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The NATIONAL GREENKEEPER

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Soil Conditions and Root Development

By DR. HOWARD B. SPRAGUE, Agronomist, New Jersey State Agricultural Experiment Station, New Brunswick, N. J. Read at the 6th Annual Educational Conference of the National Association of Greenkeepers of America, held at New York City, January 19-22.

HE 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.

Roots provide anchorage, store food, absorb water, and absorb nitrogen and miner-

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



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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.

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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

2" 3" 4" 5" 6" 7"

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

tops begins, and death normally comes in fall or early winter.

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 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.

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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 cor-

> tex, 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

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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

 $\mathcal{E}_{\text{XPERIMENTS}}$ 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, crowing root development is retarded or may even cease; the aboveground parts being dwarfed accordingly. That is, soils must contain some available water, or roots cannot penetrate the soil mass.

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



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 bairs absorb practically all of the water and nutrients required by the plant.

atures 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

water-logging and over-water-

ing is usually not the excess of

water, but the absence of suffi-

cient oxygen for plant growth

in the pore spaces of the soil.

Plants have no such efficient sys-

tem for respiration as that pos-

supplied to all of the organs, in-

SOIL TEMPERATURE

 $T_{
m emperature}$ is another im-

portant factor in root growth.

Little if any growth of roots oc-

curs when soils are frozen.

Growth of our northern grasses

begins soon after the soil temper-

cluding the roots.

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

T HE 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

T HE 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

 $T_{\rm HE}$ principles discussed 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.

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

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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

T HE 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

T HE 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

 $F_{\rm ROM}$ 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-