Grapes 101

How Grapevine Roots Grow

By Tim Martinson

Concord vine above ground and below ground. Photo by Terry Bates

Compared to the above-ground portions of a grapevine, root structure and function is more of a mystery to most growers. Roots extract nutrients and water from the soil, and are also the dominant storage organ for carbohydrates and nutrients (vine reserves) in the dormant season. They also provide physical support for the vine and produce hormones that regulate vine growth and the vine's response to environmental conditions.

But roots are hidden below ground – so their seasonal growth pattern and functions can't be directly observed. Grapevine growth and development above-ground passes through predictable phases – bud burst, bloom, veraison, harvest, and leaf fall. But the below-ground seasonal root growth cycle is less obvious.

The Big Picture

Researchers estimate that vines allocate 30 to 60% of photosynthate to root growth. On a mature vine, the surface area of roots is estimated to be somewhere around 100 m^2 – compared to 10 m^2 of above-ground leaf area. While most 'fine roots' that absorb water and nutrients are concentrated in the top meter of soil, a portion of the roots can grow to great depths (up to 30 m), and extend out several meters from the base of the vine.

Vines attempt to maintain a root:shoot ratio within a reasonable range, and vine size is highly correlated with the size of the root system.

Root Structure

Commercial vines are propagated vegetatively, and roots initially form as outgrowths of the cutting's cambium layer under conditions of high humidity. On rooted cuttings, they generally form near a shoot node. These become the main structural roots, which branch off into lateral (secondary and tertiary) roots.

Lateral branches can form at any location along the root system, and their formation depends upon the vine's ability to detect environmental cues (water, nutrient availability) and extend to those regions. Unlike shoots and leaves, which have a pre-programmed and predictable arrangement, the growth and branching patterns of roots are highly flexible – and very responsive to local soil conditions.

Root distribution on the Riparia Gloire rootstock, which tends to grow laterally near the soil surface. Other rootstocks such as 3309C tend to have a more downward growth habit. Photo by Terry Bates

Growth originates at the meristem of the root tip, where cell division occurs, which is covered by a slimy 'root cap' that protects the shoot from abrasion by soil particles. Behind this zone, there is a cell 'elongation zone', where the cells begin to form two layers. The outer layer is the cortex, where nutrient uptake and storage occurs. The inner 'stele' differentiates into the xylem and phloem, responsible for transporting water and nutrients up and down the plant.

Maximum uptake occurs several millimeters behind the root tip, where numerous root hairs are formed that greatly increase surface area for absorption. Further away from the root tip, these outer layers and root hairs are worn away, leaving the central stele and its vascular system for transport to the trunk, shoots, and other vine parts. A layer of cells outside the xylem develops into the cambium, which increases the diameter of the roots and can initiate new lateral root meristems. An exterior 'cork cambium' forms, and develops the outer hardened cell layers that contain subarin – a waxy, water-resistant substance that forms a barrier between the root's conducting tissues and the soil.

Fine roots form associations with mycorrhyzal fungi – a symbiotic relationship where the fungus enhances uptake of nutrients from the soil – and in turn get supplied with carbohydrates from the vine's photosynthesizing leaves to support their growth and development.

Seasonal Root Development

In dormancy, cells surrounding xylem vessels in the roots are stuffed with starch and nitrogen, which is deposited starting around veraison but also mobilized from leaves as they senesce in the fall. These reserves are what fuels early canopy development in the spring.

The first visible sign of the vine's transition from dormancy to active growth is often sap flow or 'bleeding' of xylem sap from pruning wounds. The driving force behind this sap flow is metabolic activity in root tissues as the soil warms up in the spring. As stored starch and proteins are converted into sugars and amino acids, they are released into the xylem. The resulting osmotic pressure (from the high concentration of sugars in xylem sap) draws water into the roots, and is enough to lift water (and nutrients) to the shoot tips – where it rehydrates buds, beginning the process of bud swell.

