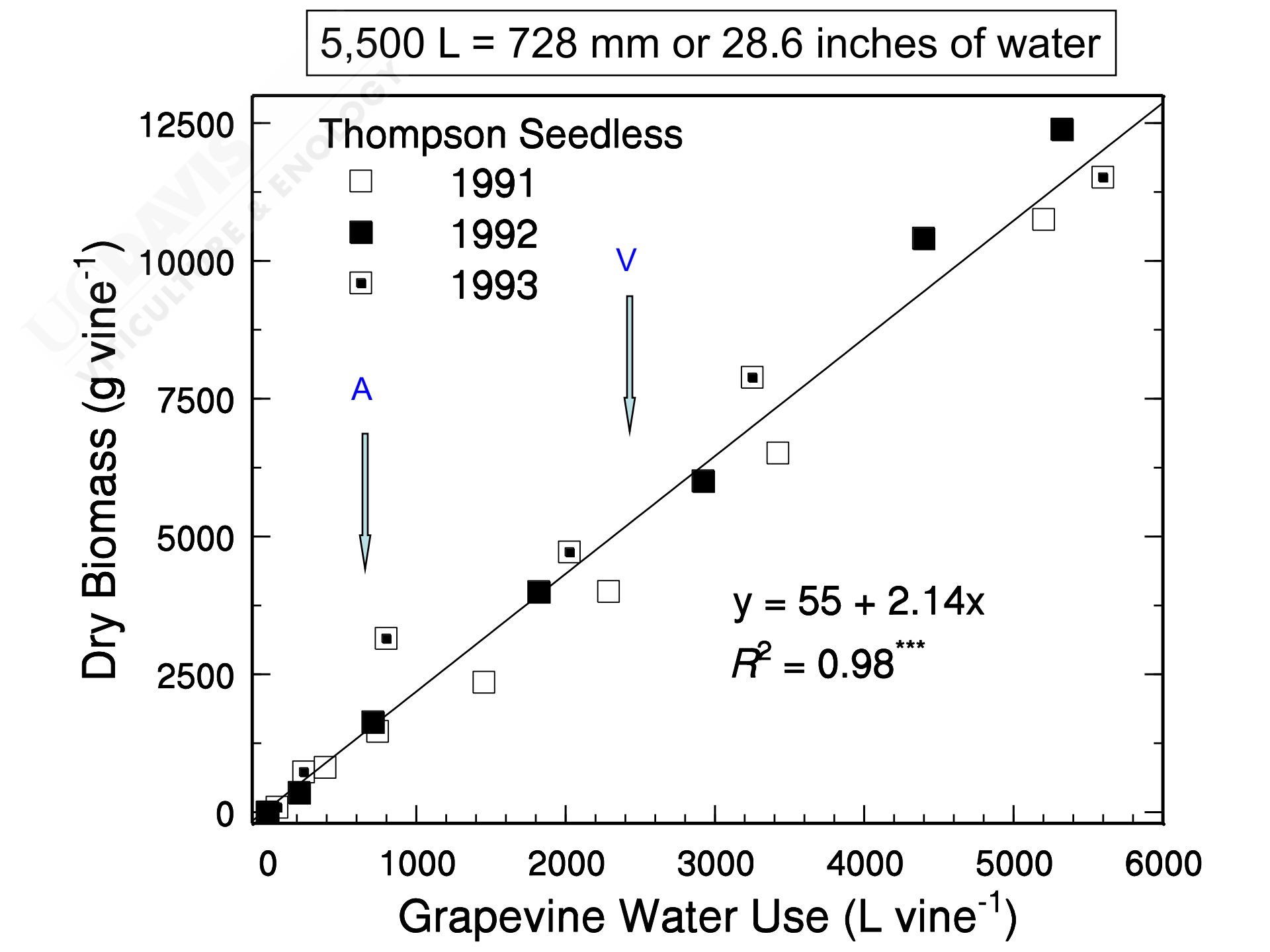
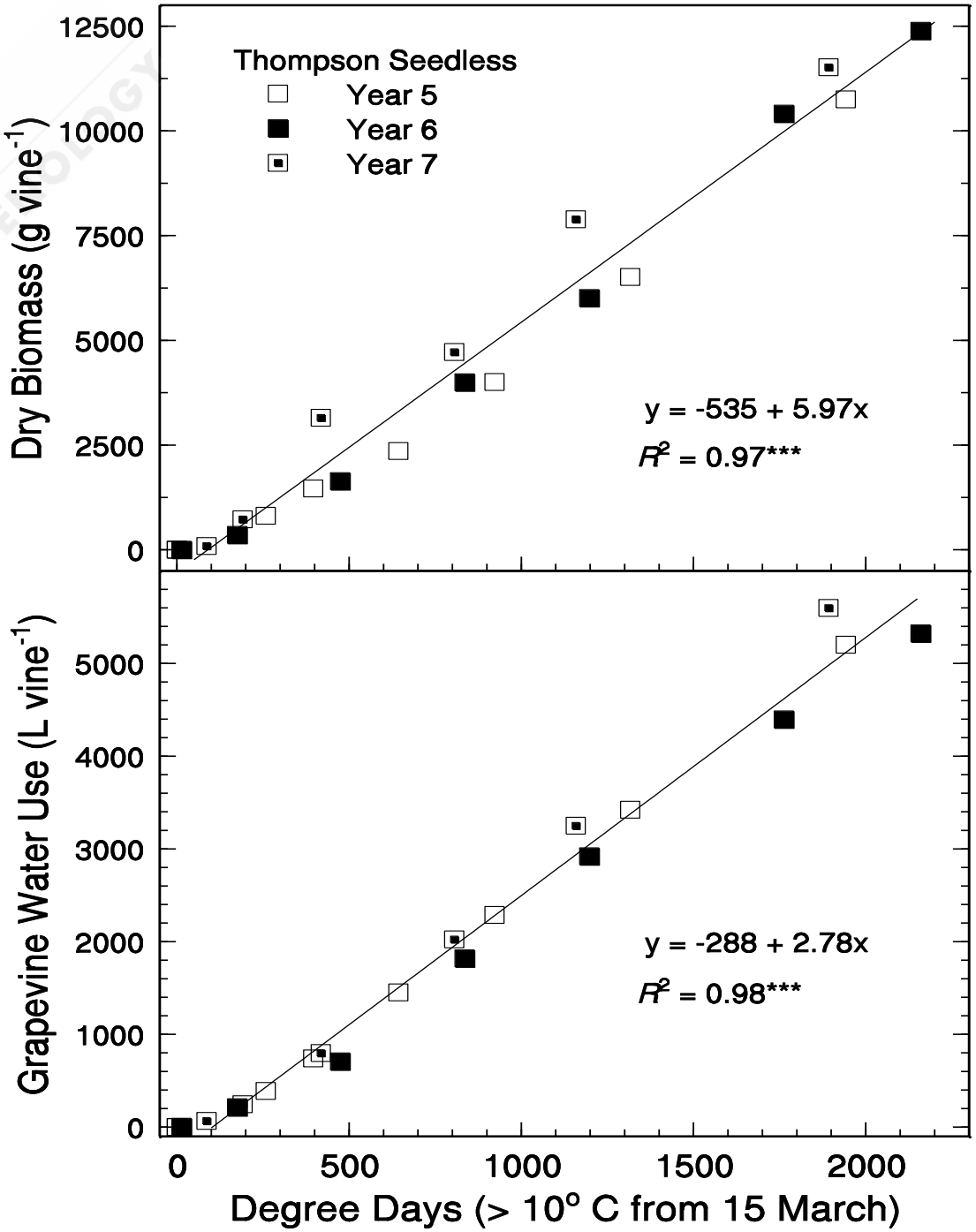
Mineral Nutrition of Grapevines

Larry E. Williams
Department of Viticulture and Enology
UC-Davis
and
Kearney Agricultural Research and Extension Center

What drives the uptake of mineral nutrients in grapevines?

