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Effect of Variations in Concentration of Mineral Nutrients Upon the Growth of Several Types of Turf Grasses

By Mary E. Reid

The problem of the specific effects of different mineral deficiencies on fine turf grasses has remained neglected too long. Information concerning the most outstanding symptoms caused by various mineral deficiencies may well be of value in diagnosing certain types of turf disorders. It would also be desirable to know the effects on turf resulting from an unbalanced relation between the quantities of different mineral substances required by plants from the soil. For example, nitrogen is sometimes the only important substance supplied in the fertilizers employed. The long-continued addition of one substance exclusively may eventually result in a very unbalanced condition of the soil with respect to the plant requirements.

With the object of discovering and establishing the chief symptoms of a deficiency and in some cases of an excess of the more important mineral elements, some experimental studies were undertaken. Plants were grown in pure quartz sand and were given mineral nutrient solutions in high, medium, and low concentrations with respect to six mineral elements—nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. A solution designated as high-phosphorus, for example, had the same concentration of the other five elements as a standard solution but varied from the standard solution in having a much higher phosphorus content. A low-phosphate solution, on the contrary, varied quantitatively from the standard only in having a much lower phosphorus content. The solution designated as "medium" in the accompanying tables was the standard solution from which the variations in composition were made.

Four types of grasses were grown in the first experiment (Metropolitan creeping bent, colonial bent, velvet bent, and Kentucky bluegrass), and in the second experiment two types (Metropolitan creeping bent and Kentucky bluegrass). Some cultures of grass were allowed to grow uncut, and others were cut in order to form a turf. The experiments continued over a period of 3 months in one case and 3½ months in the other. The first experiment was conducted in the greenhouse during the spring months and the second was conducted in the open in summer.

The results with Metropolitan creeping bent will be described somewhat fully. Results with the other grasses will be mentioned only in case of conspicuous differences. The quantitative results obtained with Metropolitan creeping bent are given in the tables, and photographs depicting the effect of variations in concentration of nitrogen, phosphorus, and potassium in the nutrient solution are shown in the three illustrations.

Nitrogen

The photograph shows the exceptional effect of variations in the quantity of nitrogen in modifying the proportions of roots to tops. Essentially the same results were obtained with velvet and colonial bents. The ratio of roots to tops of Kentucky bluegrass also varied with the quantity of nitrogen in the nutrient solution, but the differences were not nearly so great as were found with the bent grasses. With a small supply of nitrogen but an adequate supply of the other essential mineral elements, the bent grasses produced relatively large and deep root systems but small tops with little proliferation, wiry stems, reddish at the nodes, and rather stiff leaves, of small size and yellowish green in color. With an extremely large supply of nitrogen and a normally adequate supply of the other essential elements there was a weak development of the root systems but a very rapid leafy growth of the tops. The roots were short, tended to be coarse,

Effect of High, Medium, and Low Concentration of Nitrogen on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut.

Figures represent weight in grams

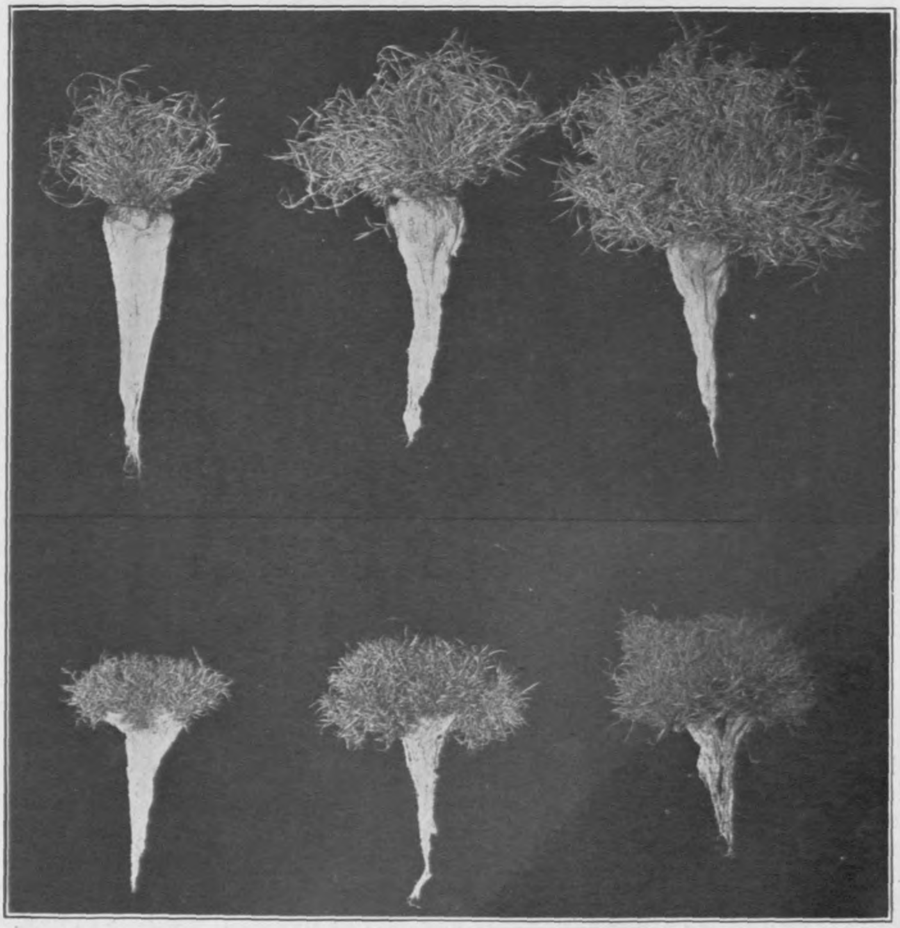
	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High nitrogen	44.8	38.5	83.3	10.5
Medium nitrogen ...	37.6	40.9	78.5	20.0
Low nitrogen	6.7	15.5	22.2	25.5
Uncut				
High nitrogen			85.0	8.0
Medium nitrogen ...			98.2	29.0
Low nitrogen			30.0	36.0
Experiment conducted in the open				
Cut to form turf				
High nitrogen	41.6	71.5	113.1	4.0
Medium nitrogen ...	29.3	52.3	81.6	7.0
Low nitrogen	4.1	21.5	25.6	11.5
Uncut				
High nitrogen			171.0	13.0
Medium nitrogen ...			130.2	22.0
Low nitrogen			31.5	25.5

not profusely branched, and tended to be reddish tan in color. The stolons of the uncut plants were long, succulent, not reddish at the nodes, and considerably branched. The leaves were bright green in color and were very easily injured by shading. Many of the lower leaves of the uncut cultures were dead, supposedly due to shading. This grass was very soft in texture and easily bruised. The medium supply of nitrogen, which was quantitatively well balanced with respect to the other mineral components of the solution, produced characteristics between the two extremes typical of the high and low nitrogen, that is, there was a better balanced relationship between the rate of growth of roots and tops, there was sufficient proliferation to produce good turf, the color was satisfactory, and the grass was neither unduly wiry nor excessively soft.

Cutting the grass reduced the total yield of the tops somewhat and it reduced very greatly the growth of the roots. This is in accord with results previously reported in the Bulletin by Harrison on the effects of cutting on the growth of roots of Kentucky bluegrass (Vol. 11, No. 11, page 210).

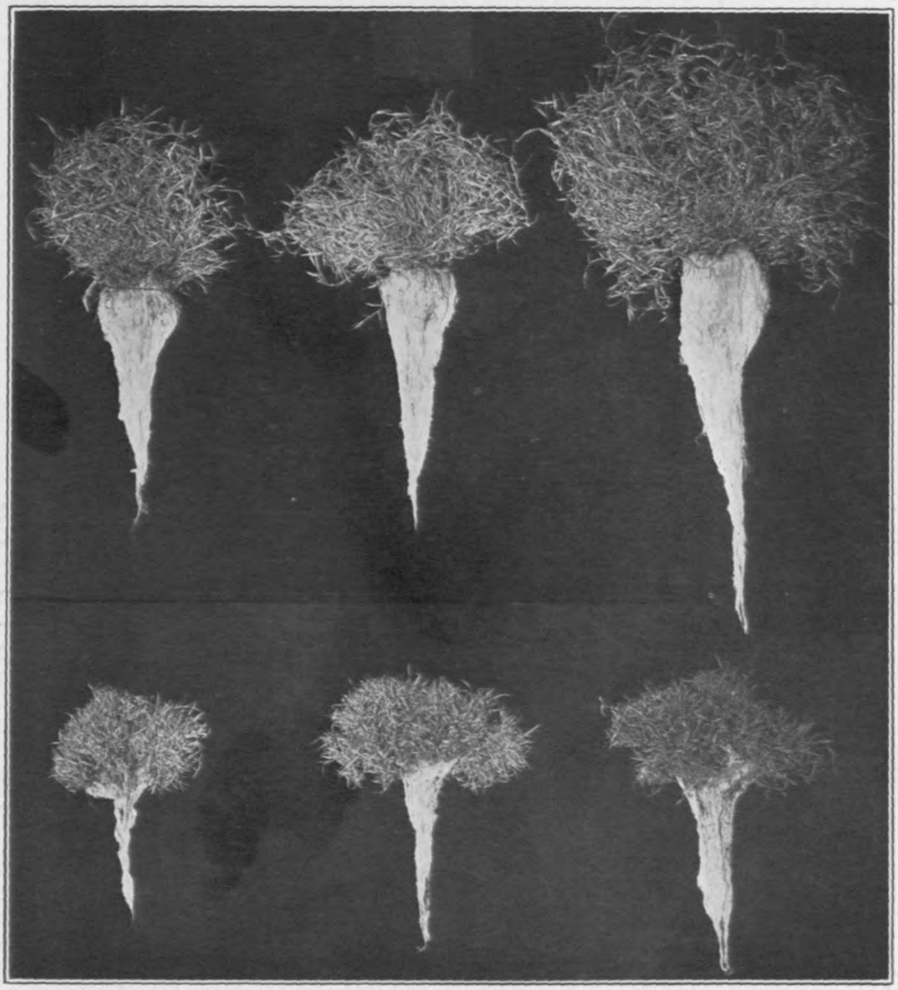
Phosphorus

The effect of varying concentrations of phosphorus on the relative rate and amount of growth of roots and tops is quite different from that produced by nitrogen. Plants grown in full sunlight in summer showed greater growth of both roots and tops with increasing concentrations of phosphorus in the nutrient solution. The high-phosphorus plants had longer and very much more branched roots than the low-phosphorus plants. The roots of the latter plants were much coarser than those of the former.



