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Soil Conditions and Root Development

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THE roots of grass plants have long been ignored or neglected. This is exceedingly unfortunate since they are a vital part of the plant. Utilization of the soil by plants is accomplished entirely by the roots. Variations in root development are probably just as pronounced as those seen in top growth, but since roots are below the ground these variations are not readily apparent. Their proper importance is seen at once, when we consider the various functions of roots.

No man in America has done more for those interested in the growing of fine turf than Doctor Sprague. His experimental garden at the New Jersey State Agricultural Experiment Station is a model of efficiency. In his work he has had the complete co-operation of the New Jersey greenkeepers

Roots provide anchorage, store food, absorb water, and absorb nitrogen and minerals. The anchorage of the plant in place obviously is necessary for an even cover of grass, but it is important likewise to permit utilization of the soil's resources, and the efficient exposure of the leaves to light. Food storage occurs partly in stems and partly in roots, but without such storage, our turf grasses would be unable to maintain vigorous growth in spite of frequent clipping, or to rejuvenate themselves after being injured.

ABSORPTION OF WATER AND NUTRIENTS

HOWEVER, it is in the absorption of water and nutrients that the plant roots are of greatest importance to the plant. Without the essential elements for growth, the permanent fixation of the plant would be of little value, and there would be no food to store. The quantities of water absorbed by plant roots are far greater than is ordinarily thought. It has been estimated that on bent greens of average quality, the grass roots must take up during the growing season at least 3,750 gallons of water for each 1,000 square feet of green. On Kentucky Blue-Redtop fairways, the amount absorbed by roots during the season is approximately 186,000 gallons per acre. In other words, the plant must take up 300 to 500 pounds of water for every pound of dry substance formed in leaves, stems and roots.

With regard to nutrients, the roots of fertilized bent putting greens must absorb, for each 1,000 square feet of surface nitrogen equivalent to that found in 15 pounds of sulfate of ammonia, phosphorus equivalent to 12 pounds of superphosphate, and potash equivalent to 6 pounds of muriate of potash. On healthy Kentucky Blue-Redtop fairways the nitrogen absorbed per acre equals that found in 400 pounds of sulfate of ammonia, phosphorus equal to 200 pounds of superphosphate, and potassium equal to 200 pounds of muriate of potash.

The absorption of these quantities of water and nutrients from the soil is an undertaking of some size. The soil is not simply a reservoir from which the roots draw the needed substances by suction. Both water and mineral substances are held by the soil with some tenactiy, and consequently the roots must make intimate contact with every group of soil particles before the water and minerals in contact with these particles may be utilized. Not only must roots penetrate every soil layer to tap its resources, but they must permeate every part of the soil mass.

Grass roots are admirably adapted for making contact with the soil particles (Figure 1). Fine roots develop in whorls at each joint of stems that are located at or below the surface of the soil. As a result there is built up a fine network of roots and their branches to form what is called a *fibrous root system*. This is very different from the tap root system of such plants as dandelions, dock, trees, etc. These fibrous roots of grasses do not live indefinitely, but usually die within a year or two and are replaced with other roots. New roots are formed most abundantly during the spring months after growth of tops begins, and death normally comes in fall or early winter.

