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NITROGEN MANAGEMENT IN VINEYARDS

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Soil mineral composition is one of the key components of viticulture terroir. Mineral elements such as calcium, iron, potassium, and nitrogen are essential for the synthesis of primary metabolites, as well as the production of many secondary metabolites such as phenolic or aromatic compounds that provide a wine with its color and most of its flavor.

Among the minerals that grapevines assimilate from the soil, nitrogen (N) is undoubtedly the one that most strongly influences vine growth and vigor and, in consequence, fruit composition. Some researchers even consider that the availability of N participates in the terroir effect since it is influenced by the soil. For example, vines generally assimilate more N when planted on gravelly soil, whereas their N status is lower when planted on clay soil.

Nitrogen requirements by winegrapes are generally estimated to be between 30 and 70 pounds of pure nutrient per acre per year, depending on the desired vigor and yield. In Texas, the availability of N naturally occurring in the soil is generally low, often making it a limiting nutrient. At harvest, fruit contains between 10 and 30 pounds of N per acre, resulting in exportation from the vineyard. This phenomenon is strongly correlated with the variety and the vigor and is considered to be the minimum amount that must be supplied each year by the soil reserve or by supplemental fertilization. However, fertilizer additions to soils must be greater than the amount required by the vine because N is rather unstable in the environment. It can volatilize into the atmosphere post-application and is also highly mobile in the soil and can be lost through leaching. In contrast, high N availability can lead to excessive grapevine vigor resulting in greater canopy management costs, increased incidence of fungal diseases, and reduced fruit quality. Therefore, it is essential to provide sufficient N for adequate plant growth, fruit quality, and yield without over-applying and stimulating excessive vigor. The management of vine N status is, therefore, crucial in grape production.

NITROGEN IN THE SOIL

In the soil, N is present in two forms: organic and inorganic. The vast majority of N is stored in its organic form, in the form of humus, stable and slowly decomposed, or fresh organic matter. The inorganic or mineral form of N exists mainly in three forms: elemental (N_2), nitrate (NO_3^-), and ammonium (NH_4^+). From a plant nutritional point of view, NO_3^- and NH_4^+ are considered as essential forms. The organic forms of N—humus and fresh organic matter—cannot be assimilated directly by the vine. A mineralization process is essential to make them bioavailable. This step is carried out by soil microorganisms. It is essential to note that mineral N is very weakly retained by the soil. In the absence of fertilization, the availability of mineral N for the vines depends on the amount of organic matter stored in the soil and its rate of mineralization. The latter will be more important if the carbon to nitrogen ratio (C/N) of the organic matter is low, the pH is close to neutral, the soil is well aerated, it is warm in temperature, and there are water reserves close to field capacity. Soil N supply is also influenced by irrigation.

Among the many factors influencing vine N status, plant material is predominant. Each variety or even each clone or rootstock has different rates of N assimilation. For example, Cabernet-Sauvignon and Pinot noir are known for their high rate of N assimilation, unlike Riesling and Grenache. At the clonal level, Sauvignon blanc clone R3 has higher assimilation of N compared with Sauvignon CL297.

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Cultural practices can also impact N availability. It is well documented that weed growth between the rows increases the competition for N between the vine and the weed, decreasing the amount of N available for the vine. In contrast, legumes, often sown as green manure, will enrich the soil with N.

Finally, the climate of the region and the environmental nuances of the vintage can also influence plant N status since they affect the rate of mineralization of the organic matter.

NITROGEN CYCLE DURING VINE DEVELOPMENT

Nitrogen reserves

The growth and development of the vine are partially dependent on its mineral reserves, including N, accumulated during the previous season. N reserves are located in the perennial parts of the vine—the roots, the trunk, and the canes—and constitute 20 to 40 percent of the plant's annual needs that are necessary for its growth. At the beginning of the season, N requirements are important to form young organs in the spring. They are mainly taken from reserves formed at the end of the previous season before root absorption takes over. Starting at veraison, if N quantities absorbed from the soil remain insufficient, a new phase of remobilization of the reserves will occur.

Nitrogen absorption

The amount of N taken from the soil varies according to the stage of vine development. Two periods of intense absorption of this nutrient include a first period between budbreak and veraison and a second period after harvest and until leaf fall. The amount of N removed from the soil increases gradually from the 3 to 5 leaf stage to 50 percent of the total N content in the pea-size stage—the first peak of N accumulation. Then, N absorption decreases between veraison and ripeness and increases after harvest. In Texas, this corresponds to early- to mid-fall, depending on the region. Nitrogen quantities absorbed after harvest constitute 30 to 40 percent of the total N and will be mainly stored in the trunk.

