# Nitrogen management in table grapes

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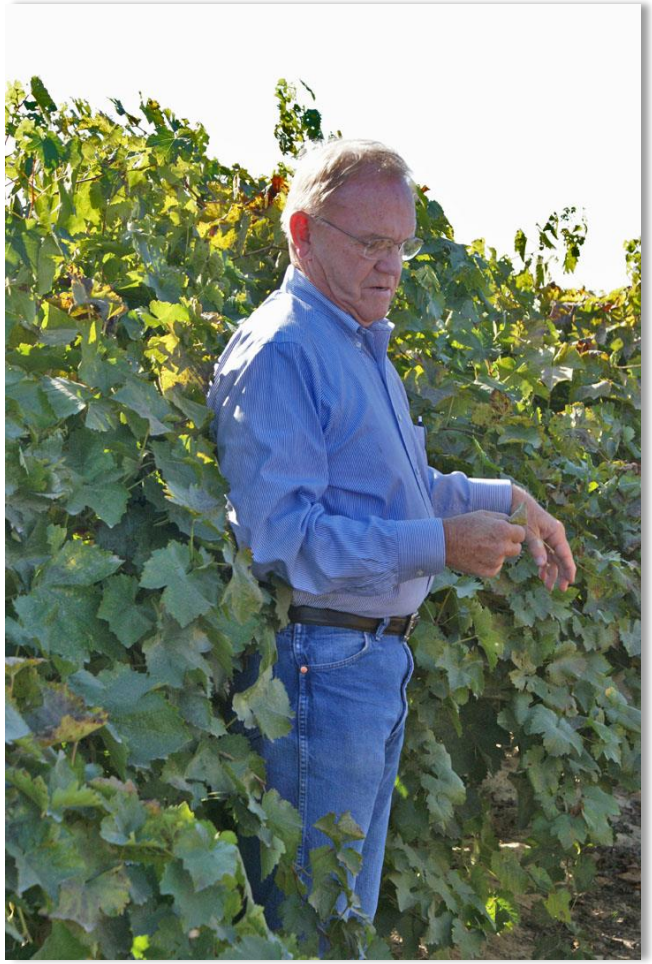
# Remembrance

- Much of what we know about grape mineral nutrition in CA is based on L. Peter Christensen's foundational studies w/ Thompson Seedless raisin grapes



# How Much N do Vines Use?

- Grapevines require less N than many other horticultural crops, but it is the most widely needed mineral nutrient in San Joaquin Valley vineyards
- Thompson Seedless raisin grapes accumulate approximately 75 lbs of N/acre in leaves, stems, and fruit
- Approximately 35 lbs of N/acre was found to be in harvested fruit; international literature suggests fresh grapes contain 1.8 to 4.1 lbs N/ton

# Match N Supply & Demand

- N applied in winter & early spring subject to excessive leaching
- N demand from budbreak to flowering is high, but early spring growth met by remobilization of stored reserves, minimizing N need at budbreak
- Cluster demand for N high after berry set, but fertilization during ripening may delay berry maturation
- Postharvest N application can be effective but should be completed by October, so only practical for early or mid-season varieties

# Monitoring Vine N Status

- Vines should fill the trellis fully, without excessive shading
- Vines with supraoptimal N grow excessively, with long internodes, large, dark green leaves
- Severely deficient vines are chlorotic, with smaller leaves and reduced shoot growth
- Tissue analysis can help verify vine N status and evaluate N fertilization program efficacy but it shouldn't be the only information used in decision making

# Objectives

- Develop seasonal vine N budgets of modern table grape varieties
- Evaluate the effects that different N fertilizer amounts and split applications have on vine N uptake and fruit yield and quality
- Estimate N fertilizer recovery efficiency ($RE_N$)
- Compare different methods for assessing N status

