Uptake, Storage, and Utilization of Soil-applied Nitrogen by Thompson Seedless as Affected by Time of Application

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A grapevine's need for nitrogen (N) is most critical during the period of rapid shoot growth in spring through bloom and early berry development. Timing of fertilizer applied to the soil necessary to maximize nitrogen in leaf tissue during this period was evaluated in two mature Thompson Seedless vineyards. Application periods, using labeled ammonium sulfate, included budbreak, July, and post harvest in late September. Application in July and September resulted in the highest content of labeled nitrogen in dormant storage tissue, and in leaf tissue during rapid spring growth and at bloom. It is apparent that labeled nitrogen stored in roots, trunk, and canes during dormancy was redistributed to support early spring growth. Nitrogen applied at budbreak had insufficient time for uptake to become a significant fraction of total N in leaf tissue by bloom.

KEY WORDS: nitrogen, fertilization, Thompson Seedless

Nitrogen is most critically needed by grapevines during the period of rapid shoot growth in the spring through bloom and early berry development. This need declines from midsummer on, as grapes ripen (5,22). It has been shown that rapid shoot elongation in the spring for both grapevines and deciduous fruit trees is heavily dependent on the redistribution of nitrogen previously stored in roots, trunk, and canes or limbs (1,7,8,9,12,13,17,18,19,20). Since the grapevine's need for nitrogen is most critical in the spring and highly dependent on storage, it can be inferred that nitrogen fertilizer should be applied when the vine can best absorb and incorporate it as part of the N reserve while minimizing nitrogen loss from the soil (leaching, denitrification). However, the time to apply fertilizer in order to maximize stored N is not known under San Joaquin Valley growing conditions, and the effect of applying fertilizer N at varying phenological stages on fruit and vine development is not fully understood.

Much of the San Joaquin Valley grape industry is located on loam or sandier textured soils with moderate to rapid drainage. Nitrogen fertilizer applied to vineyards in dormancy on moderate to rapidly drained soils is subject to severe leaching losses by budbreak. When ammonium sulfate was applied at budbreak to a vineyard on sandy soil, spring rainfall and frost protection irrigations were sufficient to severely leach nitrogen by bloom (15). Fertilizer applications should be timed to maximize uptake opportunity while minimizing leaching and other losses of nitrogen.

This study in mature Thompson Seedless vineyards evaluated the relationship between time of application of nitrogen fertilizer and uptake, storage, and utilization in petioles and blades. The primary objective was to determine when nitrogen fertilizer should be applied to maximize the concentration of fertilizer nitrogen in leaf tissue during rapid shoot growth from budbreak through bloom.

Isotopically labeled nitrogen was used to distinguish between tissue nitrogen originating from fertilizer and that derived from the large pool of indigenous soil nitrogen. Labeled fertilizer also enabled the measurement of carryover fertilizer nitrogen from one year to the next, uncomplicated by the contribution of soil N, or even by subsequent applications of unlabeled fertilizer (2,11).

Materials and Methods

Two experiments were conducted in the San Joaquin Valley, one at the University of California Kearney Agricultural Center, 1981 - 1982, and the other in a commercial vineyard near Kingsburg, Tulare County, 1983 - 1984. The soils consist of a moderate to slowly drained Hanford fine sandy loam and a moderately drained Hanford sandy loam, formed in recent granitic alluvium, at Kearney and Kingsburg, respectively. Both vineyards were furrow irrigated.

Both the Kearney and Kingsburg vineyards were planted 2.44 m between vines in a row and 3.66 m between rows. Plots consisted of three vines and were separated by two vines in the row and by border rows.

