SOIL SCIENCE

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Distribution of Corn *(Zea mays* L.*)* Roots in Two Soils in Relation to Depth of Sampling and Type of Sampler[1]

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Abstract

A high yielding field containing both Crosby silt loam and Ragsdale silty clay loam was selected for this study. The roots of the crop were sampled while the corn was in the maturation or ear filling stage. Soils cores in 15 cm (6 in.) vertical samples were taken in each soil type with a bucket auger and with a Pit-O-Matic core sampler to a depth of 152 cm (60 in) where possible. Gravel in the Crosby profiles made it impossible to sample deeper than 107 cm (42 in.) in 4 of the 5 subsampling areas. Roots and soil were separated. Dry weights of roots decreased highly significantly with depth. The 0-30 cm (0-12 in.) depths contained from 75 to 82% of the total weight of roots in the sampled profiles. Less than 2% of the roots were below 107 cm (42 in.) The bucket auger took more soil and with it more roots per 15 cm vertical sample than did the Pit-O-Matic core sampler. Sample holding diameters of these two tools were the same, but sample cuttings diameters were different.

Distribution of corn roots in soil is important because corn plants obtain water and nutrients from soil. Fehrenbacher (2, 3) has shown that physical properties of soil and their genetic horizons are related to available water-holding capacity and to root penetration and total weight. The purpose of this study was to compare vertical distribution of corn roots by using two different soil sampling tools on two different adjoining high-yielding soils.

Methods and Procedures

Hand soil sampling tools were used in this study because it was not possible to use a Kelley (1) or similar type mounted soil core sampler while the corn was growing. The hand type soil sampling tools used were a standard bucket auger[3] and a Pit-O-Matic core sampler[4] of approximately the same size, 5.5 cm ($2\frac{3}{16}$ in) inside diameter. The cutting edge diameter of the bucket auger was 7.0 cm (2¾ in), and that of the core sampler was 5.2 cm ($2\frac{1}{16}$ in).

A Crosby silt loam (Aeric Ochraqualff) and a Ragsdale silty clay loam (Typic Argiaquoll) adjacent to each other in the same field of William Franklin, Jamestown, Boone County, Indiana, were used for this study. The soils were described by D. P. Franzmeier and P. W. Harlan (personal communication). Some properties of these soils are

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[2] The author acknowledges the help of C. D. Raper, Richard Fletcher, Ethel Tudor, and Enola Ruff in conducting this research.

[3] Manufactured by Art's Machine Shop, American Falls, Idaho.

[4] Manufactured by the Soil Testing Company, Smithville, Tennessee.

TABLE 1. *Description of two soil profiles on William Frankin Farm, Boone County, Indiana, 1968.*

Soil and Horizon		Organic Matter %	Water pH	Purdue Soil Testing Laboratory Values P	K	Texture*	Color*
Ragsdale				Lbs. per A.	Lbs. per A.		
Ap 0-25 cm	(0-10 in)	2.52	7.3	436+ (V.H.)	225 (H.)	H. sicl	blk.
B21tg 25-46 cm	(10-18 in)	1.81	7.2	436+ (V.H.)	180 (M.)	sicl	dk. gray
B22tg 46-71 cm	(18-28 in)	0.35	7.1	436+ (V.H.)	180 (M.)	sicl	mottled
Clg 71-102 cm	(28-40 in)	0.34	7.6	436+ (V.H.)	150 (L.)	sil	mottled
C2g 102-198 cm	(40-78 in)	0.34	8.0	436+ (V.H.)	105 (L.)	sil	mottled
Crosby							
Ap 0-25 cm	(0-10 in)	1.20	7.3	85 (H.)	210 (M.)	sil	brn.
Blg 25-36 cm	(10-14 in)	0.48	6.1	7 (V.L.)	255 (H.)	H. sicl	mottled
B21gt 36-56 cm	(14-22 in)	0.04	6.8	2 (V.L.)	195 (M.)	sicl	mottled
B22gt 56-71 cm	(22-28 in)	0.18	7.3	436 (V.H.)	165 (M.)	cl	mottled
IICg 71-91 cm	(28-36 in)	0.04	7.8	436 (V.H.)	120 (L.)	l	mottled

Legend:
V.L. = very low
L. = low
M. = medium
H. = high
V.H. = very high

Legend:
H. = heavy
sicl = silty clay loam
sil = silt loam
cl = clay loam
l = loam
blk. = black
dk. = dark
brn. = brown

* Described by D. P. Fransmeier and P. W. Harlan.

listed in Table 1. Ragsdale is higher in organic matter, more alkaline in subsurface horizons to parent material, and has a higher strong acid phosphorus test value in the B horizon to 56 cm (22 in) than does the Crosby soil. Ragsdale is found in lower areas to which runoff comes from the higher Crosby soil.