# N Concentration in Leaves, Stems, Clusters at Different Growth Stages

| | | ---------- Organ ---------- | | |
|---|---|---|---|---|
| Cultivar | Growth Stage | Leaves | Stems | Clusters |
| | | ---------- Total N (% dry weight) ---------- | | |
| Sheegene 21 | Bloom | 4.53 | 1.80 | 3.08 |
| | Veraison | 3.10 | 0.70 | 1.10 |
| | Harvest | 2.46 | 0.80 | 0.53 |
| Flame Seedless | Bloom | 4.40 | 1.81 | 2.87 |
| | Veraison | 3.23 | 1.15 | 1.27 |
| | Harvest | 2.78 | 0.85 | 0.97 |
| Princess | Bloom | 4.33 | 1.92 | 2.98 |
| | Veraison | 2.39 | 0.65 | 1.24 |
| | Harvest | 2.06 | 0.65 | 0.80 |
| Autumn King | Bloom | 2.84 | 1.00 | 2.39 |
| | Veraison | 2.28 | 0.62 | 0.70 |
| | Harvest | 1.77 | 0.74 | 0.74 |

# Treatments

- Amount of N applied:
  - 0, no N applied as fertilizer
  - "X", the amount of N removed from the vineyard the previous year in fruit
  - "2.5X" times the amount of N removed the previous year in the fruit
- Split applications:
  - N applied in two "slug" applications; ½ the amount one month after budbreak and the other ½ after berry set
  - N applied in ten "spoon feed" applications; 1/10 the total amount at budbreak and every two weeks thereafter

# Nitrogen budget example, Scarlet Royal

| 2016 Date | Trtmnt | Total N | Δ 0 Control | Applied N | $RE_N$ |
|---|---|---|---|---|---|
| Bloom | | (g/vine) | (g/vine) | (g/vine) | (%) |
| 10 May | 0-s | **42.7** | --- | 0 | --- |
| | 0-ma | **40.3** | --- | 0 | --- |
| | x-s | **39.0** | **0** | **24.9** | **0** |
| | x-ma | **36.8** | **0** | **9.96** | **0** |
| | 2.5x-s | **46.7** | **5.2** | **62.3** | **8.3** |
| | 2.5x-ma | **38.7** | **0** | **24.9** | **0** |
| Veraison | | | | | |
| 12 July | 0-s | **103.5** | --- | 0 | --- |
| | 0-ma | **100.0** | --- | 0 | --- |
| | x-s | **137.2** | **35.4** | **49.8** | **71.0** |
| | x-ma | **123.4** | **21.6** | **29.9** | **72.2** |
| | 2.5x-s | **107.2** | **5.4** | **124.5** | **4.3** |
| | 2.5x-ma | **112.8** | **11.0** | **74.7** | **14.7** |
| Harvest | | | | | |
| 15 Aug. | 0-s | **102.5** | --- | 0 | --- |
| | 0-ma | **114.2** | --- | 0 | --- |
| | x-s | **138.7** | **30.3** | **49.8** | **60.8** |
| | x-ma | **151.6** | **43.2** | **44.8** | **96.4** |
| | 2.5x-s | **152.1** | **43.7** | **124.5** | **35.1** |
| | 2.5x-ma | **143.3** | **34.9** | **112.0** | **31.2** |

# Nitrogen Budget Example, Low N-status Flame Seedless

| 2016 Date | Treatment | Total N | Δ 0 Control | Applied N | $RE_N$ |
|---|---|---|---|---|---|
| Bloom | | (g/vine) | (g/vine) | (g/vine) | (%) |
| 28 Apr. | 0-s | **23.2** | --- | 0 | --- |
| | 0-ma | **21.9** | --- | 0 | --- |
| | x-s | **26.7** | **4.20** | **9.65** | **43.5** |
| | x-ma | **22.3** | **0** | **3.86** | **0** |
| | 2.5x-s | **28.4** | **5.87** | **24.2** | **24.3** |
| | 2.5x-ma | **23.9** | **1.35** | **9.66** | **14.0** |
| Veraison | | | | | |
| 13 Jun. | 0-s | **32.7** | --- | 0 | --- |
| | 0-ma | **28.8** | --- | 0 | --- |
| | x-s | **40.1** | **9.4** | **19.3** | **38.8** |
| | x-ma | **35.7** | **5.0** | **9.7** | **51.5** |
| | 2.5x-s | **49.4** | **18.7** | **48.3** | **38.7** |
| | 2.5x-ma | **56.2** | **25.5** | **24.2** | **105** |
| Harvest | | | | | |
| 19 Jul. | 0-s | **33.9** | --- | 0 | --- |
| | 0-ma | **34.7** | --- | 0 | --- |
| | x-s | **42.0** | **7.7** | **19.3** | **39.9** |
| | x-ma | **50.4** | **16.1** | **15.4** | **105** |
| | 2.5x-s | **55.4** | **21.1** | **48.3** | **43.7** |
| | 2.5x-ma | **69.4** | **20.5** | **38.6** | **53.1** |

