
Research News from Cornell's Viticulture and Enology Program Research Focus 2012-4

# Research Focus

## Fifteen Years of Vine Root Growth Studies in Concords

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***Figure 1.*** *Clear plastic root observation tubes were installed in this Concord vineyard at the Lake Erie Fredonia Laboratory and used with the 'minirhizotron' to make observations of root growth over 15 growing seasons.*

*Photo by Alan Lakeso*

Grape roots are the hidden half of the vine that we know is important but take for granted. We know surprisingly little about the roots under our vines. When do they grow? How long do they live? What controls their growth in amount or distribution? How do cultural practices like pruning or irrigation affect root growth? This report summarizes results from 15 years of our own research on Concord root dynamics and related studies by other researchers around the world.

### Key Concepts

- Grape roots grow primarily during the growing season in New York. In bearing Concord vines new roots were produced primarily between budbreak and veraison.
- In warmer regions new roots may be produced also in the post-harvest period and even in the winter if soils are warm.
- Concord grape roots age quickly – most live only 50-100 days and are functional for only about half of that time.
- In our studies, root growth and lifespan was not clearly affected by pruning intensity, crop level or water availability.
- Young vines can produce a great many roots but once the vine are cropping, only 10 to 20% of the vine's annual growth goes into root production.
- Mature vines have very few roots relative to cover crops or weeds on the vineyard floor, so vine roots don't compete well for water or nutrients.
- Grape roots don't have an inherent geometry so they go wherever the conditions are best. Their distribution is then affected greatly by each soil's unique combination of water, oxygen, nutrients and organic matter, and soil texture.

**Root function and growth.** Roots serve many roles in the vine. They anchor the vine, explore the soil to find and take up mineral nutrients and water, provide regulatory hormones to the top of the plant, and store reserves of carbohydrates and mineral nutrients to support the early vine growth in the spring. These are critical functions that we try to support and influence with fertilization, irrigation, soil manipulation (e.g., ripping, cultivation, liming, drainage tiles), and cover cropping.

**How to you study roots in the field?** Studying roots hidden deep in the soil is difficult, which is why we know so little about them. We have used several techniques depending on what we wanted to know. Classic methods include digging up the whole root system to get root weight, but you can only do that once. Digging a trench along the vine and counting roots found in the wall of the trench reveals root distributions. Counting roots found in soil cores is another less destructive method. A newer technique, called the minirhizotron, uses clear two-inch diameter plastic tubes, plugged at one end and inserted into the soil under the vines. At intervals of two weeks, we insert a special video camera into the tubes and photograph the roots growing over the tube to monitor when roots grow and follow individual roots to see how long they live (Comas et al., 2000 and 2005).

**When do roots grow?** Several studies in different climates have followed seasonal root production. In warm climates like California or where soils are still fairly warm in the winter, some root growth can occur during vine dormancy. During the growing season, root production tends to decline mid-season, though whether it is due to crop demand, heat stress, or water stress is not clear.


Photo by Peter Cousins

***Figure 2.*** *Photo of Concord roots Concord roots taken through the root observation tubes with a remote camera. By taking repeated photos weekly during the growing season, root growth and longevity can be followed over time.*

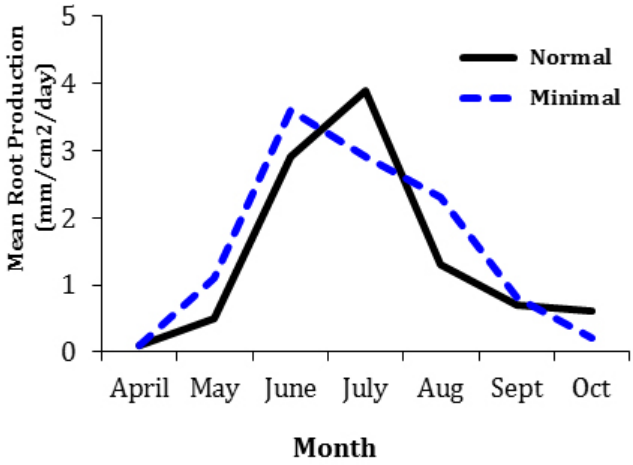


***Figure 3.*** *Five-year average seasonal pattern of new root production in mature Concord vines in Fredonia, NY with minimal and normal (balanced) pruning. Earlier root production in minimally-pruned vines reflected earlier canopy development.*

However, in own-rooted Concords in New York with crops of 7-12 tons/acre, using the minirhizotron method we found significant root growth only between budbreak and véraison (Fig. 3) (Comas et al., 2005). Root production between véraison and harvest was somewhat higher in lighter-cropping vines, though it did generally not exceed about 10 to 20% of total root production. We rarely saw much post-véraison root growth as noted in vinifera varieties in warmer seasons. A preliminary study of vinifera rootstock root production in New York suggests that there were relatively more roots produced between véraison and harvest than in the Concords, but such differences need to be confirmed.