Effect of low (left), medium, and high (right) concentrations of nitrogen upon cut and uncut Metropolitan creeping bent.

There was not much readily observable difference in the character of the top growth of the plants receiving medium and high concentrations of phosphorus, but in both the cut and uncut plants the tops of the high-phosphorus plants were larger and more branched than those of the low-phosphorus plants. The data for the high-phosphorus plants grown in the greenhouse during the spring months have not been recorded in the tables because of the possibility that the nutrient solution may have been too acid. The composition of the high-phosphorus solution was changed for the second experiment so that a pH value of approximately 6.3 was maintained throughout the course of the experiment. In other experiments dealing with the effects of different fertilizers on grasses grown in the greenhouse, there has been a general tendency for smaller increases in growth due to high-phosphorus fertilizers than there has been with plants grown in the open in summer. In other words, plants grown in the greenhouse tend to do fully as well with a medium amount of phosphorus in the nutrient solution as they do with a larger quantity. Plants grown in the open profit by a relatively large quantity, particularly with respect to growth of roots.



Effect of low (left), medium, and high (right) concentrations of phosphorus upon cut and uncut Metropolitan creeping bent.

Although it had been supposed that the phosphorus content of the high-phosphorus solution employed in the second experiment was sufficiently high to produce definitely unfavorable effects, such results were not obtained except possibly in one respect, and only in the case of the uncut plants. These plants produced an abundance of foliage of healthy color, but there appeared to be some tendency for some of the lower leaves to turn yellow. It seemed that this might be an ageing effect. There was no indication of it in the cut plants. In other types of plants, phosphates are sometimes applied to hasten maturity. Further work on this point should be done on grasses.

Effect of High, Medium, and Low Concentration of Phosphorus on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut

Figures represent weight in grams

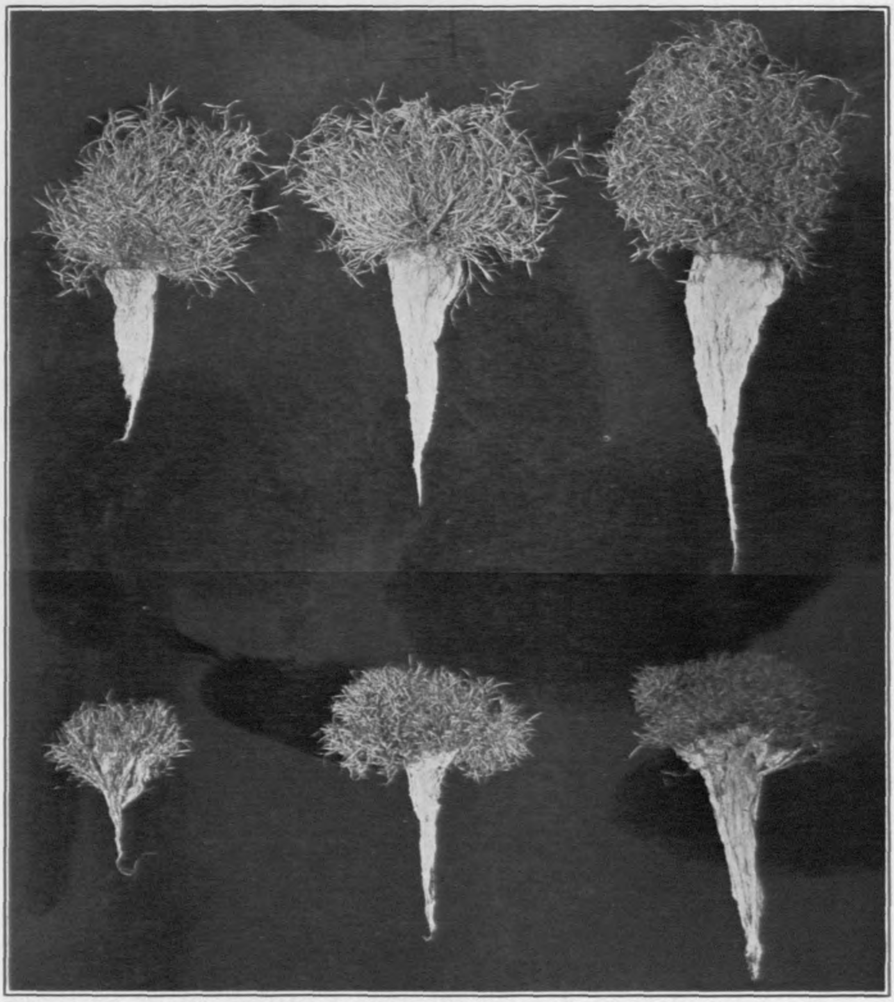
	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High phosphorus....	...	...	...	...
Medium phosphorus.	37.6	40.9	78.5	20.0
Low phosphorus.....	25.5	29.0	54.5	9.0
Uncut				
High phosphorus....			...	...
Medium phosphorus.			98.2	29.0
Low phosphorus.....			59.0	14.0
Experiment conducted in the open				
Cut to form turf				
High phosphorus....	36.7	55.5	92.2	9.5
Medium phosphorus.	29.3	52.3	81.6	7.0
Low phosphorus.....	16.0	41.0	57.0	5.9
Uncut				
High phosphorus....			159.5	33.5
Medium phosphorus.			130.2	22.0
Low phosphorus.....			93.5	19.0

The foliage of the low-phosphorus plants was stiff and somewhat stunted and of a very dark bluish green shade. This deep color developed only when nitrogen was abundant, as leaves of plants given a solution low both in nitrogen and phosphorus had a light dull green color. In other tests in which only a trace of phosphorus was supplied the stems and older leaves were of a bluish red to bronze-purple color. The low-phosphorus plants produced a very thin turf, due to the small amount of proliferation.

Potassium

There is considerable evidence that the supply of potassium should also be maintained in the soil in some degree of proportionality to that of nitrogen. If nitrogen is added to the soil in large quantities, it is probable that potassium in some form should also be added unless it is known that the soil has a suitable content of available potash. Chemical analyses of several types of grass clippings have shown that potassium ranks quantitatively second to nitrogen among the mineral elements removed from the soil. Grasses and related plants have long been known to absorb larger quantities of potassium from the soil than many other types of crop plants.

One illustration shows the effect of low, medium, and high concentrations of potassium in the nutrient solution and the first table gives the quantitative data for the same plants. The effects of varying concentrations of potassium were more marked on the roots than on the tops. Low potassium was particularly unfavorable to the growth of roots. The roots were short, coarse, not profusely branched, and tended to be somewhat soft, whereas those of plants receiving a high concentration of potassium in the nutrient solution were longer, very much more branched, finer, and appeared to be somewhat tougher. The foliage of the low-potassium plants was very soft, of a yellowish green color, showed a definite tendency to burn, and the leaves were longer and narrower than those of plants receiving more potassium. The leaves also were straight, that is, they lacked the somewhat spirally coiled or twisted effect characteristic of Metropolitan creeping bent. The high-potassium plants, both the cut and uncut, were also definitely superior to the medium-potassium plants. About the same effects of concentration of potassium in the nutrient solution were observed in the cultures grown in the greenhouse during the spring and those grown in the open in summer.



Effect of low (left), medium, and high (right) concentrations of potassium upon cut and uncut Metropolitan creeping bent.

The most noticeable characteristics of the low-potassium plants were stunting of the roots, yellow-green color of foliage, softness of texture, and tendency to bruise easily,—characteristics probably due to a weak development of the strengthening tissues.

Kentucky bluegrass showed a very interesting and striking response to potash in the number of rhizomes produced, their length

Effect of High, Medium, and Low Concentrations of Potassium on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut

Figures represent weight in grams

	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High potassium.....	54.9	35.5	90.4	27.3
Medium potassium..	37.6	40.9	78.5	20.0
Low potassium......	31.9	22.5	54.4	14.5
Uncut				
High potassium.....			100.0	40.5
Medium potassium..			98.2	29.0
Low potassium......			61.3	15.4
Experiment conducted in the open				
Cut to form turf				
High potassium.....	42.5	66.0	108.5	12.2
Medium potassium..	29.3	52.3	81.6	7.0
Low potassium......	7.2	18.0	25.2	3.0
Uncut				
High potassium.....			135.0	34.5
Medium potassium..			130.2	22.0
Low potassium......			102.0	11.5

and tendency to branch, all increasing as the potassium concentration of the nutrient solution increased. Variations in the nitrogen content of the solution produced somewhat similar effects on rhizome growth. This affords a further suggestion that some close connection exists between the utilization of nitrogen and potassium by grass plants.

Calcium

Some calcium is essential to the growth of all types of green plants. In these tests it was found that a large supply is in itself not directly necessary for the growth of the turf grasses used experimentally. It is true, however, that a fairly good supply of calcium in some soils may be beneficial to turf grasses. This applies particularly to calcium present as lime, the beneficial chemical and physical effects of which are well known. The absorption of calcium is known to be increased by sunlight, and there is some evidence in these experiments that plants grown in the open in full sunlight could obtain sufficient calcium from low-calcium solutions, whereas in the greenhouse higher concentrations were beneficial. The low-calcium solutions used in the greenhouse and out-of-doors experiments were in some respects not alike, and consequently it would not be advisable to draw any very definite conclusions as to differences in calcium requirements under conditions in the greenhouse and in the open.

There was evidence that the clipped grass was somewhat more unfavorably affected by having only a small quantity of calcium supplied than the unclipped grass. The roots of the low-calcium plants were considerably coarser and less branched than those of the medium and high-calcium plants. The foliage of the low-calcium cut plants was of a somewhat lighter color than that of the plants receiving more calcium. A slight stunting of the low-calcium plants was also evident.