The effect of cultivar and year on total fresh fruit mass at harvest, pounds of N in the fruit at harvest per acre and lbs. N per ton of fruit. Also included is the total N per vine in the leaves, stems and clusters at harvest and petiole $NO_3$-N at bloom and veraison.

| **Traver/Laton** | ---------- Fruit metrics | ---------- | | | Total Vine | $NO_3$-N |
|---|---|---|---|---|---|---|
| Cultivar | kg/vine | t/acre | lbs. N/acre | lbs. N/ton | lbs. N/acre | bloom/veraison |
| **Flame S.** | | | | | | |
| 2014 | 31.0 | 24.7 | 69.9 | 2.82 | 181 | 2854 / 1635 |
| 2015 | 32.8 | 26.1 | 76.9 | 2.94 | 134 | 1645 / 2368 |
| 2016 | 34.8 | 27.8 | 89.5 | 3.22 | 182 | 1106 / 1344 |
| **Princess** | | | | | | |
| 2015 | 24.4 | 21.9 | 57.7 | 2.63 | 160 | 1498 / 3020 |
| 2016 | 39.9 | 31.8 | 81.0 | 2.55 | 175 | 2532 / 406 |
| **A. King** | | | | | | |
| 2015 | 43.1 | 34.4 | 128 | 3.71 | 211 | 1397 / 1022 |
| **Sheegene** | | | | | | |
| 2016 | 30.1 | 24.0 | 61.6 | 2.57 | 165 | 2020 / 1747 |
| | | | | **2.92** | | |

Effect of cultivar and year on total fruit fresh mass at harvest, pounds of N in the fruit at harvest per acre and lbs. N per ton of fruit across N fertilizer treatments. Also included is the total N per vine in the leaves, stems and clusters at harvest. ‘Old’ and ‘New’ refer to different experiments.

| **Goshen** | ---------- Fruit metrics ---------- | | | | Total Vine |
|---|---|---|---|---|---|
| Cultivar | kg/vine | t/acre | lbs. N/acre | lbs. N/ton | lbs. N/acre |
| **SR ‘Old’** | | | | | |
| 2014 | 30.4 | 24.2 | 50.0 | 2.06 | 160 |
| 2015 | 51.5 | 41.1 | 79.4 | 1.93 | 184 |
| 2016 | 30.6 | 24.4 | 57.9 | 2.37 | 213 |
| **SR ‘New’** | | | | | |
| 2015 | 43.8 | 34.9 | 67.9 | 1.95 | 189 |
| 2016 | 32.8 | 26.2 | 46.7 | 1.74 | 156 |
| **CS ‘Old’** | | | | | |
| 2014 | 48.2 | 24.1 | 42.3 | 1.76 | 91 |
| 2015 | 54.4 | 27.1 | 49.4 | 1.82 | 135 |
| 2016 | 51.2 | 25.6 | 57.2 | 2.23 | 132 |
| **CS ‘New’** | | | | | |
| 2015 | 60.8 | 30.3 | 57.7 | 1.90<br>1.97 | 135 |

The effect of N treatments on total fruit fresh mass at harvest, pounds of N in the fruit at harvest per acre and lbs. N per ton of fruit of Flame Seedless and Autumn King (both Selma). Also included is the total N per vine in the leaves, stems and clusters at harvest and petiole $NO_3$-N at bloom and veraison.

| **Selma** | ---------- Fruit metrics | | | ---------- | Total Vine | $NO_3$-N |
|---|---|---|---|---|---|---|
| Cultivar | kg/vine | t/acre | lbs. N/acre | lbs. N/ton | lbs. N/acre | bloom/veraison |
| Flame S. | | | | (% dry wt.) ↓ | | |
| 0-s | 13.6 | 9.1 | 9.4 | 1.03 (0.25) | 45.1 | < 5 / < 5 |
| 0-ma | 17.0 | 11.3 | 12.6 | 1.12 (0.26) | 46.1 | 78 / < 5 |
| x-s | 15.3 | 10.2 | 12.2 | 1.20 (0.30) | 55.9 | 23 / < 5 |
| x-ma | 14.3 | 9.5 | 12.1 | 1.27 (0.30) | 67.1 | 17 / < 5 |
| 2.5x-s | 19.4 | 12.9 | 18.4 | 1.42 (0.34) | 73.7 | 203 / < 5 |
| 2.5x-ma | 18.0 | 12.0 | 19.7 | 1.64 (0.40) | 92.3 | 90 / < 5 |
| A. King | | | | | | |
| 0-s | 31.8 | 21.2 | 53.2 | 2.50 (0.75) | 141.1 | 1551 / 2026 |
| x-s | 25.9 | 17.2 | 42.2 | 2.45 (0.76) | 137.5 | 2179 / 2407 |
| 2.5x-s | 24.6 | 16.4 | 44.9 | 2.73 (0.91) | 128.3 | 2959 / 3046 |