The Kearney trial was designed as a completely randomized split plot with two main plot treatments, four subplot treatments, and three blocks. Main plot treatments compared Thompson Seedless on own roots with Thompson Seedless on 1613 rootstock, a comparison made possible by locating in a rootstock trial initiated in the mid-1960s. Subplots were fertilizer-timing treatments with $(NH_4)_2SO_4$ (112 kg/ha N) applied at different periods: 7 July 1981, 30 September 1981, 3 March 1982, and an unfertilized control. Cane, trunk, and root samples were collected on 3 March 1982 and again on 27 May 1982. Leaf blades and leaf petioles

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This research conducted in Fresno County, near Kingsurg, CA.

Presented at the 36th Annual Meeting of the American Society for Enology and Viticulture, June 1985.

The authors gratefully acknowledge the California Raisin Advisory Board and the California Table Grape Commission for their financial support.

Manuscript submitted for publication 20 June 1986.

were sampled on 4 and 27 May 1982.

The Kingsburg trial was located in a commercial own-rooted Thompson Seedless vineyard approximately thirty years old. The experimental design was a randomized complete block with six blocks and five treatments: nitrogen applied at 78 kg/ha on 4 April 1983, 27 July 1983, 22 September 1983, 15 March 1984, and an unfertilized control. Dormant cane, trunk, and root samples were taken between 5 and 11 March 1984. Leaf blades were sampled on 23 May, 20 July, 22 September 1983 and 5 April and 11 May 1984.

Root, trunk, cane, and leaf samples were a composite of all three vines in each plot. Trunk samples were taken with a 0.63 cm wood auguring bit at two sites, 30 and 60 cm above the soil surface, auguring through the trunk. Roots were sampled by excavating approximately 60 cm deep around the base of each vine. Only roots 0.6 to 1.2 cm diameter were sampled, taking a section 5 to 7 cm in length. Six to eight roots were sampled from each vine. Cane samples, consisting of one node plus internode, were taken between nodes 8 to 10 from three canes per vine. Leaf sampling consisted of 20 petioles and blades of recently matured leaves per vine; at anthesis, blades and petioles were taken opposite inflorescence. All samples were oven dried at 45°C; root samples were washed prior to drying.

Liquid ^{15}N-depleted ammonium sulfate was used to assess the uptake and utilization of applied nitrogen at both sites. Total N was determined by the Kjeldahl procedure modified to include nitrate (3). Nitrogen-15 was determined by mass spectrometry after conversion of ammonium to nitrogen gas with lithium hypobromite (10).

Table 1. Total N and % N derived from fertilizer in leaf petioles sampled at Kearney.

Date of fertilizer application	Leaf Petioles — Date of Sampling					
	10 Nov. 1981 (senescence)		4 May 1982		27 May 1982 (bloom)	
	Total N %	% N fert.[1]	Total N %	% N fert.%	Total N%	% N fert.
7 Jul. 1981	0.92a[2]	10.07a	1.83a	11.39a	1.10a	12.35a
30 Sep. 1981	0.81b	0.14b	1.69ab	6.05b	0.99ab	9.86ab
28 Mar. 1982	—	—	1.84a	1.08c	1.01ab	6.33b
Control	0.78 b	—	1.56b	—	0.89b	—
	(0.06)[3]	(2.49)	(0.16)	(1.51)	(0.13)	(4.05)

[1]Tissue nitrogen derived from fertilizer.
[2]Means within columns with like letters are not significantly different at the 5% level.
[3]Values in parentheses are LSDs, 5% level.

Table 2. Total N and % N derived from fertilizer in leaf blades sampled at Kearney.

Date of fertilizer application	Leaf Blades — Date of Sampling					
	10 Nov. 1981 (senescence)		4 May 1982		27 May 1982 (bloom)	
	Total N %	% N fert.[1]	Total N %	% N fert.	Total N %	% N fert.
7 Jul. 1981	2.10a[2]	10.16a	4.62a	11.41a	3.57a	11.5a
30 Sep. 1981	1.87b	0.46b	4.46b	4.60b	3.38bc	6.4b
28 Mar. 1982	—	—	4.66a	0.98c	3.47ab	2.7c
Control	1.89b	—	4.34b	—	3.31c	—
	(0.21)[3]	(3.30)	(0.13)	(1.8)	(0.15)	(2.7)

[1]Tissue nitrogen derived from fertilizer.
[2]Means within columns with like letters are not significantly different at the 5% level.
[3]Values in parentheses are LSDs, 5% level.