Magnesium

Magnesium is required by all green plants for the production of the substance called chlorophyll, which gives them their green color. it may possibly have other uses in the plants, but none other is definitely known. The small quantity of magnesium supplied in the

Effect of High, Medium, and Low Concentrations of Calcium on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut

Figures represent weight in grams

	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High calcium	46.3	39.4	85.7	29.5
Medium calcium	37.6	40.9	78.5	20.0
Low calcium	30.4	25.5	55.9	10.5
Uncut				
High calcium			96.0	33.5
Medium calcium			98.2	29.0
Low calcium			60.0	8.5
Experiment conducted in the open				
Cut to form turf				
High calcium	38.9	65.5	104.4	8.5
Medium calcium	29.3	52.3	81.6	7.0
Low calcium	19.2	53.0	72.2	7.0
Uncut				
High calcium			128.0	27.5
Medium calcium			130.2	22.0
Low calcium			125.0	24.5

Effect of High, Medium, and Low Concentrations of Magnesium on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut

Figures represent weight in grams

	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High magnesium	42.7	47.5	90.2	22.2
Medium magnesium	37.6	40.9	78.5	20.0
Low magnesium	33.0	33.6	66.6	10.0
Uncut				
High magnesium			103.5	29.0
Medium magnesium			98.2	29.0
Low magnesium			63.5	9.5
Experiment conducted in the open				
Cut to form turf				
High magnesium	28.9	54.5	83.4	9.0
Medium magnesium	29.3	52.3	81.6	7.0
Low magnesium	23.6	57.5	81.1	8.5
Uncut				
High magnesium			146.5	21.5
Medium magnesium			130.2	22.0
Low magnesium			160.0	31.0

low-magnesium solution in the second experiment was sufficient for normal growth in regard to size. The color of these plants was abnormal. The leaves were a dull pale green. Those of low-magnesium plants grown in the greenhouse were considerably tinged with red. The cut plants grown in the greenhouse were benefited by having at least a medium supply of magnesium in the nutrient solution.

Sulphur

Only a very small quantity of sulphur is required for growth, and this is adequately supplied in most soils. However, the addition of sulphur to some types of highly alkaline soils is very definitely beneficial to some crops. This remedial effect of sulphur, however, is undoubtedly an indirect one. By its action in the soil it may release other elements, such as potash and phosphorus, which may be present in the soil chiefly in insoluble forms. It is also possible that it has beneficial physical effects upon some kinds of soils.

Effect of High, Medium, and Low Concentration of Sulphur on Growth of Tops and Roots of Metropolitan Creeping Bent When Cut to Form Turf and When Uncut

Figures represent weight in grams

	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High sulphur	44.3	36.8	81.1	27.0
Medium sulphur.....	37.6	40.9	78.5	20.0
Low sulphur	46.6	36.0	82.6	34.5
Uncut				
High sulphur			99.0	29.5
Medium sulphur.....			98.2	29.0
Low sulphur			91.0	29.7
Experiment conducted in the open				
Cut to form turf				
High sulphur	22.6	50.5	73.1	5.0
Medium sulphur.....	29.3	52.3	81.6	7.0
Low sulphur	14.3	38.0	52.3	5.2
Uncut				
High sulphur			148.5	19.5
Medium sulphur.....			130.2	22.0
Low sulphur			137.0	32.5

Grass plants suffering from sulphur deficiency have slightly yellowish green foliage. The coloration is much like that of nitrogen-deficient plants. The low-sulphur cut plants kept in the open during the summer grew somewhat less than plants receiving more sulphur. With this one exception it was found that neither the total growth nor the proportion of roots to shoots was influenced to any extent by variations in the sulphur content of the nutrient solution.

Effects of Cutting

In all of the tests with Metropolitan creeping bent involving the six different elements and at the three concentrations it may be observed that cutting of the tops had a very restricting effect on the growth of roots. This was also true of the other three types of grasses.

Summary

It is well known that a supply of available nitrogen must be preserved in the soil in which turf grasses are grown in order to maintain a pleasing green color as well as to provide for growth. In view of the results here shown it would be highly desirable to maintain the other mineral elements, with particular attention to phosphorus and potassium, in some degree of proportion to the nitrogen.

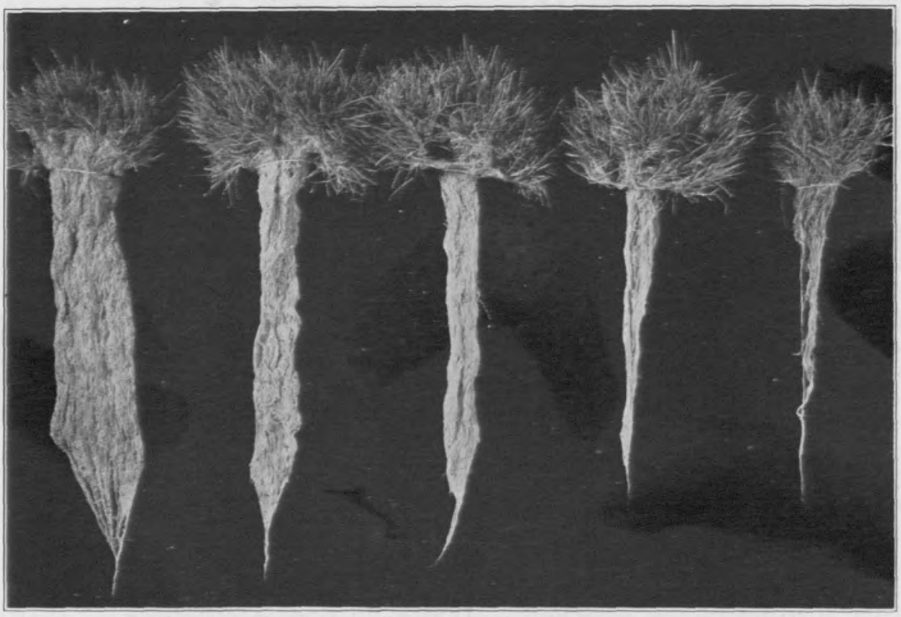
Effects of Shade on the Growth of Velvet Bent and Metropolitan Creeping Bent

By Mary E. Reid

Many putting greens are situated in partially shaded locations. It has frequently been observed that under some conditions a certain degree of exclusion of sunlight may be beneficial but under other conditions may be detrimental to turf of putting greens and also to other parts of a golf course. Shading may vary as to intensity, quality, and time of day when it occurs. Some trees with dense foliage may be situated so as to exclude all direct sunlight over a certain area of a golf course, whereas others, with a different type of foliage, may produce a speckled shade, allowing considerable direct sunlight to filter through. The differences thus produced in size and shape of shaded areas in relation to size of individual grass plants constituting the turf is a matter of primary importance. If only certain portions of a plant are shaded, the effects on growth differ from the effects if the entire plant is shaded. There is a possibility, also, that shading in the forenoon may cause different effects from shading in the afternoon. It has, in fact, been observed that grass growing in areas shaded in the forenoon and later suddenly exposed to full sunlight may wilt more quickly than grass in areas exposed all day to full sunlight. Moreover, the soil in the full sunlight area may actually appear to be drier than that in the areas in which the grass suffers from wilting.

A possible explanation for this peculiar behavior may be found in the effects of shading on the development of the roots, as is shown in the results of some experiments conducted during the past summer. Although these tests dealt chiefly with velvet bent and Metropolitan creeping bents, it is considered probable, on the basis of general observations, that other grasses, such as Kentucky bluegrass, would respond similarly to the effects of shading. The grasses experimentally employed were grown both in pots and in plots under turf conditions. The results with velvet bent and Metropolitan creeping bent grown in pots were so striking that it seems worth while to report them here briefly. In one experiment a liberal supply of superphosphate was mixed into the clay loam soil used for the test, and in another a small addition only of superphosphate was made. In the experiments with velvet bent a relatively light addition of sulphate of ammonia was also made.

Cultures in duplicate of velvet bent were grown under each of the following conditions: full sunlight; sunlight until 12, then shade; shade until 12, then full sunlight; speckled shade; and moderately deep shade. Shading was accomplished by setting the cultures under trees in locations which would furnish the desired conditions. Plants which had developed from a single plant of the 14276 strain of velvet bent were planted, the same number in each pot. The grass was cut to a height of ¾ inch several times during the course of the experiment. The water content of the soil of the various cultures was kept approximately uniform.



Cultures of velvet bent grown under five different conditions of light. Reading from left to right, (1) fully exposed to sun all day, (2) fully exposed to sun forenoon only, (3) fully exposed to sun afternoon only, (4) speckled sun all day, (5) shade all day.

The yield in grams of clippings from cultures grown under the different light conditions employed is shown in table 1. The grass kept in full sunlight grew more rapidly during the early phases of the experiment, but by the time the first cutting was made, September 10, there was no difference between the yield of clippings from these cultures and those which received full sunlight only in the forenoon. Plants that were kept in direct sunlight in the afternoon only did not grow quite so rapidly as those which were in sunlight in the forenoon only. Throughout the course of the experiment, growth of the grass shaded the entire day was much less rapid than

TABLE 1.—EFFECT OF SHADE ON VELVET BENT.

WEIGHT (IN GRAMS) OF CLIPPINGS OBTAINED AT THREE DIFFERENT DATES UNDER VARIOUS CONDITIONS OF LIGHT.

	Sun all day	*Sun forenoon only*	*Sun afternoon only*	*Speckled sun all day*	*Shade all day*
September 10	9.9	10.0	7.6	7.9	3.8
September 26	4.6	7.7	5.5	5.3	1.7
October 12	8.3	8.8	9.0	9.0	1.1
Total green weight of clippings	22.8	26.5	22.1	22.2	6.6
Total dry weight of clippings	5.2	5.7	4.7	3.5	1.6

that of cultures receiving direct sunlight for either the entire day or for half a day. Plants grown in speckled sunlight produced about the same yield of clippings as those grown in full sunlight all day or half of each day. During the latter part of the experiment the plants kept in full sunlight all day grew less rapidly than those kept in sunlight only part of the time. Undoubtedly this was because scarcity of nitrogen had become a limiting factor in growth. At the end of the test the leaves of these plants were of a lighter and more yellowish green color than those of the others,—a condition here considered to be indicative of nitrogen starvation. If more nitrogen had been supplied, undoubtedly the differences in growth between plants in sun all day and those in shade would have been considerably greater than they were in this test.