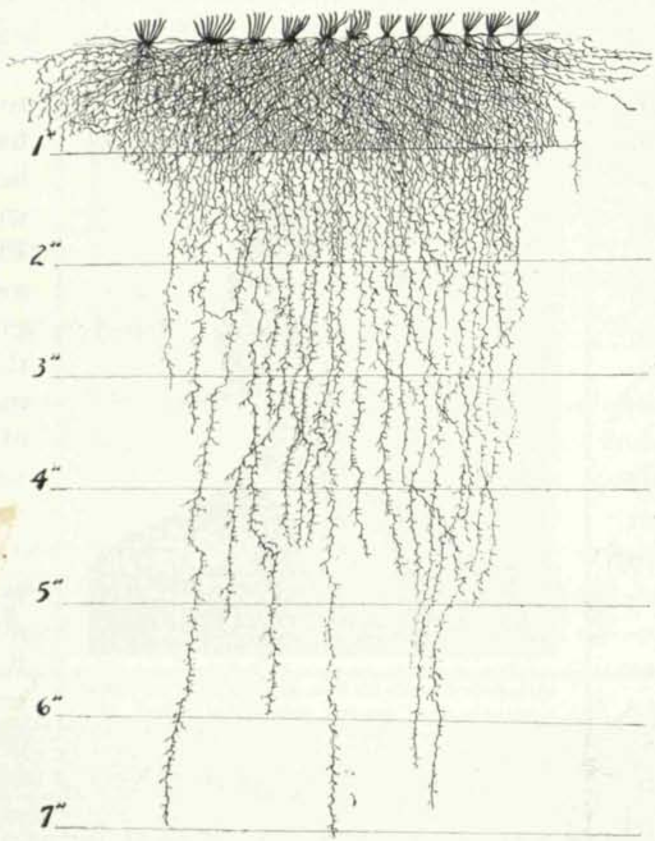

FIGURE 1—DIAGRAM SHOWING TYPICAL DISTRIBUTION OF ROOTS AT VARIOUS DEPTHS, FOR GRASS ON PUTTING GREENS

If the individual roots or branches are carefully examined (Figure 2), it will be found that at the tip there is a root-cap composed of loosely arranged cells which slough-off as the root grows and pushes between the soil particles. These cells act as a lubricant much as would oil on a bearing. Immediately back of the tip, is the growing point where new cells are constantly being formed as the root elongates. After formation, the new cells soon begin to enlarge, and the effect is to increase the length of the root and push the growing point further into the soil mass. As the cells enlarge, some of them are modified to carry on one type of work, and others to perform different functions.

Near the center of the root, certain groups of cells become elongated and the walls are thickened, for conducting water; others become adapted for the movement of foods, and both types together form the vascular strands or veins as they are sometimes called. Between these strands and the outer layers are the storage cells which comprise the cortex, and the outermost layer of cells forms the epidermis or protective coating. Certain of the epidermal cells are greatly elongated and become the root hairs.

The root hairs are of great importance since practically all of the water and nutrients absorbed by the plant enter through them, very little passing through the epidermis. Moreover, root hairs are found on roots in a very limited zone just back of the growing tip, and the individual hairs have a relatively short life. New root hairs must be formed continually to maintain normal absorption. When the root hairs have died, the epidermis of the root at that region becomes impermeable and unable to function for absorption. Since root hairs are very easily affected by soil conditions, attention must be given to this relation.

The extent of the root system and the thoroughness with which it occupies the soil mass is determined to a great extent by the system of management followed and by the nature of the soil itself. Since grass roots must be renewed more or less completely every year, the problem of controlling root development is one which cannot be ignored.

Moreover, the root hairs actually absorb most of the water and nutrients, and therefore the conditions favorable for their development and proper functioning must be present in all layers of soil occupied by the roots, if the soil is to be effectively utilized.

SOIL MOISTURE AND AERATION

EXPERIMENTS have shown that within certain limits, a relatively low water content of the soil stimulates roots to greater development, and likewise increases the abundance of root hairs. For example, plants grown in a soil with a moisture content of 19% available water have been shown to have a total root area 1.2 times as great as the leaves and stems, whereas similar plants grown in a soil with only 9% available water possessed a root area more than twice as great as the tops.

Proper drainage is important, in controlling root development, since grass roots do not penetrate water-logged soils. Thus, soils which are compact and poorly aerated will permit only scanty growth and this will be confined to the upper layers. The same grasses grown on well drained soils will be comparatively deep rooted. On the other hand, when the soil is very dry, root development is retarded or may even cease; the above-ground parts being dwarfed accordingly. That is, soils must contain some available water, or roots cannot penetrate the soil mass.

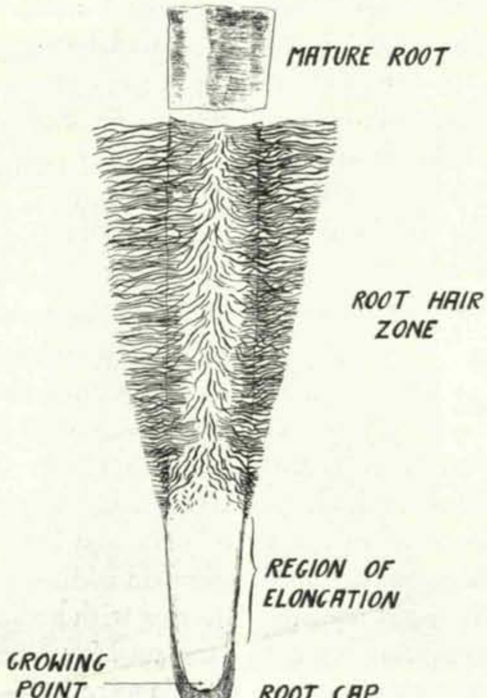

FIGURE 2—ENLARGED VIEW OF YOUNG GRASS ROOT TIP

The root-cap protects the growing point and acts as a lubricant as the root pushes through the soil. The root hairs absorb practically all of the water and nutrients required by the plant.

