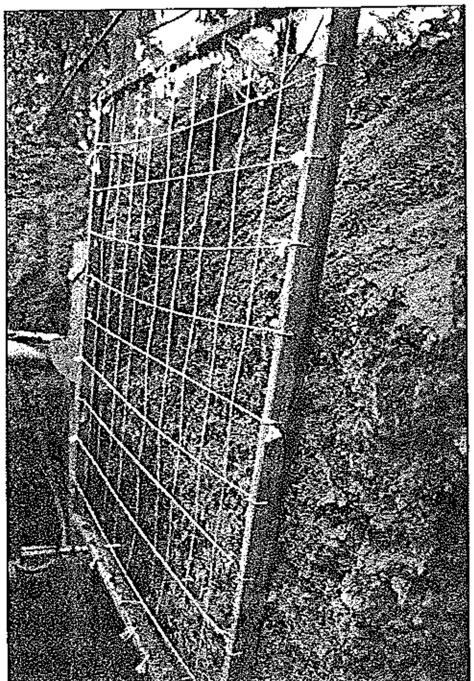

Figure I
One meter by one meter grid divided into 100 10cm² sections for measuring root number and root size of different rootstocks at different soil depths. Each of the seven rootstocks at two different vine spacings were evaluated at four different sites in the experimental plot.

Effects of rootstock and spacing on root distribution

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Introduction

Grapevine root systems can vary in rooting depth and rooting density. How evenly and deeply roots explore within the soil profile is an important characteristic of root distribution. However, the depth where the concentration of roots is greatest and how densely or evenly roots spread within the soil profile also has significant effects on root distribution patterns.

Root distribution of grapevines is largely influenced by the rootstock cultivar and the soil environment. Soils which contain impervious layers or are chemically inhospitable will restrict root growth. This is true for clay hard pans,[12] high soil acidity,[4] and high salinity.[9]

Rooting depth is also affected by soil texture. Research in Australia has shown that vines planted on coarse-textured soils are more deeply-rooted than vines planted on fine textures.[7] In addition, fine textures and impenetrable soils cause an increase in rooting density by limiting the volume of soil the vine can explore.[7,9]

Genetic differences between rootstocks also affect the rooting characteristics of vines. Rootstocks that induce differences in above-ground vegetative vigor may also have corresponding differences in their root density.[9,11]

Some studies have suggested that the rootstock determines the density of roots, while soil environment determines the distribution within the soil profile.[10,13] However, in soils without serious limitations, patterns of root distribution also seem to vary between rootstocks.[5,7,8,11]

A replicated study of the root systems of 110R, AXR#1, and St. George (grafted to Cabernet Sauvignon) in a deep soil, found that St. George had the deepest distribution of medium (2-5mm) and large (5-12mm) diameter roots.[6] St. George also had the greatest root density per unit area of a trench wall. These results correspond with above-ground data on the rootstocks which showed that St. George had the heaviest yearly pruning weights.[6] This particular study prompted further investigation into the below-ground differences between rootstocks.

Understanding the genetic differences in root distribution patterns of grapevine rootstocks will help growers make better planting decisions. If our study established differences in root distribution patterns, and these correlated with above-ground growth, rootstocks with specific root distributions could be matched with soils for more precise management of above-ground vigor.

The effect of vine spacing on root distribution is also crucial. If closer spacing simply forces roots to distribute more deeply, using close spacing to control vigor may be an ineffective grapegrowing method.

Experimental design

In our study, trenches were dug to evaluate differences between the root density and root distribution patterns of the seven rootstocks 039-16, 110R, 3309, 1616, 5C, 420A, and AXR#1 grafted to Cabernet Sauvignon.

In addition, we hoped to determine how in-row vine spacings of one meter between vines and two meters between vines affected root density and distribution. Previous research has shown that closer vine spacing increases root density,[1,2] and causes a sharper angle of soil penetration by the roots.[1]

However, there is no replicated study showing whether closer vine spacing will induce development of a deeper root system. Therefore, the purpose of our study was twofold. First, the effect of rootstock and vine spacing on root density was assessed and compared to above-ground growth. Second, differences in the root distribution of different rootstocks and vine spacing were investigated.

