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EXPERIMENTS WITH FERTILIZERS ON BLUEGRASS TURF

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One of the most common causes of poor turf is starvation. If grass is starved or if nutrients are applied in the wrong proportion or at the wrong time, weeds may overpower or even kill the grass. On the other hand, if grass is properly fed it usually will crowd out most turf weeds and will do surprisingly well on unpromising soil. The question of whether grass or some other plant shall occupy a given area is largely one of competition between plant species. Survival in this competitive struggle depends largely upon food supply, other conditions being equal.

While no exact figures are available it is safe to say that millions of pounds of fertilizers are used every year on the turf of fairways, parks, cemeteries and lawns. Much of this is effective, some is harmful and too large a proportion of it is just wasted. The kind and quantities of fertilizer to use as well as the best time of application, therefore, become matters of great importance in turf maintenance.

Since Kentucky bluegrass is the most common grass used for turf purposes in this country, the majority of the Green Sec-

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tion's experiments with fertilizers have been conducted on turf in which Kentucky bluegrass predominated. The results from various series of fertilizer experiments conducted in other sections of the country as well as numerous field observations indicate that the response of different turf grasses such as other species of bluegrass, the fescues, Bermuda grass and carpet grass is comparable to that of Kentucky bluegrass.

Needs of Grass and Cultivated Crops Differ

Grass for turf differs from the cultivated farm crops in its fertilizer requirements chiefly because of the special need on the part of the growing grass for an abundant and readily available supply of nitrogen for the rapid production of leaves. As compared with many crop plants, the much more shallow root system of most closely cut grasses makes it impossible for them to forage deep for nutrients.

In growing cultivated crops the soil is plowed and worked. Fertilizers are frequently worked or drilled into the soil. Under turf conditions the soil cannot be worked, so the applications of fertilizer are necessarily made at the surface.

A similar problem has been met in the case of grass on permanent pastures. The problems of pastures and turf differ, however, in certain ways. On a good pasture the flush of growth is in the early spring. Growth and production later decline, and during the heat of summer the grass is nearly or quite dormant. During that period livestock may be maintained on emergency pastures or be given additional grain feed. Grass for turf, however, must be kept in as good a condition as possible throughout the entire season.

The expense of feeding pasture grasses with large amounts of nitrogen would in most cases be prohibitive, and recourse is

had to encouraging an abundance of white clover (*Trifolium repens*). Clover is itself a valuable pasture plant, being high in protein and mineral content. Moreover, like other leguminous plants, it is able to use nitrogen from the air because of the bacteria in the root nodules which fix atmospheric nitrogen in a form available to plants. When roots or tops of clover or both are decayed in the ground they enrich the soil in nitrogen and thereby stimulate the growth of grass and other pasture plants.

In fertilizing pastures, therefore, much of the supply of nitrogen usually is furnished by encouraging white clover, and the fertilizing program usually is planned so as to maintain a good stand of this legume. Where this plant is not objectionable in turf, such as in some lawns and parks, white clover may well be encouraged. However, in most turf used for recreational purposes, as well as in many lawn and park areas, white clover is decidedly objectionable. In these cases a liberal use of nitrogen will usually discourage clover and produce the desired quality of turf.

Soil and Turf Under Test

The experiments, results of which are summarized in this article, were conducted at the Arlington Experiment Farm (across the Potomac River from Washington) and on the fairways of the Capital Golf and Country Club (formerly Bannockburn), Glen Echo, Md. The soil at the Capital course is a poor clay loam of the Louisa series; that at Arlington Farm is a silt loam. The soil at the Capital course was approximately neutral in reaction, having been limed some years before the experiments were started; that at the Arlington Farm was distinctly acid. Both soils were deficient in available phosphoric

acid, tests showing from 5 to 10 parts per million (p.p.m.) at the Capital course and 10 to 15 p.p.m. at the Arlington Farm, by the LaMotte-Truog method, as compared with the 40 to 50 p.p.m. usually considered sufficient on these types of soil. They were, therefore, of neutral or acid reaction and of low fertility. The topography of the areas at the Capital course varied from nearly level to rolling, with some steep slopes; that at the Arlington Farm was nearly level.

On such soils the turf was naturally thin. It had not been fertilized for many years and consisted of a sprinkling of Kentucky bluegrass, a little redtop and white clover, with a large amount of buckhorn plantain (*Plantago lanceolata*), crabgrass (*Digitaria ischaemum* and *D. sanguinalis*), some dandelions (*Taraxacum officinale*) and other weeds. At the Capital course much red fescue and some bent grass was scattered in the turf.

Kind of Fertilizer Used

The three fertilizer elements, nitrogen, phosphorus and potassium, were applied alone and in various combinations with and without lime. Several different materials supplying nitrogen and phosphorus were used. The complete fertilizers were made up in several different formulas.

Nitrogen is the nutrient most frequently deficient and the one needed in greatest abundance for the vigorous growth of grass for turf. Therefore, the rates of application of the complete fertilizers were based on the amounts of nitrogen applied.

In order to simplify the comparison of the results with different rates of application, the fertilizers are described on the basis of the pounds of nitrogen applied to 1,000 square feet. Ten pounds of a 10-6-4, or 8 1/3 pounds of a 12-6-4, or 16 2/3

pounds of a 6-12-4 are required to give a rate of 1 pound of nitrogen to 1,000 square feet.

All fertilizers were broadcast and were not watered in. The turf was not watered during the experiments. The plots differed in area and arrangement, but in all cases an unfertilized check plot adjoined every fertilized plot.

Response to Fertilizers

The response of the thin turf to fertilizers was striking. On one series at the Capital course to which complete fertilizer had been applied at different rates, a poor thin turf was transformed in 2 years into a good turf without the use of seed, watering or mechanical working. With an adequate quantity of fertilizer on these plots the number of Kentucky bluegrass shoots to a square foot increased about 1,000 per cent over the number on the unfertilized check plots.

Similar results with a complete fertilizer were secured on a series of plots at Arlington Farm. Careful estimates of the percentage of grass 5 years after the first application showed that on the fertilized plots there was over four times as much grass as on the checks. Not only did the application of fertilizers thicken the turf but it also helped in weed control.

It is well known that nitrogen stimulates growth, produces a dark color and is generally favorable to vegetative activity. An excess of nitrogen may delay flowering and fruiting. Phosphorus also stimulates growth, tends to make a sturdier plant and encourages such maturation processes as seed production. Potassium is less specific in its function, serving in a general way to accelerate such vital processes as respiration and the manufacture of carbohydrates in the leaves.

