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Title: "Grapevine rooting patterns: A comprehensive analysis and review"

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If the previous summary on the thesis project of one of the authors was the appetizer, this is the main dish right out of the oven. In this paper the authors present a comprehensive review of the root distribution patterns of different *Vitis* species.

- First, a quick look at where grapevines fit, in terms of root system, compared to other species. It is generally accepted that above-ground growth is a good indicator of root spread and maximum depth. Still, it seems that growth form –grass, herb, shrub, tree- is the main factor controlling rooting depth. Annual precipitation and soil factors, such as impenetrable layers and anoxia (lack of oxygen), also played an important role in determining root depth and shape. As a reference, if we compare grapevines with coniferous forests, grapevines have a smaller fraction of their roots in the top 60 cm, meaning more of them lying at deeper horizons. Grapevines, as a group, appear to have proportionally **deeper root distributions** compared to many plants in natural ecosystems. They also seem to have relatively **low root densities**. This would allow them to colonize soil more extensively than grasses, herbs or shrubs.

- Next, the authors review the **methods** that researchers have used to study roots. By far the most effective method has been the wall profile method, also called trench profile. The earliest researchers to use this method were Branas and Vergnes in France (1957), Nelson Shaulis in the east coast (1960), and Van Zyl in South Africa (1988). The method consists of excavating a trench of 1 to 2 meters of depth parallel to the vine row, and using a grid to record the location and size of roots intercepting the wall. Sometimes the trench wall is painted white, and the soil consequently teased away around the roots, to improve root visibility. Others have used a glass wall, called a rhizotron, to be able to see the roots through, but its use was discontinued early.

- Despite being the widespread method for root study, the authors point out a few shortcomings of the wall profile method. 1)It assumes the 3-D distribution of roots around the vine is relatively uniform. Fortunately, authors who excavated trenches perpendicular to the row did show root distributions similar to those found in parallel trenches. Still, V. champinii, whose roots tend to cluster around the drip zone area, might be one example where this is not the case. Wall profiles also 2) tend to be insensitive to the presence of mechanical barriers, such as confined areas or intrusions, that greatly affect the root distribution beyond the barrier. Finally, 3) it assumes we are looking at the roots of one vine, when in fact, there is a tremendous overlap between the roots of adjacent vines. For this later reason, the authors prefer to talk about "a community of roots of clonal individuals".

- In reviewing the root distributions reported by the different researchers, the current authors calculated a rooting index, that they call "beta" (ß), for each pattern reported. This coefficient provides an idea of the depth of the root distribution of a given rootstock, and is a good numerical reference for comparison purposes. Higher values of ß mean greater proportions of roots at deeper levels. At the end of the paper, the authors present a comprehensive 6-page table of root distributions that can be conveniently examined by genotype, by proportion of roots at deeper levels (ß), by soil type, by region, or by author. The highlights of their review follow here.

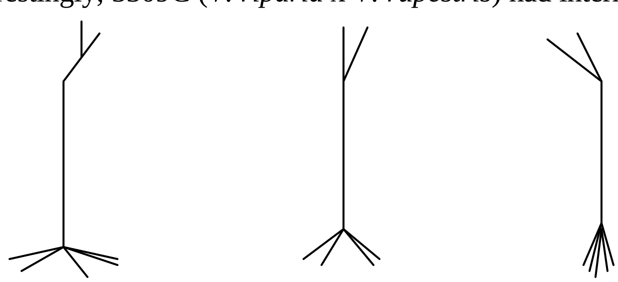
- **Vertical root distribution.** About 60% of grapevine roots were found in the top 60 cm of soil. Whenever soils contained large stones, clay layers, gravel lenses or other profile changes, root distributions became patchy, with greater root densities in defined areas. Grapevines have very deep maximum rooting depths, and reports of 6 meters and deeper are not infrequent.

- **Lateral root spread.** Studies on horizontal distribution were rare. Some authors found fairly high root densities at distances greater than a meter from the vine trunk. Another more precise study found about 15% of total biomass to be between 1.2 and 1.5 meters from the trunk. One author found that coarse-textured soils had the lowest root densities, whereas fine-textured soils had the highest. Detailed drawings of another author, dating back to 1967, indicated root spreads up to 10 meters. The current authors' observations support this type of maximum spreads.

- **Influence of soil physical properties.** Fine-textured soils have higher water-holding capacities and shallower infiltration rates than coarse-textured soils, and so, one would predict that roots in fine-textured soils would be smaller and shallower. Still, a clear correlation between texture and horizontal or vertical spreads has not been found. One author reported that root densities were low in the top 20 cm of sandy soils (coarse-textured). This might give the impression of a deeper root behavior in this type of soil. But the authors offer an alternative explanation: rapid drying and extreme temperatures may be shortening root lifespan in this type of soils. Overall, the studies reviewed point out that **soil structure, stoniness, and depth of the water table were the key determinants of vertical root distribution**, regardless of genotype or of texture. It is generally accepted that soil depth is the most important factor determining root depth distribution.

- **Influence of cultural practices.** Consistently throughout the studies, clean cultivation through tillage, and the establishment of a permanent cover crop, diminished root presence in the upper 20-30 cm of soil. Root pruning and root competition, respectively, are likely the mechanisms involved. Inversely, minimum tillage practices, mulches, plastic covers, and herbicides, all increased grapevine root densities in the upper 20 cm. One author studied the influence of deep plowing, or ripping, on root depth, but unfortunately, the study was inconclusive.

- **Influence of genotype.** Some authors found evidence that rootstocks 1103P, 101-14 Mgt, and 110R had greater depth densities than other rootstocks. In this review, the authors found that all of these rootstocks had similar root densities rather than similar rooting depths. This suggested to them that **root density may be the key difference among rootstocks responsible for the different scion performance.** In his historical work dating back to 1905, Guillon tried to classify rootstocks into those with roots that penetrated deeply ("sinker roots"), and those whose roots would grow more horizontally ("feeder roots"). He reported extreme genetic differences between emergence angles of *V. riparia* (with feeder roots), and *V. rupestris* (with sinker roots). Interestingly, 3309C (*V. riparia* x *V. rupestris*) had intermediate angles.



V. riparia **V. riparia x V. rupestris** **V. rupestris**

These studies were done with rooted cuttings. However, according to the current authors, emergence angles from cuttings may not be a good indicator of mature vine root patterns in unrestricted soil volumes.

- At the end, the authors note that sometimes rootstocks expected to have shallow roots, did not actually perform that way in their review. One example was 5C, commonly known to perform well in poorly-drained soils, and so expected to have shallow rooting behavior. In this study, 5C exhibited relatively deep-rooting behavior in most soils where it was examined. Other examples were 420A and 110R, not known as high-vigor rootstocks, yet showing deep root profiles in this review. The authors conclude that, besides root system size, more subtle factors such as root longevity, nutrient absorption capacity, and root density, may be important contributors to differences in scion performance.

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