Table 3. Total N and % N derived from fertilizer in cane, trunk, and roots sampled at Kearney during dormancy.

Date of fertilizer application	Cane		Trunk		Roots	
	Total N %	% N fert.[1]	Total N %	% N fert.	Total N %	% N fert.
7 Jul. 1981	0.99	6.94a[2]	0.43	5.72a	1.40	7.65a
30 Sep. 1981	0.90	0.66b	0.42	0.65b	1.43	1.12b
Control	0.89	—	0.41	—	1.22	—
	(ns)[3]	(2.80)	(ns)	(0.80)	(ns)	(2.30)

[1]Tissue nitrogen derived from fertilizer.
[2]Means within columns with like letters are not significantly different at the 5% level.

Results and Discussion

At Kearney, labeled nitrogen content in leaf tissue during rapid spring growth and bloom varied significantly with the period of fertilizer application (Tables 1 and 2). Labeled nitrogen was highest in leaf tissue when fertilizer was applied in July. The lowest level occurred when nitrogen was applied in March of the current year. Intermediate content resulted when N was applied in September of the previous year. The fractions of labeled nitrogen in leaf petioles was similar to that of blades (relative to application time). The

Table 4. Total N and % N derived from fertilizer in trunk and roots sampled at Kearney during bloom.

Date of fertilizer application	Trunk		Roots	
	Total N %	% N fert.[1]	Total N %	% N fert.
7 Jul. 1981	0.29	4.32a[2]	1.31	5.07a
30 Sep. 1981	0.27	1.36b	1.20	1.45b
28 Mar. 1982	0.26	0.32b	1.18	0.14b
Control	0.27	—	1.25	—
	(ns)[3]	(2.22)	(ns)	(2.47)

[1]Tissue nitrogen derived from fertilizer.
[2]Means within a column with like letters are not significantly different at the 5% level.

total nitrogen content of petioles was about one-third that of blades.

Labeled N content in storage tissue sampled during dormancy and again at bloom are given in Tables 3 and 4. Labeled nitrogen was significantly highest in cane, trunk, and roots when applied in July. At bloom, no significant difference occurred between the September and March application treatments although values for September were higher than for March.

Comparing Thompson Seedless on 1613 rootstock *vs.* own rooted Thompson Seedless, there were no significant differences in the content of labeled nitrogen in both leaf and storage tissue (Table 5).

At the Kingsburg site, nitrogen applied in July or September also resulted in the highest content of N derived from fertilizer in blades during rapid spring growth the following year (Fig. 1). By bloom, levels of labeled nitrogen were slightly but significantly higher for the September treatment compared to July. Fertilizing in the spring, either the current or previous year, re-

Table 5. Percent N derived from fertilizer in tissue comparing rootstocks at Kearney.

	Dormant			Bloom	
	Cane	Trunk	Roots	Petiole	Blades
TS (own root)	4.5	3.3	4.1	7.2	9.2
TS (1613)	3.1	3.1	4.6	6.6	9.8
	ns[1]	ns	ns	ns	ns

[1]ns indicates no significant difference between treatments.

