FERTILIZER TRIALS ON DEMONSTRATION GARDENS

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It is generally recognized that the nutritional requirements of the bent grasses are not quite the same as those of the bluegrasses. It is also recognized that variations in the climatic and soil conditions under which turf may be growing prevent identical grasses from responding in the same way to any one fertilizer in all localities. Little information is available, however, regarding the extent of the variations in the responses of the several grasses to fertilizers, or the nature and relative importance of the climatic and soil factors involved. For this reason it was considered desirable to obtain evidence on the value of fertilizers for grass grown for turf purposes under as wide a range of soil and climatic conditions as practicable.

The Green Section, in 1928, with the cooperation of 15 golf clubs, established demonstration turf gardens in widely separated sections of the country. The primary object of the fertilizer sections of these demonstration gardens was to determine whether some fertilizers which had proved desirable or undesirable under conditions as they existed at Arlington Farm would produce correspondingly good or poor results under conditions as they are found in other sections of the country. The ability of the various clubs to undertake the expense associated with these demonstration gardens was naturally limited and consequently it was not possible to include as many fertilizers as might have been desirable.

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Plan of Demonstration Gardens

The demonstration gardens were divided into plots 10 feet square. Fifteen of these plots were planted with mixed bent seed containing approximately 50 percent velvet bent, 48 percent Colonial bent and 2 percent creeping bent. In this series 11 different fertilizer combinations were applied at monthly intervals during the growing season. The bent plots were arranged with unfertilized check plots strategically placed for purposes of comparison, as is shown in the accompanying diagram.

Plan of Fertilizer Trials on Mixed Bent at Demonstration Gardens

Activated sludge.	Poultry manure tankage.	Check.	Sulfate of ammonia.	Compost and sulfate of ammonia.
Check.	Nitrate of soda.	Urea.	Ammonium phosphate.	Check.
Complete fertilizer 6-12-4	Complete fertilizer 12-6-4	Check.	Lime and sulfate of ammonia.	Bone meal.

A similar set of 10 plots was devoted to a study of the responses of Kentucky bluegrass to various fertilizer combinations. The plots were arranged as shown in the diagram on page 216. As in the mixed bent plots, each fertilized plot touched an unfertilized check plot on at least one side.

Other plots on the demonstration gardens were devoted to testing various grasses for putting green and fairway purposes, as well as to trying the effect of different heights of cut on these grasses. These plots are not related to the present subject and will not be discussed here.

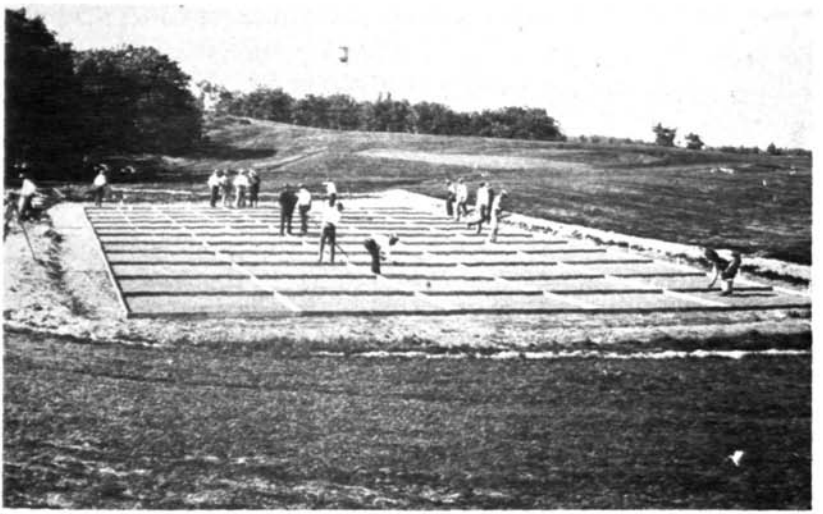
PLAN OF FERTILIZER TRIALS ON KENTUCKY BLUEGRASS AT DEMONSTRATION GARDENS

Bone meal.	Lime.	Check.	Sulfate of ammonia.	Activated sludge.
Check.	Manure.	Complete fertilizer 6-12-4	Complete fertilizer 12-6-4	Check.

Planting material and fertilizers for the demonstration gardens were furnished by the Green Section together with certain standard directions for the general care of the gardens. Details of maintenance were left to the individual greenkeepers at each of the cooperating clubs.

RECORD OF RESULTS

The plans for these gardens called for periodic reports to the Green Section on the condition of the turf on the plots. In these reports, which were submitted monthly from May to October, excellent turf was rated as 4, good turf as 3, fair as 2, and poor as 1. In determining the ratings, consideration was given to density, vigor, color, fineness, freedom from weeds, nap and any other factors which affected the quality of the grass for turf purposes. The value of each treatment was measured, therefore, in terms of the turf produced.



The planting of one of the Green Section's demonstration gardens in 1928. The view shows the strips of board in position between the plots. The strips were 3 or 4 inches wide and were set into the ground about 1 inch deep to prevent any possible washing of surface soil from one section to another. After the grass was well established the strips were removed.