# N Delayed Maturity in a Mod. to High N-status Crimson Vineyard

| Factor | Weight (g) | Length (cm) | Diameter (cm) | Firmness (g/mm) | Brix | pH | TA (%) | color[z] L | color[z] C | color[z] h |
|---|---|---|---|---|---|---|---|---|---|---|
| **N Fertilizer amount** | | | | | | | | | | |
| 0 | 6.43 | 2.77 | 1.90 | 293 | 20.8 | 3.82 | 0.39 | 27.82 b | 10.33 | 20.1 b |
| 1.0 x | 6.48 | 2.79 | 1.92 | 306 | 20.7 | 3.86 | 0.39 | 29.12 a | 10.53 | 24.5 a |
| 2.5 x | 6.24 | 2.76 | 1.92 | 301 | 20.4 | 3.87 | 0.39 | 29.54 a | 10.52 | 24.6 a |
| **Application timing** | | | | | | | | | | |
| 2 slugs | 6.35 | 2.78 | 1.92 | 300 | 20.6 | 3.83 | 0.40 | 28.82 | 10.43 | 23.6 |
| 10 applications | 6.41 | 2.77 | 1.91 | 300 | 20.7 | 3.87 | 0.38 | 28.87 | 10.48 | 22.5 |
| **Significance** | | | | | | | | | | |
| Amount | 0.63 | 0.76 | 0.75 | 0.67 | 0.45 | 0.08 | 0.59 | 0.01 | 0.82 | 0.05 |
| Timing | 0.77 | 0.60 | 0.41 | 0.91 | 0.91 | 0.08 | <0.01 | 0.82 | 0.86 | 0.36 |
| Amount x Timing | 0.24 | 0.15 | 0.29 | 0.93 | 0.24 | 0.99 | 0.79 | 0.37 | 0.17 | 0.56 |

# Effects on Maturity Can Delay Harvest; Example from Crimson Vineyard

| | First harvest | | Second harvest | | Third harvest | | Total harvested fruit | |
|---|---|---|---|---|---|---|---|---|
| Factor | Yield[y] (kg/vine) | Culls[x] (%) | Yield (kg/vine) | Culls (%) | Yield (kg/vine) | Culls (%) | Yield (kg/vine) | Culls (%) |
| **N Fertilizer amount** | | | | | | | | |
| 0 | 20.30 a | 4.16 | 6.27 | 7.0 | 10.68 | 11 | 37.25 | 8 |
| 1.0 x | 15.78 ab | 4.37 | 8.96 | 6.8 | 10.76 | 12 | 35.50 | 8 |
| 2.5 x | 12.46 b | 4.89 | 7.55 | 5.7 | 12.85 | 12 | 32.86 | 9 |
| **Application timing** | | | | | | | | |
| 2 slugs | 16.35 | 5 | 8.07 | 5.6 b | 12.21 | 11 | 36.64 | 8 |
| 10 applications | 16.01 | 4 | 7.11 | 7.4 a | 10.64 | 12 | 33.77 | 8 |
| **Significance** | | | | | | | | |
| Amount | 0.04 | 0.16 | 0.35 | 0.19 | 0.65 | 0.95 | 0.75 | 0.73 |
| Timing | 0.87 | 0.61 | 0.39 | 0.04 | 0.39 | 0.51 | 0.36 | 0.56 |
| Amount x Timing | 0.37 | 0.71 | 0.79 | 0.62 | 0.24 | 0.72 | 0.17 | 0.71 |