With the artificial watering generally practiced, one may do much to modify root development. Keeping the surface soil too moist during the early part of the season when new roots are being formed will favor development of a relatively shallow root system. Under such conditions, the turf will be easily injured by drought later in the season because of the small volume of soil from which moisture is obtained. On the other hand, reducing the quantity of water used, or withholding water as long as possible will promote a deeper root system if other soil conditions are favorable for growth.

The proportion of roots to tops is very definitely increased in relatively dry soil; whereas plants grown under conditions of plentiful moisture not only require more water for satisfactory growth but are less able to provide moisture in droughty periods because of comparatively scanty root development. Waterlogging the soil even temporarily, by watering or other means, may cause the death of roots in the flooded soil layers, thus injuring the plant. Certain grasses are more tolerant of overwatering than others, but all of the better species are injured by such conditions.

The critical factor in cases of water-logging and over-watering is usually not the excess of water, but the absence of sufficient oxygen for plant growth in the pore spaces of the soil. Plants have no such efficient system for respiration as that possessed by man, and air must be supplied to all of the organs, including the roots.

SOIL TEMPERATURE

TEMPERATURE is another important factor in root growth. Little if any growth of roots occurs when soils are frozen. Growth of our northern grasses begins soon after the soil temperatures reach 40° F. However, the soil does not warm up in spring as soon as the air, and the deeper layers are slower in warming than the upper layers. Therefore, little root growth is made until the mean daily air temperatures are at least as high as 45° F. Soils that contain a large amount of water are much colder in spring than well aerated soils which contain smaller amounts of water. Well aerated soils permit relatively early growth of roots.

NUTRIENT SUPPLY

THE supply of nutrients in an available form in the various horizons or layers of soil is an important factor in modifying the character of root systems. Roots branch more profusely in the soil layers that are liberally supplied with nutrients. Upon coming in contact with a soil layer rich in nitrogen, roots not only develop much more abundantly and branch more profusely, but they also fail to penetrate as far into the deeper soil.

On the other hand, the presence of an abundance of phosphates has been shown to increase the root development strikingly. If phosphorus is deficient in a soil, its application in an available form may be expected to greatly stimulate root length and branching.

SOIL ACIDITY

SOIL acidity and a lack of lime may also limit root penetration. The tolerance of turf grasses to soil acidity varies with the species, but all are injured to some extent by strong acidity. In some cases it may be found that the roots will penetrate only as deeply as the soil is freed of active acids. Soil acidity may effect absorption of nutrients and water even before it modifies root extent. This is due to the fact that root hairs are injured or destroyed by excessive acidity, just as they are killed by the presence of poisons in the soil water.

HEIGHT OF CUTTING

THE extent of the root system can be considerably influenced during the period of its development, by the height and frequency of cutting. Plants cut very short are able to manufacture only a limited quantity of food in the leaves. If the supply of nitrogen is abundant or excessive at this period, the tendency will be to produce luxuriant top growth without a corresponding root development. On the other hand, plants that are cut less closely may utilize considerably greater amounts of nitrogen without hampering the development of the root system. The critical point seems to be the ratio of carbohydrate food present in the plant to the supply of available nitrogen. An over-abundance of nitrogen favors top growth and retards root growth. This relation is probably most important in early spring when roots are actively growing.

FIELD STUDIES ON ROOT SYSTEMS

THE principles discusssed in the previous paragraphs apply in a general way to all grasses. What is needed for practical turf management is a better understanding of the peculiarities of each grass species. A study was made at New Brunswick in 1931 to determine the differences existing between the various grasses in the extent of their root systems under actual field conditions.

The turf examined was in its fourth year of growth, and was growing on a loam soil of average fertility. The soil was at one time cultivated, but has been in grass almost continuously for the past 8 years. The fertilization has been light and in no year was more applied than 400 pounds per acre of an 8-6-4 analysis. On April 3, 1931, all plots of grass received 10 pounds per 1000 square feet of an 8-6-4 fertilizer. One-third of the nitrogen was derived from sulfate of ammonia, 1/3 from nitrate of soda, and 1/3 from tankage. The putting turf plots, in addition to receiving fertilizer, were topdressed with a mixture of spent mushroom soil and sand on May 18, and 3 pounds of sulfate of ammonia were applied per 1000 square feet on June 8. The roots were sampled between June 20 and 26, and the results are given in Table 1.