As these tests were made on golf courses where white clover is objectionable in turf, any stimulation of clover by a fertilizer caused a lower rating for these plots. The ratings of the turf resulting from the use of some of the fertilizers are naturally quite different from those obtained from grassland experiments where white clover is valuable for forage. Likewise the ratings given here may not apply to some lawn and park areas, where white clover is not objectionable.

At the close of the 5-year period soil samples were taken at 1, 2, 3 and 4-inch depths from each of the fertilized and unfertilized plots on each of the nine demonstration gardens for which ratings over the 5-year period were available. These were tested by the Green Section staff for acidity by the Hellige-

Truog method and for available phosphoric acid (P_2O_5) by the LaMotte-Truog method. The conditions in the surface inch appeared to be more indicative of the responses of the soils to the various fertilizer applications than did those at the greater depths. Wherever reference is made to these determinations the values for the surface inch are given.

Cooperating Golf Clubs

Fifteen demonstration gardens were planted in 1928. Ten others were planted in 1929 and 1930. Some of the original gardens were soon discontinued for financial or other reasons and all were discontinued in 1933. Of the 25 gardens only 9 were kept up over the 5-year period from 1928 to 1933. In this summary of the data from the 5-year experiment, therefore, only the reports from these 9 gardens were used. They were distributed as follows:

Detroit District:	Detroit Golf Club Meadowbrook Country Club
Grand Rapids (Mich.) District:	Indian Trails Golf Course
Pittsburgh District:	Allegheny Country Club Oakmont Country Club
Boston District:	Charles River Country Club
New York District:	Century Country Club Upper Montclair Country Club Wheatley Hills Golf Club

Some of the 25 gardens were maintained for several more years and some additional observations have been made. Where results from the gardens not listed above have appeared significant they are included in the discussion.

Rates of Application of Fertilizers

Since nitrogen is of primary importance in the growth of leaves and the vegetative structure of plants, and since the object in growing grass for turf is to produce leaves rather than flowers or fruit, nitrogen assumes the position of ranking importance in the fertilizer requirements of turf grasses. On each type of grass, therefore, all of the fertilizers were applied at rates which gave the same amount of nitrogen for each fertilized plot.

Each 10 by 10-foot fertilized plot of mixed bent received one-tenth pound of nitrogen with each monthly application from May to October, inclusive, except during the months of July and August, when all applications were cut in half to reduce the danger from burning. Each plot of 100 square feet, therefore, received one-half pound of nitrogen in the 6 months. In other words, the nitrogen was applied at the annual rate of 5 pounds to 1,000 square feet. The quantities of phosphoric acid and potash applied varied with the composition of the fertilizer.

The quantities of mineral nutrients applied annually to each of the 11 plots are given in the table on page 220. For convenience the quantities are expressed in pounds to 1,000 square feet. The plot which was fertilized with a mixture of sulfate of ammonia and compost received half of its nitrogen from the sulfate of ammonia and half from the compost. The sulfate of ammonia was furnished by the Green Section but the compost was supplied by each club for its own garden. Each sample of compost was not analyzed but the amount that was prescribed was estimated on the basis of nitrogen determinations on average compost. Therefore the specific amounts of

nitrogen, phosphoric acid and potash in the compost are not known, but the average should be very close to the figures given in the table.

ANNUAL RATES OF APPLICATION OF NUTRIENTS TO MIXED BENT PLOTS ON THE DEMONSTRATION GARDENS, IN POUNDS TO 1,000 SQUARE FEET. THE PLOTS ARE ARRANGED IN DECREASING ORDER OF TOTAL AMOUNTS OF PLANT NUTRIENTS APPLIED

Fertilizer	Pounds of nutrients to 1,000 square feet		
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)
Bonemeal	5	28.00	0
Ammonium phosphate	5	21.84	0
6-12-4 Inorganic	5	10.00	3.33
12-6-4 Inorganic	5	2.50	1.67
Poultry manure tankage	5	2.50	1.30
Sulfate of ammonia and compost	5	1.25	2.50
Activated sludge	5	1.70	0.40
Urea	5	0	0
Sulfate of ammonia	5	0	0
Sulfate of ammonia and lime	5	0	0
Nitrate of soda	5	0	0
Checks	0	0	0

The bluegrass plots were seeded with a mixture of Kentucky bluegrass and redtop but the redtop was gradually crowded out. The materials tested were 6-12-4, 12-6-4, sulfate of ammonia, activated sludge, bonemeal, well-rotted stable manure and lime. As on the bent plots, all fertilizers were applied at rates to furnish equivalent quantities of nitrogen. Naturally the amounts of phosphoric acid and of potash varied with the composition of the fertilizers. The complete mixed fertilizers contained material of inorganic origin only.

In order to give the young grass a vigorous start the rates of application the first year were the same as those shown above for bent grasses. During the 4 following years the annual rates

of application were one-half of those used on mixed bent. One-half of each annual application was made in early spring and the remainder in fall.

The annual applications of nutrients to 1,000 square feet during the 4 years are shown in the table on this page. For the first year these rates were doubled.