Another interesting result is that, unlike shoot and crop development processes that tend to have consistent seasonal patterns, root production patterns were quite inconsistent from year to year. We don't really understand why, though it seems that each year the weather, soil moisture and crop level interact uniquely to affect the amount and timing of carbohydrate energy that can move down to support root growth.

**How long do new roots live?** Although a small number of roots become major roots and live as long as the vine, the overwhelmingly majority have rela-

tively short lives. Most fine roots die in the same season there were produced, just as leaves do. We have found that fine Concord grape roots have variable lifespans from as little as two weeks to a few months with a median life span of 50 to100 days (that is half the roots have died by 50 to 100 days) (Anderson et al. 2003). Importantly, though, for about half of their life fine roots are white and functional in nutrient uptake, but then they turn brown and lose much of their function (Comas et al., 2000 and Volder et al., 2009). On average, fine roots of Concord appear to be functional for only about a month. A study in Napa, California, found that the root lifespan in 1103 Paulsen and 101-14 was similar, approximately 200 days. (Fig. 4Surprisingly, several factors we examined (pruning, crop level or water availability) did not affect root lifespan very much.

**How many roots do grapes produce?** Young vines before cropping can grow a dense mat of roots, but once cropping begins root production drops mark-

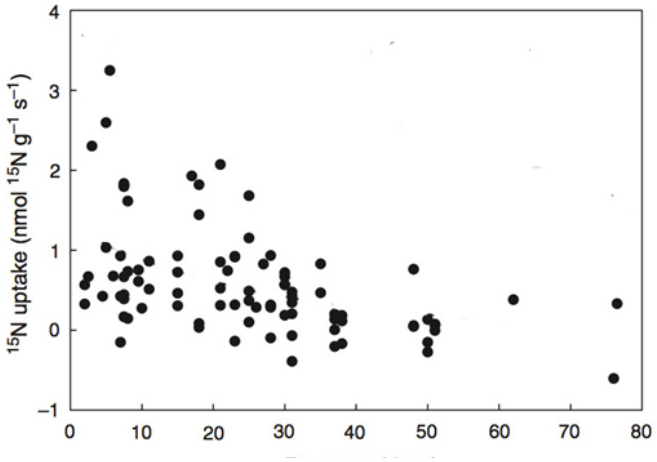


***Figure 4.*** *Concord grape root ability to take up nitrogen changes as roots age. By about 30 days when roots are no longer white the N uptake ability is greatly impaired. (Modified from Volder et al., 2009.)*

edly. Generally grape root systems of mature vines are very sparse with not many roots for the volume of soil. Several studies have found that cropping vines may put less than 10% of their yearly growth into new roots. When excavating grape root systems, it can be amazing how few roots there are on healthy productive vines. Although many plants have great numbers of fine root hairs, we have never observed root hairs on grape roots in the field on mature Concord vines. Relatively few roots and few or no root hairs suggest that grapes may have trouble exploring the soil for adequate absorption of less mobile mineral nutrients like phosphorus. However, grapes have mycorrhizae, which are microscopic symbiotic fungi in association with the roots that receive energy from the vine but provide a huge increase in absorptive surface area—so they appear to work as substitute root hairs. This helps locate and absorb nutrients that the roots could not do on their own. The role of mycorrhizae and what affects them is very poorly understood.

**What affects root distributions?** Grapevines are vines, which by nature don't have a consistent structure. Vines take on the form needed by growing wherever the conditions are best, such as over trees, along the ground, or along fences. Similarly, the form of grape root systems is mostly determined by the soil structure and availability of resources. Grape roots, like many plants, like good soil aeration, good

*Photo by Terry Bates*

***Figure 5.*** *Excavated mature field vine showing the sparse root system on mature bearing vines. Root distribution in the field varies, reflecting variable soil conditions.*

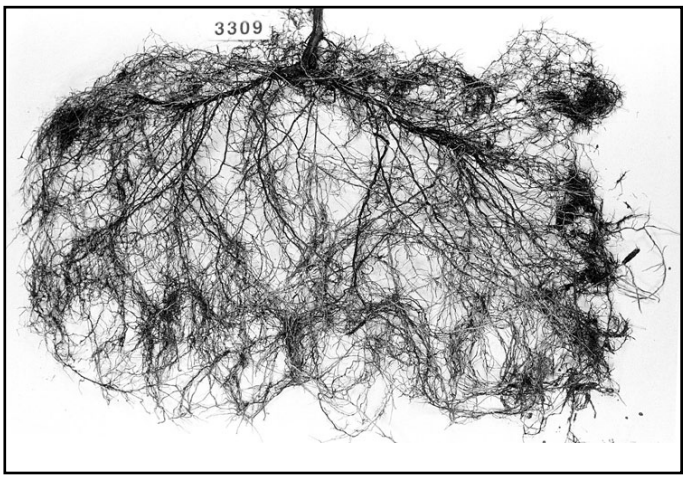


*Photo by Alan Lakso*

***Figure 6*** *Couderc 3309 rootstock after first year of growth on non-bearing vines. Note the large mass of roots produced when the young vine is not carrying a crop.*

nutrient availability (either from organic matter or from fertilizer), acceptable pH (generally between 6 and 7.5) and friable soil structure. Since these generally are greatest in the top soil layers, most grape roots will grow there. If these soil characteristics are patchy or in layers, the root system will be as well. Soil hardness, such as naturally hard layers or zones compacted by equipment, will often limit the extent of root growth. Consequently, the root distribution is much more controlled by the local soil conditions than by genetics.

