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.

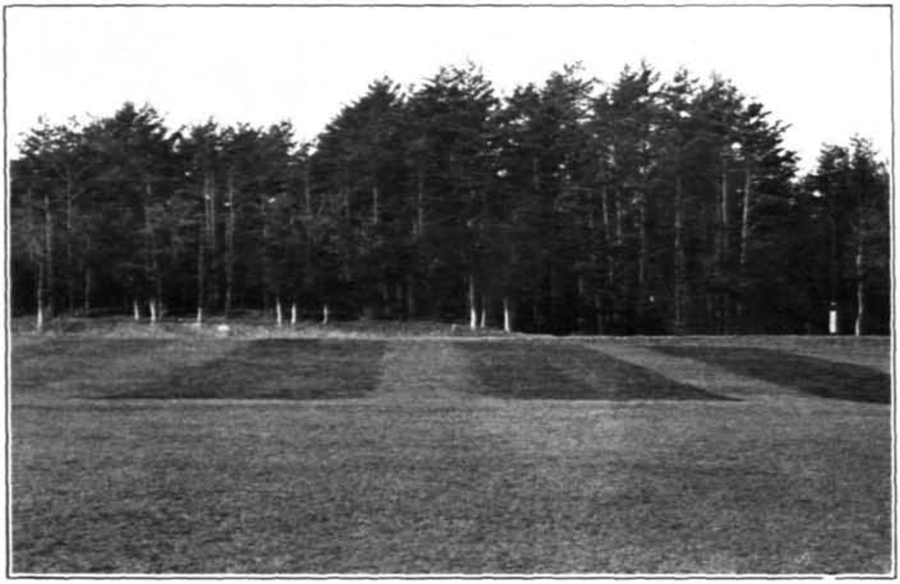
Old grass plants are able to increase and spread by root division and from buds formed on rootstocks. The young plants coming from the roots of the old plants are planted already in the soil and are protected by the old plants, so that plants so produced have a much better chance of surviving than plants 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.