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Rooting Characteristics of Apple Rootstocks at Two NC-140 Trial Locations

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Abstract

Root distribution of nine apple rootstocks at the Michigan and Ohio sites for the 1980 NC-140 Uniform Apple Regional Rootstock Trial was determined using the trench profile method. Cultural practices and training systems were similar at the two sites. The two locations differed greatly in soil type, a Marlette fine sandy loam at Michigan and a Canfield silt loam with a fragipan at Ohio. Roots were counted and separated into three size categories: less than 2 mm in diameter, 2 to 5 mm in diameter and greater then 5 mm in diameter. Number of roots counted per tree could be separated into 3 rootstock groups for the Michigan location: MAC.24 with the most roots counted per tree; OAR 1, M.26 EMLA and M.9 EMLA as the intermediate group; and M.7 EMLA, O.3, M.9, MAC.9 and M.27 EMLA with the least. In Ohio MAC.24 was the only rootstock that was clearly distinguishable from the others. Percent of roots was greatest for all rootstocks at both locations for the less than 2 mm size and least for the greater than 5 mm size. Percent of roots smaller than 2 mm was greater at the Michigan than the Ohio location. Percent of roots in the 2 to 5 mm and the greater than 5 mm categories was greater for the Ohio than the Michigan location.

Soil bulk density, texture, water content and strength have substantial influence on root growth (11). High bulk densities and hardpans restrict root penetration and alter root distribution patterns (3, 4). Adaptation of apple rootstock root systems to soil conditions is an important component in determining orchard performance and identifying and correcting possible problems such as flooding or drought by rootstock selection or cultural practices.

Characterization of root distribution patterns and adaptations to soil limitations are important to aid in rootstock selection. The objective of this study was to describe the rooting characteristics of nine clonal apple rootstocks at two NC-140 trial locations under highly different soil characteristics.

Materials and Methods

The 1980 NC-140 Uniform Apple Regional Rootstock Trial consisted of Starkspur Supreme Delicious scion (*Malus domestica* Borkh.) on 9 rootstocks: M.7 EMLA, M.9 EMLA, M.26 EMLA, M.27 EMLA, M.9, MAC.9, MAC.24, OAR 1 and O.3. Of the 15 cooperators, the sites located at Michigan State University, East Lansing, MI and Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH were used for this study. Trees were planted 3.5 m within-row and 5.5 m between-row spacing with North to South row orientation in a randomized complete block with 5 replications. Trees were trained to a central leader and received similar management practices at both sites.

The soil type at the Michigan location is a Marlette fine sandy loam (Fine-loamy, mixed, mesic Glossoboric Hapludalfs) with a bulk density of approximately 1.4 g/cm^3. This soil is described as a moderately well drained with moderate to moderately slow permeability (9). Soil type at the Ohio site is a Canfield silt loam (Fine-loamy, mixed, mesic Aquic Fragiudalfs), de-

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scribed as a moderately well drained soil with a fragipan (10). The fragipan was observed to be between 50 and 70 cm below the soil surface. Permeability is moderate above the fragipan but poor through the fragipan. The bulk density above the fragipan is between 1.3 and 1.5 g/cm^3 and greater than 1.7 g/cm^3 below the fragipan (10).

The profile wall method (7) was used to determine the number of roots. Excavation began 9 Oct. 1989 and 30 Apr. 1990 for the Ohio and Michigan sites, respectively. Since the highest proportion of roots are found within 1 m^2 from the center of the trunk of apple trees (1) trenches were excavated parallel to tree rows 0.8 m from the center of the trunks on both sides. The most common range for depth of rooting of apple is from 1 to 2 m (1); therefore, the trenches were 1.5 to 2 m deep. Grids were constructed 1.2 m deep x 1.8 m wide and divided into mapping grid squares of 30 x 30 cm. The soil profile was broken approximately 5 cm deep with spades and washed with a high pressure water gun to loosen and rinse soil from around the roots. Grids were placed over the washed profiles and roots were counted and sized on corresponding paper grids (5). Roots were classified into 3 size categories: less than 2 mm, 2 to 5 mm, and greater than 5 mm in diameter. Data was analyzed as a combined randomized complete block design.

Subsequent to root mapping roots were spray painted white to contrast with the soil and horizon interfaces were denoted with an orange painted line. Photographs were taken to illustrate the distribution pattern *in situ.*

Table 1. Mean number of roots per tree per rootstock by size of root at the Michigan and Ohio NC-140 trial locations.