On some plots in these experiments, fertilizers containing

General view of fairway fertilizer plots at the Capital Golf and Country Club 4 months after the first application was made in October, 1931. The light strips received no fertilizer; the dark strips from left to right received one application of complete fertilizer at rates of 1, 2, 4 and 8 pounds of nitrogen to 1,000 square feet, respectively. The left half of each dark strip received inorganic fertilizer and the right half, organic fertilizer at the same rate and time. The dark color indicates turf with good color and density.

only one of each of the important plant nutrients were applied. Therefore it is possible from this series of experiments to compare the results obtained from the use of any one element alone with those secured when that element was applied in combination with any one or all of the other elements.

Figures for the percentage of turf grasses, crabgrass and clover present in 1939 on some of the plots in this series at Arlington are given in the table on page 159. Except for insignificant variations, these figures are typical of the conditions during the past 3 years. Weeds such as selfheal (*Prunella vulgaris*), dandelion, buckhorn plantain and chickweed (*Stellaria* spp.) were present in varying amounts, but the percentages of

SOIL ACIDITY, PERCENTAGE OF MAJOR SPECIES PRESENT AND PER CENT DENSITY OF TOTAL VEGETATION ON SOME OF THE KENTUCKY BLUEGRASS PLOTS AT ARLINGTON FARM WHICH HAVE RECEIVED VARIOUS COMBINATIONS OF NITROGEN (N), PHOSPHORUS (P), POTASSIUM (K), AND LIME (L) FROM 1934 TO 1939. THE RESULTS GIVEN ARE TAKEN FROM RATINGS RECORDED IN OCTOBER, 1939. INORGANIC FERTILIZERS WERE USED EXCEPT IN THE ONE CASE INDICATED. THE ANNUAL APPLICATIONS WERE 2.5 POUNDS OF NITROGEN, 2.5 POUNDS OF PHOSPHORIC ACID, 1.1 POUNDS OF POTASH AND 23 POUNDS OF GROUND LIMESTONE TO 1,000 SQUARE FEET.

Materials applied	Acidity in pH	Percentage of major species present			Percent density of total vegetation
		Turf grasses	Crabgrass	Clover	
NP	4.2	70	27	Trace	80
NPL	5.2	67	1	32	95
NPKL	5.3	65	2	33	95
NPK Organic	4.9	31	3	61	80
N	4.2	29	64	Trace	70
NPK	4.3	25	65	Trace	80
NKL	5.2	24	38	32	85
NK	4.3	20	73	Trace	75
NL	5.9	14	10	71	85
None	5.0	15	25	35	60

each are not included. The density of the total vegetation is given in percent, 100 percent representing the density of ideal Kentucky bluegrass turf.

NITROGEN

In past experiments several kinds of inorganic and organic fertilizers containing nitrogen only were used. In general there was little apparent difference in the response of Kentucky bluegrass to nitrogen in these various forms. In the experiments reported here, sulfate of ammonia, cyanamide and a mixture of sulfate of ammonia and nitrate of soda were used. The annual rates of application were 0.5, 1, 2, 2.5, 4, 8 and 9 pounds of nitrogen to 1,000 square feet.

The tests on the Capital course have been more extensive than those at Arlington Farm. On these fairways the lighter rates of application increased the vigor of the crabgrass, but produced only a slightly darker color in the turf grasses without increasing the stand materially. The 8- and 9-pound applications were made only once. At the end of a 2-year period they had caused a decided reduction in buckhorn plantain. However, while there was no increase in turf grasses, there was a great increase in the amount of crabgrass. On this neutral soil similar results were obtained with sulfate of ammonia, cyanamide, a mixture of sulfate of ammonia and nitrate of soda, and sulfate of ammonia and ground limestone. In the case of this last combination, an interval of at least 3 weeks elapsed between the applications of the two materials. The turf produced by fertilizers containing nitrogen alone was decidedly inferior to that produced by fertilizers containing nitrogen, phosphorus and potassium.

At Arlington Farm the use of nitrogen at the annual rate of 2.5 pounds to 1,000 square feet in two applications has greatly reduced the number of plants of buckhorn plantain and self-heal. The condition of the turf, however, has been erratic from year to year, but usually it has been partially infested with crabgrass each summer. Frequently these plots receiving nitrogen alone have been as good as, or even better than, the plots receiving complete fertilizer containing nitrogen, phosphorus and potassium. However, the plots receiving nitrogen alone have had a far more open turf and more crabgrass than the plots receiving a complete fertilizer plus lime. These results are listed in the table on page 159.

Nitrogen plus calcium, applied as ground limestone at the annual rate of 1,000 pounds to the acre, produced little effect

the first year, as can be seen in the table on page 165. Since that time the condition of the turf has been erratic. Some years the turf on plots receiving nitrogen plus lime was superior to that on the nitrogen plots, but other years the nitrogen alone has produced the better turf.

Potassium

The application of potassium as muriate of potash alone or combined with calcium as ground limestone has produced no improvement in the composition of the turf. It should be stated, however, that these soils have had a sufficient reserve of potassium. This is also true of many other soils where turf is grown.

Nitrogen and Potassium

The plots supplied with both nitrogen and potassium received muriate of potash at the annual rate of 1.1 pound of K_2O to 1,000 square feet. The addition of the potassium did not improve the turf the first year, but since that time and until 1939 there has been a slight improvement over the plots receiving nitrogen alone. However, the data for the past season has shown the plots receiving nitrogen alone to be somewhat superior. The nitrogen-potassium plots have usually been overrun with crabgrass each summer, and half of the time they have had an even higher percentage of crabgrass than the plots receiving nitrogen alone.

During the first few years the plots receiving nitrogen and potassium plus ground limestone at the annual rate of 1,000 pounds to the acre were superior to those receiving the nitrogen and potassium alone. Since that time the effects have been reversed, so that now the nitrogen-potassium plots are somewhat

superior to the plots receiving these two elements plus calcium, in that they have nearly as much turf grass and far less clover. The nitrogen-potassium-calcium plots were superior at the end of the first year to the plots which had received nitrogen alone, but this effect has been lost gradually. Although the total vegetation was denser on the plots receiving nitrogen, potassium and calcium during 1939, they had less turf grass and more weeds than the plots receiving nitrogen alone.

Phosphorus

On the experimental areas at both the Arlington Farm and the Capital course the available phosphoric acid was low. Unfertilized soil at Arlington gave readings of phosphoric acid of 10 to 20 p.p.m. when the surface inch samples were tested by the LaMotte-Truog method. Similar samples of unfertilized soils taken from the fairways on the Capital course gave readings of 5 to 10 p.p.m.