TABLE No. 1

WEIGHTS OF ROOTS AT VARIOUS DEPTHS, POUNDS PER 1,000 SQUARE FEET OF SURFACE

New Brunswick, N. J. June 20-26, 1931

Soil Horizon	Rhode Island Bent		Velvet Bent		Seaside Bent		Hard Fescue		Kentucky Blue		Red Top	
	Lawn Length (lbs.)	Putting Length (lbs.)	Lawn Length (lbs.)	Putting Length (lbs.)	Lawn Length (lbs.)	Putting Length (lbs.)	Lawn Length (lbs.)	Putting Length (lbs.)	Lawn Length (lbs.)	Hay (lbs.)	Lawn Length (lbs.)	Hay (lbs.)
1st Inch	71.2	70.6	68.9	92.1	87.8	67.0	81.6	94.5	125.2	129.7	92.3	125.5
2nd Inch	13.1	12.4	15.1	13.8	20.4	8.9	12.4	11.4	18.5	18.2	11.0	13.0
3rd Inch	6.6	3.8	7.3	4.5	7.0	4.2	9.9	10.6	9.6	7.9	6.1	7.5
4th Inch	6.5	2.8	4.5	3.2	3.9	3.2	8.2	7.6	6.6	5.1	6.2	4.8
5th Inch	3.8	2.0	3.5	3.1	3.1	3.5	5.9	4.9	5.2	6.2	3.2	3.8
6th Inch	2.4	.7	2.8	2.0	2.7	1.7	4.6	5.5	2.8	3.9	2.7	1.8
7th Inch	1.4	.6	1.8	1.8	2.1	1.1	8.9	3.9	3.1	3.0	1.7	2.3
8th Inch	1.1	.6	1.3	.7	1.7	1.5	5.8	3.0	1.7	2.4	.8	2.4
9th Inch	.7	.3	.7	.3	1.1	.3	3.0	3.2	1.5	2.2	.7	.4
Total Root Weight	106.8	93.8	105.9	121.5	129.8	91.4	140.3	144.6	174.2	178.6	124.7	161.5
Root Weight Below 1st In.	35.6	23.2	37.0	29.4	42.0	24.2	58.7	50.1	49.0	48.9	32.4	36.0

With the exception of the Velvet Bent plots, which showed a higher fertility than the others, the soils are sufficiently similar so that comparisons may be made between the various grasses. For each grass, the plots cut at different heights were side by side, and the differences in root development have been produced by the height of cut. It should be stated that mowing occurred only twice each week; the turf was not kept as closely clipped as would occur on a well-kept golf course, and the root development is doubtless greater on these plots than would otherwise have been the case.

COMPARISON OF GRASSES CUT AT FAIRWAY LENGTH

THE total weight of the various grass roots on the fairway plots, varied from 174.2 pounds under 1000 square feet of area for Kentucky bluegrass to 105.9 for velvet bent. However, a better idea of actual root abundance is obtained by omitting the weight of roots occurring in the first inch, since these contained many creeping stems as well as roots.

For root weights below the first inch, hard fescue shows the greatest value, Kentucky bluegrass second, followed in order by seaside bent, velvet bent, Rhode Island bent, and redtop. It is noteworthy that the grasses producing the greatest total abundance of roots, also occupied the lower horizons more thoroughly. The hard fescue in particular, showed a strong development in the lower depths. This gives an indication as to one reason for this species' well-known tolerance of dry weather and droughty soils.

With a greater root growth, the grass is capable of drawing on a much larger volume of soil than would be possible with a limited root extent. Contrary to a popular belief, Kentucky bluegrass is not a typical shallow rooted species, but actually occupies the upper 5 inches of soil as well as fescue, and the next 4 inches more effectively than the bents.

The effect of height of cut on root development may be observed by comparing the roots for fairway and putting lengths, for each species. Since top dressing has buried some stems in the first inch, and these were harvested and weighed with the roots, it is desirable to eliminate this zone from consideration. Using the root weight below the first inch, it was found that the root development of the bents was about 50% greater for fairway length than for the putting length.