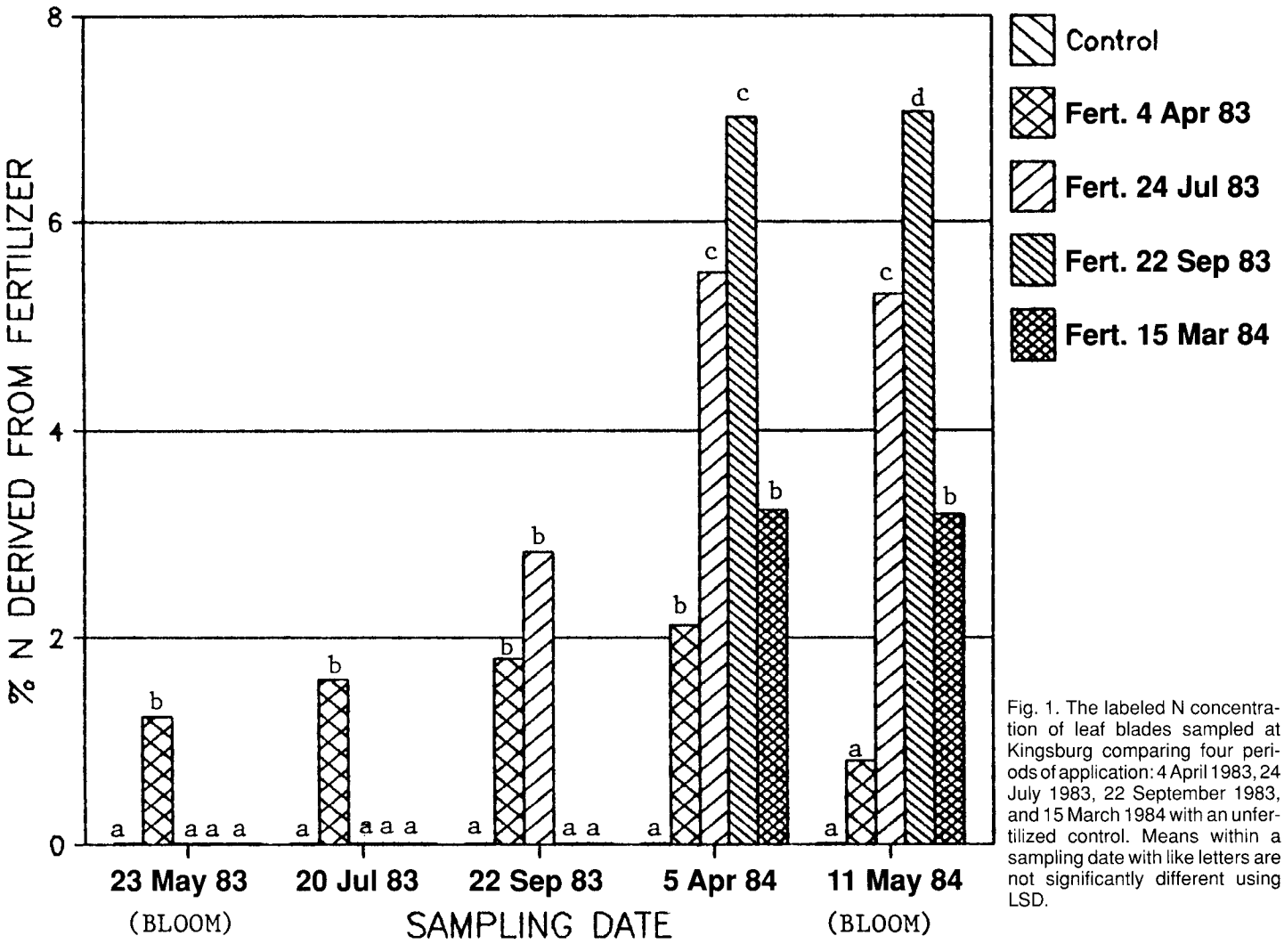

Fig. 1. The labeled N concentration of leaf blades sampled at Kingsburg comparing four periods of application: 4 April 1983, 24 July 1983, 22 September 1983, and 15 March 1984 with an unfertilized control. Means within a sampling date with like letters are not significantly different using LSD.

Table 6. Percent N derived from fertilizer in cane, trunk, and roots samples at Kingsburg during dormancy.