Where phosphorus was applied as superphosphate to either area, the turf has shown little response. There has been a slight increase in the growth of white clover, black medic (*Medicago lupulina*) and lespedeza (*Lespedeza striata*), but little immediate improvement in the grass. When lime was added in combination with phosphate there has been a decided increase in the growth of white clover, which in turn has slowly resulted in an increase in the growth of grass.

Phosphorus and Potassium

Where potassium was added with the phosphorus there has been a somewhat greater stimulation of white clover, lespedeza and black medic than when either element was applied alone. There has been practically no immediate response from the

The response of Kentucky bluegrass turf to one application of complete fertilizer at the rate of 4 pounds of nitrogen to 1,000 square feet. The light areas represent unfertilized turf. The dark area in the center represents good turf on the fertilized area. Left half of dark area was fertilized with organic and right half with inorganic fertilizer. The picture was taken 4 months after the fertilizer was applied in October, 1931.

grass but in the course of 2 or 3 years there has been a little stimulation of the turf grasses possibly caused by the nitrogen which was added by the legumes. The addition of lime to the combination of phosphorus and potassium has further increased the growth of clover and other legumes which in turn has slowly resulted in an increase in the growth of the turf grass.

Nitrogen and Phosphorus

In these experiments phosphorus was supplied in several different materials; bonemeal, superphosphate, Ammophos, and

activated sewage sludge. Since a definite amount of nitrogen as well as phosphorus was specified for each plot in this series and since some of the sources of phosphorus also carried nitrogen it was not always possible to apply the desired amount of phosphoric acid by the use of a single material without interfering with the prescribed rate of nitrogen. In such cases the chief material was supplemented by small amounts of other materials. The annual rates of application of phosphoric acid varied from 0.5 to 2.5 pounds to 1,000 square feet.

Only a moderate response from bluegrass has been noted when nitrogen was applied at the lower rate of application. However a decided improvement has been observed when phosphorus was included. Plots at Arlington which received both nitrogen and phosphoric acid at the annual rate of 2.5 pounds of each to 1,000 square feet have had a denser turf, greater abundance of bluegrass, less crabgrass and other weeds than plots receiving nitrogen alone, nitrogen-calcium, nitrogen-potassium, or nitrogen-potassium-calcium. The nitrogen-phosphorus plots have been far superior to the plots receiving complete inorganic fertilizers, showing a greater abundance of turf grasses and less crabgrass. They have had more crabgrass, however, than have the plots receiving complete organic fertilizer.

The addition of calcium together with nitrogen and phosphorus produced a much denser turf with less crabgrass than when nitrogen and phosphorus only were applied. There has been a great increase in white clover, but in spite of this increase there actually has been more grass and a denser turf. For the first few years these plots were about on a par with those receiving complete inorganic fertilizer plus lime, but since then they have been superior, having less clover and crabgrass.

ABUNDANCE OF TURF GRASSES ON SOME OF THE KENTUCKY BLUEGRASS PLOTS AT ARLINGTON FARM TO WHICH VARIOUS COMBINATIONS OF NITROGEN (N), PHOSPHORUS (P), POTASSIUM (K), AND LIME (L), WERE APPLIED. FIGURES ARE GIVEN FOR OCTOBER, 1934, AT THE END OF THE FIRST SEASON, AND FOR OCTOBER, 1939, AT THE END OF THE FIFTH SEASON. INORGANIC FERTILIZERS WERE USED EXCEPT IN THE ONE CASE INDICATED. THE ANNUAL APPLICATIONS WERE 2.5 POUNDS OF NITROGEN, 2.5 POUNDS OF PHOSPHORIC ACID, 1.1 POUNDS OF POTASH AND 23 POUNDS OF GROUND LIMESTONE TO 1,000 SQUARE FEET.

Materials applied	Percentage of turf grasses	
	October, 1934	October, 1939
NP	25	70
NPL	45	67
NPKL	55	65
NPK (organic)	20	31
N	20	29
NPK	17	25
NKL	40	24
NK	15	20
NL	20	14
None	15	15

From the results given in the table on page 159 it is apparent that on this soil nitrogen and phosphorus have produced a turf which has been more free from crabgrass and which has a much greater abundance of turf grasses than when potassium was included. This has been true whether or not calcium was supplied, although the addition of calcium has greatly decreased this difference. Evidently the calcium has overcome some of the apparently detrimental effects of the potassium.

The table on this page gives the percentage of turf grass at the end of the first year and at the end of a 5-year period in a series of plots at Arlington Farm. It will be noted that the check plots remained in about the same condition, having the same percentage of grass at the end of the 5-year period

as at the end of the first year. The plots receiving lime showed the greatest increase in turf grasses at the end of one year. This improvement, however, continued only on the plots receiving both nitrogen and phosphorus in addition to lime. At the end of the 5-year period the plots showing most marked improvement had received both nitrogen and phosphorus.

Nitrogen, Phosphorus and Potassium

In the production of most farm crops a complete fertilizer containing nitrogen, phosphorus and potassium generally has been used. These three elements are among those essential for normal plant development from germination through seed production. Grass maintained in turf is grown by highly artificial means to prolong the vegetative condition and so does not necessarily need all of these nutrients in the same proportions as do plants grown to maturity under normal conditions. In spite of the difference in nutrient requirements of crop and turf plants, many individuals have recommended the same type of fertilizers for both.

Observations on many golf courses in the past few years have indicated that where a sufficient supply of any one of the essential nutrients is available for the vigorous growth of plants further additions may not only be wasteful but actually detrimental to the turf. The results on the experimental plots at the Capital course and at Arlington have given further support to these observations.

Complete fertilizers of such diverse formulas as 12-6-4, 6-12-4, 4-12-4, 9-9-4, 6-3-2, and 6-24-2 have been used. The 6-24-2 was used in the inorganic form only, while the others were used in both the inorganic and organic forms.

