 2,800 pounds to the acre was made on November 10 to plots Nos. 10 and 11.

As described above, the 700-pound-per-acre plots received a 700-pounds-per-acre application on October 21. The 1,400-pounds-per-acre plots received a 1,400-pounds-per-acre application on October 21. The 2,800-pounds-per-acre plots received a 1,400-pound application on October 21, and a similar application on October 29. The 5,600-pounds-per-acre plots received a 1,400-pounds-per-acre application on October 21, a similar application on October 29, and a 2,800-pounds-per-acre-application on November 10. Therefore all the plots with the exception of those fertilized at the 5,600-pounds-per-acre rate got all their fertilizer in nine days with a rainstorm between applications. The 5,600-pounds-per-acre plot received one-half of its total in that time and the other half 12 days later. The fertilizers were applied in a similar manner commencing on October 12 in 1932, and again in a similar manner commencing March 30, 1933.

The winter of 1931-1932 was a comparatively mild winter in Maryland. There was little snow, but there was sufficient rainfall for any growth of grass the temperature permitted. The early spring was cool and damp and favored the growth of clover. The summer of 1932 was a hot, dry summer, and the plots received no artificial watering. Due to the dry summer the crabgrass was below normal.

The fertilizers were applied in the fall of 1932 in the same manner as in the fall of 1931. The first application was made on October 12. Final applications were made a week later. The late fall and early winter were mild, and there was an abundant growth of bluegrass until December on well fertilized plots. There was practically no change in the turf from December, 1932, until late in March, 1933.

It was decided to add an application of fertilizer in the spring of 1933, and the fertilizers were applied in March at the same rates as in the two previous falls. The spring of 1933 was a very wet one and the summer was the wettest for more than ten years. The high rainfall, aided by summer temperatures that were mostly higher than normal, caused a very heavy growth of crabgrass throughout the section in which the experiments were being conducted. In September, crabgrass on fairways and check plots commenced to ripen, and after October 16, when the first heavy frost occurred, it died and turned brown.

Results of Various Rates of Application

700 pounds per acre.—There was no burning during the experiment from any application of the fertilizers used at the rate of 700 pounds per acre. Practically no results were noticed within a month from the first application. except that the inorganic fertilizer produced a somewhat darker color in the turf. Although the winter was mild and moist there was not a great deal of improvement in either the inorganic or organic plots. In fact, the inorganic plot became worse from a golf standpoint on account of the considerable increase of clover in this plot. By early June there was an increase in the growth of grass in the inorganic plot, although the increased percentage of clover also persisted. The organic plot had not changed and was no different from the check plots, which indicated the slowness of the organic nitrogen to become available during a comparatively cool and wet spring. During the late spring and summer of 1932 a certain amount of crabgrass came into the 700-pounds-per-acre plots. The excellence of turf and percentage of crabgrass in plots at the end of the first year after fertilizer had been applied may be seen in table 1.

TABLE 1.—CONDITION OF THE TURF AT THE END OF THE CRABGRASS SEASON (FALL, 1932)

Excellence of turf is based on a maximum of 10 as representing ideal fairway condition.

Kind of fertilizer	*Rate of application (lbs. per acre)*	*Excellence of turf*	*Percentage of crabgrass*
Check		2	50
Inorganic	700	5	10
Organic	700	2	40
Check		2	50
Inorganic	1400	6	25
Organic	1400	5	45
Check		2	50
Inorganic	2800	8	40
Organic	2800	8	35
Check		2	50
Inorganic	5600	5	5
Organic	5600	8	10
Check		2	50

The fertilizers were applied again in the fall of 1932; and by winter, after the bluegrass had made all its fall growth and had recovered from the crabgrass, the inorganic plot showed only 2 per cent more clover than the average of the check plots, 8 per cent less plantain, 13 per cent less bare ground, and an increase of 20 per cent in grass coverage. The organic plot showed a 3 per cent decrease in clover, 6 per cent less plantain, 8 per cent less bare ground, and an increase of 18 per cent in grass coverage. See table 2.

TABLE 2.—CONDITION OF THE TURF AT THE END OF ONE YEAR (1932) AFTER BEING FERTILIZED FOR TWO FALLS

Excellence of turf is based on a maximum of 10 as representing ideal fairway condition.

Kind of fertilizer	*Rate of application (lbs. per acre)*	*Excellence of turf*	*Clover %*	*Plantain %*	*Bare ground %*	*Grass cover %*
Check		2	10	10	20	60
Inorganic	700	7	10	3	5	82
Organic	700	6	5	5	10	80
Check		2	10	10	20	60
Inorganic	1400	10	1	Trace.	5	94
Organic	1400	6	5	10	5	80
Check		2	5	12	20	63
Inorganic	2800	10	0	0	5	95
Organic	2800	10	2	3	2	93
Check		2	10	15	15	60
Inorganic	5600	6	0	0	20	80
Organic	5600	10	1	3	5	91
Check		2	5	10	15	70

In the spring of 1933 the fertilizers were again applied, and the grass was vigorous in both plots until the end of May, when crabgrass commenced to appear. In September the crabgrass began to ripen, and the bluegrass commenced to make excellent fall growth in these plots. In October the plots were inspected and showed results indicated in table 3. The 700-pounds-per-acre plots had received three applications of fertilizer in two years and had, as the table shows, improved greatly and showed decided clover or perennial weed control. The turf was however little, if any, better than some plots which received heavier applications after one application and one growing season.

