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

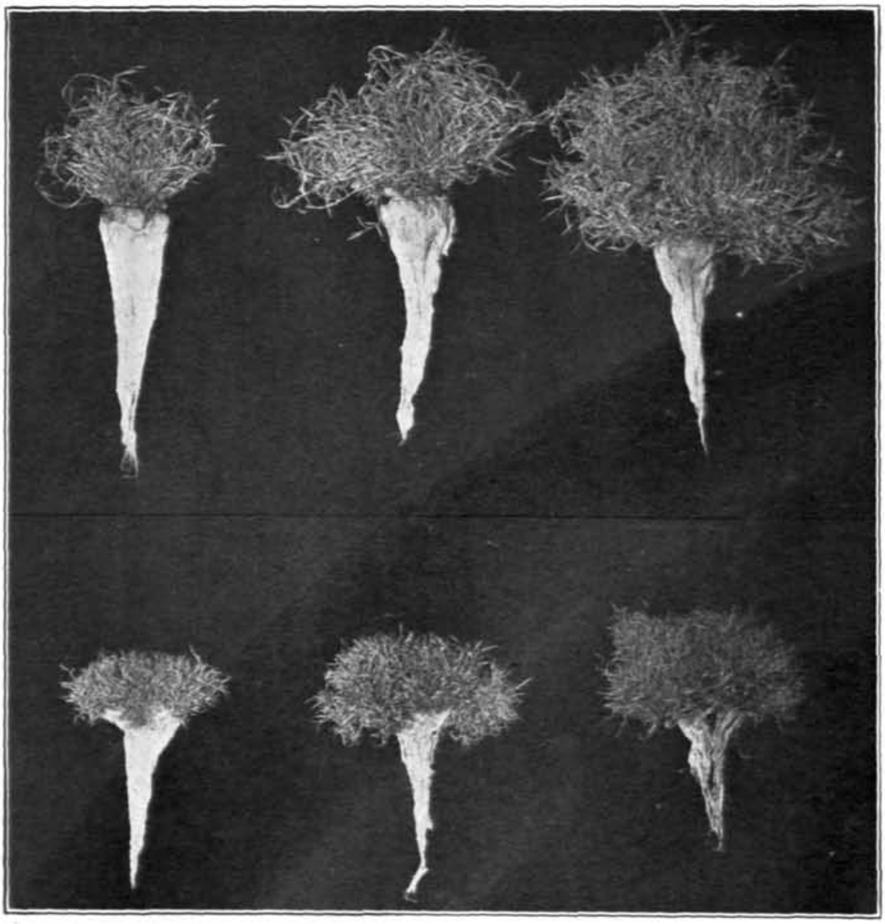
	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High nitrogen	44.8	38.5	83.3	10.5
Medium nitrogen ...	37.6	40.9	78.5	20.0
Low nitrogen	6.7	15.5	22.2	25.5
Uncut				
High nitrogen			85.0	8.0
Medium nitrogen ...			98.2	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).