# N Fertilization Increased Fruit Biomass (kg/vine) in Low N-status Vineyard

| | ---------- Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 10.3 | 11.8 | 12.6 | 13.4 |
| 10 Applications | 13.3 | 17.3 | 16.2 | 13.8 |
| Ave. Effect Amt. | 11.1 b | 12.9 ab | 16.8 a | |

# N Fertilization Improved Fruit Quality in Low N Status Vineyard

**Berry Weight**

| **(g/berry)** | ---------- N Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 3.3 | 3.9 | 4.5 | 3.9 |
| 10 Applications | 3.4 | 3.9 | 4.5 | 3.9 |
| Ave. Effect Amt. | 3.4 c | 3.9 b | 4.5 a | |

**Berry Diameter**

| **(cm)** | ---------- Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 1.75 | 1.84 | 1.93 | 1.84 |
| 10 Applications | 1.76 | 1.82 | 1.93 | 1.84 |
| Ave. Effect Amt. | 1.76 c | 1.83 b | 1.93 a | |

# Assessing vine N status

The effect of nitrogen fertilizer amount and timing of fertilizer application on nitrate nitrogen of **Flame Seedless** petioles collected either at bloom or veraison in **2016**.

## Bloom

| **$NO_3$-N (ppm dry wt.)** | ---------- N Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 23.6 b | 5.0 b | 203 a | 77.1 |
| 10 Applications | 78.2 ab | 16.8 b | 89.6 ab | 61.5 |
| Ave. Effect Amt. | 20.2 | 41.6 | 146 | |

## Veraison

| **$NO_3$-N (ppm dry wt.)** | ---------- N Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 5.4 | 5.0 | 5.0 | 5.5 |
| 10 Applications | 6.4 | 5.0 | 5.0 | 5.1 |
| Ave. Effect Amt. | 5.9 | 5.0 | 5.0 | |

The effect of nitrogen fertilizer amount and timing of fertilizer application on nitrate nitrogen of **Scarlet Royal** petioles collected either at bloom or veraison in **2016**.

