The Rhizometer — a device for measuring roots of tree seedlings

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Abstract

A photoelectric device — the rhizometer — which can be used to estimate root surface areas of seedlings is described. The advantage of this instrument is that it is rapid and non-destructive. The method gives comparable results to estimates obtained by direct measurement of diameters and lengths; in addition the estimates are highly reproducible. The technique used has considerable application in the assessment of root systems of seedlings grown under experimental conditions and also in the routine measurement of nursery production stock. Seedlings are capable of being planted out after root measurement by this technique.

In many studies of the responses of tree seedlings to various environmental factors, measurement of the root systems is of importance. The most often used measurement is that of root weight and it is common for shoot:root ratios (weight basis) to be used in comparisons of seedling development. For studies of nutrient absorption and also of the performance of seedlings when outplanted under different conditions, it is more logical to use a measure of root surface area, rather than that of weight. Recently Voigt, 1966, and Newman, 1964, have used and discussed the use of root area as a more useful parameter. Anyone who has endeavoured to determine root areas of even small seedlings by direct measurement is aware of the laborious nature of such an undertaking. A plea for studying the rooting volume of soil and for measurements of root surface area has been made by Wiersum (1961). Besides being laborious such measurements are also destructive — as is dry weight determination — and this is a further disadvantage.

Over a period of years, we have been concerned

with the measurement of tree seedlings, not only in experimental studies, but also in the assessment of nursery stock grown for outplanting and it has seemed to us that some rapid, non-destructive measurement of root systems which could directly or indirectly be related to root area is needed.

Some years ago, a number of plant physiologists used a photoelectric device for measuring leaf surface area (Frear, 1935; Withrow, 1935; Mitchell, 1936; Kramer, 1937) and a similar device seemed appropriate for the measurement of roots. Because the instrument we have designed is used primarily for root measurement we have described it as a rhizometer (Anon., 1967). Basically it consists of a light source, an aperture over the light source in which roots may be placed, a photocell to measure the reduction in light due to the roots and a galvanometer which in turn measures the decrease in output from the photocell. Figure 1 shows the rhizometer currently in use in our laboratory. A constant voltage transformer was found to be necessary to maintain a constant light source. The following are the main components:

Photocell

Weston, model 856 Type 'RR', available from Weston Industries Ltd., Newark, N.J., U.S.A.

Transformer

Sola — Type CVS, secondary voltage 118, VA 250 made by Sola-Basic Products, Toronto, Ont.

Galvanometer

Galv-o-meter — sensitivity $1\mu\text{A}$ /full scale, coil resistance 1000 ohms; critical damping resistance 10 K — available from Coleman Instruments Inc., Maywood, Ill.

Light source

Four 40 watt tungsten bulbs.

Rhizometer

Plywood construction. Base unit 20 ins. by 18 ins. by 6 ins. high. The four lamps mounted in this unit with an opening 12 ins. by 12 ins. in the top covered with a glass plate. A

series of holes drilled in the sides to allow warm air to escape. The upper unit 12 ins. by 12 ins. by 36 ins. high. The lower two inches of the upper unit has holes drilled in the plywood to act as vents for warm air. Immediately above this a frosted glass plate was installed. On this plate black cardboard or arborite sheets with openings of any convenient dimension (e.g. 10 cm. by 20 cm.) can be placed.

When measurements of root systems were made for seedlings which were to be replanted, a shallow tray made of acrylic plastic, the exact dimensions of the opening, was used and filled to the depth of one half inch with water. A sheet of plastic the same dimensions as the inside of the tray was then placed over the root to keep them in one plane. When calibrating the rhizometer all components e.g. tray, water and sheet of plastic must be in place.

Figure 1. Diagram of rhizometer showing component parts.

Calibration

For any given size of opening, the galvanometer is adjusted to read 100 when no seedlings are placed on the plate. Thin pieces of arborite or black paper of known area are then placed in the opening and readings are taken from the galvanometer. An example of a calibration curve is shown in Figure 2. It will be noted that the calibration curve is a straight line.