Mapping the roots

This replicated study was conducted in a six-year-old rootstock trial at the University of California Oakville Experimental Vineyard. Four trenches were dug for each of the seven rootstocks at one-meter and two-meters within the vine row spacings (56 trenches total). The trenches

Table I

Rootstock	Total root number per trench	Pruning weights (lbs.)
039-16	481.1	8.1
5C	447.4	4.7
3309	430.6	7.8
AXR#1	428.2	8.2
110R	383.2	8.1
1616	327.2	6.3
420A	270.9	4.1

were dug from vine trunk to vine trunk parallel to the vine row. They were two meters deep and approximately 30cm away from the vines. Trenches were either one meter or two meters long depending on vine spacing. The distance between vine rows was four meters.

Size and location of roots which intersected the trench wall were carefully mapped onto a data sheet. To assist in the mapping of roots, a one square meter wooden frame was suspended on the trench wall (Figure I). The frame contained a grid of 100 10cm² sections. All roots were recorded in one section before moving to the next square within the grid.

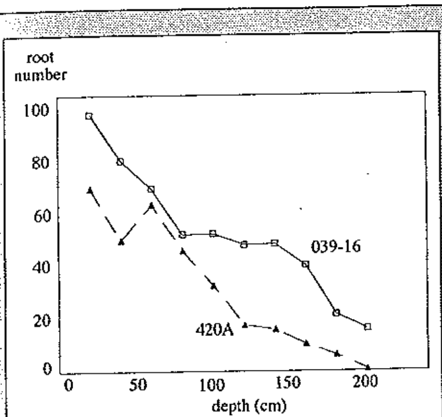

Figure II
Total root number as a function of depth for rootstocks 039-16 and 420A in Oakville, CA. Numbers represent the roots which intersected the trench wall for each depth category and are the means from four trenches two meters deep with two meters between vines.

One way to investigate root distribution patterns is to add all roots across the trench within a specific range of depth. These totals are then compared across rootstocks and vine spacings. For this reason, ten depth categories were created as follows (in centimeters): 0-20, 20-40, 40-60, 60-80, 80-100, 100-120, 120-140, 140-160, 160-180, 180-200. Statistical analysis cannot be conducted on data sets which have large variances, such as root numbers. The data must first be transformed. Therefore, statistics were calculated from the log of root numbers for each depth.

Results: root density & vigor differences

For this study, density represents the total number of roots intersected per unit area of trench wall. Regardless of vine spacing, there was a statistical difference in the total number of roots between rootstocks ($p<0.05$). Rootstock 039-16 consistently had the largest number of roots. Rootstock 420A and (to a lesser extent) 1616 had the lowest density of roots per trench. (Table I)

To compare these root densities to above-ground vigor, pruning weights from the two vines which bordered each trench were totaled and compared. A statistical difference between rootstocks was also found for pruning weights

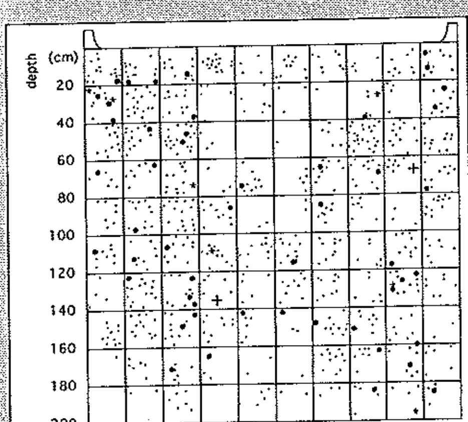

Figure III
Root map of 039-16 rootstock. Distance between vine trunks is two meters and the trench depth is two meters. Symbols represent different size categories of root diameters (· =<2mm, • = 2-5mm, * = 5-12mm, and + = >12mm).