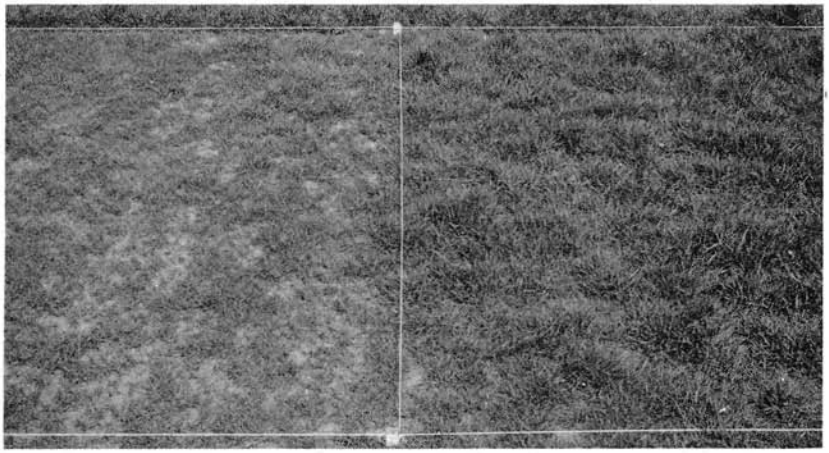
At the Capital course the turf on the plots receiving complete fertilizers has been far superior to that on the plots where nitrogen alone was used. The turf has not only been denser but there has been a greater increase in turf grasses and a corresponding reduction in crabgrass and weeds on the former than on the latter plots. There has been little apparent difference between the plots receiving the same amounts of nitrogen in the various complete fertilizers, except that the high phosphate mixtures have tended to produce more white clover.

At Arlington, where the soil was more acid, a marked response has resulted during the first 2 years from applications of complete fertilizers. Since that time, however, some of the plots receiving complete fertilizer have become badly overrun with crabgrass and during 1939 they were inferior to the plots receiving nitrogen only as well as to those receiving nitrogen and phosphorus. The plots receiving complete inorganic fertilizers have been superior to those receiving complete organic fertilizers but here the striking difference has been in the greater reduction in clover and chickweed following the application of the inorganic fertilizers. The complete fertilizer which contained phosphoric acid in amounts several times greater than the nitrogen has tended to produce some yellowing of the Kentucky bluegrass.

Where calcium was applied in addition to the complete inorganic fertilizer at Arlington there has been a striking increase in the density of the turf, an increase in clover and a reduction in crabgrass and other weeds. Even in cases where clover is objectionable, the increase in density and abundance of turf grasses and reduction of crabgrass has more than compensated for the increase in clover and has made the turf on these plots far superior to that on plots receiving complete

fertilizers without lime. This turf has also been superior to that on plots receiving nitrogen-phosphorus in that it has been much denser and has had less crabgrass.

The plots receiving inorganic complete fertilizers plus lime have had about as much crabgrass in 1939 as the plots receiving organic complete fertilizers without lime but have had decidedly less clover and chickweed. Most of the phosphorus on



Results obtained from the application of fertilizer before seeding. Plot on left not fertilized; plot on right fertilized with bonemeal previous to seeding to Kentucky bluegrass and redtop. This picture, taken in April following seeding the fall before, shows the quicker production of good turf on the plot which was fertilized before seeding.

the organic fertilizer plots was supplied in the form of bonemeal. The bonemeal contained enough calcium to prevent any appreciable change in soil acidity. The organic fertilizer plots were slightly more acid than the limed inorganic fertilizer plots yet had much more clover than any of the inorganic plots with comparable acidity.

The results from applications of the various complete fertilizers of different formulas were compared when applied at

comparable rates of nitrogen. Naturally some mixtures supplied more phosphoric acid than did others. As these soils were extremely low in available phosphoric acid, the fertilizers that supplied a much greater quantity of phosphoric acid produced the best turf the first year. However there was little difference in the quality of turf afterward. After several years the plots which received the most phosphorus had somewhat more clover.

The fertilizers with the higher proportions of nitrogen, such as a 12-6-4, produced the same quality of turf with smaller amounts of fertilizer than did those like the 6-12-4, which contained lower proportions of nitrogen. When the fertilizers were applied on a nitrogen basis the additional phosphoric acid and potash supplied by such grades as the 4-12-4 or the 6-12-4 were apparently of little value and not worth the extra cost.

The inorganic fertilizers with the highest percentage of nitrogen had a greater tendency to burn than did those with less nitrogen.

Lime

The figures in the table on page 165 indicate that on the acid soil at Arlington the use of lime at the rate of 1,000 pounds to an acre in addition to the application of any of the fertilizer combinations except that of nitrogen alone had produced by the end of the first year a striking increase in the abundance of turf grasses over the amount present on the plots receiving the respective combinations without lime. The figures in the table show that continued use of lime in combination with inorganic complete fertilizers or with the nitrogen-phosphorus mixtures has further increased the abundance of turf grasses during the 5 succeeding years. The original stand of clover

has been maintained on these plots but the density of the total vegetation has been greatly increased.

Where lime was not applied to the plots receiving complete inorganic fertilizers the clover has been eliminated but the crabgrass has been increased decidedly at the expense of the turf grasses. These results together with those on plots receiving lime in addition to the nitrogen-potassium mixture indicate that the presence of lime may have overcome in part the apparently detrimental effect of the potassium.

Likewise where lime was not applied to the plots which had received the nitrogen-phosphorus mixture, the clover has been eliminated. However, the density of the total vegetation has not been increased nor the crabgrass reduced so markedly as when lime was present in addition to nitrogen and phosphorus.

The continued use of lime on plots which had not received phosphorus has been accompanied by a gradual increase either in the amount of clover or of crabgrass at the expense of the turf grasses, so that, at the end of 5 years, there is now a smaller percentage of turf grasses on these plots than at the end of the first year.

The amount of lime used on the fertilizer plots has had little effect on the reaction of the soil. No plot in this series was made more alkaline than the pH 5.9 of the nitrogen-lime plot. While both the nitrogen-phosphorus-lime plot and the complete fertilizer-lime plot produced excellent turf, the best in the series, the soil was made only slightly less acid than the checks and was far below the neutral point of pH 7.0. Thus it appears that a neutral soil is not necessary for a good bluegrass turf, but that a satisfactory turf can be produced on an acid soil with proper fertilization. This is of particular interest to those who desire a good turf with a minimum of clover,

CONDITION OF THE TURF ON THE FERTILIZED PLOTS AT THE CAPITAL COURSE IN OCTOBER AND DECEMBER, 1932 AND OCTOBER, 1933, FOLLOWING APPLICATIONS MADE IN THE FALL OF 1931, THE FALL OF 1932 AND THE SPRING OF 1933. THE PERCENTAGE OF IMPROVEMENT OVER THE CHECK AND THE PERCENTAGE OF TURF GRASS ON EACH OF THE PLOTS IS GIVEN. THE CHECK PLOTS WERE CONSISTENTLY RATED AT 2 ON THE BASIS OF 10 AS REPRESENTING IDEAL BLUEGRASS TURF. THE RATE OF APPLICATION OF FERTILIZER IS GIVEN IN POUNDS OF NITROGEN TO 1,000 SQUARE FEET.

