Sources and Sinks: Allocation of Photosynthates during the Growing Season

**GRAPES 101**

Grapes 101 is a series of brief articles highlighting the fundamentals of cool climate grape and wine production.

By Tim Martinson

*This Pinot noir vineyard illustrates effects of excess fertility and undercropping on carbon allocation. Photographed on September 29, 2010, the shoot tips are still actively growing, while clusters show evidence of uneven ripening. Note the full green "Christmas" clusters that have developed on secondary shoots.*

Carbon compounds produced through photosynthesis, along with minerals from the soil, are transported from “sources” (photosynthetically active leaves) to “sinks” to support vine growth, fruit development, and maintenance of the vine’s permanent structure (canes, trunks, and roots). Where this photosynthate is allocated varies according to the time of the season and the needs of the vines. Put another way, the strength of the various sinks to which photosynthates are allocated varies during seasonal vine development. It also is affected by nutrient availability and soil fertility, vine water status, additional stressors such as insects and disease, and crop load – the ratio of fruit to active leaf area. Understanding how allocation of photosynthates shifts over the growing season underpins many of the viticultural practices aimed at influencing vine growth and fruit development.
• **Dormant to bloom.** Early vine growth relies on carbohydrate and nitrogen reserves stored in canes, cordons, trunks and roots. Starches are mobilized — first from the canes and then from the roots — to the developing shoot tips until mature leaves are capable of becoming “net exporters” of photosynthate to support further shoot growth and development.

• **Bloom to fruit set.** After flowers are pollinated and begin to set fruit, the fruit becomes an additional sink for photosynthates, and a portion — small at first — is diverted from growing shoot tips. In addition, bloom is when the first axillary buds for next year’s crop start to form. By this time, with carbon reserves largely depleted, the vine relies solely on this year’s canopy to support further canopy development and shoot growth as well as cluster development. Shoot tips and fruit “compete” as sinks for photosynthate. As evidence, it’s well known that if shoot tips are removed around bloom, increased allocation of photosynthate to clusters can increase fruit set — as the competing shoot tip “sinks” are temporarily eliminated.

• **Early fruit development.** By fruit set, berries have already undergone cell division in their ovaries, and have about one-third of their final number of cells. Berries continue their development through cell division, while canopy development and root growth continues.

• **Lag phase to véraison.** About a month after bloom, there is a temporary "lag" in berry growth. At this time, cell division in berries is largely complete, and seeds are beginning to form within the ovaries of the berries. After this point, berries continue to grow through cell enlargement, and berries and seeds constitute an increasingly strong “sink” for photosynthate. Shoot growth should slow dramatically by veraison as more of the photosynsathe is allocated to developing clusters.

• **Véraison and after.** Véraison signals the start of fruit ripening. Fruit composition starts to change. There is a rapid expansion of berry volume and accumulation of soluble solids. Cells — which before véraison expand through import of water through the xylem — continue expansion with water and solutes imported through the phloem. Acids — largely malate before véraison — reach their peak at véraison and begin to get broken down via respiration. Simultaneously, sugar accumulation dramatically increases. At this point, vines have a full canopy, and the developing and ripening fruit is the overwhelming “sink” for photosynthate produced by the leaves.

• **Periderm formation and dormancy.** Also after veraison, shoots begin to turn brown from the base of the shoot outward towards the tips, as the water-resistant periderm forms. As the leaves start to senesce, carbon and nitrogen from leaves is mobilized out of them to support both fruit development and the storage of reserves in vine canes, trunks and roots.

• **Harvest.** Once the crop is removed, photosynthate produced by remaining leaves is moved into permanent parts of the vine and converted to starches for storage, which will support early shoot growth and development during the next growing season.
Consequences for management:

Understanding this seasonal cycle of allocation helps explain seasonal variation in vine growth, the impact of stressors, and the effect of nutrient availability on various processes in the vineyard.

Water relations:

Water stress from fruit set through the lag phase can limit cell division, shoot growth and berry size. For wine grapes (and particularly reds), moderate stress at this time is often viewed as a positive, by limiting excess vigor and shading, and facilitating the transition from vegetative growth to fruit development. For red varieties, smaller berries resulting from water stress increase the ratio of skin to pulp, resulting in wines with deeper color and more concentrated flavors.

Excess water and nutrients:

In contrast, excess water and nutrient availability (especially nitrogen) can delay the transition from vegetative growth to fruit development. Ideally, shoot growth should slow dramatically by about a month after fruit set. If excess water and nitrogen fuel continued shoot growth through and after veraison, fruit quality suffers, and the transition to dormancy and winter hardiness will also be delayed.

Active leaf area after harvest:

A fundamental difference between cool and hot climate growing regions is the amount of time that active leaves remain on the vine after harvest. Warm climate growers almost always have an extended amount of time after harvest with active leaves. In cooler climates, the amount of time that a grapevine canopy remains active after harvest is limited, and sometimes nonexistent. Removing the “sink” of ripening grape clusters redirects photosynthate towards replenishing vine reserves and supporting acclimation to winter low temperatures. This critical period after harvest influences how resistant vines are to low winter temperatures and how early season growth will progress in the following year.

Vine balance:

Finally, understanding carbon partitioning provides key insights into the concept of vine balance – that is, managing cropping levels and vine growth so that they are in balance with each other. Overcropped vines have more fruit but less leaf area to support their development. At best, the finite amount of carbon produced by leaves is divided among too many clusters, delaying ripening. At worst, overcropping also results in fewer leaves – and less photosynthate – to support a larger crop. Delayed maturity and unripe fruit is one result. Undercropped vines allocate too much
photosynthate to vegetative growth. Without the “sink” of developing clusters to slow down shoot growth, canopies become dense and shaded – and often don’t stop growing until late in the season.

Understanding sources and sinks for photosynthate, and how they fluctuate during the season and in response to environment and viticultural practices, is a key to effective vineyard management.

**Suggested reading:**


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