ANNUAL RATES OF APPLICATION OF NUTRIENTS TO KENTUCKY BLUEGRASS PLOTS ON THE DEMONSTRATION GARDENS, IN POUNDS TO 1,000 SQUARE FEET. THE PLOTS ARE ARRANGED IN DECREASING ORDER OF TOTAL AMOUNTS OF PLANT NUTRIENTS APPLIED

Materials	Pounds of nutrients to 1,000 square feet		
	Nitrogen (N)	Phosphoric acid (P_2O_5)	Potash (K_2O)
Bonemeal	2.5	14.00	0
6-12-4 Inorganic	2.5	5.00	1.67
Stable manure	2.5	1.65	1.65
12-6-4 Inorganic	2.5	1.25	0.83
Activated sludge	2.5	0.85	0.20
Sulfate of ammonia	2.5	0	0
Lime	0	0	0
Checks	0	0	0

The stable manure was furnished by the various clubs. The instructions were to apply a specified amount of a good grade of well-rotted manure. As it was not practical to analyze each lot of manure the amount that was prescribed was based on the average analysis of numerous samples of good grade manures. Undoubtedly there were variations in the composition of the manure that was used on the different gardens. However, it can be assumed that the average amount of nitrogen added in the various gardens was very close to the amount applied to the other fertilized plots, and that the other nutrients were added in the amounts shown in the table.

AVERAGE 5-YEAR PERCENTAGE OF IMPROVEMENT OVER UNFERTILIZED PLOTS OF MIXED BENT TURF ON NINE DEMONSTRATION GARDENS. THE pH OF THE SURFACE INCH OF SOIL ON THE PLOTS AT THE CLOSE OF THE 5-YEAR PERIOD AND THE ANNUAL RATE OF APPLICATION OF PHOSPHORUS ARE INCLUDED

Fertilizer	Percentage of improvement over unfertilized plots	pH of surface inch of soil	Annual application of phosphorus (pounds P_2O_5 to 1,000 square feet)
6-12-4 Inorganic	126	5.2	10
12-6-4 Inorganic	125	5.3	2.5
Sulfate of ammonia	106	5.4	0
Ammonium phosphate	99	5.3	21.84
Activated sludge	92	6.3	1.7
Sulfate of ammonia and compost	88	5.6	1.25
Poultry manure tankage	87	6.1	2.5
Urea	76	6.3	0
Sulfate of ammonia and lime	71	6.7	0
Nitrate of soda	48	6.9	0
Bonemeal	47	6.9	28
Unfertilized plots		6.2	0

RESPONSE OF BENT TURF TO FERTILIZERS

As stated, the effect of each fertilizer was determined by the condition of the turf produced. In each case the rating of the grass on the fertilized plot was compared with that on the check plots and expressed as percentage of improvement over the average rating of the unfertilized check plots.

The average percentages of improvement of the bent grass over the 5-year period are shown in the table on this page. The annual rate of application of phosphorus and the resulting pH of the soil at the end of the 5-year period are given. The plots are arranged according to the percentage of improvement in the grass on the fertilized plots over that on the unfertilized check plots.

To measure the effect of phosphorus and potassium on the grass the improvement obtained by applications of inorganic fertilizers containing phosphoric acid and potash can be compared with the improvement resulting from the application of inorganic nitrogen alone. The 6-12-4 and 12-6-4 fertilizers both furnished nitrogen in the form of sulfate of ammonia and some ammonium phosphate.

In the table it can be seen that the improvement shown on the 6-12-4 and the 12-6-4 plots was significantly greater than that shown on the sulfate of ammonia plot. Since the nitrogen sources were ammonia compounds in the three plots and since the acidity of the soil was essentially the same on each of them, this increase in improvement may safely be credited to the presence of phosphoric acid or potash. The fact that on the average the grass on the plot fertilized with 6-12-4 was little better than that on the 12-6-4 plot, although it received 4 times as much phosphoric acid and twice as much potash, indicates that small proportions of phosphoric acid (application at one-half the rate at which nitrogen was used) and even smaller amounts of potash had improved the turf but that larger amounts had failed to appreciably increase this improvement.

Similar benefits from relatively small amounts of phosphoric acid and potash can be seen when the improvement in the turf on each of the plots receiving the organic fertilizers, activated sludge and poultry manure tankage, is compared with that on the plot receiving organic nitrogen alone in the form of urea, each receiving 5 pounds of nitrogen. The activated sludge and poultry manure tankage added phosphoric acid at annual rates of 1.7 and 2.5 pounds to 1,000 square feet, respectively, and small amounts of potash. In the table it can

be seen that both the activated sludge and the poultry manure tankage produced better turf than did the urea. The figures indicate that the grass was generally poorer and that the soil was less acid on all of these plots than on those fertilized with 6-12-4, 12-6-4 and sulfate of ammonia. The urea plot, for instance, showed an average improvement of only 76 percent over the unfertilized plots, as compared with 106 percent improvement on the sulfate of ammonia plot.

The ammonium phosphate plot received phosphoric acid at the heavy rate of nearly 22 pounds to 1,000 square feet. The average improvement shown on this plot was slightly less than that shown on the sulfate of ammonia plot. The resulting soil acidity at the end of the 5-year period was about the same on the two plots.