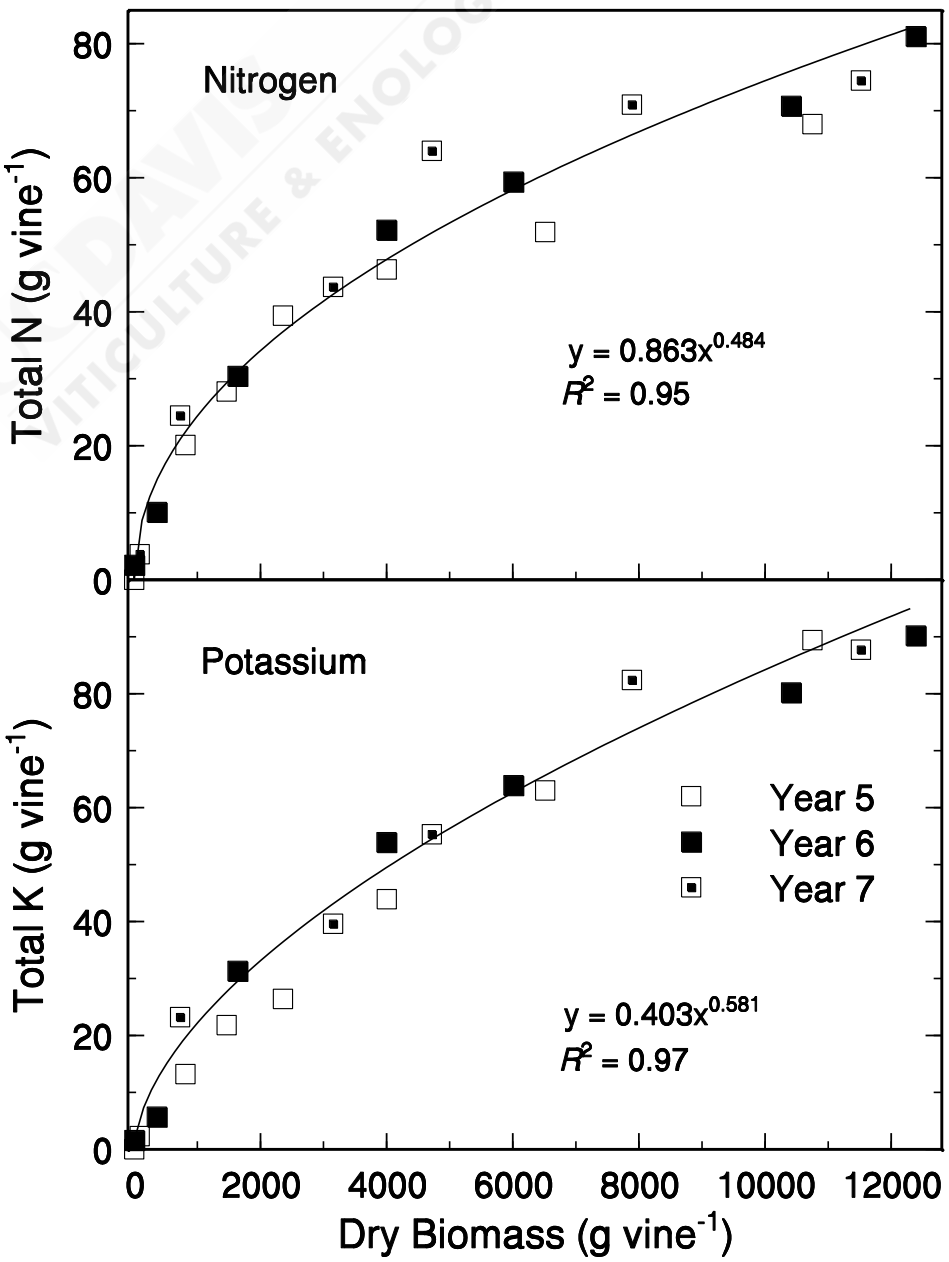
The uptake of mineral nutrients in plants is driven by growth (Ingestad, 1981) to include grapevines (Keller, 2005). Wermelinger et al. (1991) assumed that N demand was a linear function of dry biomass accumulation in their model of grapevine growth.