Kind of Fertilizer	Rate of application (Pounds of N to 1,000 square feet)	Percentage of improvement over unfertilized plots			Percentage of grass cover	
		October, 1932	December, 1932	October, 1933	December, 1932	October, 1933
Checks	0	—	—	—	60	50
Inorganic	1	150	250	300	82	86
Organic	1	0	200	300	80	86
Inorganic	2	200	400	300	94	85
Organic	2	150	200	300	80	88
Inorganic	4	300	400	0	95	50
Organic	4	300	400	−50	93	35
Inorganic	8	150	200	—	80	0
Organic	8	300	400	—	91	0

for it will be noted in the table on page 159 that when inorganic fertilizers were used the less acid the soil the more clover was present in the turf.

EXPERIMENTS ON RATES OF APPLICATION

The purpose of some of the experiments at the Capital course was to find out how much fertilizer should be used on a thin turf to bring it quickly into good condition and to determine how heavy an application the bluegrass would tolerate. The complete 6-12-4 fertilizer was applied at different rates, 700, 1,400, 2,800, and 5,600 pounds to the acre. These applica-

tions supplied approximately 1, 2, 4 and 8 pounds of nitrogen and twice that amount of phosphoric acid to 1,000 square feet. The lowest rate, therefore, was equivalent in nitrogen content to a little less than 5 pounds of sulfate of ammonia to 1,000 square feet, the highest to the extremely heavy rate of about 38 pounds.

The fertilizer was applied both in organic and in inorganic forms at each rate. The first application was made October 21, 1931. A second application was made in the fall of 1932 and a third in the spring of 1933.

The excellence of the turf was rated on the basis of a possible maximum of 10 representing ideal bluegrass turf. The increase in rating of the fertilized plots over that on the unfertilized check plots has been expressed as percentage of improvement. This percentage of improvement over the check plots should not be confused with the percentage of turf grasses present on the plots.

One Pound of Nitrogen

On this extremely thin turf, applications of fertilizer at the rate of 1 pound of nitrogen to 1,000 square feet produced no improvement during the first winter. During the following summer, however, improvement became evident on the plots that had received inorganic fertilizer at this rate. From the figures in the table on page 171 it can be seen that in October, 1932, the turf on the inorganic plots showed an improvement of 150 percent over that on the checks. The fall application increased the improvement to 250 percent by December, 1932. By October, 1933, following one more application in the spring of 1933, the percentage of improvement had been increased to 300 percent.

The plots receiving one application of organic fertilizer in the fall of 1931 showed no apparent improvement in the turf by the end of the crabgrass season. By December, 1932, after the bluegrass had made its fall growth and recovered from the crabgrass invasion, the application in that fall had produced an improvement of 200 percent. The application in the spring of 1933 increased this improvement to 300 percent which was equal to that of the turf on the inorganic plots.

Two Pounds of Nitrogen

The application of 6-12-4 inorganic fertilizer at the rate of 2 pounds of nitrogen to 1,000 square feet caused some burn as would be expected since the nitrogen applied was equal to nearly 10 pounds of sulfate of ammonia to 1,000 square feet. The grass quickly recovered, however, and made marked improvement during the winter. By spring the turf was in good condition and made further improvement during the summer of 1932. A reduction in the percentage of clover was also noted. In December, 1932, after the fall application, the turf on these plots showed an improvement of 400 percent with 94 percent of the area covered with turf grasses. As may be seen in the table, the percentage of improvement due to inorganic fertilizers dropped during the following season so that by October, 1933, these same plots showed an improvement of 300 percent with a grass cover of 85 percent.

The turf on the plots that received organic fertilizer at this rate showed some improvement by the end of the summer of 1932 but no clover control. The application in the fall of 1932 increased this improvement by December, 1932, to 200 percent. This is just half the improvement which was shown at

that time on the inorganic plots which had received fertilizer at the same rate. By October, 1933, however, after an additional application of fertilizer in the spring at the same rate the improvement on the organic plots had increased to 300 percent which was the same as that shown on the inorganic plots at that time. The percentage of grass cover on the organic plots had also increased from 80 in December, 1932, to 88 percent in October, 1933.

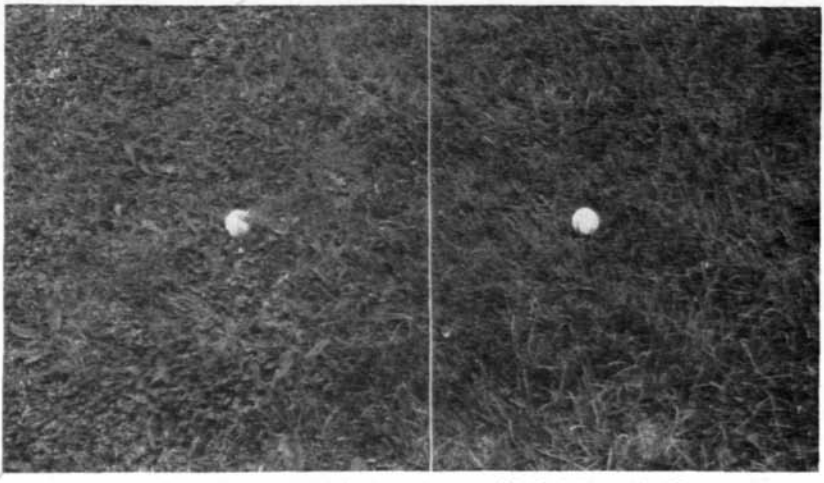
At the end of a year, after two applications, the turf on the plots fertilized at the 2-pound rate was superior to that which had received 1 pound of nitrogen. After the third application the turf on the two plots was in the same condition.

Four and Eight Pounds of Nitrogen

A 6-12-4 inorganic fertilizer used at the rate of approximately 4 pounds to 1,000 square feet, although put on in two equal applications, caused considerable burn but the grass recovered. The organic fertilizer did not burn. By March, 1932, the grass on the inorganic plots had recovered completely and was making vigorous growth. The organic fertilizer applied at this rate also stimulated the grass but not so much as did the inorganic. The inorganic plots also showed more clover and plantain control than did the organic plots.