When a large amount of phosphorus was added in the slowly available form of bonemeal there was an average improvement of only 47 percent during the course of the experiment as compared with 106 percent with sulfate of ammonia. It will be noted in the table that the pH of the soil on the bonemeal plot was much higher than that on the plots receiving sulfate of ammonia and other inorganic fertilizers. The fact that nitrate of soda which resulted in the same high pH likewise produced an improvement of only 48 percent over the checks would indicate that the practically neutral condition of the soil was significant on the bonemeal and nitrate of soda plots.

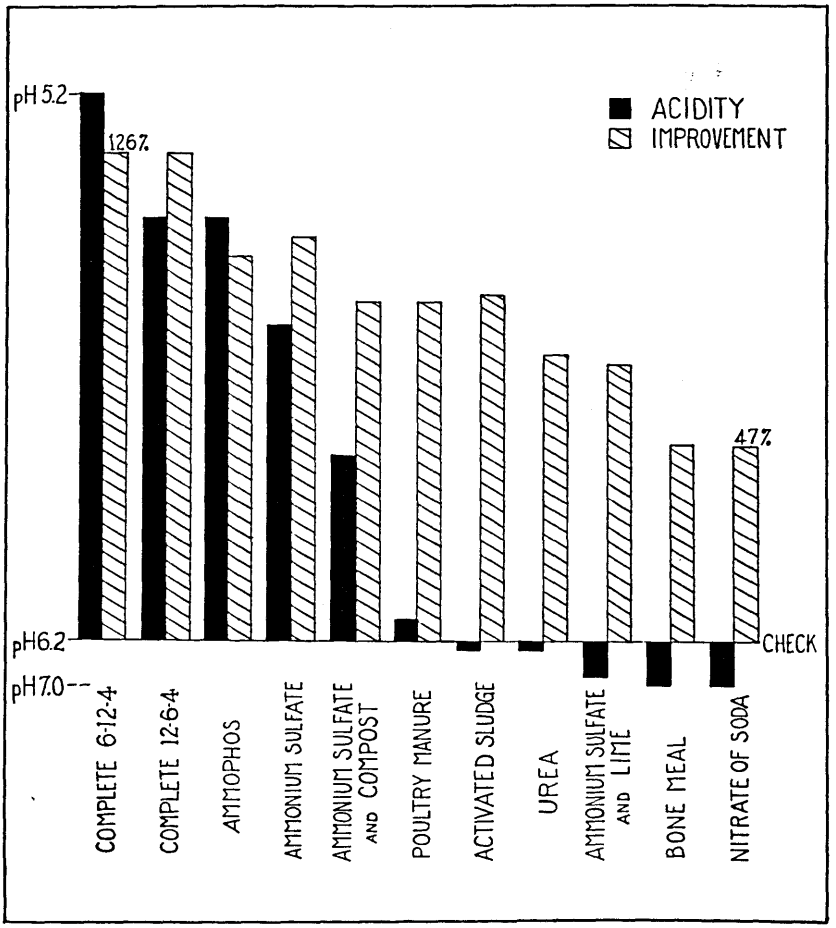
The plot receiving sulfate of ammonia and compost showed considerably less improvement than the plot receiving sulfate of ammonia alone. This was probably due to the fact that only one-half of the nitrogen was furnished by the sulfate. The other half came from compost in which the nitrogen is much more slowly available.

The grass on the plot receiving lime in addition to the sulfate of ammonia showed far less improvement than did that on the plot receiving sulfate of ammonia alone. It will be noted in the table that the acidity which was caused by sulfate of ammonia when applied alone was more than counteracted by the application of lime in addition to the sulfate of ammonia. On an average, sulfate of ammonia alone reduced the soil pH from 6.2 in the check plots to pH 5.4, whereas sulfate of ammonia and lime raised the soil pH from 6.2 in the check plots to 6.7.

The interpretation of the responses of the bents to the various fertilizer combinations used on the demonstration gardens will be discussed later in this article in the light of the results from other experiments carried on over a longer period of time.

Acidity Relations

The table on page 222 indicates that the question of acidity should be considered in any effort to interpret the results obtained from the fertilized plots of mixed bent on the demonstration gardens. The best plots were those with the most acid soils; that is, soils with readings of pH 5.2 to 5.4. In the ruled columns of the chart on page 226 the percentages of improvement are shown graphically. For purposes of comparison the actual acidity of each plot (hydrogen ion concentration) times 10 million is drawn to scale in the solid columns of the chart. The base line represents the average condition of the grass and the soil acidity (pH 6.2) of the check plots. It can easily be seen, therefore, which fertilizers produced the greatest improvement and whether they increased or decreased the acidity of the soil. The reader will notice the much greater



The average percentage of improvement in bent turf over check plots on the nine Demonstration Gardens with each of the fertilizer combinations, and the average soil acidity produced in the surface inch of soil by each of the fertilizers. The improvement is given in the ruled columns and the acidity (Hydrogen-ion concentration) times 10 million, in the solid columns. The base line represents the condition of turf and the soil acidity of the surface inch of soil on the unfertilized plots. The pH equivalent of the actual acidity is given at the left for the most acid plot, the check plot and the neutral plot. Also, the greatest and least percentages of improvement are given above their respective columns.