TABLE 3.—CONDITION OF THE TURF AT THE END OF TWO YEARS (1933) AFTER BEING FERTILIZED FOR TWO FALLS AND ONE SPRING

Excellence of turf is based on a maximum of 10 as representing ideal fairway condition.

Kind of fertilizer	*Rate of application (lbs. per acre)*	*Excellence of turf*	*Clover %*	*Plantain %*	*Bare ground %*	*Grass cover %*
Check		2	15	10	25	50
Inorganic	700	8	6	0	8	86
Organic	700	8	10	2	2	86
Check		2	15	10	25	50
Inorganic	1400	8	0	0	15	85
Organic	1400	8	4	2	6	88
Check		2	10	15	25	50
Inorganic	2800	2	0	0	50	50
Organic	2800	1	0	0	65	35
Check		2	15	15	20	50
Inorganic	5600	0	0	0	100	0
Organic	5600	0	0	0	100	0
Check		2	15	15	20	50

1,400 pounds per acre.—The fertilizers were applied in October, 1931, in one application of 1,400 pounds per acre. Within a few days it was noticed that the inorganic plot was severely burned. No burning was noticed on the organic plot at any time during the experiment. The grass commenced to take on a dark green appearance on the organic plot a few days after the first rain following the application. Within three weeks the inorganic plot was recovering from the burning and the bluegrass was putting out leaves in small patches. By March, 1932, the inorganic plot had completely recovered and was making better growth than the organic plot. The bluegrass was making good growth in both plots, but the inorganic plot was growing the faster and showed a reduction in clover, which the organic plot did not.

By early June of 1932 both plots were holding their own against any increase in clover, but crabgrass was commencing to appear. In September the plots were inspected again before being fertilized and showed improvements as indicated in table 1. By October the bluegrass in these plots had pushed above the crabgrass enough to hide the brown color of the dead plants.

The fertilizers were applied in October, 1932, the same as in 1931, and the inorganic plot was only slightly burned and the growth of the grass was not retarded to any extent. In December, 1932, the plots were examined (see table 2), and the inorganic plot showed almost complete control of clover and plantain. The coverage of bluegrass in the inorganic plot had increased from about 62 per cent to 94 per cent. This increase was made by replacing almost 19 per cent of weedy turf and covering about 13 per cent of bare ground. This was done in one year with two applications of fertilizer and without any seeding, topdressing with soil, or artificial watering. The grass was also greatly increased in the organic plot, but there was less clover and plantain control. Since the inorganic plot was hardly burned by the fertilizer applied in the fall of 1932, it appears that the nature of the fertilizer rather than the effect of burning caused the weed control.

In March, 1933, the third application of fertilizer was made and a fairly bad burn was noted on the inorganic plot. The grass quickly recovered, however, and the bluegrass was in vigorous condition before the commencement of the crabgrass season. By July 15 it was evident that crabgrass was crowding out the bluegrass in these plots. During October the crabgrass died and the bluegrass was making excellent growth in the plots. The condition of the plots as observed at that time is outlined in tables 3 and 4. It will be noted that these plots show more bare ground than at the end of the 1932 season. This bare ground is almost entirely due to the fact that in some small areas the bluegrass was entirely smothered by the heavy growth of crabgrass during the summer of 1933.

TABLE 4.—COUNT OF PLANTS AND SHOOTS ON THE BEST PLOTS IN THE EXPERIMENT AT THE END OF TWO YEARS (1933)

Kind of fertilizer	*Rate of application per acre*	*Shoots per square foot*	*Approximate plants per square foot*	*Shoots per plant*
Inorganic	1400 pounds	2160	240	8
Organic	1400 pounds	2000	400	5
Average of checks		256	80	3

Table 4 shows approximately 1,000 per cent increase in Kentucky bluegrass shoots in the fertilized plots over the unfertilized or check plots.

2,800 pounds per acre.—The first application was made in October, 1931, and was put on both the organic and inorganic fertilizer plots in two parts; that is, 1,400 pounds was applied first and a second 1,400 pounds following the first rain, which occurred in eight days after the first application, to complete the 2,800 pounds. There was no burning at any time from the applications of organic fertilizer, and the organic plot was growing rapidly within three weeks from the first application. The inorganic plot was severely burned by the first part (1,400 pounds) of the application, but the second 1,400 pounds was applied nevertheless, and within two weeks from the last application the Kentucky bluegrass was commencing to recover.

The winter of 1931-1932 was mild and there was considerable growth on these plots. By March the inorganic plot had completely recovered and was making better growth than the organic. Both inorganic and organic fertilizers had forced the Kentucky bluegrass remarkably, and the extent to which the bluegrass had spread and thickened the turf in such a short time (October 31 to April 1) was almost unbelievable. There was almost complete clover and partial plantain control in the inorganic, and partial control of both in the organic plot. By early June the bluegrass was still improving but crabgrass was commencing to appear. In September the plots were inspected and the percentage of crabgrass estimated. See table 1.