Soil and root samples were taken between August 9 and August 14, 1968, after midsilk date of this corn crop, while the ears were still filling and while the brace roots were still growing. The variety was Northrup King 610 planted April 27. For the soil and root sampling and for yield determinations, a nested design suggested by W. E. Nyquist (personal communication) was used. Soils were main treatments. Five replications or subsampling areas approximately 15.3 m (50 ft) apart, located in the center and on the points of the compass, were used in each soil type. Within each sublocation, depths were sampled to 152 cm (60 in) where possible, in 15 cm (6 in) vertical increments starting at the surface. At each sublocation two samplers, the standard bucket auger and the Pit-O-Matic core sampler, were used, one on each side of a corn plant located 18 cm (7.1 in) from another corn plant in the row and 96.5 cm (38 in) from plants in adjoining rows. Surface increments in the row touched the stalk.

Soil and root subsamples for each 15 cm increment were put in paper bags and air dried at room temperature. Prior to separating roots from soil, the samples were dried at 38° C (100° F) for 24 hours and weighed. After the dried sample was broken up into smaller pieces with a mortar and pestle, the roots were separated from the soil by the method of Raper (5). This consisted of a wet screening procedure with oscillation in a saturated calgonite solution. Tweezers and flotation in water were used where soil particles containing roots failed to break down. Roots were placed in steel cans and dried at 38° C for 24 hours, weighed, and placed in labeled plastic bags for reference.

Corn grain yields were taken in 1968 in the same five sub-locations on each soil where the soil and root samples were taken. Yields are reported with 15.5% moisture in the grain.

Weights of roots, soil plus roots (roots were less than 1% of the total weight), and yields were subjected to analyses of variance and F tests of significance.

Results and Discussion

Weight of roots per 15 cm depth of soil sampled decreased highly significantly from the 0-15 cm depth to the 15-30 cm depth. The average root weight of the 0-15 cm depth was 1.33 grams or 67% of the total root weight to 152 cm (60 in) depth and that of the 15-30 cm depth was 0.22 grams or 11% of the total root weight to 152 cm (60 in) depth. Even though average root weights declined as soil depth increased below 30 cm depth, these differences in root weights were not significant at 19 to 1 or greater odds. These averages are shown in Table 2 for all depths sampled, both soils, and both soil sampling tools. Part of the

TABLE 2. *Weight of corn roots per soil subsample taken in 15 cm (6 in) depth increments with two sampling tools on two soils. William Franklin Farm, Boone County, Indiana, 1968.*

Sampling Depth		Bucket Auger Sampler			Core Sampler		
cm	in.	Av. wt. per subsample grams	Range in wt. per sub-sample grams	% of total weight	Av. wt. per subsample grams	Range in wt. per sub-sample grams	% of total weight
			Crosby silt loam				
0- 15	0- 6	1.7376 (5)	1.0695-3.0948	72.63	0.9311 (5)	0.2778-1.4462	55.07
15- 30	6-12	.2180 (5)	.0752- .4731	9.11	.3495 (5)	.1550- .6200	20.67
30- 46	12-18	.1966 (5)	.1101- .3348	8.22	.1140 (5)	.0662- .1902	6.74
46- 61	18-24	.1075 (5)	.0286- .1362	4.49	.1502 (5)	.0942- .1960	8.88
61- 76	24-30	.0929 (5)	.0185- .1921	3.88	.0817 (5)	.0596- .1064	4.83
76- 91	30-36	.0253 (5)	.0005- .0472	1.06	.0470 (5)	.0109- .1081	2.78
91-107	36-42	.0100 (2)	.0012- .0188	.42	.0170 (3)	.0060- .0341	1.01
107-122	42-48	.0001 (1)	None	.00	.0002 (1)	None	.01
122-137	48-54	.0019 (1)	None	.08	.0000 (0)	None	.00
137-152	54-60	.0026 (1)	None	.11	.0000 (0)	None	.00
	Total	2.3925		100.00	1.6907		99.99
			Ragsdale silty clay loam				
0- 15	0- 6	1.4833 (5)	0.5846-1.8871	73.54	1.1767 (5)	0.5266-2.5576	65.10
15- 30	6-12	.1145 (5)	.0559- .1420	5.67	.1986 (5)	.0699- .2800	10.99
30- 46	12-18	.1090 (5)	.0221- .2250	5.40	.1249 (5)	.0394- .2947	6.91
46- 61	18-24	.0801 (5)	.0351- .1746	3.97	.1080 (5)	.0219- .2796	5.97
61- 76	24-30	.0825 (5)	.0538- .1239	4.09	.0449 (5)	.0181- .0880	2.48
76- 91	30-36	.0700 (5)	.0161- .0843	3.47	.0636 (5)	.0087- .1502	3.52
91-107	36-42	.0413 (5)	.0033- .0769	2.65	.0679 (5)	.0138- .1400	3.76
107-122	42-48	.0128 (5)	.0024- .0299	.64	.0162 (5)	.0001- .0376	.90
122-137	48-54	.0184 (5)	.0017- .0495	.91	.0054 (5)	.0002- .0137	.30
137-152	54-60	.0052 (5)	.0014- .0133	.26	.0014 (5)	.0000- .0041	.08
	Total	2.0171		100.00	1.8076		100.01