5,500 L = 728 mm or 28.6 inches of water
Thompson Seedless
1991
1992
1993
A
V
y = 55 + 2.14x
R2 = 0.98***
Dry Biomass (g vine-1)
Grapevine Water Use (L vine-1)
0
2500
5000
7500
10000
12500
0
1000
2000
3000
4000
5000
6000

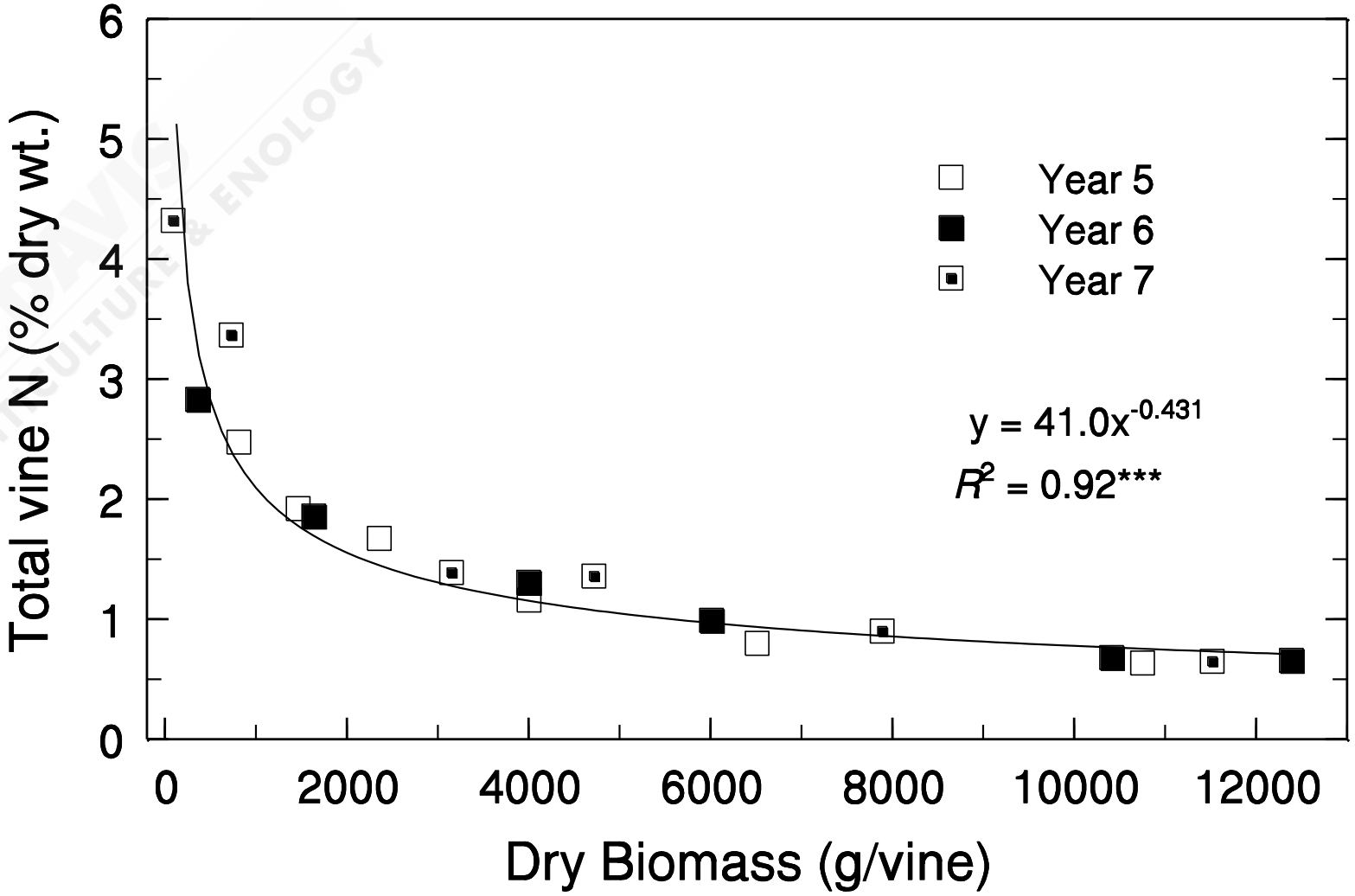

Thompson Seedless
Year 5
Year 6
Year 7
Dry Biomass (g vine-1)
y = -535 + 5.97x
R2 = 0.97***
Grapevine Water Use (L vine-1)
y = -288 + 2.78x
R2 = 0.98***