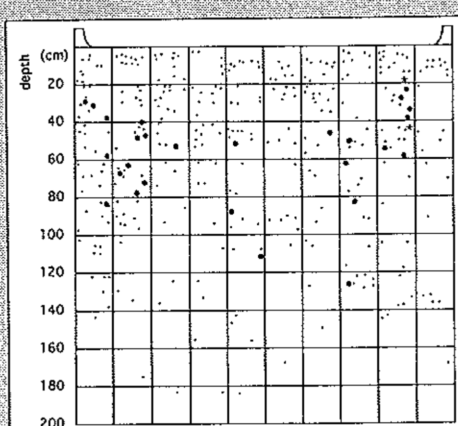

Figure IV
Root map of 420A rootstock. Distance between vine trunks is two meters and the trench depth is two meters. Symbols represent the different size categories of root diameters (· =<2mm, • = 2-5mm, * = 5-12mm, and + = >12mm).

(p<0.001). Rootstocks AXR#1, 039-16, 110R, and 3309 had greater pruning weights than either 5C or 420A. (Table I)

There are some consistencies between pruning weights and total numbers of roots for these rootstocks. Most significantly, 420A had the fewest roots and the lowest pruning weight. Rootstocks 039-16, 5C, 3309, AXR#1, and 110R had large numbers of roots, and all but 5C had high pruning weights. The relatively large amount of crop in relation to the total leaf areas per vine of 5C may explain this discrepancy.

Vine spacing had a significant effect on both root density and above-ground vigor. The density of roots per unit of trench area was higher for the closer spacing. The density of roots per square meter of trench was 151 for one meter spacing and 125 for two meter spacing, suggesting that vines, at closer spacing, more effectively explore the soil environment. Nevertheless, competition for resources (water, nutrients, and probably light) are reflected in lower total roots on the trench face and lower pruning weights for vines spaced one meter apart.

Root distribution differences

Roots were found to a depth of two meters in almost every trench. Therefore, the rooting depth did not differ between rootstocks or vine spacings. However, the distribution of roots within the soil profile did vary with rootstock, as shown by a significant interaction of rootstock with depth (p<0.05).

Statistically, 420A had a more shallow root distribution than 039-16 (Figure II). All other rootstocks had distributions between these two extremes. Nevertheless, trends in these root distribution studies suggested that 1616 and 5C also had more shallow root systems and 110R and AXR#1 had deeper distributions. Rootstock 3309 did not have a particularly deep rooting pattern, but appeared more evenly distributed in the soil profile than the other rootstocks.

Rootstock 039-16 had more roots than 420A for all depth categories below one meter. (Figure II). Root distribution maps for rootstocks 039-16 and 420A (Figures III and IV) show that 039-16 had not only a deeper total root distribution than 420A, but it had more roots of a larger diameter.

In contrast to the rootstock effect, there was no statistical effect of vine spacing on the location of roots within the soil profile, suggesting that closer vine spacing did not induce a deeper distribution of roots. Soil in this vineyard is a gravelly clay loam and is drip-irrigated several times during the summer. In more droughty soils or under dry-farming conditions, deeper root systems may occur at closer spacing.

Neutron probe readings from the vineyard also suggest that there were no differences in depth and distribution of roots between the two vine spacings. Water was removed faster from the soil with one meter vine spacing, presumably because of the higher root density. However, water was removed in the same pattern for both vine spacings down to a depth of two meters.

Summary

In this study, root density corresponded well to above ground vigor. Specifically, rootstocks with small root systems, such as 420A, had low aboveground vigor. Closer vine spacing caused competition for resources (smaller plants) and more intense soil resource utilization (higher root densities).

At the Oakville Experimental Vineyard, closer vine spacing did not induce deeper root distribution, suggesting that this may be a useful method of vigor control. Rootstock cultivar had a signficant effect on the distribution of roots, with 420A, 1616, and 5C having the most shallow root systems and 039-16, AXR#1, and 110R having deeper root systems.

We believe differences in rootstock rooting patterns will be important when making planting decisions provided that site, variety, vine spacing, and trellising have also been considered. Understanding how rootstock may affect the distribution of roots may also be important in vineyard management practices such as irrigation scheduling and cover crop selection. ■

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