Date of fertilizer application	% nitrogen derived from fertilizer		
	Cane	Trunk	Roots
0	0.0b[1]	0.0b	0.0b
14 Apr. 1983	0.41b	1.70ab	0.0b
24 Jul. 1983	3.91a	2.01ab	5.35a
22 Sep. 1983	2.83a	4.01a	3.03ab
	(1.34)[2]	(2.69)	(3.41)

[1]Means within columns with like letters are not significantly different at the 5% level
[2]Values in parentheses are LSDs, 5% level.

Table 7. Total nitrogen (%) in leaf blades, canes, trunk, and roots at Kingsburg.

Tissue sampled	Sampling date					
	23 May 83 (Bloom)	20 Jul. 83	22 Sep. 83	1984 (Dormant)	5 May 84	11 May 84 (Bloom)
Blades	3.88	3.53	2.36	—	5.13	3.76
Cane	—	—	—	0.95	—	—
Trunk	—	—	—	0.54	—	—
Roots	—	—	—	1.6	—	—

[1]No significant difference between treatments; therefore, values represent average of all treatments and replicates (N = 30).

sulted in the lowest content of labeled nitrogen in leaf blades. Levels of labeled nitrogen in dormant cane, trunk, and root tissue were generally higher when fertilizer was applied in July or September compared to spring application (Table 6).

The effect of soil pH on the rate at which nitrogen is available for uptake may possibly explain why September fertilization was the best timing at Kingsburg; July was better at Kearney. Soil samples were taken from the surface 30 cm at both sites. The pH of the saturated paste was near neutral at Kingsburg but acidic at Kearney, where the pH of many samples was below 6, thus slowing nitrification of the ammonium sulfate. The late September application allowed only three or four weeks for uptake to occur before senescence. Thus, low soil pH at Kearney may have delayed nitrification, thus inhibiting the amount of nitrogen available for uptake before dormancy.

Grapevines fertilized in the fall should have an active, healthy canopy for three to four weeks after application. When uptake time is limited, an immediately available nitrate source of nitrogen fertilizer would be a better choice when fertilizing in the fall.

At Kingsburg, no significant differences occurred between treatments when comparing total nitrogen in leaf and dormant tissue (Table 7); at Kearney, measurement of total nitrogen did not provide clear differences between treatments (Tables 1, 2, 3, 4). This underscores the value of using labeled nitrogen to study fertilizer timing under field conditions.

More information is needed on how summer fertilization affects both maturity and nitrogen content of fruit. Additional study is also needed to evaluate the effect of post harvest N applications on late season growth stimulation and cane maturity.

It is apparent from this study that nitrogen derived from fertilizer applied in July and September was stored in dormant roots, trunk, and canes and then redistributed to support early spring growth. Nitrogen applied in the spring had insufficient time for vine uptake to become a significant fraction of total N in vegetative growth by bloom. Early spring applications may also be subject to leaching and denitrification losses before the grapevine is capable of significant uptake.

Entire vines could not be harvested in this study; therefore, total uptake of fertilizer nitrogen was not quantified. However, the objective was to determine an application period that would optimize the content of nitrogen derived from fertilizer in leaf tissue during rapid growth in the spring through bloom. In this regard, the authors conclude that an application of nitrogen during the summer or post harvest (three to four weeks prior to leaf senescence) was more efficient than at budbreak in the spring.

Conclusions

Application periods of labeled nitrogen fertilizer were compared in mature Thompson Seedless vineyards in the San Joaquin Valley of California. Application in July or postharvest in late September resulted in the highest content of labeled nitrogen both in dormant storage tissue and in leaf tissue during rapid spring growth and at bloom. Labeled nitrogen in root, trunk, and cane tissue was redistributed to support early spring growth. Nitrogen applied at budbreak had insufficient time for uptake to become a significant fraction of total N in leaf tissue by bloom. Early spring applications may have been subject to leaching and denitrification losses before significant uptake occurred.

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