Degree Days (> 10° C from 15 March)
0
2500
5000
7500
10000
12500
1000
3000
4000
500
1000
1500
2000

Summary:

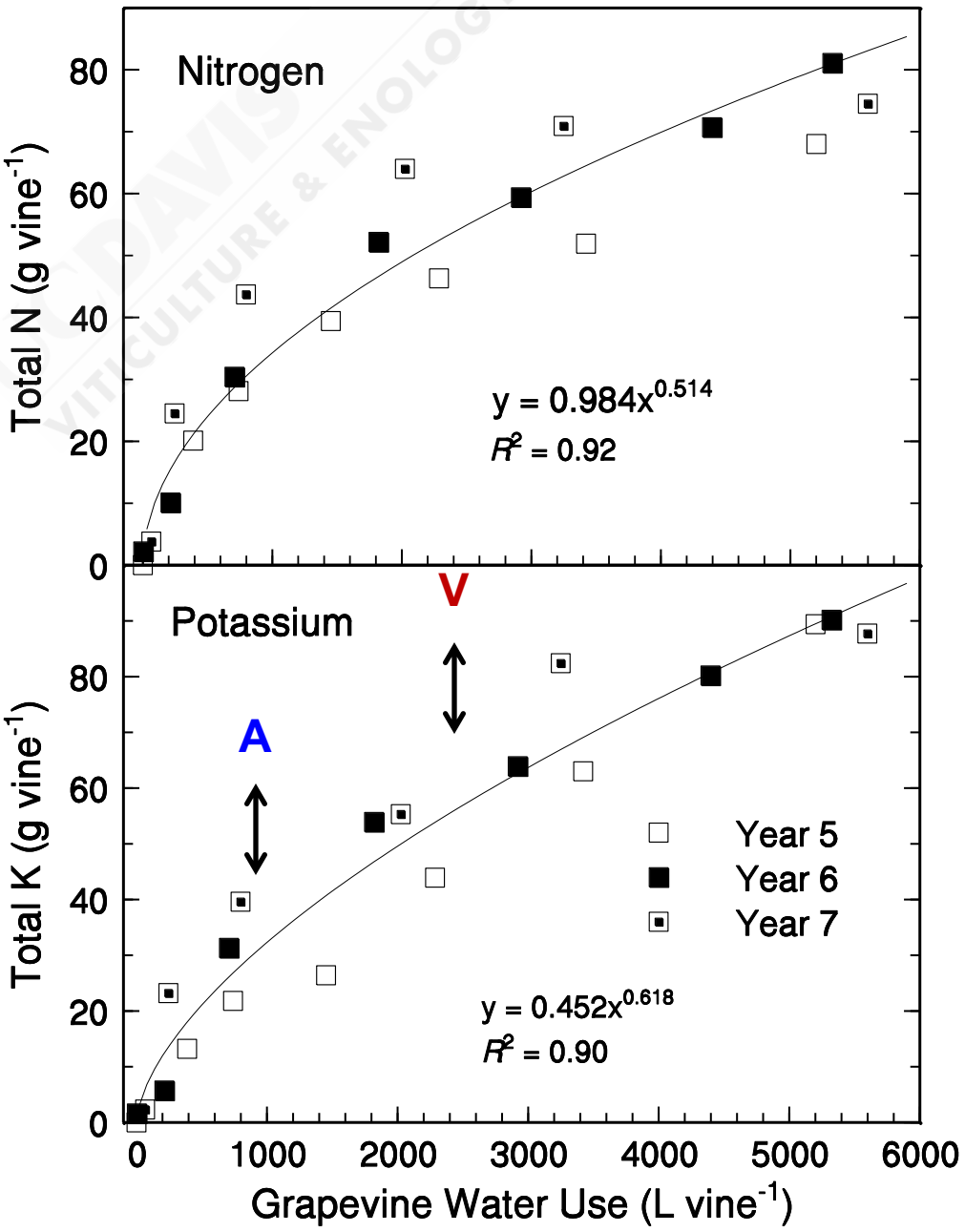
- Dry biomass production of field-grown Thompson Seedless grapevines was a linear function of grapevine water use across the growing season.
- Dry biomass production of field-grown Thompson Seedless and water use were also a linear function of degree-days (temperature).