COMPARISON OF GRASSES CUT AT PUTTING LENGTH

THE reduction in abundance of roots on putting turf is clearly shown in the second inch of soil, and becomes more and more striking in the lower levels. The more abundant development of velvet bent as compared with Rhode Island bent is associated with greater fertility of the soil on the velvet plot, but the relatively large growth of roots on seaside bent putting turf is apparently typical of the grass and is not caused by greater fertility of soil. Hard fescue cut at putting length shows a large root development, but it is only fair to state that the grass was largely killed in July as a result of clipping at the putting length.

HEIGHT OF CUT ON FAIRWAY GRASSES

IT IS of interest to compare the root development of Kentucky bluegrass and redtop cut at 7/8" with that of adjacent plants allowed to grow as for hay. In the case of bluegrass, cutting at fairway length did not restrict root growth at all, whereas with redtop such mowing appreciably reduced root abundance below the 6th inch. This is in harmony with the observations that bluegrass will maintain active growth year after year if cut properly, whereas redtop tends to die after the second or third year when cut regularly at the height of 1 inch or less.

RATIO OF ROOT GROWTH TO QUANTITY OF CLIPPINGS

FROM the standpoint of the water economy of the plant, the ratio of root extent to yield of tops is quite important. When top growth is heavy and root development scanty, serious difficulties may be experienced in maintaining a satisfactory supply of moisture. On the other hand, grass species that produce a vigorous root growth and a moderate or limited top growth should endure droughty conditions much more satisfactorily.

The total yields of dry matter produced in clippings from the beginning of the growing season until July 1, is shown in Table 2, along with the quantity of roots found in late June. The weight of the green clippings was 3 to 4 times as great as when dried, because of the water content, but both root and clipping weights are reported on the dried basis in this table.

It may be startling to find the root weights exceeding that of the clippings, but such is the case, and obviously roots have been grossly underesti-

TABLE No. 2

WEIGHTS OF ROOTS AND CLIPPINGS OF VARIOUS SPECIES OF GRASSES, IN POUNDS PER 1,000 SQUARE FEET OF SURFACE AREA

New Brunswick, N. J. Season of 1931

Species of Grasses	Grass Cut at Putting Length, $\frac{4}{16}$"				Grass Cut at Lawn Length, ⅞"				
	Total Wt. of Roots in 1st 9" of Soil 6-23-31	Root Wt. Below 1st Inch 6-23-31	Yield of Clippings From April to July 1	Ratio of Roots Bel. 1st Inch to Total Yield of Clippings	Total Wt. of Roots in 1st 9" of Soil 6-23-31	Root Wt. Below 1st Inch 6-23-31	Yield of Clippings From April to July 1	Ratio Total Roots to Total Clippings	Ratio Roots Bel. 1st Inch to Total Clippings
R. I. Bent	93.7	23.1	26.5	.87	106.9	35.7	27.4	3.90	1.30
Velvet Bent	121.5	29.5	26.9	1.10	105.9	37.1	25.3	4.19	1.47
Seaside Bent	91.5	24.5	28.7	.85	130.0	42.2	14.3	9.09	2.95
Hard Fescue	144.6	50.0	66.7	.75	140.3	58.7	27.2	5.16	2.16
	Grass Uncut As for Hay				Grass Cut at Lawn Length, ⅞"				
Kentucky Blue Grass	178.6	48.9	......	......	174.3	49.1	46.9	3.72	1.05
Red Top	161.5	36.0	......	......	124.7	32.4	29.5	4.23	1.10

mated in importance. When the roots of the first inch are disregarded, the weights of roots are nearly as great as those of tops on turf cut at putting length, and is 30 to 300% greater on grass cut at fairway height. The high ratio of roots to tops of the velvet bent cut at ¼ inch may be due to the high fertility of the soil on that plot, or it may indicate the natural character of the species.

ROOT DEVELOPMENT AND SOIL ANALYSES

ONE important feature of these studies is the almost universal tendency for growth to stop in the 8th or 9th inch. The condition is likely associated with the fact that this soil has been plowed to a maximum depth of about 8 inches during the time it was farmed. The lime and fertilizer used for the crops in that period were mixed with the plow zone but probably did not greatly affect the subsoil. To prove this point it is necessary to correlate soil analyses with root development. This has been done, and the details are reported for three of the grass species in Tables 3, 4 and 5. (See page 12).