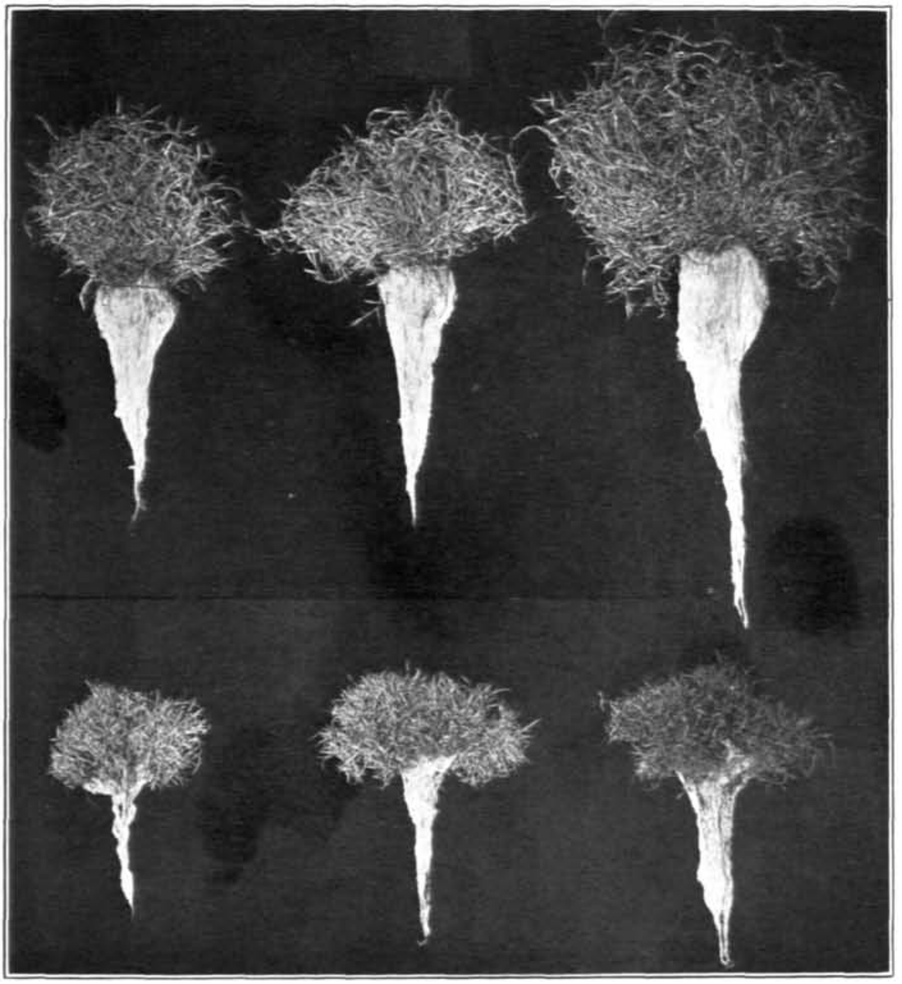
Phosphorus

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

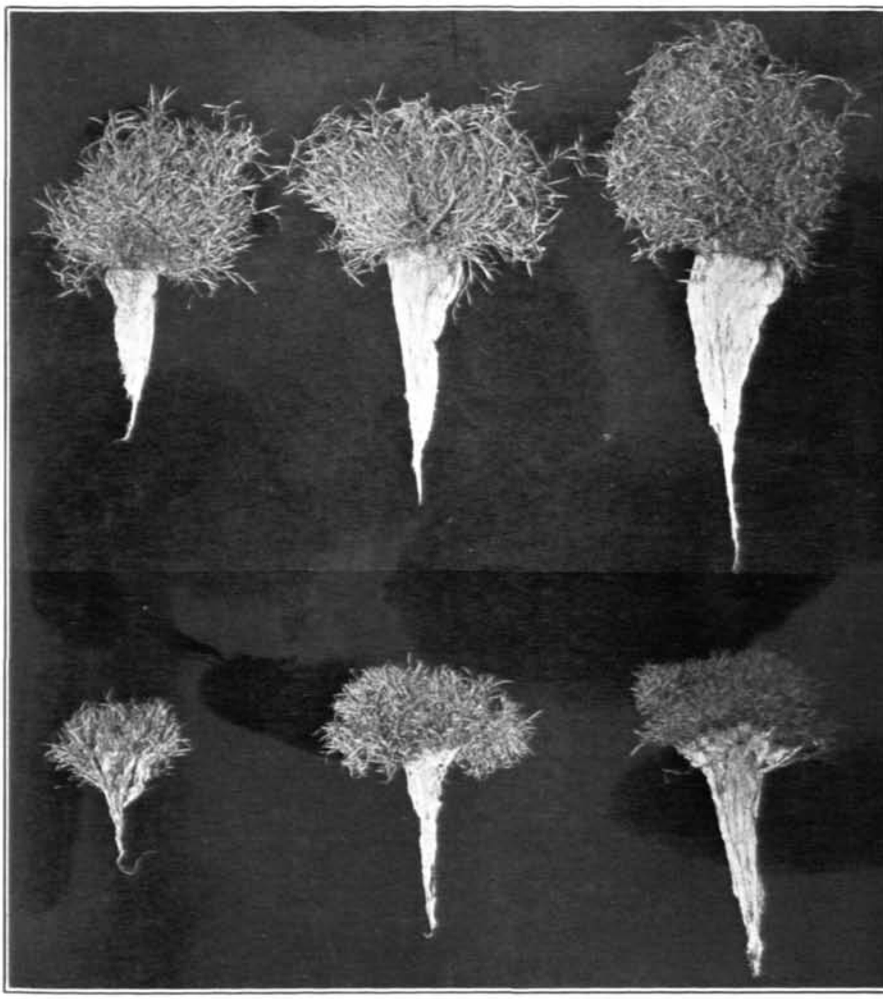
	Total clippings	*Final harvest of tops*	*Total yield of tops*	*Roots*
Experiment conducted in the greenhouse				
Cut to form turf				
High phosphorus....	...	...	...	...
Medium phosphorus.	37.6	40.9	78.5	20.0
Low phosphorus.....	25.5	29.0	54.5	9.0
Uncut				
High phosphorus....			...	...
Medium phosphorus.			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