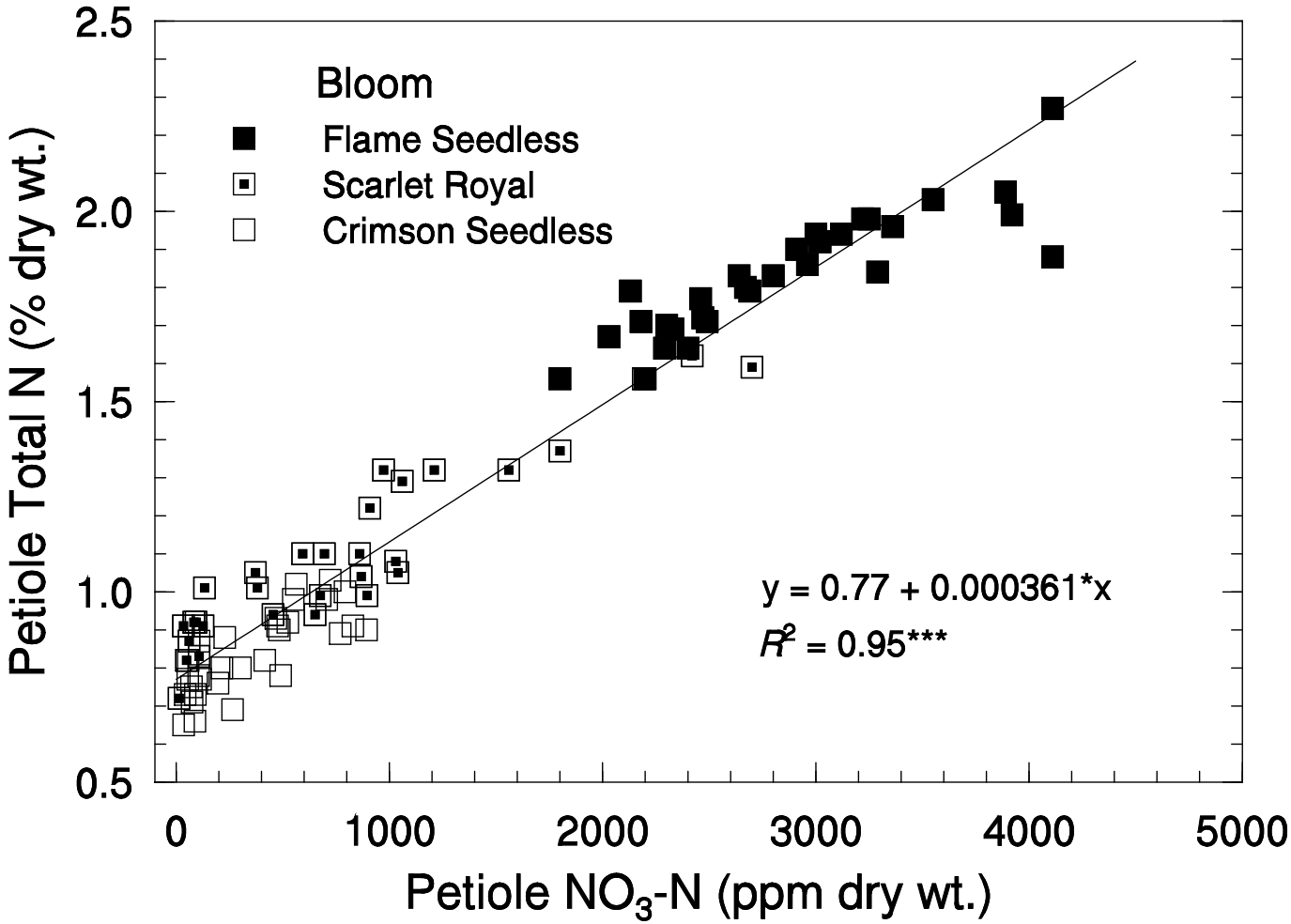
## Bloom

| **$NO_3$-N (ppm dry wt.)** | ---------- N Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 206 | 1147 | 1456 | 954 |
| 10 Applications | 406 | 997 | 1332 | 912 |
| Ave. Effect Amt. | 306 b | 1072 a | 1394 a | |