RHODE ISLAND BENT

FIRST, consider the case of Rhode Island Bent grass. The acidity of the various soil zones is given in terms of the P. H. scale. On this scale, 7.0 is neutrality, 6.0 represents mild acidity, 5.5 strong acidity, and 5.0—very strong acidity. The most acid layers of soil are those near the surface. Undoubtedly this is partly caused by the absorption of lime from these layers in greater quantities that in the lower levels where roots are less abundant. A contributing factor is the greater leaching effect of water on the surface layers. However, the failure of roots to penetrate the lower horizons can not be attributed to the acidity of the soil, since the soils become less acid as roots decrease in abundance.

The readily available phosphorus is reported in parts per million (P. P. M.) since the percentage values are low. One per cent by weight is equal to 10,000 parts per million. The data presented show that the soluble phosphorus content of the soil is low in the upper 2 or 3 inches, high from the 3rd to 6th inches, and then falls sharply at the 8th and 9th inches. The low phosphorus values near the surface are the result of heavy absorption by the roots in these zones; and the values in the 5th and 6th inches probably represent the quantity present before absorption began. The low concentrations of readily available phosphorus in the 9th inch indicate that the soil is naturally low in this constituent, and the quantity present in the plow zone is principally the residue from past fertilizations.

The organic matter content of the soil has been measured by determining the carbon present. Carbon makes up about one-half of the soil organic matter. These values fall off sharply as the lower portion of the plow zone is reached, and one may assume that much of the organic matter present has been supplied either by plant roots which were confined to the upper 8 inches, or by manure and crop residues that were mixed with soil during cultivation in previous years.

Since organic matter contains most of the reserve supply of soil nitrogen, we may conclude that the soil below 8 inches is much less abundantly sup-

TABLE No. 3

Development of Roots and Tops of RHODE ISLAND BENT, and the Relation to Soil Conditions

Soil Horizon	Cut at Lawn Length, 7/8"				Cut at Putting Length, 1/4"			
	Weight of Roots Under 1000 Sq. Ft. of Area lbs.	Acidity of Soil P.H.	Readily Available Phosphorus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent	Weight of Roots Under 1000 Sq. Ft. of Area lbs.	Acidity of Soil P.H.	Readily Available Phosphorus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent
1st Inch	71.2	5.3	113	2.5	70.6	5.3	148	2.4
2nd Inch	13.1	5.1	112	2.3	12.4	5.2	150	2.1
3rd Inch	6.6	5.2	173	2.1	3.8	5.3	184	2.4
4th Inch	6.5	5.4	210	2.2	2.8	5.4	200	2.3
5th Inch	3.8	5.4	213	2.2	2.0	5.5	226	2.3
6th Inch	2.4	5.5	206	2.0	.7	5.6	228	2.4
7th Inch	1.4	5.5	219	1.5	.6	5.6	184	2.3
8th Inch	1.1	5.5	212	1.5	.6	5.6	151	2.1
9th Inch	.7	5.6	147	1.4	.3	5.6	109	1.8
Total root weight	106.8				93.8			
Root weight below 1st inch	35.6				23.2			
Total wt. of tops, Ap-June 30	27.4				26.5			
Ration of roots below 1st inch to tops	1.30				.87			

TABLE No. 4

Development of Roots and Tops of SEASIDE BENT, and the Relation to Soil Conditions

Soil Horizon	Cut at Lawn Length, 7/8"				Cut at Putting Length, 1/4"			
	Weight of Roots Under 1000 Sq. Ft. of Surface Area lbs.	Acidity of Soil P.H.	Readily Available Phosphorus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent	Weight of Roots Under 1000 Sq. Ft. of Surface Area lbs.	Acidity of Soil P.H.	Readily Available Phosphorus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent
1st Inch	87.8	5.2	104	2.6	67.0	5.8	114	2.4
2nd Inch	20.4	5.3	118	2.0	8.9	5.5	118	2.1
3rd Inch	7.0	5.4	131	2.1	4.2	5.5	135	2.0
4th Inch	3.9	5.5	156	2.1	3.2	5.5	132	2.0
5th Inch	3.1	5.7	166	2.1	3.5	5.5	139	2.2
6th Inch	2.7	5.8	153	2.1	1.7	5.6	148	2.1
7th Inch	2.1	5.8	128	2.0	1.1	5.6	153	2.0
8th Inch	1.7	6.0	119	2.0	1.5	5.7	142	1.9
9th Inch	1.1	5.9	100	2.0	.3	5.7	110	1.8
Total root weight	130.0				91.5			
Root weight below 1st inch	42.2				24.5			
Tot. wght. tops Ap.-June 30	14.3				28.7			
Ratio of roots below 1st inch to tops	2.95				.85			

