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Best Management Practices for Nitrogen Fertilization of Grapevines

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Introduction

Nitrate contamination of California's groundwater is widespread, and according to the State Water Resources Control Board is a more serious problem than water pollution with pesticide (2). It is important, therefore, when using nitrogen (N) fertilizer to apply **best management practices** that optimize N use efficiency. Nitrogen should be applied when vine uptake is rapid, and N rates should not exceed vine requirements. Nitrogen inputs from irrigation water, crop residues, and mineralization of soil organic matter must be considered when determining N fertilizer requirements. Irrigations must be accurately scheduled and applied to minimize leaching losses of nitrate from the root system. The potential for increasing N fertilizer efficiency in vineyards has greatly improved in recent years with new information on N fertilizer timing, the grapevine's N demand, and maximizing irrigation efficiency.

When to Apply Nitrogen

Nitrogen should be applied during the growing season, preferably after budbreak through fruit set, or postharvest (September). When fertilizing postharvest, the canopy should be healthy and functional; applications should be made before October in the San Joaquin Valley. In some viticultural areas or with late varieties, the season may be too short after harvest for effective uptake to occur. On soils highly susceptible to leaching, a split application of N (fruit set + postharvest) will minimize leaching losses. Nitrogen should not be applied during the dormant period or early spring especially on sandy, rapidly drained soils. Timing of N application does not vary with method of irrigation.

Supporting Research

Nitrogen is most critically needed by grapevines during the period of rapid shoot growth in the spring through bloom and early berry development. The need for N declines from midsummer to senescence (4,28). Grapevines and deciduous fruit trees depend heavily on redistribution of N previously stored in roots, trunk, and canes or limbs to support spring growth (1,8,9,10,11,13,20,23,24,25,26). Since the grapevine's need for N is most critical in the spring and highly dependent on storage, it can be inferred that fertilizer should be applied when the vine can best absorb and incorporate it as part of the N reserve while minimizing N loss from the soil (leaching, denitrification).

Time of fertilization, using isotopically labeled N, was studied in mature, furrow irrigated, "Thompson Seedless" vineyards in the San Joaquin Valley (20). Application in July or late September (postharvest) resulted in the highest concentration of labeled N in both dormant storage tissue and in leaf tissue during rapid spring growth and at bloom. Nitrogen applied at budbreak had insufficient time for uptake to become a significant fraction of total N in leaf tissue by bloom. When labeled ammonium sulfate was applied at budbreak to a vineyard on sandy soil, spring rainfall and frost protection irrigations severely leached soil N by bloom (19).

Nitrogen applications should be made to coincide with periods of rapid N uptake. Studies with potted vines indicated N uptake peaks from budbreak to veraison and from harvest to leaf fall (8). Studies in furrow irrigated, mature "Thompson Seedless" vineyards indicated the rate of N uptake is more rapid from fruit set to veraison than from budbreak to bloom. The rate of N uptake late in the season is rapid, with newly absorbed N incorporated into storage tissue (18,20).

There is concern that applying N during the periods from bloom until veraison or postharvest could result in greater vine growth and production problems than traditional dormant applications. However, studies in the San Joaquin Valley have found fertilization during these periods is compatible with fruit development and vine growth (5,18). Fruit soluble solids were similar for all period of N application, although N fertilization generally reduced soluble solids. Berry weight, titratable acidity, pH, and total N of fruit juice were not affected by N fertilization, regardless of timing. Cane maturity was not affected by fertilization during the growing season. In one trial with "Thompson Seedless", late shoot growth was slightly increased with N applied at veraison and, to a lesser degree, postharvest (5). In viticultural areas where winter damage is a concern, more work is needed on the effect of N timing and on the hardening off process.

How Much Nitrogen to Apply

The principal objective of N fertilization is to maximize crop development rather than vegetative growth. Grapevines have a small N demand relative to many other fruit crops. The N requirement for stems, leaves, and fruit measured in "Thompson Seedless" grapevines used for raisin production in the San Joaquin Valley was 84 $kg.ha^{-1}$. Approximately 35 $kg.ha^{-1}$ was removed by the crop and the remainder recycled (27). This would suggest that the annual N demand would be approximately 25 to 50 $kg.ha^{-1}$ depending on crop size. Recent studies in the San Joaquin Valley indicate "Thompson Seedless" yields and fruit quality can be sustained with 25 to 50 $kg.ha^{-1}$ N applied annually (5).

The amount of N fertilizer required varies with yield, soil type, and irrigation efficiency. Nitrogen inputs from irrigation water, crop residue, and the mineralization of soil organic matter must also be considered. Fertilization may not be necessary when high levels of NO_3 are present in irrigation water, or when legume cover crops are grown. Fertilization practices can be monitored by bloomtime petiole sampling for nitrate analysis (4, 6). Vines should be closely observed, adjusting N rates according to vine vigor and production.