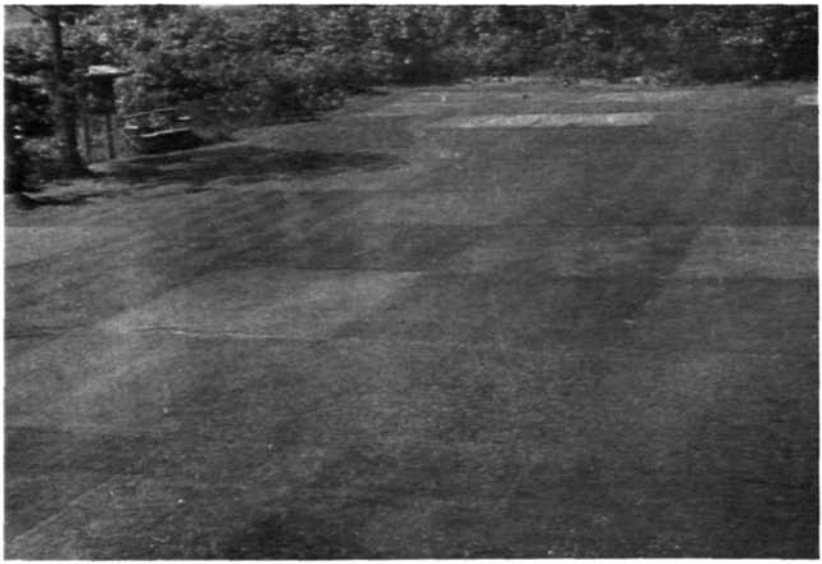
difference in acidity between pH 5.2 and 6.2 than between 6.2 and 7.0. The difference between the acidity of pH 5.0 and 6.0 is 10 times greater than that between pH 6.0 and 7.0. It is apparent that, with the exception of activated sludge, the more acid the plots (the lower the pH) the greater the improvement which is shown in the turf.

Soil Acidity and Response to Fertilizer

The acidity of the original soil as indicated by the pH of the check plots on the 9 different gardens varied from pH 4.7 at Wheatley Hills to pH 7.5 at Meadowbrook. A preliminary comparison of the ratings of the fertilizer plots at the individual gardens together with the results of the soil tests made on samples from each of these plots indicated that there was a significant difference between the response of the mixed bent to fertilizers on distinctly acid and on alkaline soils.

The gardens have been classified into three groups on the basis of the acidity of their untreated soil. On four gardens the soil was distinctly acid, with the soil pH below 6.0; on three the soil was slightly acid, with the pH between 6 and 7; and on two the soil was alkaline, with the pH above 7.0. The average response of the bent grasses to each of the 11 fertilizer combinations for each group of the demonstration gardens was calculated and plotted on the chart shown on page 232.

It appears significant that with each fertilizer treatment, with the single exception of that of nitrate of soda, the gardens with the distinctly acid soil showed most improvement in the turf, those with slightly acid soil showed less improvement, whereas those with alkaline soil gave decidedly the least response.



A view of one of the demonstration turf gardens planted by the Green Section showing some striking variations in the plots from different fertilizer applications.

On the alkaline soils the fertilizers had least effect on the acidity of the soil. Apparently the soil on the alkaline gardens was well buffered against any change in soil acidity. In the table on page 229 it can be seen that the acidity of the fertilized plots on the gardens having naturally acid soils varied from pH 4.5 to 4.8 (on those plots fertilized with the inorganic complete mixtures) to pH 6.5 to 7.0 (on the bonemeal and nitrate of soda plots) a range of 2 full pH units. On the other hand, on the alkaline gardens the acidity of the plots varied within the very limited range of from pH 6.5 to 7.3 on the least acid plots, to 7.5 on the most alkaline plots—a range of only 0.2 to 1.0 pH unit.

SOIL ACIDITY OF CHECK PLOTS EXPRESSED IN pH AND RANGE IN SOIL pH OF THE FERTILIZED PLOTS ON THE NINE DEMONSTRATION GARDENS

Gardens	pH of soil on check plots	Range in soil pH of fertilized plots	
		Most acid plot	Least acid or alkaline plot
Most acid gardens			
Wheatley Hills	4.7	4.5	6.5
Oakmont	5.3	4.5	7.0
Charles River	5.7	4.5	6.8
Upper Montclair	5.8	4.8	7.0
Moderately acid gardens			
Century	6.3	4.5	7.2
Allegheny	6.6	4.8	6.8
Detroit	6.7	5.0	7.0
Alkaline gardens			
Indian Trails	7.2	6.5	7.5
Meadowbrook	7.5	7.3	7.5

RESPONSE OF KENTUCKY BLUEGRASS TURF TO FERTILIZER

The method of recording the effect of fertilizers on the Kentucky bluegrass series was the same as that already described for the mixed bent plots. As the scoring was done by greenkeepers and others interested in golf courses the emphasis was placed on grass development. Stimulation of clover or other legumes and weeds lowered the score. These ratings are consequently not likely to be in accord with many obtained from fertilizer experiments on bluegrass where the objective is to produce a mixture of grass and clover for pasture or other purposes.