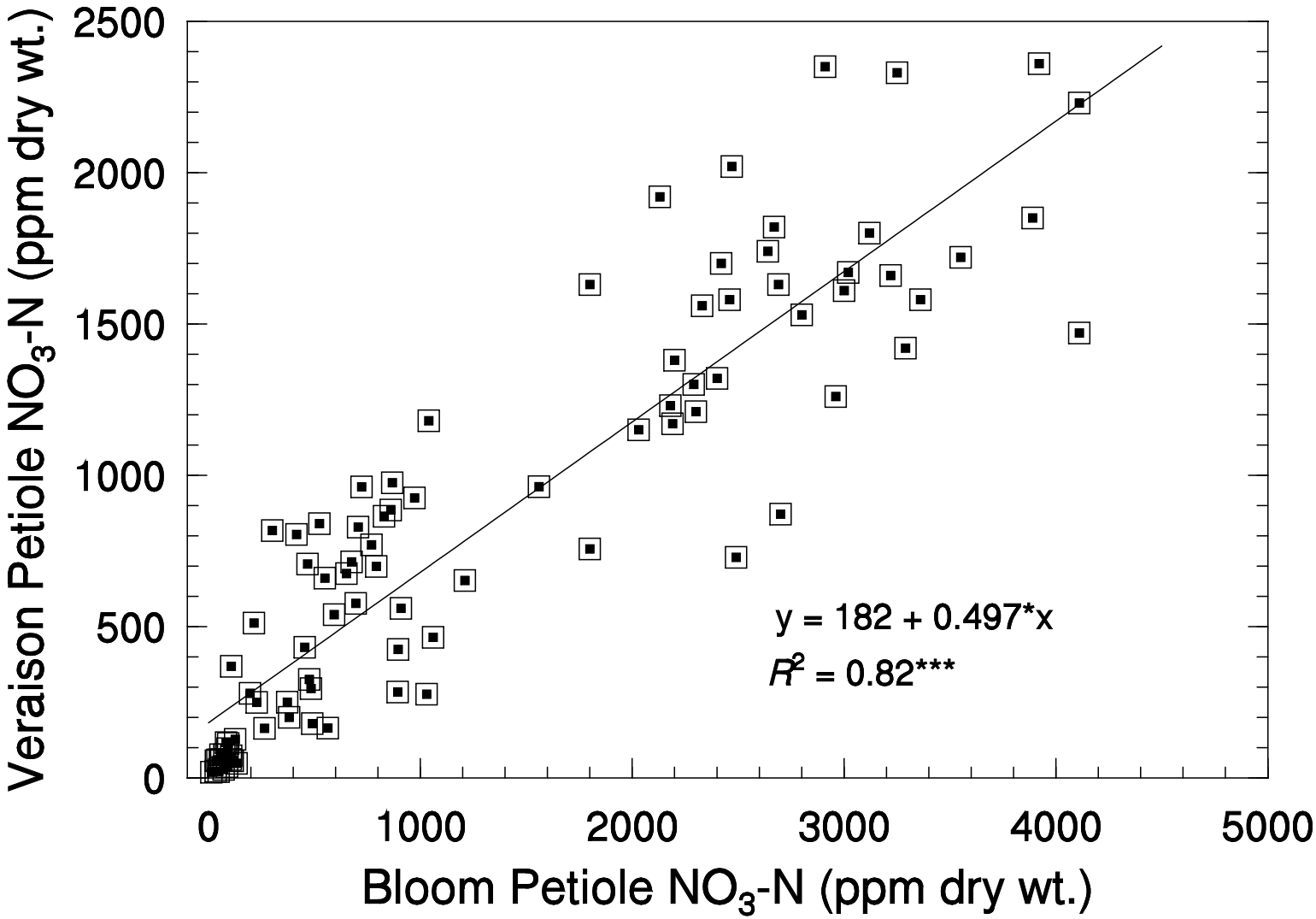
## Veraison

| **$NO_3$-N (ppm dry wt.)** | ---------- N Fertilizer Amount ---------- | | | Ave. Effect |
|---|---|---|---|---|
| Fertilizer Timing | 0 | 1.0 x | 2.5 x | Timing |
| 2 Slug Applications | 102 | 955 | 1994 | 1017 |
| 10 Applications | 167 | 838 | 1406 | 804 |
| Ave. Effect Amt. | 135 c | 897 b | 1700 a | |

# Relationship between total N and $NO_3$-N in the petioles at bloom across the three cultivars in 2014.



# Relationship between veraison petiole $NO_3$-N and bloom petiole $NO_3$-N of all three cultivars.



# N in irrigation water

“You can’t manage what you don’t measure”,
California Sustainable Winegrowing Alliance

# Applied water, and amount of N in water & applied as fertilizer, 2016

| Applied | | Irrigation Type | Scarlet Royal | Crimson Seedless | Flame Seedless | Autumn King |
|---|---|---|---|---|---|---|
| **Water** | Gal./vine | Drip | 1329 | 1396 | 1299 | 1125 |
| | | Flood | 0 | 309 | ----- | ----- |
| | | Total | 1329 | 1705 | 1299 | 1125 |
| | inches | Total | 32.4 | 30.0 | 28.9 | 25.0 |
| **$NO_3$-N** | (ppm) | --- | 4.27 | 5.37 | 1.97 | 3.23 |
| **N equiv.** | | lbs. N/acre | 34.2 | 34.6 | 12.9 | 18.2 |
| **App. N** | x | lbs. N/acre | 79.4 | 49.4 | 25.7 | 34.2 |
| | 2.5x | lbs. N/acre | 198 | 123.5 | 64.3 | 85.5 |

# Summary

- Petiole $NO_3$-N, $NH_4$N and total N (% dry wt.) respond to fertilizer treatments and are highly correlated with one another on each sample date and between the bloom and veraison sampling dates
- Petiole nutrient status is also highly correlated with leaf and stem total N concentration on the various sample dates.

# Summary

- Fresh fruit generally contained 2 to 3 lbs N per ton, and was somewhat correlated with petiole analyses at bloom and veraison.
- The amount of N per acre in fruit (lbs./acre) depends on yield as expected.
- N in the annual growth of vines ranged from ~ 100 to 200 lbs. per acre
- Approximately 30 to 40% of the N in annual growth was partitioned to fruit and should be replaced
- N in the irrigation water and soil profile should be considered in deciding how much to apply.

# Summary

- Fertilizer recovery efficiency is reduced by excessive N applications, and improved by splitting N applications, as long as the total amount of N applied is not excessive
- Excess N can delay fruit coloring and thereby reduce the amount of fruit harvested in the first pick
- Insufficient N can reduce fruit size and impair coloring.

# Where more data are needed

- N needs of N deficient vines
- Refining split applications to increase practicality while maintain high $RE_N$

# Larry Williams

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