These plots were among the three most highly rated plots of the series and showed a crabgrass content of 40 per cent for inorganic and 35 per cent for organic fertilizer. The remaining vegetation (about 55 per cent) on these plots was almost entirely bluegrass. The check plots contained 50 per cent of crabgrass and the remaining turf was made up of about 18 per cent of bare ground, 7 per cent of clover, 12 per cent of plantain, and about 13 per cent of Kentucky bluegrass. Crabgrass, though undesirable chiefly because of its seasonal nature, makes good summer turf when mixed with bluegrass, and this explains why turf received high ratings in table 1, even though it contained 30 to 40 per cent of crabgrass. In these cases the turf was solid and thick, due to the density of the bluegrass plants, whereas check plots were rated low because the turf was thin and patchy and apart from the crabgrass was principally clover and various weeds. By October the crabgrass was dead in these plots fertilized at the 2,800-pound rate, and the bluegrass was quickly pushing above the crabgrass remains.

The 2,800-pounds-per-acre plot at the Bannockburn Golf Club as it appeared 4 months after receiving the first application of fertilizer. The light areas are not fertilized. The dark, fertilized area shows late fall and winter growth. The growth in fall, winter, and early spring is most important in getting bluegrass well established before the severe summer weather arrives.

The fertilizers were applied in the fall of 1932 in the same manner as in 1931. The first part of the application (1,400 pounds) was made on October 12 and the second part (1,400 pounds) was made after a rain a week later. The inorganic plot was only slightly burned after these applications and was not set back as in 1931. Table 2 gives the condition of the turf during the winter of 1932-1933. These results indicate the condition of the turf after it had thrown off the effect of the 1932 crabgrass. The increase in Kentucky bluegrass was found to be higher in the inorganic plot than in any other plot in the series. It showed a bluegrass covering of 95 per cent as against an average of 62 per cent in check plots. This makes an increase of 33 per cent in bluegrass coverage after two applications of 2,800 pounds per acre of inorganic fertilizer in a little over one year. The results in the organic plot were not far behind those in the inorganic, as its covering was 93 per cent for Kentucky bluegrass; it had 3 per cent less bare ground than this inorganic plot and 5 per cent more clover and plantain.

The fertilizer was again applied in the spring of 1933 and a bad burn was noted on the inorganic plot a few days after the first 1,400-pound application. The bluegrass recovered, however, and was growing well at the commencement of the crabgrass season at the end of May. The summer of 1933 was very much suited to the growth of crabgrass, and the growth in these plots was tremendous. By August 15 it was difficult to find any bluegrass in these plots, so completely had they been taken over by crabgrass. During September crabgrass commenced to ripen in the check plots and died after October 16 when the first heavy frost occurred. In the 2,800-pound-per-acre plots, however, the crabgrass did not ripen until several weeks after the crabgrass in the checks ripened, and it continued to make vigorous growth until the first heavy frost. The Kentucky bluegrass in check plots and plots more lightly fertilized commenced to make good growth by the end of September and to overcome the crabgrass. The Kentucky bluegrass on these 2,800-pounds-per-acre plots, however, made slow recovery, and when table 3 was made it was found that a great deal of the bluegrass was dead. Apparently the excessively heavy and prolonged growth of crabgrass in these plots killed all clover and weeds as well as a large percentage of the bluegrass by smothering.

5,600 pounds per acre.—These plots received the 5,600-pounds-per-acre applications in two lots of 2,800 pounds per acre each. There was always a severe burn on the inorganic plot when the first half (2,800 pounds per acre) was applied, but the second half was applied even though the turf was badly burned. The inorganic plot was severely burned at each season the fertilizer was applied—that is, fall of 1931, fall of 1932, and spring of 1933; but in every case the Kentucky bluegrass recovered. The results of the inorganic fertilizer at this rate were not as good as those of the 2,800-pounds-per-acre rate. The clover and weeds were practically eradicated with the first application, but later in the experiment the percentage of bare ground still remained high and it was thought that the continued severe burning with each application may have prevented some of the bare areas from filling in. There was 20 per cent of bare ground in the fall of 1932, as shown by table 2, as against 5 per cent of bare ground with the 2,800-pounds inorganic plot. Since the 2,800-pound inorganic rate also eliminated clover and weeds and at the same time reduced the bare ground in the plot from 18 to 5 per cent it is apparent that there was no need of applying more than the 2,800-pound rate of inorganic fertilizer.

The organic fertilizer application was also applied in two parts at 2,800 pounds per acre per application and at no time was there any burning. The results by the fall of 1932 (see table 2), however, were not as good as with the 2,800 organic rate, so that there seems no reason to apply more than 2,800 pounds per acre of such fertilizer.

With both inorganic and organic plots the final results were even worse than with the 2,800-pounds-per-acre rates. The Kentucky bluegrass in both these plots failed to survive the prolific crabgrass growth of the summer of 1933, and the plots were left bare when the experiment ended (see table 3).

It is not known how much the 1933 spring fertilizing influenced the tremendous growth of crabgrass which crowded out so much bluegrass on the 2,800- and 5,600-pounds-per-acre plots during the summer of 1933. There are too many factors to consider to enable one to draw definite conclusions. The summer of 1933 was more ideal for crabgrass growth than the summers of 1931 and 1932. The crabgrass injured the bluegrass less the lower the fertilizer rates, which indicates that it was the excess fertility in the soil over and above what the spring growth of bluegrass used that fertilized the crabgrass. If such is the case it is much more likely that an excess of fertilizer will remain in the soil after spring fertilizing to feed the crabgrass during the late spring and summer, than after fall fertilizing.