Application of N in excess of vine requirements increases potential for NO_3 pollution and can be detrimental to vine growth and production. Excess N is a more common problem in San Joaquin Valley vineyards than N deficiency (4). Problems created by excess N include excess vigor, poor bud fruitfulness, excessive berry drop, bud necrosis, delayed crop maturity, and increased levels of stem necrosis disorder, bunch rot, and leafhopper activity.

Water Management

Certainly, rate and timing of N application are important aspects when developing a best management practice. Most critical, however, is the efficient management of irrigation water to minimize leaching and denitrification. Irrigations must be accurately scheduled and applied, and irrigation systems must be properly designed, operated, and maintained.

Water management in vineyards has improved with increased knowledge of crop water requirements and evapotranspiration (ET). The relative constancy of evaporative demand in the San Joaquin Valley and the availability of long-term ET records have resulted in the development of practical and efficient drip irrigation schedules (16). Water budgets that consider ET, water storage in the root zone, and allowable depletion between irrigations have improved efficiency of high volume irrigation.

Advantages with Drip Irrigation

Drip irrigation, when managed properly, can achieve high irrigation efficiency primarily by minimizing water flow below the root zone but also from reduced surface evaporation and runoff (15,16). The potential for increased irrigation efficiency is greatest on sandy, well drained soils, texturally nonuniform fields, and hilly terrain.

Drip irrigation wets a limited area of the root zone. Nutrients applied through the system are placed where roots are concentrated and uptake is supported by high soil-water matrix potentials when irrigations are properly scheduled; N uptake is impeded by under or over irrigation. This provides an ideal environment for uptake of N and other nutrients applied through the system (7,15). Fertilization through a drip system is relatively easy and offers an opportunity for multiple applications.

Multiple applications, however, do not necessarily improve uptake and utilization of N. The value of multiple applications with a drip system was studied in the San Joaquin Valley in a mature, "Thompson Seedless" raisin vineyard and using isotopically labeled ammonium sulfate (17). Irrigations were accurately scheduled and monitored to meet vine requirements while minimizing leaching. To test the value of single versus multiple applications, 40 $kg.ha^{-1}$ N was applied as follows: single using 40 $kg.ha^{-1}$ N (1x) applied 4 April 1984; 20 $kg.ha^{-1}$ applied 4 April 1984 plus 20 $kg.ha^{-1}$ four weeks later (2X); eight weekly applications of 5 kg.ha-1 N (8X) beginning 4 April 84.

The results, presented in Table 1, show no clear advantage in multiple applications. The percent N derived from fertilizer in leaves, roots, trunk, and canes did not vary with application technique.

Multiple applications of N through a drip system would probably improve N uptake efficiency when irrigations are not managed efficiently, or on very sandy soils. Also, multiple applications using small amounts of N should be considered to reduce the potential for salt injury or N toxicity.

Future Directions

Cover crops affect cycling of N in the root zone and the N status of the grapevine (21,22). Winter cover crops can reduce nitrate leaching to groundwater by taking up excess nitrate in the soil during an otherwise fallow winter period. Mineralized N from incorporated cover crop residues can then become available to the grapevine during summer months, thus contributing to more efficient nitrogen cycling. To manage excess N, summer cover crops, such as sudan or perennial grass sods, compete with the vine for NO_3 during periods of rapid uptake and reduce the N status of the vine.

Our research team is currently evaluating the effect of various floor management systems on the N status of the vine and the annual dynamics of the inorganic N pool in the root system. Non-tillage and reduced tillage methods are included in these studies along with various cover cropping systems: annually seeded winter growing grasses and legumes; reseeding winter annual grasses and legumes; perennial grasses and legumes; and summer annuals. Our objective is to further the understanding of how to best manage N in grape culture.

Table 1. The % N derived from fertilizer in leaves samples 7/18/94, 9/20/84 and 5/7/85; a root, trunk and canes sampled in dormancy.

Fertilizer partitioning treatments	**Total N[1] applied (kg.ha-1)**	**% Fertilizer Nitrogen**							
		----------Leaves----------						**Storage tissue[2] dormant**	
		7/18/84		**9/2/84**		**5/7/85**			
Check	0	0	a[3]	0	a	0	a	0	a
1 application (4/27)	40	8.48	b	9.26	b	4.17	b	5.19	b
2 applications (4/27, 5/11)	40	8.53	b	9.55	b	5.01	b	4.51	b
8 applications (weekly, 4/27 to 6/19)	40	8.68	b	9.10	b	5.80	b	4.78	b

[1] ^{15}N-depleted ammonium sulfate applied 1984.

[2] Values represent average for root, trunk, and cane samples.

[3] Means within columns with like letters are not significantly different at the 5% level.

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