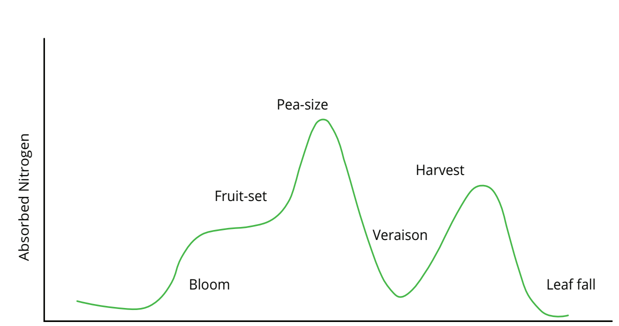

Figure 1. Dynamics of vine N uptake during the season. *(Adapted from Conradie 1980)*

Transport and remobilization

Nitrogen is transported in comparable quantities to all vine organs by the xylem, driving the sap rich in water and nutrients from the soil to the leaves, and the phloem, transporting the carbohydrate-rich sap.

Starting at bloom, total N concentration of the shoots increases gradually to reach its maximum level at the end of the vegetative growth. This increase is due to a translocation of this element from the leaves to the shoots and the perennial parts. Nitrogen content in the aerial parts of the plant, the limbs and petioles, reaches its maximum in the early stages of development, concordant with the phase where N uptake peaks then decreases over the season with minimum values at harvest or in the fall.

Dynamics and location of nitrogen in the berry

In the berry, a significant allocation of N begins after flowering, thus causing a drop in the content of this macroelement in the perennial parts of the plant despite the continuous supply from the roots. Therefore, cluster development and N reserve formation seem to be two antagonistic processes. The translocation of N in the grape berry increases gradually during ripening. Nitrogen is accumulated mainly 2 weeks before the pea-size stage and then after mid-veraison. During these two periods, the berry accumulates more than 50 percent of the N present in the plant. At the end of the ripeness stage, a large amount of N is transported from the roots to the berries.

SYMPTOMS OF NITROGEN DEFICIENCY

- General chlorosis (yellowing) of the lower and older leaves. As deficiency worsens, younger leaves will show symptoms.
- Slow vine growth, short internodes, and small leaves.
- Reduction of yield.

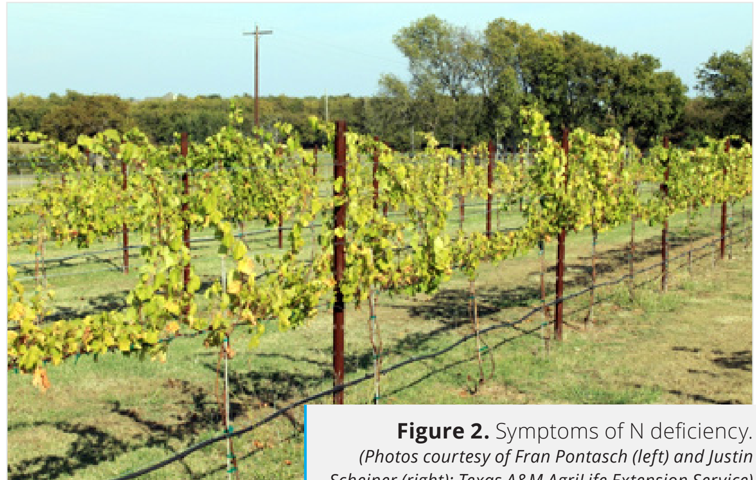

Figure 2. Symptoms of N deficiency. *(Photos courtesy of Fran Pontasch (left) and Justin Scheiner (right); Texas A&M AgriLife Extension Service)*

NITROGEN FERTILIZATION

Nitrogen fertilization stimulates N metabolism and, consequently, protein synthesis. Two periods of fertilization are recommended depending on the stage of development and must be reasoned according to indicators of soil and vine N status. The first period is between budbreak and fruit-set when N uptake and plant needs are at a maximum. The second period is the post-harvest stage when reserves for the following season growth are constituted. Small quantities via drip irrigation—5 to 15 pounds of N per acre—are recommended at this second period. If N application is made close to leaf drop, uptake will be low, and N will be leached through the soil profile. Large applications of N should be avoided later in the season to ensure that shoots properly harden off and acclimate for winter.

In vineyards deficient in N, a foliar N supply between flowering and veraison generally increases yeast available nitrogen (YAN), which is the combination of free amino nitrogen, ammonia, and ammonium that is available for the wine yeast to use during fermentation. Note that foliar sprays provide a short-term benefit to the vine but do not address the inherent deficiency in the soil.

Application prior to budbreak is of no value since N uptake is low, and the vine is still using N from reserves. In addition, N should not be applied close to flowering as it may result in bunch shatter. Applications around veraison and during ripening should also be avoided as this could promote excess growth and decrease berry quality.

Fertilization is generally accompanied by an increase in leaf area coupled with an increase of chlorophyll synthesis and development of storage tissues such as the trunk, the shoots, and the roots.