( ) No. of subsamples in this average. When less than (5) it was impossible to get more because of gravel.

wide ranges in weight per subsample in the 0-15 cm and 15-30 cm samples can be attributed to presence of brace roots. There were brace roots in some samples and not in others. However, after drying it was impossible to determine rapidly what was a brace root and what was not. Foth (4) found that brace root growth increased total root weight of corn nearly 50% between the 67th and 80th days after planting. Harvests in this experiment were made between the 104th and 109th days after planting—probably before total brace root growth was completed.

Another possible explanation in the wide range in root weights is related to the method of sampling. Samples of soil and roots were taken out of the hole after each successive 15 cm depth was reached. This allowed extra soil and roots which fell into the hole to be brought up. Coefficients of variation of the dry weights of soil samples (with very small weights of roots in them) varied from 14% up to 18%. However, coefficients of variation of corn root weights found in these soil samples ranged from a low of 62% to a high of 125%. These are extremely high coefficients of variation. When variation in weights of soil samples and root samples is compared, it is found that root weights were four to seven times as variable as weights of soil samples. This indicates that corn roots were not uniformly distributed in the soils sampled (Table 2).

Root weights from the bucket auger averaged 27% heavier than those from the core sampler in samples taken to 91 cm (36 in). This difference was significant at 4 to 1 odds and was expected because of the wider cutting edge of the bucket auger. The cutting diameter of the bucket auger was 35% wider than that of the core sampler. However, the average weight of soil and roots per 15 cm increment taken by the bucket auger was 699 g. This compared to 465 g for the core sampler increment or 50% more. The difference of 234 g was highly significant. Root samples taken by the bucket auger were macerated and harder to separate than those taken with the core sampler. However, the bucket auger was able to by-pass stones and sample to a greater depth in one sublocation than was the core sampler in Crosby soil. Gravel in pockets probably laid down by water prevented sampling any deeper than 122 cm (48 in) with the core sampler in Crosby soil. In the one sublocation where it was possible to sample to the desired depth (152 cm or 60 in) on the Crosby soil, root weights were less than the averages found in Ragsdale soil at the same depths. However, it was possible to sample all depths to 152 cm at all sublocations of the Ragsdale soil. There were no significant differences between the two soils in root weights found to 91 cm. Below this, other sampling procedures are needed to determine whether or not Ragsdale has more roots at greater depths than has Crosby. The methods used in this study to sample corn roots in Crosby soil below 91 cm were not satisfactory.

Yields of corn grain averaged 10,057 kg per ha (160 bu per A) on the Ragsdale soil in 1968. On the Crosby soil, yields were 8809 kg per ha (140 bu per A). The difference in yields of 1248 kg per ha (20 bu per A) was significant at 19 to 1 odds. Since the rainfall of 2.77 cm

(1.09 in) in July and 7.29 cm (2.87 in) in August was deficient, the less gravelly Ragsdale soil must have supplied more water to the crop—probably because of deeper root penetration.

Summary

Roots were sampled from five sublocations of both a Crosby silt loam and a Ragsdale silty clay loam in the same field. Two types of sampling tools were used to obtain vertical soil cores. Subsamples were taken by 15 cm (6 in) increments from the surface down to 152 cm (60 in) where possible. The roots were separated from the soil. Highly significant differences were found between root weights from the 0-15 cm (0-6 in) depth subsamples and root weights from subsamples taken below that. About 67% of the total weight of roots to a depth of 152 cm was found in the 0-15 cm subsamples. Weight of roots rapidly declined from the 0-15 cm depth to the 137-152 cm (54-60 in) depth. Gravel in the Crosby profiles made it impossible to sample deeper than 107 cm (42 in) in 4 of the 5 sublocations. The standard bucket auger with wider effective cutting diameter took more soil and with it, 27% more roots than did the Pit-O-Matic core sampler. The bucket auger macerated the roots while the core sampler did not. The very wide range in root weights taken in subsamples to 30 cm depth (12 in) was partially explained by the presence of brace roots in some subsamples and not in others. It was shown that weight of roots in soil subsamples was four to seven times as variable as the weights of the soil from which they came. Grain yields of corn in 1968 of 10057 kg per ha (160 bu per A) on the Ragsdale soil were significantly greater than the 8809 kg per ha (140 bu per A) on the Crosby soil. Since July and August were relatively dry, the less gravelly Ragsdale soil apparently supplied more available water—probably because of deeper root penetration.

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