The applications were repeated in the fall of 1932 and by December of that year the turf on both the inorganic and the organic plots was considered to be nearly perfect. As shown in the table on page 171, the improvement on both the inorganic and the organic plots was 400 percent, and the percentage of grass cover was estimated at 95 and 93 percent, respectively. As in the previous year, the inorganic plots showed better clover and plantain control than did the organic plots.

The application in the spring of 1933 resulted in a decided deterioration of the turf because of the heavy invasion of crabgrass during the following summer. The weather conditions during that summer were particularly favorable for the growth of crabgrass, so that after the crabgrass was dead in the late fall of 1933 the turf on the plots receiving inorganic fertilizer at the rate of 4 pounds of nitrogen to 1,000 square feet was



Reduction of weeds and increase in density of an established Kentucky bluegrass turf on a neutral soil, by the application of 6-12-4 inorganic fertilizer at the rate of 4 pounds of nitrogen to 1,000 square feet. Fertilizers were applied to the plot on the right in October, 1931; October, 1932; and March, 1933. The picture was taken in May, 1933. Note the abundance of buckhorn plantain and clover in the unfertilized plot on the left as compared with the dense, weed-free bluegrass turf on the fertilized plot on the right.

no better than that on the check plots. The turf on the organic plots was poorer than that on the unfertilized plots. These poor results in October, 1933, with both inorganic and organic fertilizers applied at the rate of 4 pounds of nitrogen may be compared to the 300 percent improvement shown on the plots which had been receiving the same fertilizers over the same period of time at the rate of 2 pounds of nitrogen.

Response of old established Kentucky bluegrass turf at the Capital Golf and Country Club to 12-6-4 inorganic fertilizer applied in October at the rate of 8 pounds of nitrogen to 1,000 square feet. Left, dense vigorous turf on fertilized area; right, thin, weedy turf on the unfertilized strip. The picture was taken 5½ months after the application of the fertilizer and before the first spring mowing of the fairway.

When applied at the rate of 8 pounds of nitrogen to 1,000 square feet, both the inorganic and the organic fertilizers were put on in two equal applications. Each application of the inorganic fertilizer at this rate burned the turf seriously. There was some recovery every year, but at the end of each season the turf was inferior to that which had received the same fertilizer at the 4-pound rate.

During the summer of 1933, after the final applications of fertilizer had been made, there was a very heavy infestation of crabgrass. This infestation was so severe that it entirely

crowded out the bluegrass on the plots fertilized at the 8-pound rate.

During this favorable season for crabgrass the lower the fertilizer rate the less the bluegrass was injured by the crabgrass. This indicates that the excess fertility in the soil, over and above what the spring growth of bluegrass used, stimulated the excessive growth of crabgrass.

Two applications of inorganic fertilizer at the 4-pound rate of nitrogen produced no better results than the 2-pound rate. A third application at the 4-pound rate was harmful. Unlike the results with the inorganics, two applications of the organic fertilizer at the 4-pound rate of nitrogen did produce better results than the 2-pound rate. As was the case with inorganic fertilizer, a third application at the 4-pound rate was harmful. The use of 8 pounds of nitrogen in either inorganic or organic form resulted in a poorer stand of turf grasses and in a greater increase of crabgrass at the end of the first 2 years than did any of the other rates of application. The poorer condition of the turf grasses was apparently due to excessive stimulation of crabgrass.

Varying Rates of Application

In a later series of experiments the effects of a heavy initial application of fertilizer followed by smaller amounts annually were compared with those obtained from a light initial application followed by the same amount each year.

Where applications of a complete fertilizer containing 1 pound of inorganic nitrogen to 1,000 square feet were used for only 1 year the grass improved but the response was not sustained. The following year the turf reverted to its original condition. With a heavier initial fertilization at the rate of 4 pounds of organic or inorganic nitrogen to 1,000 square feet,

response was much more marked. This improvement was maintained when this fertilization was followed by annual applications at the rate of 1 pound of nitrogen to 1,000 square feet. However, when the initial fertilization at the 1-pound rate was followed by annual applications at the same rate the turf produced after several years was as good as that on the plots to which fertilizer at the rate of 4 pounds of nitrogen were applied the first year, followed by annual applications at the 1-pound rate.

Light applications made year after year brought results but these were more quickly secured by a heavy initial fertilization followed by light applications to maintain the quality of the turf.

Rates of Application at Arlington

Similar results were obtained on some of the plots at the Arlington Farm. In some of the tests a 9-9-4 was used at the rate of 1,200 pounds to the acre, half being applied in the spring and half in the fall. This equals an annual application of nitrogen at the rate of 108 pounds to the acre, or nearly 2.5 pounds to 1,000 square feet.

The turf on plots treated with a mixture of organic and inorganic fertilizers at one-half the above rate was inferior to that where the full rate was used. The turf produced by this mixture applied at the full rate was not so good as that produced by inorganic fertilizers applied at the same rate.

Organic Compared with Inorganic Fertilizers

As already stated, at the Capital course the inorganic mixed fertilizers used at the rate of about 2 pounds of nitrogen to 1,000 square feet burned the grass; the organic fertilizers did

not burn even when applied at the rate of nearly 4 pounds of nitrogen to 1,000 square feet in a single application. At the lower rates of application the results from organic fertilizers were inferior to those from inorganic fertilizers until the third application had been made. After three applications, however, the turf on the plots which had received organic fertilizers at the 1- and 2-pound rates was equal to that on the plots which had received inorganic fertilizer at the same rate. Even after 1 year the results obtained with the organic fertilizer at the 4-pound rate were equal to those obtained with the inorganic fertilizer at this rate.

In control of clover and plantain, however, the organic fell behind the inorganic fertilizer when both were applied at the 1- and 2-pound rates. When applied at the 4- and 8-pound rates both fertilizers produced the same control.

In the Arlington Farm experiments the organic fertilizers produced a fair response after 2 years but weeds later invaded these plots much more than the plots which received inorganic fertilizers. In June, 1939, weeds were more than five times as abundant on the plots which received 9-9-4 organic as on those which received 9-9-4 inorganic plus lime.

Organic Fertilizers and Soil Organic Matter

The claim has been made that organic fertilizers are desirable because they increase the organic matter of the soil.