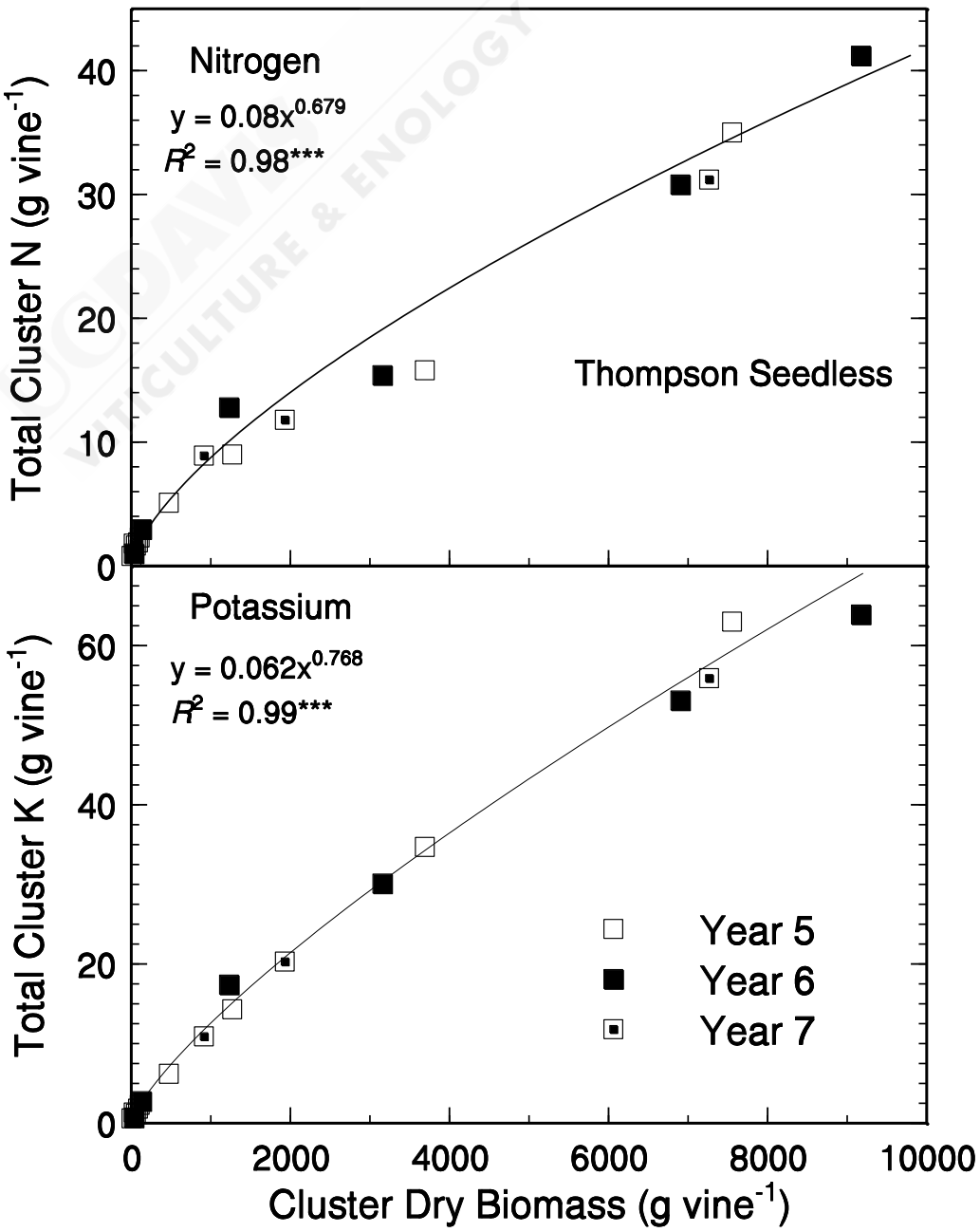
The relationships between the accumulation of N or K And dry biomass accumulation of Thompson Seedless vines during the course of the growing season. These values are the **sum of leaves, stems and clusters**. Similar relationships are found when N and K are plotted as a function of individual vine organs' (leaves, stems and clusters) dry biomass accumulation.



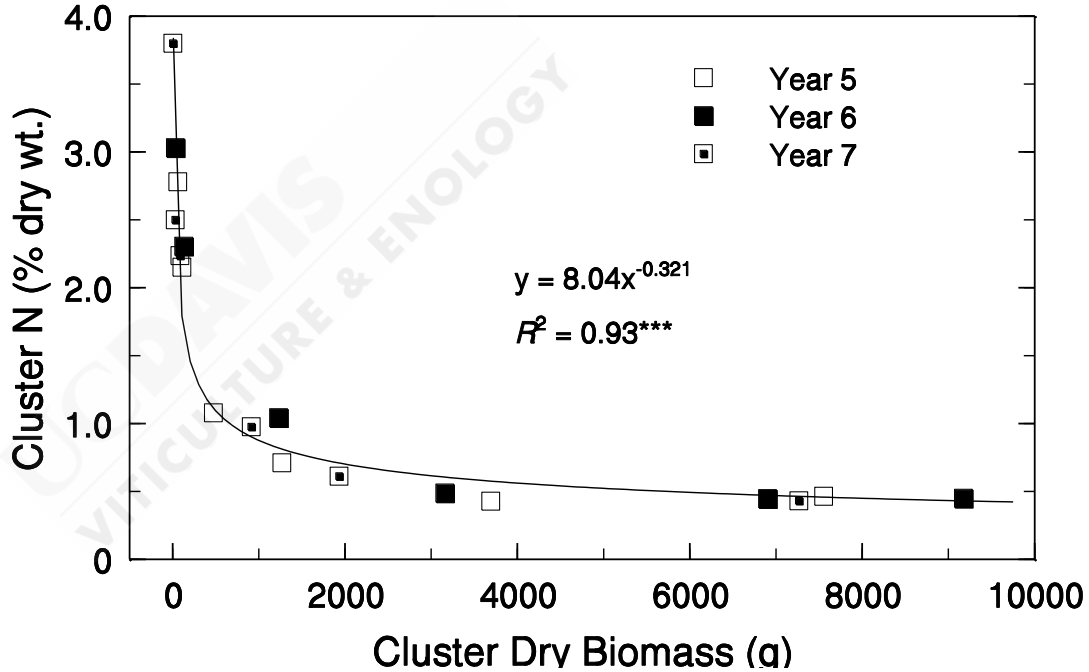
The relationship between the concentration of N (sum of the leaves, stems and clusters) and dry biomass accumulation during the course of the growing season. Similar relationships are found when N is plotted as a function of individual vine organs.