The 5,600-pounds-per-acre plot at the Bannockburn Golf Club as it appeared 5½ months after having been fertilized in October, 1931, at the 5,600-pound rate. The fertilized area on the left shows a remarkable growth of Kentucky bluegrass. Adjoining it on the right is the thin, weedy growth of the unfertilized check plot. This growth took place before the first spring mowing on the course.

There was a thin scattering of spots of Chewings fescue and colonial bent in the area chosen for this test. These spots were so small that they were not considered in describing the turf. However, it has been noted that the spots of both the fescue and the bent have developed with the bluegrass and have held their own. Since there was a great preponderance in the proportion of bluegrass to fescue and bent, it therefore seems that if the heavy fertilizing had been detrimental to these grasses they would have almost if not totally disappeared.

In describing the experiment mention was made that the turf experimented with was made up of Kentucky bluegrass, clover, plantains, dandelion, chickweeds, and crabgrass in season. Later in the article the dandelions and chickweeds were not mentioned. There was a comparatively small percentage of dandelions in these plots and their control was practically the same as the plantain control which is indicated throughout the article and in the tables. Chickweed made up a comparatively small amount of the turf treated, and its control was proportionately the same as the clover control.

Application of Results

This experiment is being continued in order to get further data on the subject; but in the meantime, due to the fact that the observations reported to date tend to substantiate other experimental work and observations, there seems to be no reason why some of the results described here can not be applied in a practical way elsewhere. The 700-pounds-per-acre plots which have received two fall and one spring applications have improved greatly, but the turf is not yet as dense as the plots receiving heavier applications after only one or two previous applications. It therefore seems that a club wishing to get thick turf and freedom from clover and certain weeds had better fertilize heavily for one or two falls rather than fertilize lightly for a number of years without gaining the results desired.

In order to get maximum results the following spring, it is indicated that as much as 2,800 pounds per acre of fertilizer similar to what was used in the experiment should be applied in the fall. If other fertilizers are used than the 6-12-4 fertilizer used in the experiment the rates should be on a similar nitrogen basis. The experiment indicates also that it is possible to gain dense Kentucky bluegrass turf which is practically free of clover and perennial weeds if as much as 1,400 pounds of an inorganic, or 2,800 pounds of an organic fertilizer, analyzing as high as 6-12-4 is used two successive falls. When an application of 1,400 pounds of organic fertilizer is applied for two falls and one spring, as in this experiment, the results should be about the same as with 1,400 pounds of inorganic fertilizer applied for two falls only. If the organic fertilizer were applied for three falls instead of two falls and one spring the results would probably be as good or better. The fall fertilizers were not applied until October, but in sections of the country which have earlier and more severe winters than Washington it is likely that the fertilizer treatments should start late in September.

Inorganic fertilizer burned when 1,400 pounds per acre were applied at one time, but the Kentucky bluegrass soon recovered.

Organic fertilizer did not burn when 2,800 pounds per acre were applied at one time. The burning effect of the soluble nitrogen fertilizers, such as sulphate of ammonia, ammo-phos, and urea, and the potassium carriers, such as muriate or sulphate of potash, must be taken into account when considering the power of fertilizers to burn turf.

This experiment bore out the fact which many previous experiments have demonstrated, namely, that organic fertilizer is slower-acting than inorganic. Hence in the comparison of inorganic and organic fertilizers, the organic fertilizers might give as good results as the inorganic when applied at the same rates; but due to the nature of the material, the organic fertilizer would take longer to produce these results. Also once the desired results have been obtained, the organic fertilizer may be expected to have a more lasting effect than inorganic fertilizers.

Effect of Fertilizers on Crabgrass

In October, 1933, the series was inspected and results observed as shown in table 3. From that table it will be seen that during the summer of 1933 considerable bluegrass was lost in plots 7 and 8, and no bluegrass remained in plots 10 and 11. These plots were the 2,800 and 5,600-pounds-per-acre applications of both inorganic and organic. Apparently there was such a heavy and prolonged growth of crabgrass in these plots that Kentucky bluegrass was smothered. When the crabgrass eventually died in October, there was no life left in the injured Kentucky bluegrass rootstocks and nothing took the place of the crabgrass. It is quite significant, however, that in plots 4 and 5, which received 1,400-pounds-per-acre fertilizer, the Kentucky bluegrass survived the heavy crabgrass growth of the 1933 season, and when the crabgrass weakened in the fall the bluegrass recovered rapidly and almost completely replaced the crabgrass. This might be taken to indicate that there is a point where the soil is built up to such a high state of fertility that there is a growth of crabgrass sufficiently dense and prolonged to completely smother the bluegrass. The possibility that burning at the time of application might have been a factor apparently need not be considered. There was no burning in plots 8 and 11, which received organic fertilizers, and yet the bluegrass died in these two plots the same as it did in the two plots which received similar rates of inorganic fertilizer and which were badly burned.

The crabgrass factor must be considered when analyzing fairway fertilizer results in this part of the country. When the experiment was started it was calculated that the check areas were made up of about 8 per cent of clover, 11 per cent of plantains, 18 per cent of bare ground, and 62 per cent of Kentucky bluegrass. After the heavy crabgrass growth during the summer of 1933 the fairways were found to be made up of approximately 14 per cent of clover, 13 per cent of plantains, 23 per cent of bare ground, and 50 per cent of Kentucky bluegrass. It therefore shows that the summers of heavy crabgrass growth materially set back bluegrass fairways. In this case the percentage of clover, weeds, and bare ground was increased and the coverage of bluegrass decreased by 12 per cent. The decrease in weeds and bare ground and the large increase in the percentage of bluegrass coverage in some of the fertilized plots were all the more remarkable when one considers the setback the checks or untreated fairway received due to the luxuriant crabgrass growth during 1933.