Bonemeal, which is an example of an organic fertilizer, contains approximately 75 percent of mineral compounds and 25 percent of organic matter. If bonemeal were applied at the rate of 1 ton to the acre it would, therefore, be supplying only 500 pounds of organic matter. It is estimated that an acre of soil to a depth of 6 inches weighs 2 million pounds,

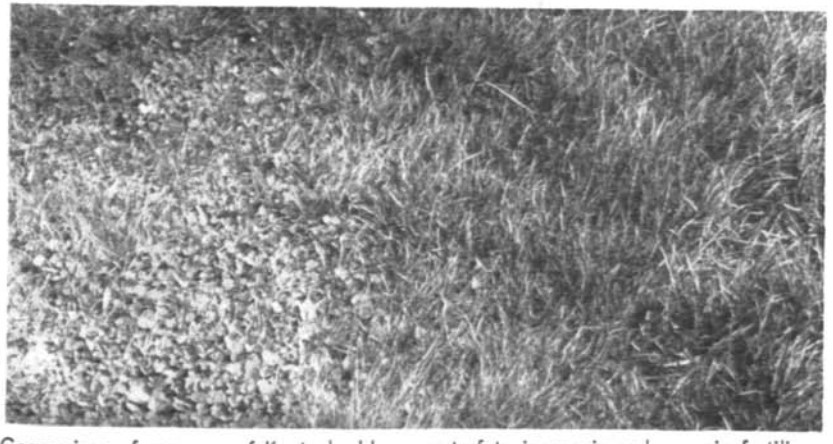
so an application of 1 ton of bonemeal to the acre would be equivalent to adding only one-half pound of organic matter to a ton of soil. Since the greater part of the organic matter is soon broken down and used by the plants or is leached out, this one-half pound of organic matter is reduced even further. The amount of organic matter added to the soil by a commercial organic fertilizer is too small to warrant consideration.

The most abundant source of organic matter in the soil is the vigorous root growth of well-fertilized grass. The use of any fertilizer that will stimulate root growth will result in an increase in the organic matter in the soil. This was confirmed by the experiments at the Capital course where both organic and inorganic fertilizers were used in large amounts. A study of the organic matter content of the plots made at the close of the experiment showed that on the plots receiving inorganic fertilizer the organic matter content had been increased by an average of 5.59 tons to the acre and on the plots receiving organic fertilizer by an average of 5.58 tons, almost exactly the same amount. The organic fertilizer did not of itself increase the organic matter in the soil but did so indirectly by stimulating root growth in exactly the same way and apparently to the same degree as was done by the inorganic fertilizer.

Lasting Effects of Fertilizers

The lasting effect of fertilizers can still be observed on the Capital course series of 1931. On these plots 6-12-4 fertilizers were applied at the annual rates of approximately 1, 2, 4 and 8 pounds of nitrogen to 1,000 square feet. Three applications were made, fall 1931 and 1932 and spring 1933. No fertilizers have been applied since.

The bluegrass on the areas which received fertilizer at the rate of 4 and 8 pounds of nitrogen was entirely killed by the heavy invasion of crabgrass during the 1933 season. These two areas were seeded to Kentucky bluegrass during the late



Comparison of response of Kentucky bluegrass turf to inorganic and organic fertilizers. This picture was taken 6 months after the first application of fertilizer was made in October, 1931, at the rate of 4 pounds of nitrogen to 1,000 square feet. The area on the left received organic fertilizer and that on the right, inorganic. The dense vigorous bluegrass on the right shows the quicker response obtained from the application of inorganic fertilizers than from the application of organic fertilizers at the same time and rate. Clover is conspicuous in the organic plot on the left and absent on the inorganic plot on the right.

winter of 1934. Only a fair stand was secured at that time but this rapidly improved and established a good turf.

Observations made in the fall of 1939 showed that the entire area still stands out from the surrounding poor unfertilized turf. Even where the lighter applications were made the grass is still better than the unfertilized turf after 6 years without additional fertilizer. The turf today is best on the areas which received the greatest quantities of fertilizer.

While buckhorn plantain is still the dominant plant on the surrounding area it is rare on the fertilized section. Contrary

to what was true in December, 1933, crabgrass is not now so abundant on the more heavily fertilized areas as on those that received fertilizers at the rate of 2 pounds of nitrogen to 1,000 square feet. Apparently the good growth of bluegrass has helped to keep out the crabgrass.

All of the areas which received inorganic fertilizer are now somewhat better than those which received organic fertilizer. Contrary to general belief, the organic fertilizer in this case has not done better in the long run than the inorganic fertilizer.

Lines between the fertilized and check areas are no longer as sharp as shown in the illustration on page 158, for there is an irregular fringe of improved turf around each fertilized plot. When the fertilizers were applied, every precaution was taken to prevent any of the material from falling outside of the plots. Since the irregular border of improved turf is present on the up-hill side of the fertilized plots the improvement in this area must be due to clippings thrown up by the high-speed mowers, rather than to wash. This is further borne out by the fact that by far the most prominent borders extend in the same directions as the mowers are operated, while the borders in the opposite directions are negligible. It would seem, then, that at least part of the lasting effect of fertilizer is due to the release of nutrients during the decay of clippings returned to the soil.

Time to Apply Fertilizers

The time when fertilizers should be applied to bluegrass turf is of especial importance in sections where summer annual weeds, as crabgrass, are prevalent. If applied at the wrong time the fertilizer may merely stimulate the annual weeds and because of the severe competition they offer, the stand of Kentucky bluegrass may be seriously injured.

Where summer weeds are a problem, fertilizer should be applied when it will do the bluegrass the most good and the crabgrass the least. Bluegrass makes its best growth in fall and early spring and the need for nutrients is greatest at that time. The thickening of the turf resulting from fall applications of fertilizer is one of the best insurances against annual weeds invading the turf the following year. This has been shown in every experiment in which sufficient fertilizer was applied to stimulate the turf grasses without burning them seriously.

On the Capital course two fall applications of complete inorganic fertilizer at the rate of 1 pound of nitrogen to 1,000 square feet increased the percentage of grass cover from 63 on the check to 94; reduced the percentage of white clover from 8 on the check to 1, plantain from 11 to zero and the area of bare ground from 18 to 5.

When, however, spring applications were made on the same series a heavy infestation of crabgrass resulted. The competition from crabgrass was so severe on the heavily fertilized plots that the bluegrass was ruined. In a special test on this point one series of plots was fertilized in the fall of 1933. A similar application was made on May 1, 1934, on another series of plots. By July 3, 1934, the plots receiving inorganic fertilizer in fall had 82 percent bluegrass and 15 percent crabgrass, while those receiving the same fertilizer in late spring had 10 percent bluegrass and 90 percent crabgrass. Fall fertilizing produced a turf that kept out most of the crabgrass while with spring fertilizing the crabgrass quickly dominated.