APPLICATION METHODS

Direct soil surface application – Dry N fertilizers are applied directly to the soil surface either by banding in the weed-free strip under the trellis where vine roots are concentrated or by broadcasting over the vineyard floor in clean, cultivated vineyards. The disadvantage of such applications is the dependence on rainfall for incorporation and availability. Some growers mix N with their herbicide sprays to enhance herbicide activity and as a source of nutrition. Use caution when banding so as not to apply N to the base of the crown, which could burn the vine.

Fertigation – This is generally a more efficient technique since N is applied in small amounts at regular intervals rather than at a large rate all at once, as done by direct soil surface application. On sandy soils, multiple applications of small amounts are recommended to reduce the risk of salt injury and to compensate for potential greater losses of N via leaching.

Foliar application – This application method provides limited short-term benefits during a particular phenological stage of vine growth. Very small applications of N in the form of urea may be used to correct visual symptoms of deficiency. With foliar applications, a risk of leaf burn can occur when sprays are done between bloom and harvest.

NITROGEN SOURCES

Dry N for soil surface application – Examples: Urea (46% N), calcium nitrate (15% N), potassium nitrate (13% N), ammonium sulfate (21% N), monoammonium phosphate (11% N), and diammonium phosphate (18% N). The N percentage given for fertilizers indicates the percent by weight of N (i.e., 100 pounds of urea (46% N) contains 46 pounds of N).

Liquid N for soil application – Examples: Aqua ammonia (20%), calcium ammonium nitrate (32%), urea ammonium nitrate (32%), urea (23%), and ammonium nitrate (20%).

Complete fertilizers – Fertilizers such as 10-10-10 could also be considered, but only if both phosphorous (P) and potassium (K) are also needed.

If using ammoniacal formulations of N, the fertilizer must be incorporated into the soil by tillage or rainfall; otherwise, valuable N may be lost through volatilization.

Manure and other organic matter – Compost or cover crop litter can act as alternative sources for nitrogen. The release of N available to the vine is a prolonged process and should be a part of a long-term nutrient management strategy. Two concerns of relying on organic matter as a nutrient source for N. First, it is difficult to assess N concentration due to the variability of each source as well as the mineralization rate each season. Second, oftentimes adding organic matter also provides other nutrients, which may be a disadvantage. An example would include cow manure. It does contain N but also much higher rates of P.

Leguminous cover crops – A winter legume such as vetch or clover can be a good slow-release source of N and can improve N availability in the soil.

VINE NITROGEN STATUS AND ITS EFFECT ON VINE GROWTH AND GRAPE COMPOSITION

Bell and Henschke explicitly described the effect of N nutrition on vine growth and berry composition in 2005. In their review, they mentioned that N deficiency, defined by low vigor and a YAN less than 100 milligrams per liter, leads to a decrease in growth and yield as well as yellowing of the leaves. The presence in the must of low concentrations of YAN causes delays or difficulties in fermentation and results in the presence of hydrogen sulfide or undesirable sulfur compounds in the wine. This deficiency can be caused by insufficient availability of mineral N in the soil, but also by strong water stress which prevents the assimilation of N by the root system. A YAN value close to 200 milligrams per liter is recommended to ensure a smooth running of the fermentation.

In contrast, an excessive N supply causes increased yield, vigor, photosynthetic activity, and susceptibility to *Botrytis cinerea*. Among other things, the excessive vigor alters canopy microclimate, thus resulting in a decrease of temperature and radiation received by various organs—leaves, buds, and clusters. Radiation decrease reduces the concentration of anthocyanins, terpenes, and total phenols in the berry. Moreover, the low temperature inside the canopy causes high titratable acidity and a low pH due to an increase in malic acid content. A reduction in temperature can also cause a slower maturation rate resulting in insufficient phenolic maturity at harvest.

NITROGEN FERTILIZATION IN TEXAS

In Texas, the majority of vineyard soils, particularly sandy soils, are naturally low in organic matter. In consequence, N fertilization may be critical for optimal vine growth and fruit quality, especially following each subsequent harvest. Because N has an increased risk of volatilization into the atmosphere and high leaching potential on these types of soils, N application should be made more frequently by adding small doses at each application. A split application between the 3- to 5-inch leaf stage and fruit-set is recommended with quantities depending on tissue testing and overall vine visual observations. As mentioned previously, attention should be made to the variety planted and the scion or rootstock combination, as some cultivars have a tendency to better assimilate N and the potential of excessive vigor that influences vine health and grape quality.

SUMMARY

- Testing – Petiole analysis at bloom and/or veraison to determine the amount of N to be added. Soil analysis is of no value.
- Time of application – Between budbreak and fruit-set and/or post-harvest.
- Application methods – 1) Direct soil surface application; 2) Fertigation (recommended); 3) Foliar application.
- Application rates – Heavy application: 50 to 70 pounds N/acre; Moderate application: 40 to 50 pounds N/acre; Light/maintenance application: 20 to 30 pounds N/acre.