It seems likely that in the crabgrass districts a combination of chemical control and heavy fertilizing will be necessary in order to remove this pest from competition with bluegrass and other turf grasses. Suggestions for the control of crabgrass with chemicals is contained elsewhere in this number of the Bulletin in the article describing experiments on the control of various turf weeds with sodium chlorate and other chemicals.

Change in Soil Reaction

The soil in these experiments showed a neutral (pH 7) reaction before the fertilizers were applied. By comparing the average of the reactions found at each inch depth of the top four inches of the various plots after the fertilizer had been applied it was found that the soil reaction was scarcely changed in the plots receiving the organic fertilizer even when as much as four tons to the acre was applied.

In the plots receiving the inorganic fertilizer there was an increase in acidity. Assuming that the increased acidity was due largely to the sulphate of ammonia in this fertilizer it may be calculated from the amount of sulphate of ammonia applied in the complete fertilizer, that it required approximately one ton of sulphate of ammonia to the acre to increase the acidity 1.2 degrees (from pH 7 to pH 5.8). From these results it may be seen that it requires a large amount of sulphate of ammonia to increase soil acidity to any extent in certain soils. Usually fine soils, such as clay and silt loams, resist change in acidity more than sandy soils. A fine soil which is alkaline or neutral may be subjected to prolonged or severe acidifying influences before showing acid reactions.

Increase of Available Phosphorus

It is known how much phosphoric acid has been applied to each plot during the course of the experiment. In August, 1933, soil samples were taken at depths of 1 inch or less, 1 to 2 inches, 2 to 3 inches, and 3 to 4 inches, from each plot and from the check plots. Determinations of the pounds of available phosphorus to the acre were made by the Truog method, and the increase due to the fertilizer applications is given in table 5.

TABLE 5.—INCREASE OF AVAILABLE PHOSPHORUS FROM A 6-12-4 FERTILIZER AT VARIOUS RATES OF APPLICATION

	Application (pounds per acre)	*Increase (pounds per acre)*
Check plots	.....	...
Inorganic—700-pound rate (3 applications)	2,100	...
Organic—700-pound rate (3 applications)	2,100	...
Inorganic—1,400-pound rate (3 applications)	4,200	39
Organic—1,400-pound rate (3 applications)	4,200	22
Inorganic—2,800-pound rate (3 applications)	8,400	89
Organic—2,800-pound rate (3 applications)	8,400	73
Inorganic—5,600-pound rate (3 applications)	16,800	93
Organic—5,600-pound rate (3 applications)	16,800	105

From these results it may be seen that a total application amounting to over one ton of 6-12-4 fertilizer to an acre failed to show an increase in the amount of available phosphorus in the soil when the tests were made four months after the fertilizer had been applied. Higher rates however showed decided increases. Due to the fact that considerable nitrogen was applied there was a large growth of leaves, stems, and roots in the turf, and no doubt a great deal of phosphorus was used by the plant in producing this growth. If phosphoric acid had been applied in a higher proportion to the nitrogen, or if some material containing phosphoric acid but no nitrogen had been applied alone, it is possible that the soil would have shown a higher increase in available phosphoric acid.

Table 6 shows a number of points regarding the penetration of phosphoric acid in the soil when applied in inorganic and organic forms. The fertilizers and rates used have been described elsewhere in this article. Table 6 shows 23.7 pounds greater accumulation in the top inch of phosphoric acid from the organic source than from the inorganic. There is an accumulation of 138.7 pounds of phosphoric acid in the top inch in the plots receiving organic fertilizer and 115 pounds in the plots receiving inorganic fertilizer. This difference is due probably to the fact that the phosphoric acid from the organic source is less soluble. This fact is further borne out in the table by comparing the total accumulation below a one-inch depth. The increase of phosphoric acid below the top inch is about 47 per cent greater in the inorganic fertilizer plots than in the organic. The increase below the top inch with the inorganic fertilizer was 37.5 pounds to the acre and with the organic only 17.9 pounds to the acre. The penetration of the phosphoric acid to depths where the roots may come in contact with it is of importance in supplying adequate quantities of this material to the plant.

TABLE 6.—PENETRATION OF AVAILABLE PHOSPHORIC ACID TO DIFFERENT DEPTHS AS EVIDENCED BY ITS INCREASE IN THE SOIL OF FERTILIZED PLOTS OVER ITS PRESENCE IN THE SOIL OF UNFERTILIZED CHECK PLOTS. THE FIGURES FOR EACH DEPTH SHOWN ARE AVERAGES FOR FOUR PLOTS FERTILIZED RESPECTIVELY AT RATES OF 700, 1,400, 2,800, AND 5,600 POUNDS PER ACRE.