Rootstock	Total roots	Roots < 2 mm	Roots 2 to 5 mm	Roots > 5 mm
		Michigan		
MAC.24	2166 a[y]	2051 a	65 bcd	50 b
OAR 1	1579 abc	1458 abc	82 bc	39 bcd
M.7 EMLA	959 cd	903 cd	35 f	22 ef
M.26 EMLA	1325 bcd	1266 bcd	41 def	18 ef
O.3	859 cd	812 cd	33 f	14 ef
M.9 EMLA	1208 cd	1157 bcd	36 ef	16 ef
M.9	813 cd	772 cd	27 f	14 ef
MAC.9	740 d	705 d	28 f	6 f
M.27 EMLA	646 d	614 d	24 f	8 f
		Ohio		
MAC.24	1970 ab	1782 ab	119 a	70 a
OAR 1	1113 cd	984 cd	89 b	40 bc
M.7 EMLA	1133 cd	1041 cd	61 cde	31 cde
M.26 EMLA	1007 cd	952 cd	35 f	21 ef
O.3	892 cd	804 cd	50 def	38 bcd
M.9 EMLA	709 d	644 d	43 def	23 def
M.9	698 d	643 d	37 ef	17 ef
MAC.9	945 cd	892 cd	41 ef	14 e

[y]Mean separation for each column by Duncan's multiple range test at the 5% level.

Results and Discussion

The analysis of variance for the root mapping indicated no interaction between the east or west profile of the tree; therefore, both profiles were combined for analysis. At both locations MAC.24 produced the greater number of roots in all size categories.

There was more separation between rootstocks at the Michigan location with generally three groups distinguished based on the number of total roots and roots in the three size categories (Table 1). Generally, MAC.24 had the most roots per tree; OAR 1, M.26 EMLA and M.9 EMLA had intermediate numbers; and M.7 EMLA, O.3, M.9, MAC.9 and M.27 EMLA had the least roots.

M.27 EMLA was not included in the root mapping of the Ohio site since all but one replicate had died before excavation. There was little difference between the other rootstocks depending on the size category. MAC.24 had more total roots and roots of each size category than the other rootstocks. Three categories were evident in the 2 to 5 mm class: MAC.24 and OAR 1 had the most roots per tree, M.7 EMLA, O.3 and M.9 EMLA had intermediate numbers and M.26 EMLA, MAC.9 and M.9 had the least roots. Roots greater than 5 mm also could be separated into 3 groups with MAC.24 had the most roots per tree followed by M.7 EMLA, OAR 1 and O.3 had intermediate numbers and M.26 EMLA, MAC.9, M.9 EMLA and M.9 had the least roots per tree.

There was little significant difference between the same rootstocks in number of roots counted at the two locations. The differences were noted in the two categories of root size larger than 2 mm. In the 2 to 5 mm category, MAC.24 and M.7 EMLA had fewer roots counted at the Michigan than the Ohio location (Table 1). For roots larger than 5 mm, MAC.24 and O.3 had fewer roots counted at the Michigan versus the Ohio site (Table 1).

Rootstock appeared to affect root number to a greater effect than location. The effect of a rootstock and soil type on number of roots has been discussed by various authors. Rogers and Vyvyan (8) discussed the effect of heavy clay, loam and light sands on several apple rootstocks. Four Malling rootstocks and three soil types were studied. A difference was noted between rootstocks and soil type. The total weight of the root system increased from clay to the sand to loam. Mikhail and El-Zeftawi (6) found a rootstock and soil effect in their study of two sandy soils and a sandy loam and three rootstocks on number of roots of citrus. Cleopatra mandarin produced the most roots followed by Rangpur lime and the least on sweet orange. The sweet orange produced

Table 2. Percent of roots per tree per rootstock by size of root at the Michigan and Ohio NC-140 trial locations.

Rootstock	Roots < 2 mm	Roots 2 to 5 mm	Roots > 5 mm
	Michigan		
MAC.24	95	3	2
OAR 1	92	5	3
M.7 EMLA	94	4	2
M.26 EMLA	96	3	1
O.3	94	4	2
M.9 EMLA	96	3	1
M.9	95	3	2
MAC.9	95	4	1
M.27 EMLA	95	4	1
	Ohio		
MAC.24	90	6	4
OAR 1	88	8	4
M.7 EMLA	92	5	3
M.26 EMLA	95	3	2
O.3	90	6	4
M.9 EMLA	91	6	3
M.9	92	5	3
MAC.9	94	4	2

