How Study of Root System Tells Story of Soil

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A STUDY WAS made at New Brunswick, N. J., 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 lbs. per acre of an 8-6-4 analysis. In 1931, all plots of grass received 10 lbs. per 1,000 sq. ft. of an 8-6-4 fertilizer on April 3. One-third of the nitrogen was derived from sulphate of ammonia, ⅓ from nitrate of soda, and ⅓ from tankage. The putting turf plots, in addition to receiving fertilizer, were top-dressed with a mixture of spent mushroom soil and sand on May 18, and 3 lbs. of sulphate of ammonia were applied per 1,000 sq. ft. on June 8. The roots were sampled between June 20 and 26, and the results are given in Table 1.

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 at Fairway Length

The total weight of the various grass roots on the fairway plots, varied from 174.2 pounds under 1,000 sq. ft. 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 per cent greater for fairway length than for the putting length.

Comparison 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

TABLE 1—Weights of Roots at Various Depths, Pounds Per 1,000 Sq. Ft. of Surface—New Brunswick, N. J., June, 1931

Soil Horizon.	R. Island Bent: Lawn Length. (Lbs.).	R. Island Bent: Putting Length. (Lbs.).	Velvet Bent: Lawn Length. (Lbs.).	Velvet Bent: Putting Length. (Lbs.).	Seaside Bent: Lawn Length. (Lbs.).	Seaside Bent: Putting Length. (Lbs.).	Hard Fescue: Lawn Length. (Lbs.).	Hard Fescue: Putting Length. (Lbs.)	Ky. Bluegrass: Lawn Length. (Lbs.).	Ky. Bluegrass: Hay. (Lbs.).	Redtop: Lawn Length. (Lbs.).	Redtop: Hay. (Lbs.).
First 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
Second 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
Third 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
Fourth 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
Fifth 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
Sixth inch	2.4	.7	2.8	2.0	2.7	1.7	4.6	5.5	2.8	3.9	2.7	1.8
Seventh inch	1.4	.6	1.8	1.8	2.1	1.1	8.9	3.9	3.1	3.0	1.7	2.3
Eighth inch	1.1	.6	1.3	.7	1.7	1.5	5.8	3.0	1.7	2.4	.8	2.4
Ninth 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 first inch	35.6	23.2	37.0	29.4	42.0	24.4	58.7	50.1	49.0	48.9	32.4	36.0

TABLE 2—Weights of Roots and Clippings, Pounds Per 1,000 Sq. Ft. of Surface—New Brunswick, N. J.—Season of 1931.

Species of Grasses.	Grass Cut at Putting Length, 4/16": Total Weight of Roots in 1st 9" of Soil. 6/23/31.	Root Weight Below 1st Inch. 6/23/31.	Yield of Clippings from April 1 to July 1.	Ratio of Roots Below 1st Inch to Total Yield of Clippings.	Grass Cut at Lawn Length, ⅞": Total Weight of Roots in 1st 9" of Soil. 6/23/31.	Root Weight Below 1st Inch. 6/23/31.	Yield of Clippings from April to July 1.	Ratio Total Roots to Total Clippings.	Ratio Roots Below 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"				
Ky. bluegrass	178.6	48.9	....	...	174.3	49.1	46.9	3.72	1.05
Redtop	161.5	36.0	....	...	124.7	32.4	29.5	4.23	1.10

July as a result of clipping at the putting length.

Height of Fairway Cut

It is of interest to compare the root development of Kentucky bluegrass and redtop cut at ⅞ ins. 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 in. or less.

Root-Clipping Ratio

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 dfficulties 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 underestimated 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 per cent greater on grass cut at fairway