TABLE No. 5

Development of Roots and Tops of KENTUCKY BLUE GRASS and the Relation to Soil Conditions

Soil Horizon	Cut at Lawn Length, 7/8"				Cut for Hay			
	Weight of Roots Under 1000 Sq. Ft. of Surface Area lbs.	Acidity of Soil P.H.	Readily Available Phosphurus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent	Weight of Roots Under 1000 Sq. Ft. of Surface Area lbs.	Acidity of Soil P.H.	Readily Available Phosphrus in Soil P.P.M.	Organic Carbon Content of Soil Per Cent
1st Inch	125.2	5.6	122	2.3	129.7	5.4	121	2.3
2nd Inch	18.5	5.7	133	1.9	18.2	5.5	152	2.1
3rd Inch	9.6	5.7	143	1.9	7.9	5.6	143	2.0
4th Inch	6.6	5.7	125	1.9	5.1	5.5	150	2.0
5th Inch	5.2	5.7	133	1.9	6.2	5.7	151	1.9
6th Inch	2.8	5.7	137	2.0	3.9	5.7	160	2.0
7th Inch	3.1	5.7	100	1.8	3.0	5.6	133	1.7
8th Inch	1.7	5.7	45	1.2	2.4	5.5	122	1.6
9th Inch	1.5	5.7	35	1.0	2.2	5.5	96	1.4
Total root weight	174.2				178.6			
Root weight below 1st inch	49.0				48.9			
Tot. wght. tops, Ap.-June 30	46.9							
Ratio of roots below 1st inch to tops	1.05							

plied with both nitrogen and phosphorus and therefore is less suitable for root occupation than the upper soil. The failure of turf cut at fairway length to penetrate deeper than the upper 8 inches may be attributed in part to this condition.

On the turf cut at ¼", the root abundance falls away sharply below the fifth inch, whereas the nutrient supply in the soil is nearly at its best at this depth. In this case, the failure of the roots to penetrate more deeply must be sought in the treatment given the grass, such as the height and frequency of cutting, the kind, amount, and time of application of nitrogenous fertilizers, the supply of moisture, etc. Considerably more nitrogen was supplied to the putting turf than to the fairway grass, and this may have sufficiently modified the balance between the carbohydrate food reserves and nitrogen to limit the development of the root system. At any rate it is clear that mowing at ¼ inch greatly reduces root penetration, even with Rhode Island Bent which is well adapted to close clipping.

SEASIDE BENT

WITH Seaside Bent, much the same relation exists between root development and soil conditions as was noted for Rhode Island Bent, thus proving that the results obtained were not due to chance. Failure of roots on turf of fairway length to penetrate lower horizons more abundantly may be attributed in part to the lower fertility of such zones. However, the structure of the lower soil layers, and the ease with which air and water move through them may also be important factors, although no proof on these points is yet available. On the ¼" turf, however, the limitation in root development must be sought in some other factor than those measured, probably in the system of management being followed.

KENTUCKY BLUEGRASS

THE evidence that reduced fertility of the lower horizons restricts root development is again found on Kentucky Bluegrass plots, both when cut at fairway length and when uncut. Even with this grass the evidence is not strong enough to warrant the conclusion that all of the important factors controlling root development have been included. Soil aeration must still be considered, even though these are well drained soils with fairly good structure.

(Continued on page 30)

Something New

Greenkeepers of golf courses and growers of fine turf generally will hail the advent of a new inexpensive, All-Purpose Spreader, just put on the market by the Root Manufacturing Company, 1051 Power Avenue, Cleveland, Ohio.

The Root spreader is operated by hand, with finger touch control, so that it is able to handle not only all kinds of fertilizers and topdressings, but grass seed as well. The makers claim that it can handle the finest bent seeds as light as three pounds per thousand square feet.

This new spreader is built for heavy duty work and has the feature of triple roll agitation, which prevents packing of the material, even though moist. The operator, walking behind the spreader can control the distribution with the result that there is no waste, which makes for economy.

This company has also put on the market a Weed Killer, which uses dry ammonium sulphate and is very efficient. This eliminates the use of liquid poisons and is a stimulant to the grass.

The spreader sells for $50.00 and the Weed Killer for $1.00, f. o. b. Cleveland. Complete particulars will be furnished upon request.

New Rotary Booklet

Double Rotary Sprinkler Company, Coco-Cola Building, Kansas City, Missouri, has just issued a new booklet on the Double Rotary Sprinkler, which shows by text and photographs the many advantages of this product.

