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SURFACE AREA MEASUREMENT OF CORN ROOT SYSTEMS[1]

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ABSTRACT

The density or amount of roots per unit of soil is important when evaluating the use of soil water and nutrients by plants. The most commonly used measurement of roots is mass, but more recently root length measurements have been reported. We believe root surface area is of critical importance in assessing water and nutrient uptake. We are presenting a method whereby this characteristic can be determined using roots washed from soil cores which are photographed followed by the developed film being scanned with an Image Analyzer to determine the area. This value is multiplied by π assuming the roots are cylindrical to give the total surface area of the roots. The accuracy of the technique was checked by calculating the root length using an average root diameter of 0.05 cm. The calculated lengths were comparable to published values giving credibility to the technique.

Additional index words: **Root length, Root activity.**

Root density or the amount of roots per unit volume of soil plays a central role in any consideration of the absorption of water and nutrients from soil. Root density can be expressed in terms of root length, mass, or surface area per unit volume of soil. The mass of roots per unit soil volume is frequently used, because of the relative ease of determination of mass (e.g., Bloodworth et al., 1958; Eaton, 1931; Foth, 1962; Kmoch et al., 1957). A technique often used to determine root length has been described by Newman (1966) and developed into a computer-controlled tech-ing. Pieces of trash and other foreign material that also floated were removed from the root samples using forceps. Excess water was removed from the cleaned root material and the samples were stored in a freezer until the surface area measurements as described below could be made.

To determine the root surface area, the washed root samples were thawed (if necessary), spread on a clear glass to eliminate as much overlap as possible, and placed on a uniformly back-lighted table. Photographing was done as soon as possible after spreading to minimize drying and shrinkage. The uniformity of lighting was checked with a light meter. Some large samples required splitting into two and sometimes three subsamples to avoid overlap. The samples were photographed with a 35 mm camera with an f2.8/50 mm lens set at f5.6 at 1/60 sec using high contrast copy film, Kodak number 5069[3]. The exposure was chosen to obtain maximum contrast in the image of the roots. Photographing was done in a room with indirect lighting of medium to low intensity. The camera lens was placed at a minimum of 152 cm from the glass containing the root sample so that the exposed film contained the root sample in an area no larger than 1.2 × 1.0 cm in the center of each frame. A 35 mm negative is about 2.4 × 3.5 cm. This was necessary to avoid subsequent problems with the Image

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of the experimental area is classified as a Weld silt loam, a member of the fine, montmorillonitic, mesic Aridic Paleustolls.

Soil cores 7.6 cm in diameter by 14.6 cm long were taken from plots in which corn was being grown in each of two growing seasons. A hydraulic powered soil sampler was used to force the sleeved coring tool into the soil. Profiles of cores were taken directly under the plant crown, and at one-fourth and one-half the distance to the adjacent row. The profiles extended to a depth at which no roots were observed at the bottom of the core when removed. Depending on location of the core with respect to the plant the depth of rooting moved.

To assist in distinguishing the current root growth from that of previous growing seasons, profiles of cores were taken from a nearby fallow area that had been planted to corn during the previous season. The samples from the fallow area were taken at the same manner and at the same times that the cropped areas were sampled.

Core samples were collected at the eight-leaf, tasseling, early dent, and maturity growth stages in the 1st year and at the 12-leaf, tasseling and early dent growth stages in the 2nd year. At each sampling four plants were used. At the time of sampling, the stem diameter of the first node above the soil surface, leaf area, and total dry matter of aboveground plant parts were determined. Stem diameter was used as the basis for plant selection. Ten plants from four areas in the field, but not in the area to be sampled, were marked as representative of the field and their average stem diameter was used to select plants for sampling.

The cores were subjected to a washing technique to remove the roots from the soil. If there was to be substantial delay in proceeding with the washing procedure, the cores were frozen for storage.

To remove the roots from the soil, each core was placed in a bucket and soaked in water with a dispersing agent (Calgon) for 1 to 3 hours. A small stream of tap water was used to disintegrate the core, and loosen the roots from the soil. The root material floated to the surface of the water in the bucket and was caught on a 200-mesh screen as the water overflowed through a spout at the top of the bucket. No notable difference in flotation of roots was observed between those washed fresh and those frozen before washing. Pieces of trash and other foreign material that also floated were removed from the root samples using forceps. Excess water was removed from the cleaned root material and the samples were stored in a freezer until the surface area measurements as described below could be made.

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After each root sample was photographed, it was weighed.

RESULTS

Root surface area values obtained in the fallow area for each sample depth and location were subtracted from the corresponding sample depths and locations where the plants were growing in an attempt to report results for the root surface area of actively growing plants. The quantity of roots found in the samples from the fallow area was highest at the first sampling and decreased with maturation of the crop. This would be expected as normal deterioration of roots would occur during this time.

The root surface area density vs. depth at various stages of plant growth for one of the growing seasons (1974) are shown in Fig. 1 through 4. The results for the other season were similar, although not identical, and are not shown. These results indicate that the technique is sensitive to changes in rooting density with time, depth, and lateral proximity of sampling to the plant.

A confirmation of the accuracy of the method was made by using the frames of thread and calculating their length from the relationship. The calculated values of surface area of thread were all within ± 2.0 mm^2 of the actual surface area of the thread. Thus, the method does provide an accurate means of determining the surface area of small cylinders such as roots.