	Increase in pounds per acre	
	Inorganic fertilizer plots	*Organic fertilizer plots*
At depth of 1 inch or less	115	138.7
At depth of 1 to 2 inches	68.7	26.2
At depth of 2 to 3 inches	17.5	8.7
At depth of 3 to 4 inches	26.2	18.7
Averages of the four depths	56.8	48

Other data, not given in the table, showed that fairly heavy applications of fertilizer were required in this experiment before the phosphoric acid commenced to accumulate below the surface inch. In the 700-pounds-per-acre plots there was no accumulation of phosphoric acid in the second inch or below. In the 1,400-pounds-per-acre plots phosphoric acid from the organic source failed to reach the second inch, but the inorganic penetrated to the fourth inch. With higher rates correspondingly more phosphoric acid from the inorganic source penetrated to the fourth inch. In the 2,800-pounds-per-acre plots phosphoric acid from the organic source also penetrated to the fourth inch, and correspondingly more penetrated with the higher rate of application.

Effect of Inorganic and Organic Fertilizers on Organic Content of the Soil

The claims of some fertilizer dealers that the use of organic fertilizers increases the organic-matter content of the soil much more than does the use of inorganic fertilizers were considered in the experiment. It was thought that the abnormally heavy applications of fertilizers to be used on some plots in the experiment would tend to show wide differences in soil organic matter if the above contention were true.

The organic matter in the soils in the plots was determined by loss on ignition. The organic matter was found to be high in the top inch and to become less at each inch of depth until the organic matter in the fourth inch became less than half the amount in the top inch. The organic contents of the soil to a depth of four inches was found by averaging the organic content of each different depth. By this method the organic content of the check plots was found to be 3 per cent, and a considerable increase of organic matter was found in all fertilized plots.

The amounts of humus found in the soil are considerable. As the plants grow, new roots are formed and finally die and thus increase the organic matter in the soil. Also on fine turf the clippings may materially increase the soil organic matter under certain conditions.

An acre of soil one foot deep weighs approximately 4,000,000 pounds, and it was calculated that the 3 per cent of organic matter contained in the 1/3-foot in the check plots amounted to approximately 20 tons. The plots which were fertilized three times in two years with 700, 1,400, 2,800, and 5,600 pounds per acre showed an increase of 5.6, 6.1, 5.6, and 5.2 tons of organic matter to the acre, respectively, for the inorganic fertilizer plots. The organic fertilizer plots showed an increase of 4.5, 6.2, 4.9, and 6.8 tons to the acre, respectively.

It is interesting to note that the average increase per acre in the inorganic plots was 5.59 tons as against 5.58 tons in the organic plots. There were altogether 15.7 tons of fertilizer applied on the inorganic fertilizer plots, and the same amount on the organic fertilizer plots.

It has been frequently claimed that it is economical to pay a premium for organic fertilizers over the cost of inorganic fertilizers of the same analysis. The argument in favor of this additional expense being that the organic fertilizers would increase the soil organic matter, the implication was, if not so stated, that the inorganic fertilizers do not increase the soil organic matter. In such a contention the power of the turf grasses, and other crops for that matter, to manufacture their own organic matter from carbon dioxide in the air, is ignored. When one considers the results of this experiment, in which a soil comparatively low in organic matter for soil which has been in sod so many years, and the fact that a great deal more fertilizer was applied than normally, it seems reasonable to expect that these particular claims regarding organic fertilizers would have been confirmed if they were founded on fact.

The increase of organic matter in the soil was surprisingly close in both cases. The inorganic fertilizer plots gained 20 pounds of organic matter to the acre over the organic, but this small difference is well within the range of experimental error. Organic fertilizers have sufficient in their favor to be used for their fertilizing value alone, and apparently if they are of value as a fertilizer most of their organic matter is lost in decomposition while becoming available to the plants.

This experiment also indicates that it might be more economical and practical to build up the organic matter on fairways and other large turf areas by fertilizing rather than by direct application of organic materials of nonfertilizing value which are often used for this purpose. The 5.5 tons of organic matter to the acre built up in the soil by fertilizing is calculated on a dry-weight basis, and is actually humus incorporated in the soil. It represents something like two or three times this amount in more bulky organic materials, such as well-rotted manure, peat, leaf mold, and other materials commonly used to increase organic matter in soil. Also when such more bulky materials are used they must be incorporated in the soil by cultivation or other methods which can not be employed conveniently on turf areas.

Summary

A comparison was made, in the experiment described, of the effects of a 6-12-4 organic and a 6-12-4 inorganic fertilizer applied to a thin turf of Kentucky bluegrass on a fairway in the vicinity of Washington, D. C. The fertilizers were applied in October, 1931, October, 1932, and March, 1933.

By heavy applications of fertilizers, a thin turf of Kentucky bluegrass was built up during the fall and spring growing seasons to a thick, dense turf free from clover and certain perennial weeds.

Some burning of the grass was observed where inorganic fertilizer was used in a single application at the rate of 1,400 pounds to the acre, but in all such cases the Kentucky bluegrass soon recovered. The organic fertilizers did not burn even when applied at the heaviest rates.

Plots which received two fall and one spring application at the rate of 700 pounds to the acre have greatly improved, but their turf is not yet as dense as plots which received heavier applications after only one or two previous applications.

The experiment has not shown how long turf brought to a condition of excellence with either inorganic or organic fertilizers can be maintained before exhibiting the need for additional fertilizer. It is however known that turf once brought to a thick, vigorous condition produces a great improvement in the condition of the soil, is less affected by conditions of weather, and may maintain itself in excellent shape for a number of years without additional fertilizer.