TABLE 2.—EFFECT OF SHADE ON VELVET BENT.

WEIGHT (IN GRAMS) OF TOPS AND ROOTS PRODUCED AT END OF TEST (OCTOBER 30) UNDER VARIOUS CONDITIONS OF LIGHT.

	Sun all day	*Sun fore-noon only*	*Sun after-noon only*	*Speckled sun all day*	*Shade all day*
Green weights:					
Tops	25.3	27.9	25.4	28.5	10.5
Roots	44.4	18.1	14.3	7.4	2.9
Total	69.7	46.0	39.7	35.9	13.4
Dry weights:					
Tops	6.1	5.7	5.1	4.6	2.1
Roots	9.8	3.1	2.5	1.4	.5
Total	15.9	8.8	7.6	6.0	2.6
Ratio of tops to roots:					
Green weight	.6	1.5	1.7	3.9	3.6
Dry weight	.6	1.8	2.1	3.2	3.9

Table 2 shows the weights of tops and roots of the grass at the end of the experiment, October 30, and the illustration shows the appearance of the plants. The weights of tops and roots of duplicate cultures for each of the five different conditions of illumination were in close agreement with those of the corresponding plants shown in the photograph. There was not much difference in the growth of tops of the first four groups, all of which received some direct sunlight. The shaded plants had much less branching at the crown than those of the four groups receiving direct sunlight. The leaves were long, slender, weak, and of a bright but comparatively light green color. During the ten weeks' period of growth a complete ground cover was not produced, as was true under each of the four other conditions for growth. The individual plants could be readily discerned.

In contrast to the similarity in yield of tops of the four groups of plants receiving some direct sunlight were the striking differences in the weight, number, and length of roots produced. There appeared to be a direct relation between the amount of root growth and the length of daily duration of exposure to direct sunlight,—the longer the period, the larger the root system. The plants grown in full sunlight produced a dry weight of roots 18 times greater than the plants grown in shade, 7 times greater than those grown in speckled shade, and more than 3 times greater than those receiving full sunlight in the forenoon or afternoon only.

Table 3 summarizes the quantitative results of the entire experiment (clippings plus plants at final harvest) calculated on a green-weight basis. The differences in ratios of weights of tops to weights of roots under the different conditions for growth suggest an important reason why grass may wilt more quickly under one condition than under another. If atmospheric conditions are such as to produce rapidly drying effects, plants with poorly developed root systems will naturally suffer more quickly than those with extensively developed roots.

TABLE 3.—EFFECT OF SHADE ON VELVET BENT.

SUMMARY OF RESULTS SHOWN IN TABLES 1 AND 2 (FOR GREEN WEIGHTS ONLY) AT TIME OF FINAL HARVEST.

	Sun all day	*Sun forenoon only*	*Sun afternoon only*	*Speckled sun all day*	*Shade all day*
Cuttings, total weight (table 1)	22.8	26.5	22.1	22.2	6.6
Tops Oct.30 (table 2) ..	25.3	27.9	25.4	28.5	10.5
Tops, grand total ..	48.1	54.4	47.5	50.7	17.1
Roots, total weight (table 2)	44.4	18.1	14.3	7.4	2.9
Ratio of tops to roots ..	1.1	3.0	3.3	6.9	5.9

The unfavorable effects resulting from weakly developed root systems are usually augmented by another factor. When exposed to conditions favoring rapid evaporation, such as high temperature, dry atmosphere, and wind, some grasses have a greater tendency than most plants to give off moisture through the leaves faster than they take it in through the roots. Their leaves are thus rather poorly adapted for conserving moisture. The mechanism controlling the opening and closing of the breathing pores may be less effectively developed for conserving moisture than that of most other types of leaves.

If velvet bent were grown in situations having a comparatively moist atmosphere in which there would never be danger of producing dessication effects (such as those previously mentioned, in which a weakly developed root system would be inadequate for its needs), it might thrive in partially shaded situations as well as if not better than in full sunlight. As far as top growth is concerned, there is evidence that in partial shade it may grow as well as if not better than in full sunlight. Its response to sunlight or partial shade would be dependent upon the type of soil. In poor soils it might grow faster in partial shade; in highly fertile soils faster in full sunlight.

Somewhat similar experiments were also conducted with Metropolitan creeping bent. Some cultures were grown in full sunlight, others in partial shade. The latter condition was attained by placing the plants under a lath screen so constructed as to reduce the direct sunlight to less than one-half the normal amount. The 1½-inch laths were placed 1 inch apart with a north-to-south direction. With this arrangement every portion of each culture was in direct sunlight for a portion of the day.

It was found that Metropolitan creeping bent was less tolerant of shade than velvet bent. The tops of the partially shaded plants grew so slowly that it seemed advisable to leave them uncut throughout the course of the experiment. As with velvet bent, there was very little proliferation, the stems were weak, internodes long, and the leaves light green in color. Table 4 gives the quantitative results. It may be observed that shading had a more restricting effect on root than on top growth. The green weight of roots of the plants kept in full sunlight was 8 times greater than that of the partially shaded plants. Under the experimental conditions employed, there was no benefit in any way resulting from the shading of the Metropolitan bent. Possibly some benefits might have been observed had somewhat more light been provided to the partially shaded cultures.

TABLE 4.—EFFECT OF SHADE ON METROPOLITAN CREEPING BENT.
WEIGHT (IN GRAMS) OF CLIPPINGS, TOPS, AND ROOTS PRODUCED UNDER FULL SUNLIGHT AND PARTIAL SHADE.

	Full sunlight	*Partial shade*
Weight of clippings removed at end of experiment	24.7	Left uncut
Weight of tops at end of experiment	40.2	19.3
Total weight of clippings and tops	64.9	19.3
Weight of roots at end of experiment	19.4	2.3
Ratio of weight of tops to roots	3.3	8.3

The results of these experiments as shown in the tables and photograph give definite evidence that shade, if not too intense, may have a beneficial effect upon top growth of velvet bent in a soil of low fertility, but that root growth may be dangerously restricted, the reduction being approximately in proportion to the degree of exclusion of light. No beneficial results of shading Metropolitan creeping bent were observed under the conditions of shading employed. It is possible, however, that somewhat different results would be obtained if the plants were under less shaded conditions.

Violet rays an aid in seed identification.—Although it makes little difference to southern golf clubs whether they use perennial (English) ryegrass or Italian ryegrass as a winter turf on their dormant Bermuda greens, the seed analyst is often called upon to identify these two kinds of seed. Sometimes seeds of these two grasses are indistinguishable by ordinary means. It has been discovered that violet rays would produce a glow on white filter paper on which the roots of certain plants are growing. With ryegrass seeds it is found that these rays when falling upon paper on which Italian ryegrass seeds are germinating will produce this glow, but not so with perennial ryegrass seeds. The reason for this peculiar behavior of the two varieties of seed is an entire mystery, but the test is admirably adapted for identification of the two varieties. The first experiments were conducted with a special violet-ray lamp, but later experiments revealed that an ordinary lamp would answer the purpose if a special light filter is used to shut out the visible rays.

Chemical fertilizers may be mixed with compost at any time that is convenient provided the compost is kept under cover. These fertilizers do not lose their strength under such conditions.

Relationship Between Fertilizing and Drainage in the Occurrence of Brownpatch

By Arnold S. Dahl

The grass on putting greens tends to grow more slowly and to be weaker in the hot periods of the summer than in the cooler periods of the growing season, when a very rapid and vigorous growth takes place. Many greenkeepers desire to keep the turf growing as vigorously in the summer as during the cooler months of the spring and fall. Abundant fertilization or poor drainage particularly during the late spring and summer may cause a restriction of the root system, and shallow-rooted plants thus produced find it difficult to survive the unfavorable periods of the summer. Abundant fertilization may also cause an overstimulation of the grass which, although producing a turf apparently healthy and vigorous, yet leaves it particularly susceptible to fungus diseases and other injuries that may occur during the hot periods of the year.

For some time there has been a need for more definite information as to the correlation between fertilization and drainage and the occurrence of disease. Many observations have been made, and reports of experimental work at the Arlington turf garden given, as to the greater severity of disease on succulent fast-growing turf as opposed to a harder and slower-growing turf. A careful check on these observations and reports was thought to be desirable, especially on areas which were well drained and those poorly drained. A series of plots was therefore planned which would contain areas heavily fertilized, areas lightly fertilized, and areas not fertilized. These plots were laid out side by side with a series on well drained soil and a duplicate series on poorly drained soil.

The area selected for these tests is located under conditions that are favorable to severe attacks of brownpatch. It is on a low area on Arlington Farm on the bank of a river. The lower part of the area is not tile-drained and is only a few feet above the water level at high tide, and occasionally the water comes up to within a few feet of the turf. Another part of the area is raised four feet above the low level; this section is tile-drained and the water is carried off within reasonable time. The subsoil in this area is a silt loam and the topsoil a rich loam. The plots were 2 years old at the beginning of the 1933 season. The turf was of colonial bent, being selected for the purpose because of its susceptibility to brownpatch.

The whole area is surrounded by trees, so that most of it is shaded a greater part of the day. This retards evaporation of water, and the soil dries very slowly after a rain. The trees also form an air pocket so that winds are checked and the air drainage is very poor. During the past season of 1933 there has been an abundance of rainfall, which has kept the lower part of the area almost constantly soaked with water and supplied the upper part with more water than it would ordinarily have had with artificial watering. At one time during the season a flood from the river brought the water up so that the higher area was under water for several hours. All of these conditions are favorable to severe attacks of brownpatch and under such severe conditions brownpatch was at least slightly active on 89 per cent of the days from June to mid-September and severe attacks occurred on 56 per cent of the days during the same period.