The makers claim that the famous Double Rotary principle prevents any wasting of water; in fact it actually saves water as it covers a larger area most evenly and thoroughly.

By its rotating principle, the Double Rotary sprinkles a circular area up to eighty feet in diameter—more than five thousand square feet—depending upon city water pressure. Also easily adjusted to sprinkle smaller areas down to fifteen feet in diameter.

The Double Rotary Junior sprinkler, which sells for $7.50, is especially designed to meet every need of the home owner. It is ample to take care of lawns and flower gardens and may be adjusted to meet all requirements.

Every sprinkler sold by this company is personally guaranteed by Lou E. Holland, president of the Double Rotary Sprinkler Company.

Soil Conditions and Root Development

(Continued from page 13)

In closing, it may be said that the studies here reported do not pretend to completely solve the important problem of root behavior. However, they do serve to emphasize the importance of roots in growing turf, and show certain of the relations existing between root occupation and soil conditions. It is hoped that further investigation will indicate treatments that may be adopted to improve root development, both for soils before grass is planted, and on turf that is established. An additional extremely important point to consider is the range of soil conditions that will facilitate the development of root hairs on roots that are present, and the absorption of water and nutrients.

Jacobsen Gives Figures

Jacobsen Manufacturing Company, 735 Washington Avenue, Racine, Wisconsin, is quite pleased with a letter from the Kilbourn Country Club, Franksville, Wisconsin, with regard to the experience they had with the Jacobsen power mowers. This is a course of twenty-seven holes with Washington Bent greens and has been in play for three years.

We quote the following from a letter written by the Green committee chairman:

"An accurate cost record was kept for all operations on the course during the season and you will note that the cost of greens mowing for twenty-seven greens amounted to only about $15.56 per green for the entire season or approximately 13c per cutting.

"With power mowers it is not necessary to mow the greens more than five times a week, whereas if hand mowers were used, it would be necessary to mow them every day, the growth of the greens being so heavy that it would be hard to mow a two days' growth with a hand mower. The turf actually becomes stronger by letting it grow one or two days each week without cutting. This does not interfere with the playing qualities of the course as days are selected when the play is not so heavy.

"We attribute the immunity of our greens to Brown Patch to the frequent brushing and top dressing of the greens, especially during the hot, dry weather. Brushing of the greens whenever the growth appeared stunted or during the early season when the growth was at its height, kept the greens from matting and improved the grain of the Bent. This is easily done with the brush attachment as furnished with the 24″ Power Putting Green Mowers and also makes it possible to brush in thoroughly, light applications of good top dressing material. Frequent applications of top dressing is in our opinion, much superior to the use of chemicals and provides excellent cushion to hold a pitched ball.

Statement of the Ownership, Management, Circulation, etc., required by the Act of Congress of August 24, 1912, of THE NATIONAL GREENKEEPER, published monthly a Cleveland, Ohio, for April 1, 1932.

State of Ohio, County of Cuyahoga, ss.

Before me, a Notary Public, in and for the State and county aforesaid, personally appeared Robt. E. Power, who, having been duly sworn according to law, deposes and says that he is the Editor of the National Greenkeeper and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, (and if a daily paper the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business managers, are:

Publisher, The National Greenkeeper, Inc., 405 Caxton Bldg., Cleveland, Ohio; Editor, Managing Editor and Business Manager, Robt. E. Power, 11609 Lake Ave., Cleveland, Ohio.

2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

The National Greenkeeper, Inc., 405 Caxton Bldg., Cleveland, Ohio. Robt. E. Power, 11609 Lake Ave., Cleveland, Ohio; Frank H. Clark, 2848 Drummond Rd., Shaker Hts., Ohio; H. L. Richey, 3263 E. Fairfax Rd., Cleveland, Ohio; Frank H. Pelton, 19110 S. Woodland Rd., Shaker Hts., Ohio; F. E. Percy, 3159 South Moreland Blvd., Shaker Hts., Ohio; C. F. Lowe, Aurora, Ohio; Frank M. Power, 11609 Lake Ave., Cleveland, Ohio; M. J. Fox, 15002 Superior Rd., Cleveland Heights, Ohio.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: (If there are none, so state.) None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

ROBERT E. POWER, Editor.

Sworn to and subscribed before me this 11th day of April, 1932.

H. W. Slack.

My commission expires Jan. 8, 1935.