The fertilizers were applied on the basis of equal quantities of nitrogen with varying amounts of phosphoric acid and potash, as shown in the table on page 221. To hasten the establishment of the turf they were used at double the usual rate

during the first year. Therefore the total quantities used in the 5-year period were six times the amounts shown in the table.

The average effects over the 5-year period of the several fertilizers and lime on Kentucky bluegrass turf are shown in the table on this page. On the opposite page are given the percentages of improvements over the unfertilized turf on the several plots for each year.

AVERAGE 5-YEAR PERCENTAGE OF IMPROVEMENT OVER UNFERTILIZED PLOTS OF KENTUCKY BLUEGRASS TURF, AVERAGE pH OF SURFACE INCH OF SOIL AT CLOSE OF 5-YEAR PERIOD, AND TOTAL PHOSPHORUS APPLIED IN 5 YEARS, ON NINE DEMONSTRATION GARDENS

Materials applied	Percentage of improvement over unfertilized plots	Average pH of surface inch of soil	Total phosphorus applied in 5 years (pounds P_2O_5 to 1,000 square feet)
6-12-4 Inorganic	69	5.2	30.0
Activated sludge	62	5.8	5.1
12-6-4 Inorganic	62	5.2	7.5
Bonemeal	56	6.3	84.0
Sulfate of ammonia	44	5.3	0
Lime	23	6.9	0
Stable manure	21	6.1	9.9
Check	..	6.2	0

Climatic variations naturally affect the condition of turf with or without fertilizer. The ratings of the unfertilized check plots, therefore, varied from year to year. By using figures that indicate improvement over the check plots this variation in the unfertilized turf due to seasonal differences is taken into consideration. It will be noted that in 1931 every fertilized plot showed the lowest percentage of improvement of any year. This was the year when the unfertilized

turf was at its best, which in part accounts for the lower figures of improvement due to fertilizers. In the case of the organic fertilizers the lower ratings in 1931 were found to be due entirely to the higher ratings of the checks. On the other

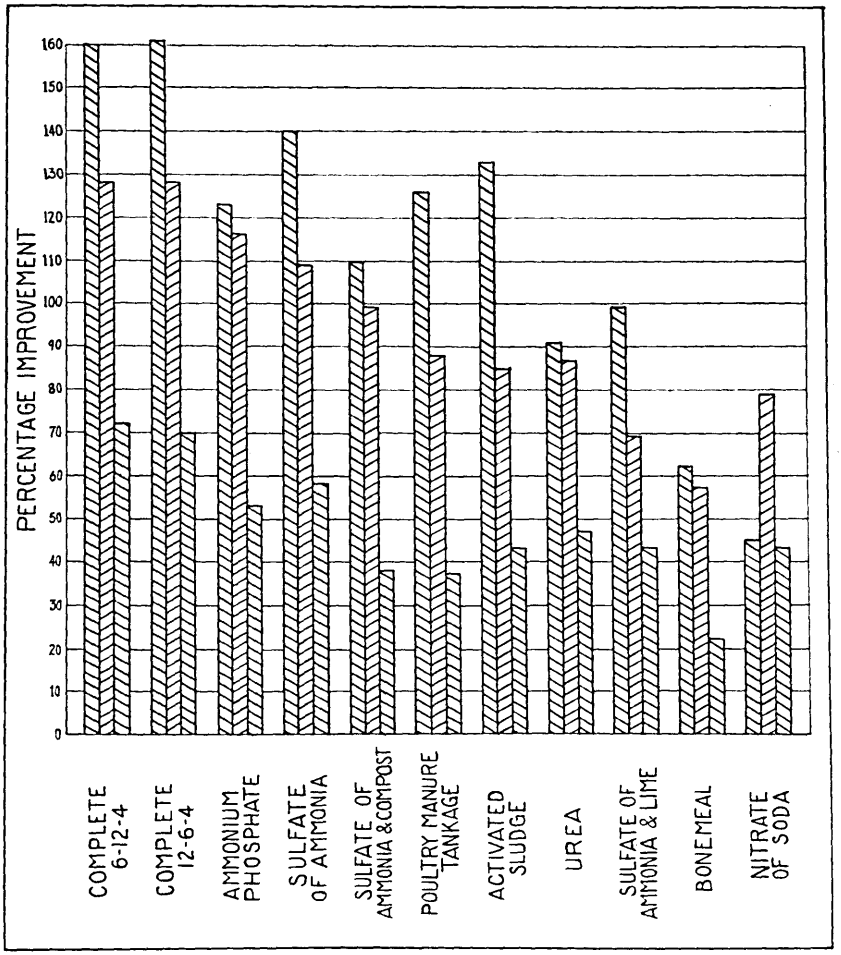
PERCENTAGES OF IMPROVEMENT OF KENTUCKY BLUEGRASS TURF OVER UNFERTILIZED PLOTS ON NINE DEMONSTRATION GARDENS FOR EACH OF 5 YEARS, 1929-1933. PLOTS ARE ARRANGED IN THE ORDER OF AVERAGE IMPROVEMENT OVER 5-YEAR PERIOD