The fertilizer selected for these tests was sulphate of ammonia, since it is readily available to the plants and causes a succulent growth and a quick response of the grass. This fertilizer when applied abundantly makes grass more susceptible to brownpatch, as has been proved in other tests that have been made previously. The treatments were divided into three classes—heavily fertilized, lightly fertilized, and checks which received no fertilizer. The heavily fertilized plots received 23 pounds of sulphate of ammonia to 1,000 square feet during the period from April to August. The first applications were at the rate of 5 pounds to 1,000 square feet. This rate was cut to 4 pounds in the early summer, and 3 pounds were applied during the midsummer period. This amount of fertilizer may not be considered overfertilization on many putting greens, particularly for greens on sandy soil, but for greens located in low pocketed areas with poor drainage and stiff soil it proved much more than is necessary or good for the turf.

The lightly fertilized plots received 8 pounds of sulphate of ammonia for the same period. The first application of the year was at the rate of 5 pounds to 1,000 square feet, and 1 pound to 1,000 square feet in the subsequent treatments. This amount of fertilizer was sufficient to keep a good growth of grass on the plots during the season, and in a drier year when the fertilizer would not have leached out as quickly less might have been applied to obtain a lightly fertilized turf.

During the month of May all of the plots were given fungicidal treatments to check brownpatch so as to give the grass a chance to respond to the fertilizer before the advent of the brownpatch season in June. These treatments consisted of 3 ounces of corrosive sublimate and calomel in the proportion of 1 part of corrosive sublimate to 2 parts of calomel mixed with topdressing and watered. After June 1 only half of each plot was treated for brownpatch and the other half was left untreated for the rest of the season. The treatments during June were at the rate of 2 ounces to 1,000 square feet and during the rest of the summer at the rate of 1 ounce to 1,000 square feet. Where an ounce of fungicide was applied, corrosive sublimate alone was used because of its rapidity in checking the disease, which became so serious that treatments had to be applied frequently.

Brownpatch developed in the untreated areas during most of the summer. There were only a few days when the disease was not active on some part of the test plots. During the summer, only on one or two occasions did any brownpatch appear in the treated areas, and on those occasions the attacks were small isolated spots which did little damage. It was necessary to treat every week, and in some weeks when it was hot and humid it was necessary to treat oftener than once a week.

On these plots, where every condition was favorable to severe and frequent attacks of brownpatch, almost complete control was obtained. At the end of the season some of the untreated plots were almost completely covered with areas injured by the disease, and many of these areas had to be reseeded to reestablish the turf.

During the course of the experiment the occurrence of brownpatch on the untreated plots was noted. A record of severe and light attacks was kept; the accompanying table gives a summary of these records. In making this arbitrary division between light and severe attacks consideration was given to the total number and size of affected areas as well as to the amount of damage resulting from the attack. Therefore an attack which affected a large proportion of turf might be classed as a light attack if the total damage to the turf was light. On the other hand, if an attack resulted in serious damage to turf it might be regarded as a severe attack even though a relatively small amount of turf was involved. As a general rule, however, there was a direct relation between the area affected and the amount of injury resulting from any attack.

NUMBER OF ATTACKS OF BROWNPATCH ON HEAVILY AND LIGHTLY FERTILIZED PLOTS AND ON CHECK PLOTS ON WELL DRAINED AND POORLY DRAINED AREAS.

	WELL DRAINED			POORLY DRAINED		
	Heavily fertilized	*Lightly fertilized*	*Check*	*Heavily fertilized*	*Lightly fertilized*	*Check*
Severe attacks	26	18	12	27	27	18
Light attacks	15	19	18	14	14	24
Total	41	37	30	41	41	42

It will be noted from the table that on the well drained areas the heavily fertilized plots had 26 severe attacks of brownpatch while the lightly fertilized plots had 18 and the checks only 12. The heavily fertilized plots had fewer light attacks of the disease than the lightly fertilized or the check plots. However, the heavily fertilized plots had a total of 41 attacks of disease, which is 37 per cent more than the checks. The lightly fertilized plots had a total of 37 attacks, or 21 per cent more than the checks. There is not a great difference between the total number of attacks on the lightly and heavily fertilized areas, but the attacks that did occur on the heavily fertilized plots were much more severe.

The first occurrence of the disease in the season took place on the heavily fertilized plots, and these attacks were severe. The first few attacks that occurred on the lightly fertilized plots were light compared to those on the heavily fertilized plots. Later in the season severe attacks occurred on both the heavily and lightly fertilized areas. This indicates that when the turf is succulent and growing fast the grass is more susceptible than when it is not. In the early part of the year, when the temperature is not as favorable for the fungus, the disease will not develop as severely if the grass is not particularly susceptible. Later in the season, when temperature conditions are more favorable for the development of the fungus, the disease may attack grass which is not succulent and susceptible.

On the poorly drained area the heavily and lightly fertilized plots had the same number of severe and light attacks, 27 and 14 respectively. The number of severe attacks on the fertilized plots was 50 per cent greater than on the unfertilized check plots. The check plots had more light attacks than the fertilized plots and about the same total number of attacks, but the damage they caused was much less severe. In this area the moisture content of the soil was high at all times and conditions were favorable for the development of the disease. The fungus attacked the grass whether it was fertilized or not, but the unfertilized grass suffered far fewer severe attacks and was not as severely injured.

The heavily fertilized plots had about the same number of severe and light attacks on the well drained as on the undrained areas. This indicates that when too much fertilizer is applied disease will occur as frequently on well drained as on poorly drained turf. However, the injury is often more severe and the grass does not recover as quickly on the poorly drained areas. On the lightly fertilized plots there were 50 per cent more severe attacks on the poorly drained than on the well drained areas. The poorly drained check plots also had 50 per cent more severe attacks than the drained check plots. In both instances there were more light attacks on the well drained than on the poorly drained plots, showing that when conditions were favorable for fungus growth the attack was apt to be more severe on the poorly drained than on the well drained plots. The total number of attacks on the poorly drained check plots was 40 per cent greater than on the well drained check plots, so that evidently the rapid draining of the water gave the turf some measure of protection from the disease.

Severe attacks of brownpatch can in a large measure be prevented or lessened in many cases by providing good drainage. On putting greens where a healthy and vigorous growth of turf is desired at all seasons of the year every means should be taken to encourage such healthy and vigorous growth. Therefore the green should be provided with drainage, both surface and underdrainage, efficient enough to remove excessive water with reasonable rapidity during wet seasons.

The conclusion may be drawn from these experiments that overfertilization of turf and poor drainage may cause frequent and severe attacks of brownpatch. The time to fertilize and the amount of fertilizer to apply depend on the condition of the grass, the location of the putting greens, drainage, amount of rainfall during season, type of soil, weather conditions, natural richness of soil, and type of grass. It is not possible to give a general recommendation of the amount and kind of fertilizer to apply to greens, since each green must be treated differently, according to its requirements and to the season. It is important, however, to be careful with fertilizers and to apply only as much as is necessary to keep the turf in good putting condition without making it succulent. Turf on poorly drained areas may be much more seriously injured by overfertilization than turf on well drained areas, and when grass is injured by disease or any other condition recovery is much slower on poorly drained areas. Less fertilizer is needed to keep grass in a healthy condition on poorly drained soil, because there is no leaching of plant nutrients; such grass tends to grow more slowly, and less fertilizer is used in a certain period of time.

The title "poor man's weatherglass" has been earned by a species of nonpoisonous mushroom of the genus Geaster (earth star), which serves as a barometer on account of its sensitivity to changes in atmospheric humidity. It grows in woods and sandy places and on partly cleared land. The two outer coats of its puffball split into sections which remain united at the top of the ball. These two coats however do not absorb moisture in the same degree, with the result that when the relative humidity is high the sections of the outer coats stand out from the plant, and when the humidity is low the inner coat contracts more than the outer coat so that the sections curve sharply inward. This mushroom is also known as the barometer earth-star.

Usefulness of Kentucky Bluegrass and Canada Bluegrass in Turfs as Affected by Their Habits of Growth

By Morgan W. Evans and John E. Ely
Bureau of Plant Industry, United States Department of Agriculture

There are two species of grass belonging to the genus Poa commonly known as bluegrasses, both natives of the Old World but now very widely disseminated in North America which have become of great economic importance here. One of them, Kentucky bluegrass (*Poa pratensis*), is very extensively used in lawns, on the fairways and tees of golf courses, and elsewhere for turfs. It is quite commonly regarded as the best grass for these purposes. The other, Canada bluegrass (*Poa compressa*), is rarely or never used on lawns or in similar situations.

Each of these grasses has its own peculiar soil requirements. Although both grow under the climatic conditions existing in the humid parts of the northern United States and southern Canada, sometimes even in the same vicinity, yet usually they do not grow in mixture. Generally, Kentucky bluegrass grows on comparatively fertile soils, Canada bluegrass on poorer soils. In some localities, its ability to thrive under conditions unfavorable to Kentucky bluegrass makes Canada bluegrass a valuable species for pastures or even for meadows. A striking illustration of the differences in adaptability of these grasses was observed, a number of years ago, along a roadside near New London, Ohio. Kentucky bluegrass was growing in an almost pure stand in the surface soil along the fence separating the roadway from the adjacent field. Near the roadbed there was a cut, on the sloping face of which the subsoil was exposed. On this subsoil there was a practically pure stand of Canada bluegrass. The line of demarcation between the areas occupied by the two grasses was as distinct as the differences between the soil and subsoil.

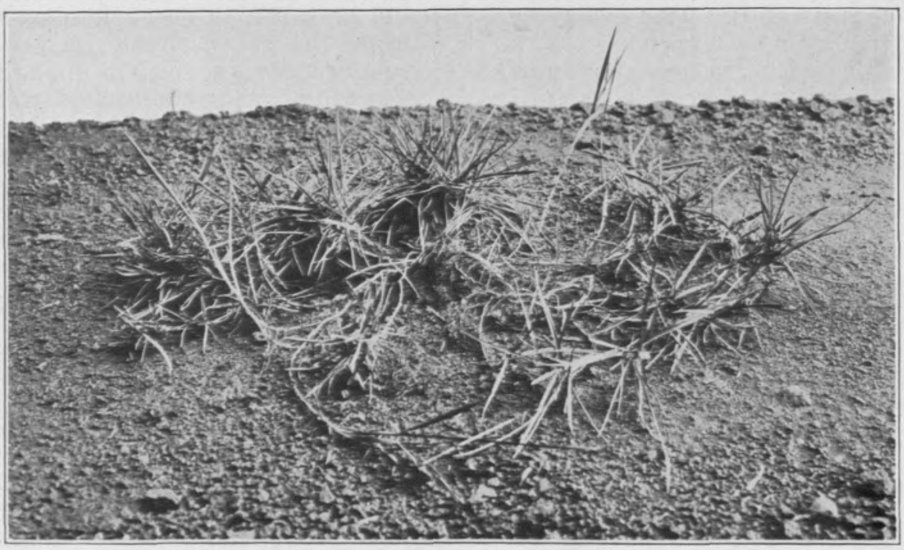


Figure 1.—A plant of Kentucky bluegrass. The soil has been removed so that the underground rooting stems are visible.