TABLE 3—Development of Roots and Tops, and Relation to Soil Conditions

Soil Horizon.	Weight of Roots Under 1,000 Sq. Ft. of Area. Lbs.	Acidity of Soil. pH.	Readily Available Phosphorus in Soil. P. P. M.	Organic Carbon Content of Soil. Per cent.	Weight of Roots, Under 1,000 Sq. Ft. of Area. Lbs.	Acidity of Soil. pH.	Readily Available Phosphorus in Soil. P. P. M.	Organic Carbon Content of Soil. Per cent.
RHODE ISLAND BENT	Cut at Lawn Length, ⅞"				Cut at Putting Length, ¼"			
First inch	71.2	5.3	113	2.5	70.6	5.3	148	2.4
Second inch	13.1	5.1	112	2.3	12.4	5.2	150	2.1
Third inch	6.6	5.2	173	2.1	3.8	5.3	184	2.4
Fourth inch	6.5	5.4	210	2.2	2.8	5.4	200	2.3
Fifth inch	3.8	5.4	213	2.2	2.0	5.5	226	2.3
Sixth inch	2.4	5.5	206	2.0	.7	5.6	228	2.4
Seventh inch	1.4	5.5	219	1.5	.6	5.6	184	2.3
Eighth inch	1.1	5.5	212	1.5	.6	5.6	151	2.1
Ninth inch	.7	5.6	147	1.4	.3	5.6	109	1.8
Total root weight	106.8	...	...	...	93.8	...	...	...
Root weight below first inch	35.6	...	...	...	23.2	...	...	...
Total wt. of top, April–June 30	27.4	...	...	...	26.5	...	...	...
Ratio, roots below 1st in. to top	1.30	...	...	...	.87	...	...	...
SEASIDE BENT	Cut at Lawn Length, ⅞"				Cut at Putting Length, ¼"			
First inch	87.8	5.2	104	2.6	67.0	5.8	114	2.4
Second inch	20.4	5.3	118	2.0	8.9	5.5	118	2.1
Third inch	7.0	5.4	131	2.1	4.2	5.5	135	2.0
Fourth inch	3.9	5.5	156	2.1	3.2	5.5	132	2.0
Fifth inch	3.1	5.7	166	2.1	3.5	5.5	139	2.2
Sixth inch	2.7	5.8	153	2.1	1.7	5.6	148	2.1
Seventh inch	2.1	5.8	128	2.0	1.1	5.6	153	2.0
Eighth inch	1.7	6.0	119	2.0	1.5	5.7	142	1.9
Ninth inch	1.1	5.9	100	2.0	.3	5.7	110	1.8
Total root weight	130.0	...	...	...	91.5	...	...	...
Root weight below first inch	42.2	...	...	...	24.5	...	...	...
Total wt. of tops, April–June 30.	14.3	...	...	...	28.7	...	...	...
Ratio, roots below 1st in. to top	2.95	...	...	...	.85	...	...	...
KENTUCKY BLUEGRASS	Cut at Lawn Length, ⅞"				Cut for Hay			
First inch	125.2	5.6	122	2.3	129.7	5.4	121	2.3
Second inch	18.5	5.7	133	1.9	18.2	5.5	152	2.1
Third inch	9.6	5.7	143	1.9	7.9	5.6	143	2.0
Fourth inch	6.6	5.7	125	1.9	5.1	5.5	150	2.0
Fifth inch	5.2	5.7	133	1.9	6.2	5.7	151	1.9
Sixth inch	2.8	5.7	137	2.0	3.9	5.7	160	2.0
Seventh inch	3.1	5.7	100	1.8	3.0	5.6	133	1.7
Eighth inch	1.7	5.7	45	1.2	2.4	5.5	122	1.6
Ninth 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 first inch	49.0	...	...	...	48.9	...	...	...
Total wt. of tops, April–June 30.	46.9	...	...	...	....	...	...	...
Ratio, roots below 1st in. to tops	1.05	...	...	...	....	...	...	...

height. The high ratio of roots to tops of the velvet bent cut at ¼ in. 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 ins. 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 Table 3.

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 pH 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 than 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 those 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 indicates 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 ½ 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 the 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 supplied 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-inch, 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-inch 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.

In conclusion, it may be said that the studies here reported do not pretend to solve completely 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.

LOOK BEFORE LEAPING

Test Other Fellow's Idea Before Adopting It

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AT THE MEETING of the greenkeepers of Podunk County the other day, Joe Grumpus of the Spongy Fairway C. C. told the boys that Greely's Great Grass Grower for Golf Greens was the best fertilizer on the market and that he had had excellent results on his course. Well, Joe's course is built on an old farm in the valley that was worked by a thrifty old Dutch farmer who believed that when you took something out of the ground you had to return something. Consequently, when they built the course, they had an ideal soil. What grass they grew! Most any kind of fertilizer would show results and even an application of sawdust would have pepped up the grass.

All the boys knew that Joe's place looked darned good and took his word for it that his fertilizer was the berries, and every one was hurt in the rush to place their orders for the famous fertilizer for fastidious fairways.

Results: Bill Binks got results in the low spots where the soil was pretty good. Jimmy Jones said he could see no improvement in his grass. Benny Brown got a good crop of weeds and the others preferred not to talk about it.

Moral: Try it on the dog first. In other words, they should have tried a couple of hundred pounds before they tried a couple of carloads.' What is sauce for the goose may not be sauce for the gander. If they got results from the couple of hundred pounds, then it was time enough to order the carload. The poor greenkeepers thought they were doing the right thing, but they jumped at conclusions too soon. Try out new products on a small scale first and if they produce, you have found something.

Some courses have been fertilized spring and fall for many years. Others have seen fertilizer only the time they were seeded and then very sparingly. The course that had lots of fertilizer was living off past feeding in lots of cases. Most anything would show some signs of fertilization. On the starved course, the grass was so hungry that 400 pounds per acre just gave each grass plant a taste and whetted the appetitie all the more.

Does It Fit You?

All these points must be taken into consideration when you adopt the other fellows idea. Will it pay you to do the same and use the same as he does. Think it over before you jump.

The same goes for the other fellow's methods and practices. The tractor and mowers he is using may give him wonderful results but would not give you the same. The one you are using may work fine for your purposes but would be a big flop on his course. Bent greens may be what his members want but your members would not care for them. He might like his power mowers for his greens but if you were to use them you might be dissatisfied. Its up to you to figure out your best methods and equipment and practices. You are the one who is responsible for your course and if there is trouble you are the one to blame.

Very recently, I heard a noted greenkeeper who has had some good jobs in this