These tests have shown that in the Washington district fertilizers should be applied in the fall. When spring applications of fertilizers have been made in this region best results have been obtained by very early applications rather than in

late April or May. Spring applications at about one-half the rate of the fall applications have produced better results than the heavier rates.

It is likely that in sections where the winters are not too severe fertilizers may be applied at any time during the winter as the grass seems to have the ability to utilize fertilizers even where little or no active growth is being made. Farther north, however, where the ground is frozen for a long period during the winter, much of the fertilizer applied to the frozen ground might be lost in run-off.

Tests conducted by the Green Section several years ago indicated that late and heavy fertilizing with nitrogen should be avoided in regions where snow mold is troublesome. It has been shown that grass stimulated into late growth is more susceptible to snow mold than grass that has not been stimulated by late fertilizing.

Weed Control with Fertilizers

The improvement of the grass on plots receiving complete fertilizer was accompanied in every case by a reduction in all weeds except crabgrass. Crabgrass flourished on those plots which received extremely heavy applications of fertilizers, on those fertilized in the spring, and on the acid plots which received complete fertilizer but no lime. On acid soil the least crabgrass was on the plots receiving either complete fertilizer plus lime or on plots receiving nitrogen, phosphorus and lime. On the neutral soil similar results were secured with these fertilizers without the addition of lime.

Both at the Capital course and at the Arlington Farm one of the most abundant weeds was buckhorn plantain. This is still plentiful on the check plots and on the surrounding areas

but has practically disappeared from most of the fertilized plots, especially from those receiving inorganic fertilizers.

A 6-12-4 inorganic fertilizer applied at the rates of 2 and 4 pounds of nitrogen to 1,000 square feet eliminated practically all perennial weeds and clover after two applications. When no further nitrogen was added, clover reinfested these plots after several years. Perennial weeds were also reduced but not wholly eliminated by the heavier applications of organic fertilizer, indicating that in this case elimination of the weeds was mainly due to increased competition from the grass.

On the Arlington Farm where the soil was acid, applications of the 9-9-4 inorganic fertilizer reduced the weed content of the turf excepting crabgrass, from 58 percent in 1934 to 14 percent in October, 1939, and wholly suppressed the clover. Every summer, however, the crabgrass on these plots was much more abundant than on the checks. When lime was applied annually in addition to the complete inorganic fertilizer, weeds excepting crabgrass and clover were reduced from 58 percent in 1934 to 1 percent in 1939. These annual applications of lime reduced the percentage of crabgrass during each summer from an average of 65 on the unlimed fertilized plots to about 2, and at the same time encouraged the clover until in 1939, although there was no clover on the unlimed plot, there was 33 percent on the limed plot. It should be noted that in these tests lime was applied annually, rather than every second or third year. Had the applications been made at the wider intervals the same benefits might have resulted without as much stimulation of clover.

The 9-9-4 organic fertilizer on this series at Arlington reduced the weeds, excepting crabgrass and clover from 58 to 32 percent only. Crabgrass was reduced from 26 percent in 1934

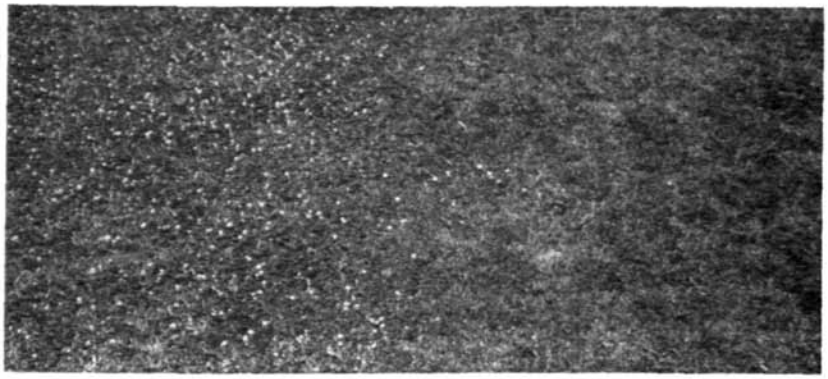
to less than 3 percent in 1939. Clover was encouraged so that in 1939 it comprised 40 percent of the total vegetation.

Suppression of weeds was most marked in the case of buckhorn plantain which was nearly eliminated on all of the fertilized plots, while the average percentage on the check plots was 17. The elimination of the plantain was somewhat more complete on the inorganic than on the organic plots.

A series of plots laid out in the fall of 1936 received 6-3-2 organic and inorganic fertilizers at the annual rate of 2 pounds of nitrogen to 1,000 square feet. Observations made in June, 1938, showed that chickweed had greatly increased on the plot receiving the organic fertilizer. Both the organic and the inorganic fertilizer had reduced the clover and had slightly affected the buckhorn plantain.

Weed Control with Fertilizers and Arsenicals

Both arsenicals and complete fertilizers were applied on some plots. Arsenic acid was used at 1 pound and sodium arsenite at one-half pound to 1,000 square feet. Both were applied dry, mixed with sand, in April. While the fertilizers alone applied at the rate of 1 pound of nitrogen to 1,000 square feet reduced the clover and plantain to some extent but did not reduce the chickweed, the addition of arsenicals practically eliminated the chickweed and clover and further reduced the plantain. On the other hand, there was somewhat more crabgrass on the plots treated with arsenic acid and sodium arsenite than on those which received fertilizers only. This may have been due to the fact that the crabgrass was able to take over the areas vacated by the chickweed and clover more quickly than was the bluegrass. The plots treated with arsenic acid



The control of clover and buckhorn plantain in old established Kentucky bluegrass turf by the application of fertilizers. The weed-free plot on the right had received a 9-9-4 inorganic fertilizer every spring and fall from the spring of 1934 to the spring of 1938, inclusive, at the annual rate of 2.5 pounds of nitrogen to 1,000 square feet. The picture was taken in June, 1938. The plot on the left in which clover and plantain predominate had received no fertilizer during this time.

and fertilizers had a better stand of bluegrass than those to which fertilizers alone were applied.

Summary

The results of a number of experiments with fertilizers chiefly on old weedy turf composed largely of Kentucky bluegrass have been reported. These experiments were conducted in part at the Arlington Experiment Farm and in part on the grounds of the Capital Golf and Country Club near Washington.

In these experiments a thin weedy turf was transformed into a dense turf free of weeds in two years by moderate fertilization without the use of seed, water or mechanical working. The transformation was even more rapid with extremely heavy applications.

The best turf on the acid soil was produced with a combi-