Good soil water availability is also a key factor in root production. An example is that in arid regions, where most water and many nutrients are provided by drip irrigation, roots will grow primarily in the wetted area under the drippers. In the eastern United States this occurs much less because we tend to have more consistent rains that allow roots to grow and take up nutrients from more soil. Drying soil may initially stimulate root growth in young non-cropping vines, but in mature cropping vines we found that dry soil was detrimental to root production and also to root health and function (Huang et al., 2005). However, too much water may lead to flooding and a lack of oxygen that is very detrimental to the root systems of grapes, so good soil drainage is a key for vineyards. This means that while almost every soil situation may give a different root distribution;, some general patterns do exist. A study of root distributions of several rootstock genotypes in over 100 root wall maps (Smart et al., 2006) were quite consistent with depth, with about 80% of roots in the top meter of soil. This is likely simply because the top meter or so had the best conditions of oxygen, organic matter and nutrients.

As mentioned above, grapes generally have relatively few roots compared to many plants. Grasses and other plants that are used as cover crops have 100 to 1,000 times the root length per soil volume as grapes. This means that grape roots do not generally compete well for nutrients and water against cover crops or weeds that have much denser root systems. This is a reason why we often keep weeds from under the vines so the grape roots have some topsoil to get established without competition. Conversely, the same competitive relationship can be utilized to try to reduce excess vine vigor with row-middle or under-trellis cover crops. Again, however, soil structure can be important. If the soil is deep, fertile and with high water-holding capacity, we have found that vine roots can just redistribute by growing deeper under the cover crop, reducing the inhibiting effect. If, however, the soil is shallow and especially if the covers go under the trellis, the vine roots may be "boxed in" and vine growth may be reduced as the vine is only left grow in the subsoil. So the same treatments may give differing results depending on the soil characteristics at each site.

**Does crop level affect root production?** Economic pressures have led Concord growers to increase yields and reduce inputs by using minimal pruning. In response to the concern that the higher yields may debilitate root systems, we conducted a long term study of balanced versus minimal pruning of mature own-rooted Concord vines to determine if the heavier crops typical of minimal pruning debilitated the root system. Although the crop levels averaged 25% higher, we did not see evidence of a reduction in fine root production (Comas et al. 2005). This may have been due to a compensatory reduction in investment in shoots in minimally-pruned vines (that is, pruning weight if they were pruned).

To uncouple pruning effects from cropping effects, we then monitored the root production in 120-node Concords (with irrigation available) as affected by crop thinning at 30 days after bloom to crops varying from about 4 to 12 tons/acre for five years. We were able to maintain the top yield and the yield differences for the full five years. Surprisingly, we found no consistent effect of crop level on new fine root production (Eissenstat et al, 2009; Lakso et al., 2009). That may reflect the relatively late thinning, but the timing was based on industry practice. After five years we excavated 48 entire vines with various crop levels and found that there was a decline in medium-sized roots that are primarily storage and transport organs rather than fine absorbing roots. So it appears that heavy cropping may gradually reduce the root reserves, but does not appear to reduce the production of the fine absorbing roots each year. Although vine performance at 12 tons/acre was maintained for five years in these well-managed and irrigated vines, the trend of reducing the small storage roots could not continue, so finding and balancing the right crop is important for vineyard sustainability.

It should be noted that observations from these and other studies suggest that if additional stresses occur such as poor nutrient status, water or pest stress, the

effects of crop on the roots may be greater. This suggests that to have high sustained yields as needed in juice grapes or bulk wine grapes, it is necessary to limit as much as possible any external stresses. For premium wine grapes with restricted yields, debilitation of root systems is much less likely. Indeed, excessively low yields may stimulate large root systems that then support excessive vine vigor. Much more research is needed in those situations.

**Can we control vine roots like we do the tops?** We have found in our studies of Concords—as other have—that grape root systems grow horizontally or vertically whenever and wherever the conditions allow or are best. Consequently, the growth and distribution patterns of roots will vary with every combination of soil and management (e.g., irrigation, fertility, cover cropping). We don't understand enough about roots to be able to really control them, so at this time it is best to understand the factors that limit their growth and function. We can then support them appropriately.

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