As previously stated, most published information on roots is reported as either mass per soil volume or length per soil volume. To compare our results with the root length information in the literature we used the following equation:

$$\text{length/cm}^3\text{ soil} = \text{surface area/cm}^3\text{ soil}/\pi D$$

where average root D = 0.05 cm (Milthorpe and Moorby, 1974). Using the average surface area for the rooting depth of the corn, we calculated root lengths ranging from 0.40 to 2.60 cm/cm^3 of soil depending

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[4] Interpretation Systems, Inc., Lawrence, KS 66044. Mention of product name does not imply endorsement by the USDA.

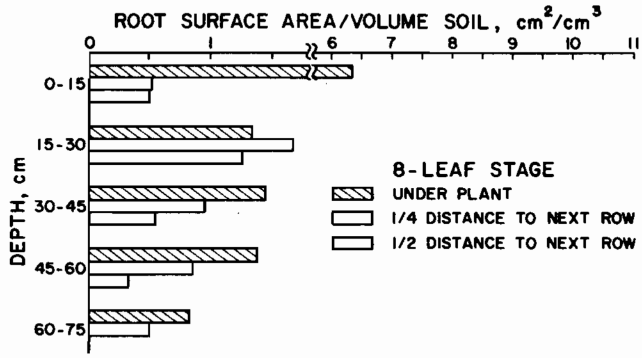

Fig. 1. Surface area of corn roots as related to location in the soil profile and at different proximities to the plant at the eight-leaf growth stage.

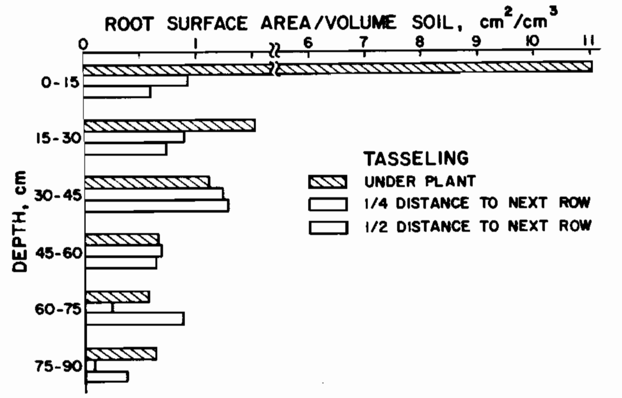

Fig. 2. Surface area of corn roots as related to location in the soil profile and at different proximities to the plant at tasseling.

on the time of sampling. Root lengths for the rooting depth of corn found by Barber (1971) ranged from 0.7 to 3.0 cm/cm^3 of soil and Allmaras et al. (1975) reported 0.43 cm of root/cm^3 of soil. In the Auburn rhizotron, Taylor and Klepper (1973) reported that in the rooting depth of corn grown in a loamy sand, root lengths ranged from 1.15 to 5.32 cm/cm^3 of soil.

The root lengths calculated from the surface area measurements in our technique are comparable to the reported root lengths indicating that our surface area values are reasonable. The time of the growing season, corn hybrid, soil properties, and water distribution within the soil profile will all influence root development, therefore differences would be expected. Also, the washing technique and screen mesh size used to catch the roots are potential sources of error and may contribute to differences between what we found and other published information.

We attempted to relate surface area to mass, but found no consistent relation. This is consonant with attempts to relate root length to mass by Allmaras et al. (1975). We also attempted to relate surface area to stem diameter of the first node, leaf area, and total dry matter, but no consistent relationship could be found between samplings.

We believe that the technique provides a useful measurement of root activity with respect to water and nutrient uptake by root systems.

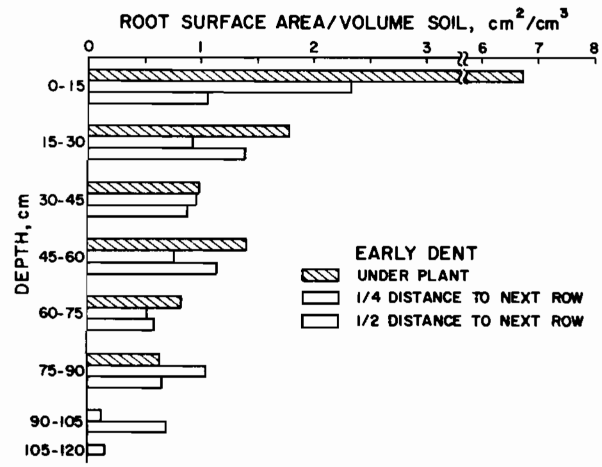

Fig. 3. Surface area of corn roots as related to location in the soil profile and at different proximities to the plant at the early dent growth stage.

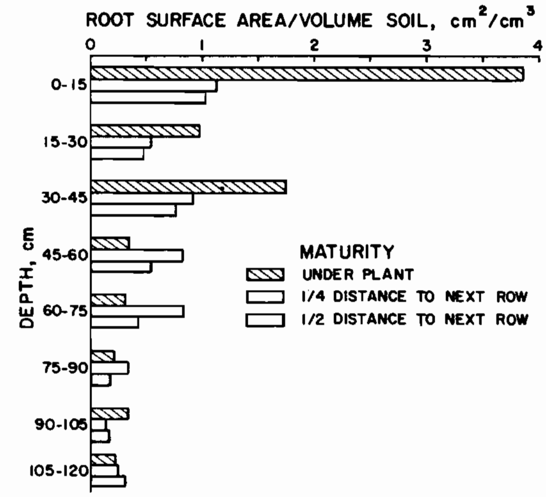

Fig. 4. Surface area of corn roots as related to location in the soil profile and at different proximities to the plant at maturity.

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