Canada bluegrass might have some value for turfs, if it did not have certain habits of growth which make it almost wholly unfitted for this purpose. Some of the differences in the habits of growth of Kentucky bluegrass and Canada bluegrass are illustrated in figures 1 and 2. These photographs were made on May 3, 1932. Each plant had developed from a single stem or shoot, like those illustrated in figure 4, which was transplanted about the middle of May, 1931. On the day when the photographs shown in figures 1 and 2 were made, each plant was dug up, and the soil was carefully washed away from the roots and the underground rooting stems. The plants are shown in the illustrations with about the same arrangement of their parts as they had when growing in the soil.

Both grasses grow and spread outwards in the same way—namely, by means of underground rooting stems, technically known as rhizomes. After one of these rhizomes has continued its growth, usually for several months, and has extended outwards for a distance of perhaps several inches from the point of its origin, it turns upwards to the surface of the soil. From the bud or growing point at its tip, an above-ground shoot forms.

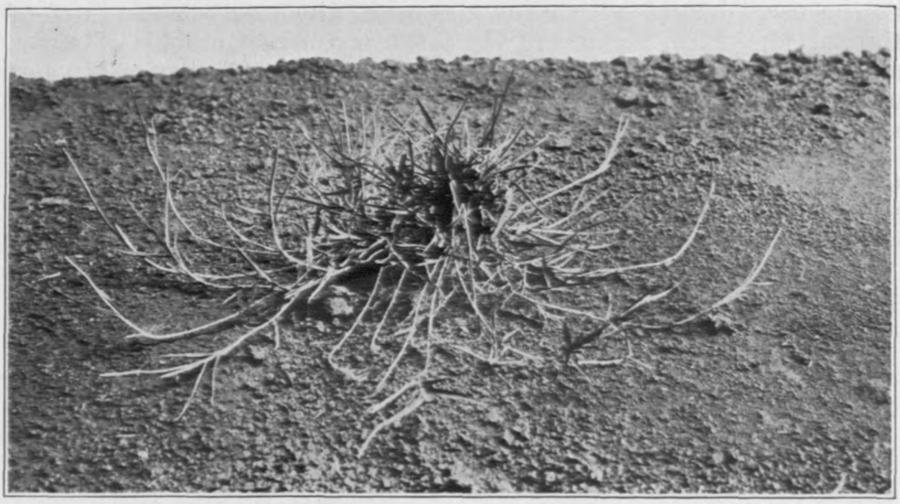


Figure 2.—A plant of Canada bluegrass, with the rooting stems exposed to view. Canada bluegrass plants are less leafy than those of Kentucky bluegrass.

At this stage of their development, an important difference occurs in the growing habits of the two species. On the plants of Kentucky bluegrass, at all times during the spring, summer, and fall, new branch shoots continue to form on older ones. On the plants of Canada bluegrass, on the other hand, during the spring and summer relatively few branches grow on the shoots which terminate the rooting stems. Although during the fall, on the stems of Canada bluegrass, branches do develop in large numbers, even then the leaves do not create the appearance of leafiness characteristic of the plants of Kentucky bluegrass.

The tendency of the plants of Kentucky bluegrass to produce numerous branch shoots and leaves, and the opposite tendency in the plants of Canada bluegrass, are indicated in figures 1 and 2.

The stems also of Kentucky bluegrass and of Canada bluegrass differ in the manner in which they grow in length. This difference largely explains the adaptability in the one, and the lack of it in the other, for use on closely mown turfs.

Except in the spring, on those shoots which produce seed heads, the stems of Kentucky bluegrass make a hardly perceptible growth in length. The growing point from which new leaves arise on each stem consequently remains near the surface of the soil. If the grass is cut with a lawn mower, the bases of the older leaves remain attached to the shoot, and new leaves continue to be produced from the growing point.

In the stems of Canada bluegrass, on the other hand, at all or nearly all seasons of the year when active growth takes place, the internodes of which they are composed become elongated, usually to at least a considerable fraction of an inch in length. As a result of this elongation, the growing point from which new leaves form gradually becomes elevated above the surface of the soil, where it is likely to be cut off, if the turf of which the stem is a part is mowed at the usual height with a lawn mower. The newly mown turf of Canada bluegrass, because of the large number of stubble of stems and relatively few leaves, has an appearance somewhat suggestive of a scrubbing brush. The sparsely leafed Canada bluegrass turfs which are mowed at frequent intervals make a thin covering of the soil. Experience has shown that other grasses and weeds encroach into a Canada bluegrass lawn to a much greater extent than in lawns of grasses which maintain a more dense soil cover of leaves, such as there is in a good lawn of Kentucky bluegrass.

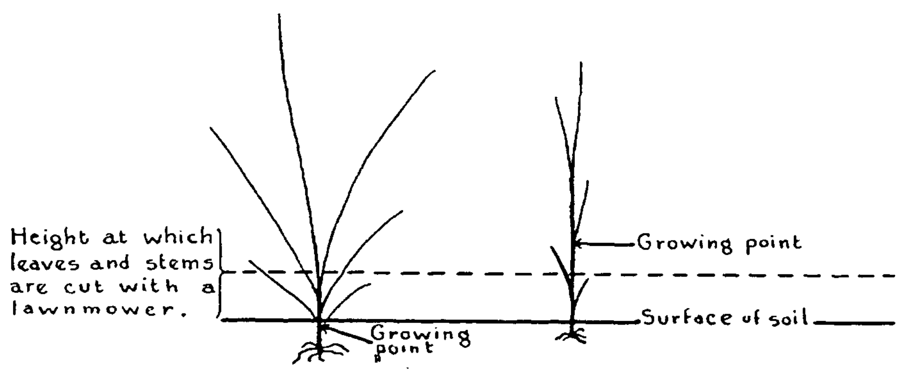


Figure 3.—Kentucky bluegrass (left), Canada bluegrass (right). The approximate positions of the growing points of the shoots are here shown with reference to height of cut and height of growing point.

The difference in the way in which the stems of Kentucky bluegrass and Canada bluegrass grow in length is illustrated diagramatically in Figure 3. The lower horizontal line represents the surface of the soil, and the upper one represents the altitude at which grass leaves and stems are cut with a lawn mower. In the Kentucky bluegrass plant at the left, which is composed of a single shoot with its leaves and roots, the position of the growing point is somewhere near the surface of the soil. In the plant of Canada bluegrass at the right, likewise composed of a single shoot, the growing point is above the elevation where the stem would be cut off by a lawn mower, consequently no further growth could take place from it after the lawn is mowed. In order that a shoot of this kind may resume its growth, enough time must elapse for buds near its base to expand and produce new branch shoots.

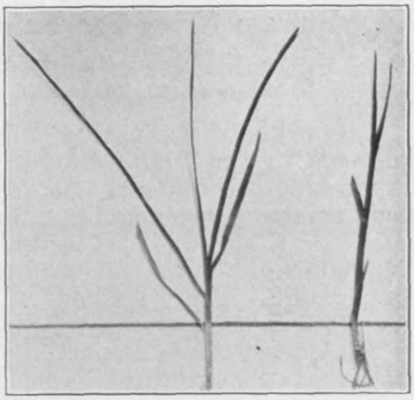


Figure 4.—The shoot at the left is from a plant of Kentucky bluegrass, the one at the right from a plant of Canada bluegrass. The growing point of shoots of Kentucky bluegrass usually are at or slightly beneath the surface of the soil; in the shoots of Canada bluegrass the growing points gradually become elevated above the surface of the soil.

In figure 4, an actual specimen of a shoot of Kentucky bluegrass is shown at the left, and one of Canada bluegrass at the right. If these specimens had been dissected, their growing points could have been found, probably at positions corresponding approximately to those indicated in the diagrams in figure 3. In a younger shoot of Canada bluegrass the growing point might be lower, where it would not be cut off by the lawn mower. As the shoot would become older, however, the stem eventually would become longer, and the growing point would become high enough to be cut off when the lawn is mowed at a later time.

Some greenkeepers find that they can treat their greens more quickly by the dry method of applying fungicides, and the absence of any need for costly equipment is also an advantage. In this method the chemicals are diluted by mixing them with dry soil or sand, to give them bulk so that they can be applied more easily and uniformly. Usually about 8 quarts of soil or sand is used for each 1,000 square feet of turf. The soil should be comparatively dry and finely-screened. It is necessary to obtain a uniform mixture of the chemical and soil and to pulverize all the lumps, for if any lumps are permitted to lie on the turf they are likely to cause severe burns. An efficient method of mixing the chemical with soil is to first mix it with dry, sharp sand; preferably about twice as much sand as chemical should be used. These are rolled together with a rolling pin or a piece of pipe. In rolling them together the lumps are broken by the grinding action of the sand. The rolling should be continued until a uniform mixture is obtained as indicated by the absence of streaks. This mixture of sand and chemical is then mixed with the soil and broadcast over the green.

Whether the fungicide is applied with a sprayer or by the dry method it is usually watered thoroughly immediately after the application.