As buds start to swell, shoot tips produce auxins that are eventually transported (through the phloem) down to the roots to stimulate root growth. These interact with giberellins produced at the root tips (promoting cell elongation). This process takes time, because the dormant buds are isolated from the vine's vascular system, and need to reconnect– a process that is thought to be completed around bloom (see How Grapevines Reconnect in the Spring).

So root growth lags behind shoot growth in the spring – and the dry weight of roots actually declines between bud burst and bloom, as stored reserves are mobilized to support early season shoot growth. As the canopy emerges, root growth speeds up, reaching a peak between bloom and early fruit development, then declining gradually during fruit ripening.

Although root biomass increases from its low point around bloom until leaf fall, much of the biomass is concentrated in larger, permanent structural roots. Fine roots are where the uptake of nutrients and water occur. They are short-lived (<5 wk) and frequently replaced – quite likely because they exhaust local nutrient and water supply. As the grapevine canopy becomes well-established after bloom, a portion of the photosynthate returns to the roots and replenishes vine reserves – a process that accelerates as fruit ripens, periderm forms and canopy growth ceases.

Response to Environmental Stresses and Management

- *Canopy manipulation.* Root growth is responsive to auxin flow from buds and new shoots. Light pruning and high early leaf area will stimulate root growth. Severe pruning or winter injury that limits early season shoot growth will also limit root growth. Hedging that removes shoot tips will temporarily result in a pause in root growth.

- *Water Stress*. During the growing season, transpiration of water vapor through leaf stomates drives most uptake of water from the soil (see *How grapevines respond to water stress*). As soil water gets depleted, transpiration demand exceeds uptake by the roots. As soils dry out, root tissues increase production of abscissic acid (ABA), which is transported to the leaves and signals the stomates to close, reducing water loss but also reducing CO_2 exchange needed for photosynthesis. Shoot growth slows, but ABA may induce the opposite effect in roots. It seems to block transport of K^+ (Potassium ions) into the xylem, inducing import of water to growing root tissues. Under mild water stress, roots can therefore maintain growth and exploit new (less depleted) soil.
- *Excess water*: It's a truism that vines 'don't like wet feet' – and do better in coarse-textured soils than in fine-textured soils. Root respiration requires the uptake of soil dissolved oxygen, which is rapidly depleted in water logged soils. Over an extended period of waterlogging, the lack of respiration limits cell function and nutrient and water uptake by the roots.
- *Nutrient excess*: Vine demand generally drives nutrient uptake – and feedback mechanisms can 'shut off' nutrient uptake. But uptake can exceed vine growth requirements and the excess supply can accumulate in the vine – often within vacuoles in cells, where they provide insurance against nutrient depletion.
- *Nutrient shortage*: When nutrients are deficient, shoot growth slows, due to growth-limiting supplies in the cells. Roots take up and deplete nutrients in the surrounding root zone. Local depletion can shift uptake to other roots exploring more nutrient-rich areas. If the overall vine supply is deficient in macronutrients (N, P, K), root cells reduce production of cytokinins, which when transported to growing shoot tips stimulate cell growth and division. But lower levels of cytokinins in roots in response to N deficiency can increase the rate of root growth – presumably so that roots can improve nutrient uptake by exploiting new soil that has not been depleted of nutrients.

The vine's root system is hidden underground, but its growth and overall 'share' of the photosynthates assimilated by the vine is critically important to the health and development of the above-ground shoots, leaves, and fruit. Roots take up nutrients, supply water, provide support, and produce hormones that regulate overall vine growth. They form a symbiotic relationship with mycorrhizal fungi – which enhances nutrient and water absorption beyond what the roots themselves could supply. They have a flexible growth habit that is responsive to variable soil conditions. They are the most important storage organs that provide the sugars and nitrogen that fuels early-season vine growth. Although we can't often directly observe them, their functions are equally as important as the canopy and fruit that producers intensively manage. And they do it mostly without interference from us.

Reference:

Keller, M. 2010. *The science of grapevines: anatomy and physiology*. Academic Press. First edition.

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