Materials applied	1929	1930	1931	1932	1933
6-12-4 Inorganic	101	77	28	62	78
Activated sludge	57	59	42	64	89
12-6-4 Inorganic	88	65	32	58	67
Bonemeal	49	56	37	60	78
Sulfate of ammonia	67	44	13	39	56
Lime	12	19	10	32	41
Stable manure	26	18	14	16	33

hand the three inorganic fertilizers showed a decided falling off in ratings in the four gardens in the New York and Boston districts. In these two districts rainfall had been above normal, particularly following the fertilizer applications the previous fall. In the other districts there had been less than normal rainfall and the percentages of improvement were not lower than they were in other years. This difference in rainfall may have had some bearing on the response to the inorganic fertilizers due to excessive leaching of nitrogen from the soil.

The figures indicate that the turf was established most rapidly on the plots receiving the two complete inorganic fertilizers. They maintained this lead for 2 years but thereafter were equalled or surpassed by the activated sludge and the bonemeal.

The 6-12-4 plot showed the highest percentage of improvement over the 5-year period but, as shown below, the differ-



Response of the mixed bent grasses to fertilizers on soils of varying acidity. The results are expressed in percentage of improvement over the check plots. The three columns shown for each fertilizer, reading from left to right, represent the average percentage of improvement for four gardens with unfertilized soils with pH below 6.0, three gardens with pH between 6.0 and 7.0, and two gardens with pH above 7.0.

ence was unimportant. This lead over the activated sludge was due to the decided differences in the ratings of the first 2 years. In the ratings for the 5 years the 6-12-4 led the sludge on only four gardens but the percentages of improvement in these cases were sufficiently high to offset the figures from the five gardens where the sludge led the 6-12-4. In two of these five gardens the differences in ratings were very small.

The activated sludge led the 12-6-4 by a small fraction over the 5-year period in spite of the slower start. In this case also the sludge led in five gardens whereas on the other four gardens it was inferior to the 12-6-4.

The 12-6-4 fertilizer gave results superior to 6-12-4 on two gardens and tied it on two others. On two other gardens there were only trivial differences between the plots with these two fertilizers. On only three gardens did the 6-12-4 lead the 12-6-4 by a significant margin. This lead was maintained in 4 of the 5 years of the test. In order to apply the same quantities of nitrogen to these plots it was necessary to use twice as much 6-12-4 as 12-6-4. Consequently the plot receiving 6-12-4 had four times as much phosphoric acid and twice as much potash as the plot receiving 12-6-4.

It is interesting to compare results on the plot fertilized with sulfate of ammonia alone with those obtained on the plots fertilized with the two complete inorganic fertilizers in which most of the nitrogen was supplied in the form of sulfate of ammonia. During the first year the sulfate of ammonia was in third place but well below the complete inorganic fertilizers. It remained well below them throughout the test period, indicating the need for phosphoric acid or potash. By comparing the results on the different gardens it was found that the complete inorganic mixtures led the sulfate of am-

monia on seven gardens. The sulfate of ammonia was superior to the two complete fertilizers on two gardens but in only one case was this difference large enough to be considered of any importance.

In the table showing the yearly ratings it will be noted that, with the exception of 1931, there was a steady betterment of the turf in the plots receiving the two organic fertilizers—activated sludge and bonemeal. Even in that year the proportionate drop in improvement was much less in these two plots than in the three plots receiving inorganic fertilizers. The percentage of improvement during the fifth year as compared with the first year was 32 higher for activated sludge and 29 higher for bonemeal.

RESPONSE OF MIXED BENTS AND KENTUCKY BLUEGRASS TO THE SAME FERTILIZERS. RESULTS ARE EXPRESSED IN PERCENTAGE OF IMPROVEMENT OVER RATINGS OF THE GRASSES ON UNFERTILIZED PLOTS. THE BLUEGRASS PLOTS RECEIVED 60 PERCENT OF THE AMOUNT OF FERTILIZER APPLIED TO THE BENTS IN 5 YEARS

Fertilizer	Percentage of improvement	
	Mixed bents	Kentucky bluegrass
6-12-4 Inorganic	126	69
12-6-4 Inorganic	125	62
Sulfate of ammonia	106	44
Activated sludge	92	62
Bonemeal	47	56

The ratings of the plot receiving bonemeal put this fertilizer in fourth place in the total ratings. It led the 6-12-4 however in three gardens but in each case the margin was a narrow one. It likewise led the activated sludge on three gardens and the 12-6-4 on four gardens by comparatively narrow margins.

Although not classed as a fertilizer, lime produced an average improvement of bluegrass turf greater than that obtained

with manure. It will be noted that the improvement in the first year was less than a third that of the last year. The relatively large increase in improvement the last year was mainly due to the great increase on one garden even though the unfertilized soil on this garden was nearly neutral.

The stable manure produced the least improvement of all the materials tested. In spite of the fact that the manure added more total plant food than was added by the 12-6-4 or the activated sludge it improved the turf only a third as much as these two fertilizers.