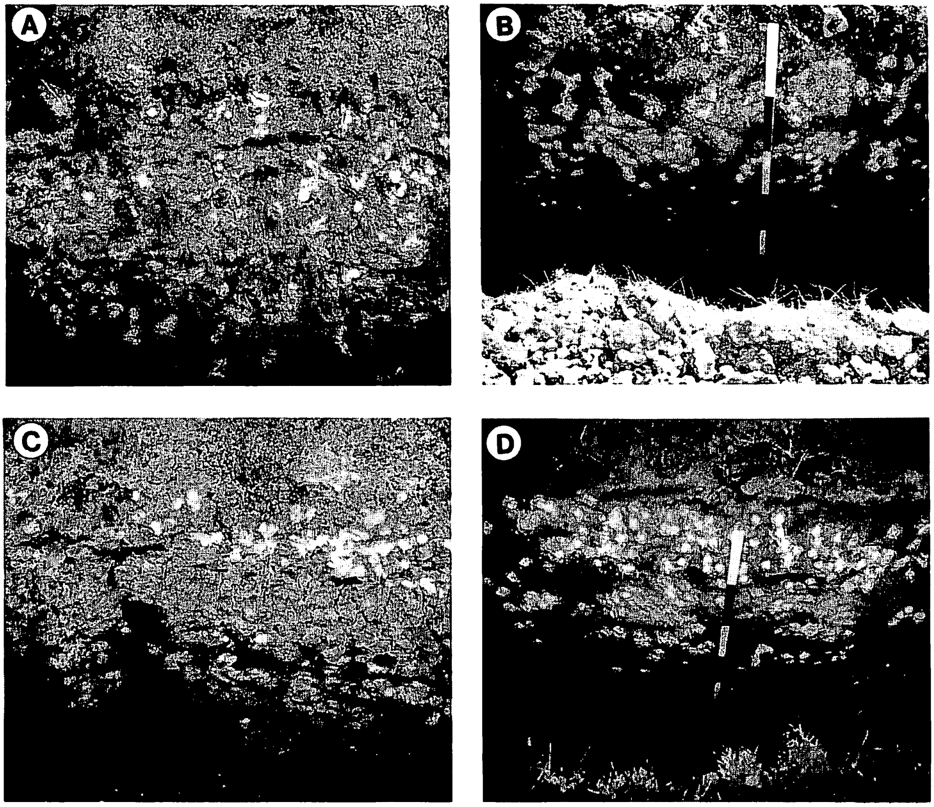

Figure 1. Root distribution of two rootstocks at the Michigan and Ohio locations. A. M.26 EMLA rootstock at the Michigan site. B. M.26 EMLA rootstock at the Ohio site. C. MAC.9 rootstock at the Michigan site. D. MAC.9 rootstock at the Ohio site. Roots were spray painted white. The black and white sections of the bar in B and D are 30 cm each.

the most roots on the Barmera sand, Cleopatra on the Moorook sandy loam and Rangpur lime on the Murray sand.

The distribution pattern of M.26 EMLA and MAC.9 at both locations are shown in Fig. 1. Most of the roots at the Ohio site appear to be confined to the top 70 cm while they are well distributed through the profile at the Michigan site. M.26 EMLA has roots well distributed in all layers of the soil profile at the Michigan site (Fig. 1A) while there are few roots in the lower horizon at the Ohio site (Fig. 1B). Root distribution of MAC.9 at the Michigan location (Fig. 1C) is more sparse than the Ohio location (Fig 1D). This indicates adaptation of MAC.9 to heavy soils with M.26 EMLA and the other rootstocks are not affected by soil type as far as total number of roots.

Soil physical conditions affect root growth, especially mechanical impedance which is related to soil bulk density (3). Cemented or highly compacted pans present a physical barrier that severely limits root penetration (3, 4). This would explain the limitation of the root system to the upper layers of the Ohio soil while no restriction of the root system is seen at the Michigan location.

The percent of roots less than 2 mm was between 92-96% and 88-95% for the Michigan and Ohio site, respectively (Table 2). The percent of roots in the 2 to 5 mm category was generally 3 or 4% at the Michigan location while usually 5% or greater at the Ohio location. The percent of roots greater than 5 mm was from 1 to 2% at the Michigan site and typically 3 to 4% at the Ohio location. The percent of roots between 2 to 5 mm and greater than 5 mm in size was greater at the Ohio site except for M.26 EMLA for the former and MAC.9 for both size categories. Of the nine rootstocks, M.26 EMLA, M.7 EMLA and MAC.9 showed little to no change in percent of roots in each size category between the two locations. The rootstocks MAC.24, M.9 EMLA, OAR 1 and O.3 showed the greatest effect by site in percent roots in each size category. These results agree with a report by Beukes (2) showing an effect of soil type on percent of roots in different size categories.

In this study, the rootstock had the greatest effect on number of roots per tree. Rootstocks were similar at both locations with respect to total number of roots counted and roots less than 2 mm with only three rootstocks with differences in the other size categories. Percent of roots in each size category was affected by location with more roots larger than 2 mm at the Ohio site but were more evenly distributed at all depths at the Michigan site.

Many aspects of tree root systems are similar, yet soil environment causes modifications moderated by genotype. The distribution pattern and size of root systems is integral to the understanding of stresses perceived by the root system. Characterizing the root systems of different genotypes under different soil environments is necessary to understand how these two factors affect adaptation of plants to soil stresses under different conditions and locations.

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