The experiment bore out the fact which many previous experiments have demonstrated, namely, that organic fertilizer is slower-acting than inorganic.

The inorganic fertilizer increased the soil acidity probably due to its content of sulphate of ammonia. The organic fertilizers did not affect the soil acidity.

There was a decided increase in the content of the available phosphoric acid in the surface inch of the fertilized plots. There was only a small increase in the phosphoric acid below the two-inch level.

It was shown that the phosphoric acid from the inorganic fertilizer penetrated to the 2d, 3d, and 4th inches more readily than the phosphoric acid from the organic fertilizer.

It was found that the organic-matter content of the soil was greatly increased by the heavy applications of fertilizers. The inorganic fertilizer proved equally as effective as the organic fertilizer in adding organic matter to the soil.

Burning over the rough in fall or winter is generally considered to be good practice. It doesn't hurt the turf grasses and destroys insects and weed seeds.

Annual Report of the Green Section for 1933

By Ganson Depew
Chairman, Executive Committee

The Green Section is glad to report that it has been able to efficiently continue many of its activities during 1933, notwithstanding the work was crippled very materially by the reduction in its budget to $28,062, as compared with $44,759 for 1932. By exercising rigid economies, we were able to keep within the budget.

Since 1929, due to the business depression, available funds have been reduced over 40 percent. This has interfered greatly with the continuation of experiments started years ago, and which, to be of constant value, must be continued. Research work must also be continued in adequate study to solve the many and ever-increasing turf problems of the numerous golf clubs of the country. Many are yet to be satisfactorily solved, and a much larger technical staff could well be employed to obtain valuable information in the interest of turf maintenance and economy.

General Activities During the Year

The Staff has been enabled to perform its necessary travel to clubs and meetings through generous contributions by private clubs and other associations and organizations. There was a continued demand for all types of information on economy in course maintenance, disease, and other unfavorable influences. During the year a larger proportion of the member clubs than usual requested the Green Section to examine and report on seed and soil samples and to give advice on numerous maintenance and construction problems. The advisory service has been carried on through correspondence and, as much as possible, by personal interviews on golf courses, Green Section gardens, in offices, and in laboratories.

The principal research of the Green Section has been conducted at Arlington, Washington, and at the Mid-West Turf Garden, Chicago. A number of experiments were also conducted on golf courses in chosen localities on turf maintained under heavy playing conditions. These tests were conducted through arrangements made with the golf club committees. Also, much valuable data has been accumulated through demonstration gardens established at various selected parts of the country. The extension or educational work has been carried on through various Green Section meetings and exhibits. Summer meetings were held, attended by large numbers of greenkeepers and chairmen of green committees. Educational work has been also carried on through the Bulletin and by selected articles in certain other publications. The Green Section staff has also helped in the educational work of the national and the various sectional greenkeepers' organizations and of greenkeepers' short courses held at various state colleges.

Experimental Work

Experimental work was continued at Arlington, supplemented with tests on local golf courses under playing conditions. Interesting observations were made on different species and strains of grass for putting green purposes and different mixtures for fairway purposes. Earthworms were particularly troublesome, as they were elsewhere in the country, and remained so in spite of repeated trials of remedies hitherto effective. Considerable work was done in testing some new remedies. Particularly good opportunity was afforded for advanced studies of brownpatch on a low-lying, shaded, more humid area planted to fine turf beside the Potomac River. This garden continued to prove its value, since, due to its location, disease studies may be continued there at times when diseases are inactive on the main garden with its open exposure. The systematic study of fertilizers, which has been under way for some years, was also continued. An experiment on the effect of different rates of inorganic and organic complete mixed fertilizers on bluegrass fairway turf was continued on a nearby golf course, and information regarding turf improvements, increased soil fertility, and organic matter in soil was obtained. Weed control studies were continued. Many positive results were obtained in controlling with chemicals a number of weeds, particularly crabgrass on fairways. With some further work on this subject, results should be obtained which should prove extremely valuable especially to the many golf clubs in the large area where crabgrass is the most troublesome turf problem.

The Mid-West Turf Garden contains different sets of tests, supplementary to the Arlington work. Many of these tests were planned to procure a more complete understanding of the specific problems of the Middle West. Part of the original work planned has been discontinued, in order to curtail expense.

Demonstration Gardens

The series of demonstration turf gardens continued to provide much information for those interested in turf maintenance on courses in the vicinity of the gardens. There are now 18 gardens in various sections of the United States, and one in Canada, which is maintained through cooperation with the Royal Canadian Golf Association. The Green Section has had splendid cooperation from those in charge of the courses where these demonstration gardens are located. Extensive reports have been received regularly this year and assembled for publication. Soil samples were sent in upon request. The taking of a number of samples from each plot, packing and shipping them, required considerable work on the part of the greenkeepers in charge of these gardens. The Green Section appreciates their cooperation. An analysis of these soils from plots, most of which have received specific treatments for five years, should produce valuable information.

Well-attended gatherings of golf club officials and greenkeepers have been held at the gardens, and the behavior of the different grasses, fertilizers, and other treatments has been discussed on the grounds. At many of these meetings members of the Green Section staff have been present to explain the work. It has been found that discussions of turf problems are much more valuable where such demonstrations are at hand than are discussions of similar problems indoors, where direct examples of results cannot be exhibited.