Kentucky Bluegrass and Soil Acidity

When the figures showing turf improvement in the table on page 230 are compared with those in the column of pH values it is apparent that there is no such uniform relationship between them as is the case in the bent series.

It is generally believed that Kentucky bluegrass grows best in soil that is nearly neutral. With this point of view in mind it is interesting to note that the three fertilizers at the top of the list had each made the soil more acid than in the unfertilized check plots.

Some interesting facts become apparent with a study of the average improvement produced by the various fertilizers on the individual gardens. The two highest rates of improvement occurred on the garden with an original soil pH of 5.3, next to the most acid of the series, and these high improvements were produced by the two fertilizers, the complete inorganics, with the strongest tendency to make the soil more acid. The next two highest rates of improvement were produced with the same fertilizers on a slightly acid soil with a pH of 6.7.

Sulfate of ammonia, which also tends to make the soil more acid, gave its best results on next to the most acid garden and its next best results on an alkaline garden. The pH of these gardens was changed from 5.3 to 4.8 in the first instance and from 7.1 to 5.5 in the second. Activated sludge, which also tends to increase soil acidity, made its best showing on one of the more acid gardens, the pH changing from 5.7 to 4.9.

Lime, one of our most effective materials for decreasing soil acidity, made its best showing on the bluegrass plots on a garden with a nearly neutral soil having a pH of 6.6. On a garden with a pH of 6.7 the lime plot was even poorer than the check and again made a very poor showing on a garden with a pH of 5.7. Lime made its second best showing on the most acid garden.

Comparison of Mixed Bents and Kentucky Bluegrass

It is interesting to compare in the table on page 234 the response of mixed bents with that of Kentucky bluegrass to some fertilizers applied under the varying environmental and cultural conditions of the nine gardens. In this connection it should be borne in mind that the bents are considered as acid-tolerant grasses whereas Kentucky bluegrass is considered as preferring a more nearly neutral soil. The Kentucky bluegrass plots received in the 5 years 60 percent of the amount of fertilizer applied to the bents. The figure for each fertilizer represents the average improvement obtained on the nine demonstration gardens during the 5 years. The average rating of the mixed bents on the unfertilized plots was 38 percent and that of Kentucky bluegrass was 40 percent of the maximum score possible with the rating method in use. The con-

dition of the turf on these check plots was typical of that on most unfertilized areas.

The response of Kentucky bluegrass to the complete inorganic fertilizers corresponded to that of the bent grasses. Both grasses produced the best turf on plots which had been fertilized with 6-12-4 inorganic fertilizer and which had an acidity of pH 5.2 at the close of the experiment. The bent grasses, which received about 1.7 times as much fertilizer as did the Kentucky bluegrass, showed 1.8 times as much improvement with the 6-12-4, 2 times as much with the 12-6-4, and 1.5 times as much with activated sludge, as did the Kentucky bluegrass, although in the bents the improvement produced with 6-12-4 and 12-6-4 was about one-third again as much as with activated sludge.

The outstanding difference between the two grasses in this comparison was in their response to sulfate of ammonia. Sulfate of ammonia was a particularly favorable source of nitrogen for bent. The improvement shown in bent fertilized with sulfate of ammonia was second only to that shown in bent fertilized with the complete inorganic fertilizers. On the other hand, the Kentucky bluegrass plots fertilized with sulfate of ammonia alone were the poorest of all of the fertilized plots included in this comparison. Nevertheless where sulfate of ammonia was used in conjunction with superphosphate and muriate of potash, it gave good results on Kentucky bluegrass as well as on bents, as is evidenced by the improvement recorded for the 6-12-4 and the 12-6-4 plots.

Kentucky bluegrass responded more favorably to bonemeal than did the mixed bents. Although the bent plots received 1.7 times as much bonemeal as did the Kentucky bluegrass plots, they showed only 0.84 times as much improvement.

In general the results under these widely varying conditions were similar to those obtained with these fertilizers on the same grasses at Arlington Experiment Farm, as described elsewhere in this issue of TURF CULTURE.

SUMMARY AND DISCUSSION

Demonstration turf gardens were established by the Green Section on golf courses in different parts of the country. These gardens included series of plots for testing the responses of the bent grasses and Kentucky bluegrass to different fertilizers under various soil and climatic conditions.

This article reports the results of the fertilizer tests from the nine gardens which were continued over a 5-year period, from 1929 to 1933 inclusive.

Although these tests were conducted for only 5 years it is interesting to compare the results with those obtained from the bent plots on the Arlington Turf Garden, some of which have been fertilized with a single combination of materials for the past 18 years, and have been under continuous observation during that time.

The application of nitrogen at the annual rate of 5 pounds to 1,000 square feet has consistently improved bent turf, the amount of improvement varying with the source of nitrogen, the other fertilizer ingredients with which the nitrogen source was combined, and the acidity of the soil.

On the demonstration gardens, the most decided improvement was produced in bent turf with the 6-12-4 and the 12-6-4 inorganic mixtures. There was appreciably more improvement over the unfertilized turf in these plots than in the ones which received sulfate of ammonia alone or ammonium phosphate. Since the nitrogen in these mixtures was supplied