Buffalo Grass for Fairways in the Plains States

By David A. Savage,
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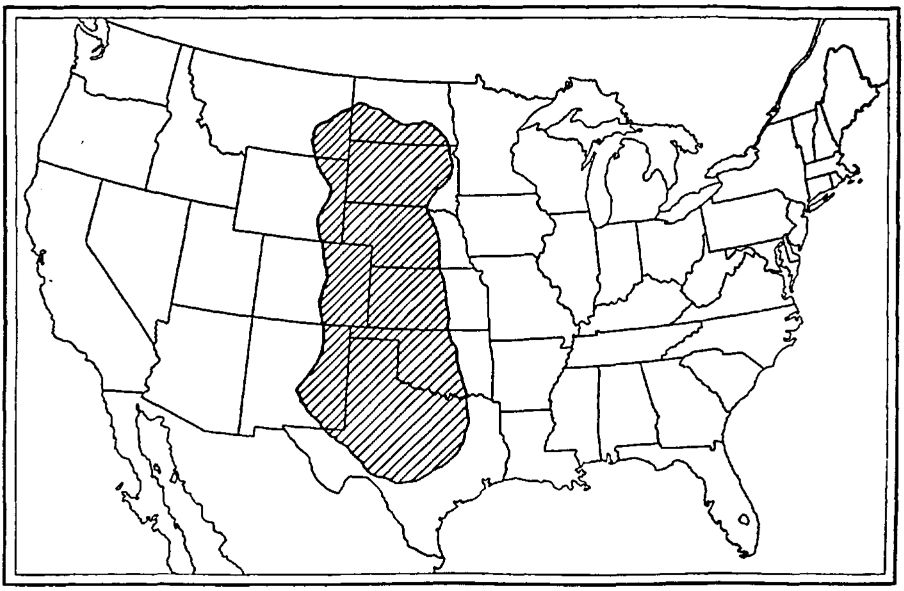
The value of the native buffalo grass (*Buchloe dactyloides*) for fairways in the Plains States has long been recognized by those familiar with the grass. As seed of this grass has, however, never been available commercially, due to the difficulty encountered in gathering it and due also to its low germination, all efforts to establish stands of the grass have been confined to vegetative methods of propagation. These methods of propagation have been under study since 1929 at the Fort Hays Branch Experiment Station, Hays, Kans., by the United States Department of Agriculture in cooperation with the Kansas Agricultural Experiment Station, and have now reached a stage which seems to warrant the recommendation of methods of propagation to golf courses interested in the establishment of this valuable grass on fairways in the Plains States.[1]



Area over which buffalo grass occurs naturally.

Buffalo grass occurs naturally over the area shown in the accompanying map. This area embraces over 500,000 square miles of the Great Plains. Throughout this region of major distribution there are many areas in which it occurs sparingly or not at all. It is found in purest stands on the plains west of the 99th degree of longitude in Kansas and east of the 5,000-foot contour line in Colorado. Scattered areas, varying in size from small patches to large meadows, occur east of the 99th meridian, but the principal grasses in this more humid section are the bluestems, which often give way to buffalo grass on the higher lands or when overgrazed. In the region where

[1] A more complete account of these experiments will be published by the United States Department of Agriculture, and in such form will be available to those interested.

it is most widely distributed, buffalo grass will require very little care or attention when once established on fairways. It also grows well and spreads rapidly in the marginal areas when protected from invasion.

Buffalo grass is best adapted to the heavier types of well drained upland soil in the area referred to above. It will not thrive on pure sand or on soils high in sand content, but has been found to grow well on sandy loam soil containing some clay. This grass is especially well adapted to the class of soils regionally referred to as "hard lands," which produce heavy yields of wheat and other crops when placed under cultivation and properly farmed.

The results of limited experiments conducted at this station indicate that buffalo grass may be propagated by setting out rooted or unrooted stolons in moist soil. The stolons will take root and grow in much the same manner as strawberry plants under especially favorable moisture conditions. This is a rather slow, tedious method and will succeed only if the soil is kept moist for some time after the stolons are set out. This method of propagation is not consistently successful on strictly dry land or practical on an extensive scale. Covering an entire area completely with sods is practical only for very small areas, such as lawns, where the chief consideration is immediate results without regard to the costs involved.

Transplanting Pieces of Sod

Source of supply of sods.—The buffalo grass sods should be obtained from a virgin stand of nearly pure buffalo grass. It is possible to find such areas in most localities throughout the central Great Plains. Most of these areas contain a small mixture of grama grass, which is not very objectionable. Under natural conditions buffalo grass occurs in mixtures containing about equal numbers of staminate and pistillate plants with occasional patches consisting of pure stands of one sex. Whenever it is feasible to do so the exclusive use of pistillate or so-called female plants for lawn or fairway purposes is preferred. A turf composed entirely of pistillate plants with leaves wholly covering the stems is much more attractive than a turf containing staminate or so-called male plants. The brown spikelets of the latter rise above the leaves and detract from the green appearance of the turf.

Cutting the sods.—For this purpose a sod cutter is preferred to a plow. The former disturbs the roots less and makes a smooth, clean cut which facilitates the handling and transplanting operations. A satisfactory sod cutter may be constructed with comparative ease and at little expense by bolting a sharpened U-shaped, flat steel blade on sled runners or frames similar to those on a walking plow. A series of holes bored in the vertical ends of the blade to which sliders are attached allows for adjusting the depth of the cut. The blade should be shaped so as to cut a strip of sod about 12 inches wide. When the soil is well moistened by heavy rains, a two-horse team can pull a 12-inch sod cutter. Where it is desired to cut the sods in strips narrowerer than 12 inches, vertical knives similar to the fins of a crowning plow may be fastened to the U-shaped blade, so that two or three strips, 4 to 6 inches in width, may be cut with one operation. These strips usually are cut with a sharp spade to the final size desired before loading them on a wagon or truck for transporting.

Cutting the sods in alternate strips, leaving an uncut area between, allows the buffalo grass to spread and rapidly heal the scars or furrows left by the cutter. Strips of sod cut in this manner in the spring of the year usually have become re-covered with grass by the end of the first season at Hays. If it is desired to maintain the original smooth surface of the prairie, these furrows may be filled in with fresh soil, taking care to leave no heavy deposit of soil on the adjoining uncut areas. A few years after this is done, it is impossible to detect that any sods had been removed. If the native sod is from sloping land, it is important to cut the strips on the contour to control erosion. Observance of these precautions will encourage the owners of buffalo grass grazing land to provide sods to those who have none of the grass available.

Rate of transplanting.—The amount of sod material required to transplant a given area of land depends upon the manner in which the work is done. An acre of cultivated land when transplanted with 4-inch cubes spaced 3 feet apart requires about 2 square rods of original sod material or a strip 12 inches wide and 538 feet long. Four and one-half times that amount or about 9 square rods are required when the cubes are spaced 2 feet apart, and 9 times the amount or 18 square rods when the sods are spaced 1 foot apart. Double broadcasting with a common manure spreader requires the use of sod material equivalent to the amount needed to space 12-inch squares of sod 3 feet apart. By this method 1/9 of an acre of sod, obtained by the alternate stripping of at least double that area of native grass, will cover an acre of cultivated land.

Optimum transplanting season.—Buffalo grass has been successfully transplanted at Hays every month from March to August, inclusive. The moisture content of the sods at transplanting time and the rainfall conditions afterwards determine the rapidity of spread to a greater extent than the particular month in which the work is done. The slight differences noted in the dates of transplanting indicate that the best time to move the sods is in March and April, preferably before spring growth has started and immediately following a heavy rain.

Sizes of sods.—Twelve different sizes, ranging in surface area from 2 to 17 inches square and in depth from 2 to 4 inches, have been compared in annual transplantings at this station since 1929. According to the results of these studies, the 4-inch cubes were the most convenient size to transplant and the most efficient in spread. Larger sizes spread faster but not so rapidly in proportion to their original areas. Large pieces may be used to advantage if it is found convenient to do so and the source of supply is plentiful. Smaller sods, particularly those 2 inches square and 4 inches deep, spread much more slowly than the 4-inch cubes.

Small sods, ranging in surface area from 2 to 6 inches square, spread considerably faster when cut to a depth of 4 inches than when cut to a depth of 2 inches. The spread of sods larger in surface area was not noticeably affected by the difference in depth of cutting.

Width of spacing.—Experiments in spacing buffalo grass sods were started at this station in 1929 and repeated each year thereafter. The results of these studies indicate that 4-inch cubes or pieces 6 inches square and 4 inches deep, when alternately spaced 1 foot apart, will spread to cover the intervening spaces in one year under local dry-land conditions. Similar sods spaced 3 feet apart required less than three years to make a complete cover of grass. At the end of five seasons the sods spaced 6 feet apart had spread to cover practically all of the intervening spaces, as shown in the accompanying illustration. Transplantings of the sod in solid rows 6 inches wide and 3 feet apart spread much faster but less efficiently, considering the amount of original sod material used, than individual sods spaced 3 feet apart. The alternate or off-set method of spacing the sods in rows resulted in more efficient spread and faster coverage of the intervening spaces than regular checked spacing.

Precautions in transplanting.—While buffalo grass may be transplanted with reasonable assurance of becoming established and spreading rapidly, considerable care is necessary when it is desired to obtain a smooth, even surface of grass. To accomplish this end, the land to be resodded should be leveled and graded well in advance. Imbedding the sods level with the surface of the ground, either in holes dug by hand or in carefully plowed furrows, is important if it is desired to use the resultant area for golf or lawn purposes. If the sods are set too deep, loose soil washes over them and retards the spread of the grass. If the sods are not set deep enough, the soil may erode from around them leaving the ultimate surface rather bumpy and unlevel. High winds also contribute towards a roughened condition of a transplanted area by blowing soil particles from around the sods and depositing dust in the grass. While care in transplanting is helpful in obtaining a smooth surface of grass, proper treatment after transplanting may serve to correct a rough surface condition caused by careless transplanting or wind and water erosion.

Methods of resodding large areas.—Resodding large areas is considered to be a practical possibility from a study of all the results obtained at this station.

Pieces of sod, varying in surface area from 2 to 17 inches square, and cut to a depth of 1 or 2 inches, have been successfully transplanted by merely dropping them on freshly and deeply cultivated land and pressing them level with the surface of the ground with a heavily weighted surface packer. This eliminates the tedious labor involved in digging holes or plowing furrows and setting the sods out by hand.