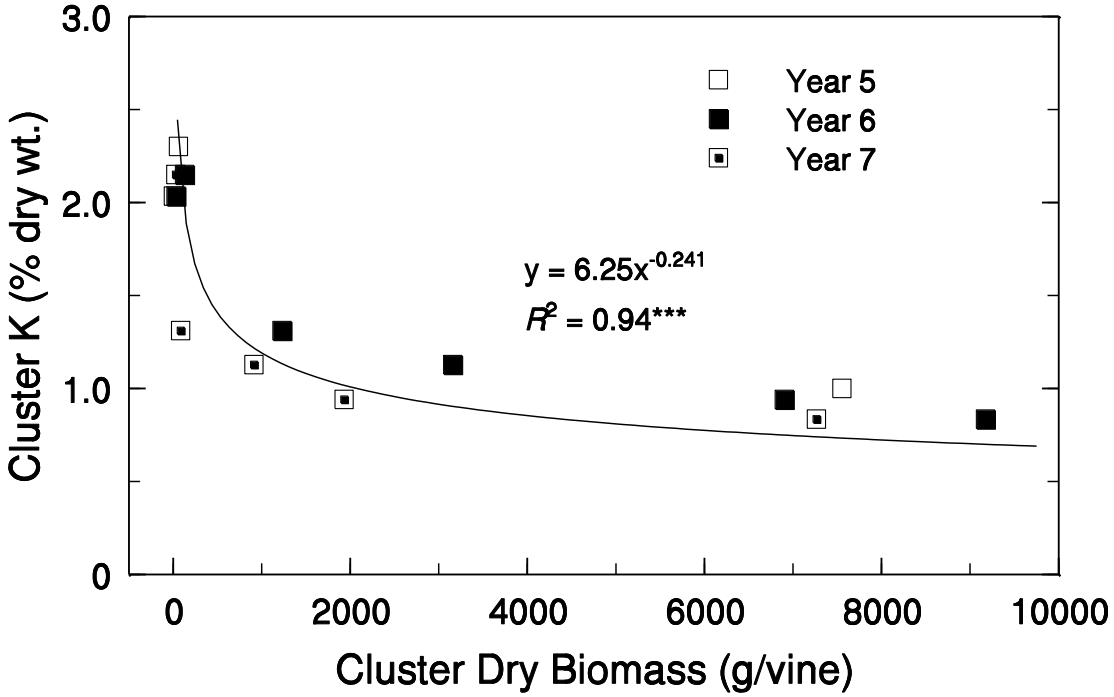


Relationships between the accumulation of N or K and grapevine water use during the course of the growing season. The N & K values are the sum of leaves, stems and clusters.