Measurement of Roots

Roots to be measured are spread across the aperture and held in one plane by a glass plate. Alternatively the water filled plastic tray may be used if the seedlings are to be replanted. A reading is then taken from the galvanometer. This read-

Figure 2. Calibration curve for an aperture of 200 sq. cm. (20 x 10 cm.).

ing may be converted to an area by using the calibration curve (Figure 2). This area value is a silhouette area but can be converted to a total surface area by multiplying by π , assuming the roots are circular in cross-section.

Two main sources of error may occur. First, roots may cross one another and this may lead to underestimates of the area. This source of error is minimized if care is taken to spread the roots out when they are laid on the plate. Second, because some roots, especially those which are actively elongating may be translucent they will not give the same reduction as equal-sized roots which are opaque. In small seedlings the roots may be dipped in a dark-coloured vegetable dye to increase their opacity. For larger seedlings the proportion of translucent roots may be so small that differences due to this factor may be ignored.

Accuracy and Reproducibility

Several tests of accuracy were made in which estimates of root surface areas of seedlings, using the rhizometer, were compared with estimates ob-

Table 1

Results of measurement of root areas (a) by direct measurement and (b) by rhizometer.

Seedling No.	Root area by Direct measurement (cm ²)	Root area by rhizometer (cm ²)
1	4.3	3.9
2	8.0	9.2
3	10.7	9.7
4	12.7	9.2
5	7.2	6.8
6	5.9	6.8
7	7.0	7.7
8	8.4	7.3
9	5.9	8.2
10	5.9	4.8
11	8.6	9.2
12	5.8	4.8
13	6.1	6.8
14	6.5	8.7
15	17.0	16.0
16	9.1	13.9
17	24.7	23.2
18	20.2	18.1
19	23.4	14.8
20	19.4	20.6
21	26.1	25.3
22	21.4	23.7
23	32.1	27.9
24	20.0	20.6
25	22.0	21.2
26	19.6	19.5
27	25.6	25.3
28	27.4	30.6
29	25.3	30.6
30	57.4	49.5

Regression of rhizometer root area on direct measurement root area:
 where Y = rhizometer measurement of root area (cm²) R = 0.98
 and X = direct measurement of root area (cm²)

tained by direct measurement using a microscope with a calibrated eye piece to measure root diameters and root lengths. Table 1 shows data obtained for 30 jack pine (*Pinus banksiana* Lamb.) ranging in weights from 24 to 996 milligrams. It will be seen that a high significant linear relationship existed between estimated root surface areas

(rhizometer) and the surface areas obtained by direct measurement.

A study was made of the reproducibility of the method. Ten separate estimates of root areas, using the rhizometer were made for ten seedlings. For each seedling, no two estimates were made consecutively. The results are given in Table 2.

Table 2

Mean root areas (10 readings for each seedling), standard errors of means and coefficients of variation.

Seedling No.	Mean Root Area (mm ²)	Standard Error of the mean (mm ²)	coefficient of Variation (%)
1	1963	31	5.0
2	2246	28	3.9
3	2659	23	2.8
4	2883	28	3.1
5	3099	40	4.1
6	3313	39	3.7
7	3922	68	5.5
8	4458	33	2.4
9	4460	49	3.3
10	5199	42	2.5

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Applications

This method of measuring root surface area is a rapid one. In the laboratory, the time taken to place a seedling on the plate and take a reading was slightly less than a minute. The preparation of the seedlings, i.e. the careful washing of the root systems so that no soil particles adhere is of great importance. During the latter part of 1967 over a thousand seedlings, sampled from the nurseries of the Ontario Department of Lands and Forests were measured in this way. In these nursery measurements the readings were not multiplied by π to convert to total root area, but were designated as **root surface indices**.

The rhizometer has been used in the field to measure root systems of trees grown under different treatments and then subsequently out-planted. No damage to root systems from measurement has been encountered.

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