Educational Program

The expenses of these summer meetings, including travel, were paid for by organizations in the districts interested. A series of meetings were held as follows:

May 31—Keller Golf Course, St. Paul, Minn.
June 9—Mid-West Turf Garden, Mill Road Farm Golf Course, Everett, Ill.

Aug. 7—Pine Valley Golf Club, Clementon, N. J.
Aug. 7—Philadelphia Country Club, West Conshohocken, Pa.
Aug. 9—Westwood Country Club, Clayton, Mo.
Aug. 21—Municipal Golf Course, Niagara Falls, N. Y.
Aug. 21—Santa Monica Municipal Golf Course, Santa Monica, Cal.
Sept. 11—Los Angeles Country Club, Los Angeles, Cal.
Sept. 14—Kenwood Country Club, Cincinnati, Ohio.
Sept. 18—Canterbury Golf Club, Cleveland, Ohio.
Sept. 20—Detroit Golf Club, Detroit, Mich.
Sept. 22—Wakonda Country Club, Des Moines, Iowa.
Sept. 25—Tulsa Country Club, Tulsa, Okla.
Sept. 25—Claremont Country Club, Oakland, Cal.
Oct. 10—Charles River Country Club, Newton Centre, Mass.

The Green Section also assisted in other educational programs. These included short courses given by the Pennsylvania State College of Agriculture, State College, Pa.; Michigan State College of Agriculture, East Lansing, Mich.; Iowa State College, Ames, Iowa; and the Annual Convention of the National Association of Greenkeepers of America. Members of the Green Section staff were present at various other local gatherings of chairmen of green committees and greenkeepers, in addition to the above meetings.

Correspondence and Service to Member Clubs

The staff was able to keep up with the usual large amount of seasonal correspondence with member clubs regarding the various problems encountered last season. Several periods of high humidity and heat occasioned serious turf problems on putting greens in several parts of the country which required considerable attention by the staff, including correspondence, soil examinations, and inspection trips. Increased interest in information regarding soil improvement, fairway watering, and weed control was noticeable. The Green Section was able to supply helpful information in these instances.

The staff visited a large number of courses on request and gave advice on numerous turf problems. Due to the demands, at certain times, on the time of the staff, it was not always possible to visit courses immediately upon being requested. With few exceptions, however, it was eventually possible to visit the golf clubs which desired such service, and in some instances clubs were saved travel expense money by grouping the requests so that two or three clubs in one vicinity could be visited while the Green Section representative was in that neighborhood. During 1933, members of our staff visited courses located in 25 states, including California and Oregon, and in Canada, Mexico, Cuba, and Panama. The staff traveled over 50,000 miles in service, extension, and research work, which was paid for by clubs requesting the visits.

Green Section Bulletin

The plan started in 1932 of publishing the Bulletin in six numbers instead of 12 was continued in 1933, grouping related material in a single number and making them in two cases much larger than the old monthly numbers. Some subjects cannot be effectively handled in Bulletins of smaller size, and under the old system of 12 numbers to the volume it was necessary to break up this material into two or three separate numbers.

QUESTIONS AND ANSWERS

All questions sent to the Green Section will be answered in a letter to the writer as promptly as possible. The more interesting of these questions, with concise answers, will appear in this column. If your experience leads you to disagree with any answer here given it is your privilege and duty to write to the Green Section. While most of the answers are of general application, it must be borne in mind that each recommendation is intended specifically for the locality designated at the end of the question.

Slime mold fungus on turf.—I am sending you a piece of sod on which is fungus growth which I have never seen before. Any information on it will be appreciated. (Oregon)

ANSWER.—This is one of the slime mold fungi which frequently occur on grass. Ordinarily they do not do any damage beyond temporarily disfiguring the turf. Usually they turn black when they become old enough to produce spores and then can be readily washed from the grass and no damage is apparent. In some cases there is a slight injury. There are different species of this type of fungus and some variation of species under different conditions.

Sulphur water for irrigation purposes.—In drilling for water on our course we struck sulphur water. Would this be suitable for use on putting greens? (Ohio)

ANSWER.—Sulphur water is frequently used on golf courses without any apparent harmful effects. However, in most cases it is aerated by spraying it into the air, which removes the sulphur fumes. It depends upon the concentration of the sulphur as to whether it is safe to use on golf courses or not. We suggest that you have the water analysed. If you send us a report on the analysis we shall be glad to give you further advice on the subject.

Creeping bent nursery going to seed.—This season all the grass in our creeping bent nursery seems to be going to seed. Can this tendency be discouraged? If not, does it harm the stolons? (Ohio)

ANSWER.—We do not know of any way in which the tendency of creeping bent stolons to produce seed in a nursery can be discouraged except by cutting them with a mower. However, this does not always work, because so much of the seed is produced so close to the ground that it is difficult to reach the seed heads with a mower under nursery conditions without injuring the grass. We have found that stolons or plants which have produced seed are just as satisfactory for planting, but the growth of the stolons is somewhat checked during the time the seed is being produced. If nurseries are left for a long time in the same area, seed production is objectionable since the seed does not produce plants identical with the parent. Grass planted from stolons produced from seed formed in the nursery might be undesirable.

Anyone who hopes to achieve success, even the average, must know more, or at least as much, about some one thing as any other one, and not only know, but know how to do—and how to utilize his experience and knowledge for the benefit of others.

—Theodore N. Vail.