This time-saving method of transplanting, which has been rather well tested and found to be both practical and successful, may be put into practice in several ways. One suggestion is to cut the sods at a depth of 1 to 2 inches, using a 12-inch sod cutter equipped with erect dividing blades so as to cut three strips 4 inches wide at one operation. Cutting the strips into sods of a convenient length, 4 to 12 inches, may then be accomplished with rapidity, using a sharp spade. The sods are then loaded on a wagon or truck and hauled to the field, which has been disked or plowed to a depth of 4 inches and leveled.

A three-man crew can unload the sods in a comparatively short time. One man drives the truck or wagon and two men unload the sods. If the sods are thrown to the ground, they must be handled with reasonable care to prevent them from landing grass side down. To eliminate this possibility and save time, the sods may be unloaded in sheet-iron chutes fastened to the wagon and dragging on the ground far enough in the rear to prevent the sods from overturning as they slide off the incline. In this manner the sods are rapidly transferred from the wagon to the surface of the cultivated land, where they are pressed into the ground with a heavily weighted packer. If the nature of the soil is such as to cause some difficulty in packing the sods level with the surface of the ground, shovel attachments may be fastened to the bottom of the sheet-iron chutes, thus providing a furrow for the sods.

The unloading operation may be further facilitated by using a manure spreader with the reel removed and platforms fastened to the sides of the rear end for the unloading men to stand on. The driver can then operate the apron-moving lever and keep the men supplied with sods at the rear, so that there need be no delay in unloading. Such work should be started on the higher elevations, so that, if it is not completed at once, seed washing down from the higher land will assist in resodding the lower areas.

Broadcasting the turf.—Broadcasting small pieces of buffalo grass turf on recently cultivated land and packing afterwards has been successful only under favorable rainfall conditions at this station.

In 1930 a manure spreader was successfully used in broadcasting the sods. At first the sods were cut into small pieces the same as for broadcasting by hand, loaded on the manure spreader, and scattered with the machine. This distributed the sods rather evenly over the freshly cultivated ground but shook most of the soil off the roots, causing the grass to dry out rapidly. To overcome this difficulty and eliminate the task of chopping the sods into small pieces, shallow strips of sod in sizes as large in surface area as could be handled conveniently with a shovel were used. The spreader reel not only unloaded the sods satisfactorily but broke them up into rather small pieces without shaking so much soil off the roots, and scattered them rather evenly over the ground. The manure spreader in full gear was passed over the ground twice, leaving an even covering of small sods on the cultivate soil, which was firmly packed immediately after broadcasting.

This work was followed immediately by favorable rains, which caused most of the pieces of grass to renew growth satisfactorily. The spread of the grass was just as fast as that of 4-inch cubes transplanted 3 feet apart, and the final surface was smoother than that of the sods set out by hand.

Successful reestablishment of the grass also resulted from similar work conducted in 1931. However, the broadcasting operations in 1932 and 1933 were followed by periods of dry, windy weather, from which none of the grass survived, indicating that broadcasting is not a safe practice for all conditions.

Treatment After Transplanting or Broadcasting

Packing the land with a heavily weighted surface packer after the sods are set out or broadcast is altogether essential in securing a rapid start of the grass and assuring a smooth surface. Irrigating resodded areas is seldom necessary but may be helpful when the water is sparingly and judiciously applied. Too much water is decidedly detrimental to the growth, as it encourages the competitive development of weeds and less desirable grasses, but a few light and timely applications will be helpful in starting the grass. When set out on low, poorly drained areas, the grass soon succumbs to an excess of water and is replaced by the less desirable taller grasses.

Buffalo grass spreads almost entirely by surface runners, which should not be disturbed by hoeing or cultivating after the sods are set out. It is well to clip at intervals throughout the season to control other growth and admit sunlight essential to the spread of the grass. Clipping will not wholly destroy but will reduce competing growth and leave a stubble over the land sufficient to minimize the roughening effects of erosion and soil blowing. A mowing machine or a high-cut lawn mower, cutting at a height of 2 inches, will cut the taller grasses without unduly injuring the prostrate buffalo grass. Observations indicate that persistent and repeated close clippings of buffalo grass with an ordinary lawn mower weakens the grass and encourages the inroads of weeds.

The uneven surfaces caused by wind and water erosion or careless transplanting may be leveled by topdressing after the grass has become fully established on such areas as lawns, golf courses, or football fields, where a smooth surface is desired. Depressions in the turf may be filled by periodic applications of a fine layer of soil, being careful not to cover the leaves entirely.

QUESTIONS AND ANSWERS

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

Use of peat in preparing sandy soil for putting green purposes.—How valuable is peat in preparing a sandy soil in the construction of putting greens? In what amount should it be used on a soil that is almost pure sand? (New Jersey)

ANSWER.—Peat would be very desirable in supplying organic matter in preparing a top soil for your putting greens. For best results about 20 cubic yards of peat would be required for a green of 6,000 square feet. The peat should be disked in and thoroughly mixed with the top 4 inches of soil.

How can we get rid of annual bluegrass? (Ontario)

ANSWER.—It is practically impossible to get rid of annual bluegrass (*Poa annua*) in putting greens, by ordinary methods, once it has been allowed to go to seed in the greens. It will produce seed even when kept closely cut. When it first appears in a green as scattered individual plants it can be removed by hand weeding. If it has developed into more or less solid patches, these may be removed with a hole cutter or a turf plugger. When, however, it is fairly well dispersed through a green it is necessary to remove all the sod and replant the green, weeding out any annual bluegrass afterwards as fast as it appears. Much can be done to prevent the grass from getting into a putting green. In the first place, care must be taken not to use topdressing material which might contain seed of annual bluegrass. A great many golf courses are unconsciously putting annual bluegrass seed on their greens through the medium of topdressing. In order to detect the presence of the seed in topdressing material, a sample of the material may be put in a greenhouse and kept watered until all seed contained germinates and the identity of the plants can be determined. In the second place, care must be taken to protect a green from overwash from surrounding higher areas in which annual bluegrass occurs. This can be done by placing swales or sand traps so as to intercept the overwash.

Steam sterilization of soil under growing turf.—An apparatus has been shown to us for forcing steam below the roots of grass and it is suggested that by its use insects in the soil will be killed and the nitrogen content of the soil increased. Could this apparatus be advantageously used on putting greens? (Ohio)

ANSWER.—Steam sterilization of soil for killing weed seeds before the soil is used for planting crops has been practiced for some time, and you will find the process described in the Bulletin of September, 1930. We doubt, however, that steam could be forced into soil under growing turf without a certain amount of the steam filtering around the roots of the grass and thus killing it. No doubt the steam would kill the insects and worms in the soil and tend to make more nitrogen and other plant food available, but if at the same time it destroyed the turf the results would not be so favorable. We do not know of any work that has been attempted with a view to sterilizing soil underneath turf and are therefore unable to say to what extent the turf might be injured. It might be well to have the machine tried out to ascertain its effect on soil insects and on the turf underneath which the test is made.

Fertilizers for rose bushes.—We have had excellent results in our rose gardens by fertilizing twice a year with a mixture of pulverized cow manure and bone meal. We are told, however, that a certain specially prepared fertilizer should be used on roses, since it contains necessary elements not found in the mixture we have been using. Have you any information on this matter? (New York)

ANSWER.—The United States Department of Agriculture informs us that it has found nothing better for roses than the mixture of pulverized cow manure and bone meal applied to the bushes twice a year.

Reseeding greens.—Within a few weeks we must entirely reseed one of our greens and patches on other greens. In what manner can this best be done? (New York)

ANSWER.—In reseeding a green we would rake the existing turf and cut it as close as possible, and then spike the green, seed, and apply topdressing and fertilizer. If convenient, the seed, topdressing, and fertilizer may be mixed together. The turf should not be spiked too deep, since seed washed to the bottom of holes that are too deep, and then covered with topdressing, might not germinate.

Should putting greens be watered in daytime or at night? (New Jersey)

ANSWER.—We believe that, everything considered, it is best during summer to water putting greens in the early morning. The reason for this is that the fungi which cause common turf diseases depend upon sufficient moisture and heat to make growth on the turf. The surface of a dry putting green would be less humid on hot nights than one that had been sprinkled. For that reason there is less spread of disease on putting greens at night if the surface is dry. In the control of fungus diseases it is advisable to get the dew off the greens as early as possible in the morning so that the grass may dry quickly. It has been found that watering the greens breaks the surface tension of the drops of dew on the grass, so that it dries much more quickly in the morning after it has been watered. Watering has the same effect on greens in this respect as poling and switching. It is true that there will usually be more moisture lost by evaporation from early morning watering than from night watering, due to the influence of the sun; but if the greens are watered thoroughly in the morning sufficient water will be stored in the soil to carry the greens through the following night, as the roots will tend to get in contact with the water which has sunk below the surface. Even though the surface is dry in the evening it will be frequently found damp before morning because there is a gradual rise of water in the soil. It has frequently been proved that, contrary to common superstition, watering putting greens in the sunlight does no harm. Another argument in favor of early morning watering is that greens are usually more economically and thoroughly watered then, since it is easier to keep track of the men engaged in this work in daylight than after dark.

Utilizing local strains of Bermuda grass on tees.—While bluegrass is abundant in our section it is not sufficiently vigorous to withstand the hard usage occurring on our tees, especially those calling for an iron shot. We also have a wild Bermuda grass here, commonly known as wire grass, which, however, seems to be ideal for our tees, as we have tried some out on the tees and with excellent results. It is difficult to find a sufficient quantity of this Bermuda grass for our purposes. We are sending you a specimen of the grass and should be glad to know where we may obtain seed or stolons of it. The grass loses its green color and becomes brown with the first frost, but it leaves a heavy mat during the winter months and becomes green again the following May. (Virginia)

ANSWER.—Bermuda grass varies considerably and consequently there are a great many distinct strains. However these have not been isolated and therefore we cannot identify your sample with any particular strain. You could plant Bermuda seed, but the chances are that this strain which is growing under your conditions is more hardy and better adapted to your section than the majority of plants that would be produced from seed. Bermuda grass grows luxuriantly in nurseries, and it is therefore suggested that you plant a nursery of such patches of the grass as you may find possessing the best appearance. The stolons or the sod produced in this nursery could then be used for planting your tees.

When the interval between intellectual classes and the practical classes is too great, the former will possess no influence, the latter will reap no benefit.

—Henry Thomas Buckle.