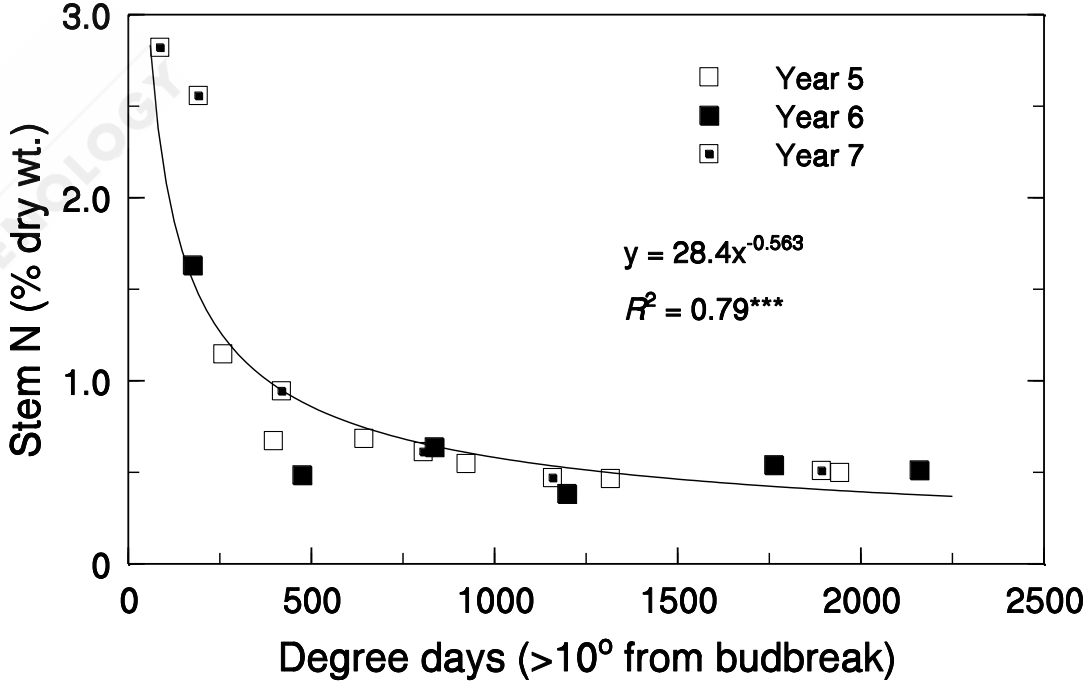
The relationships between the accumulation of N and K in the cluster and the accumulation of cluster dry biomass.

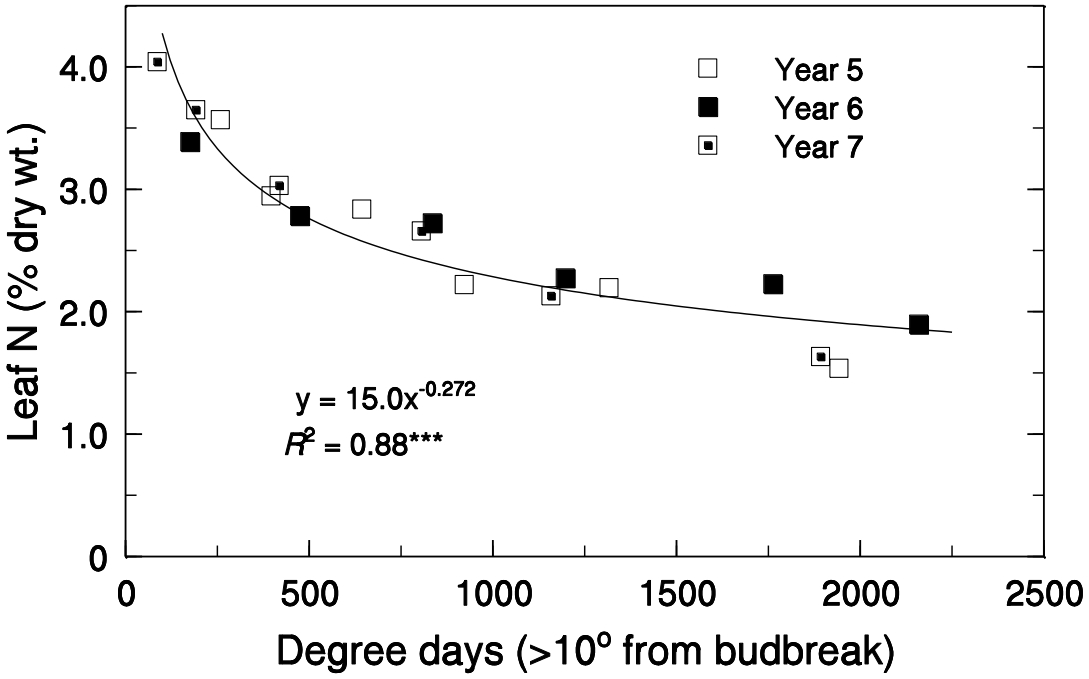


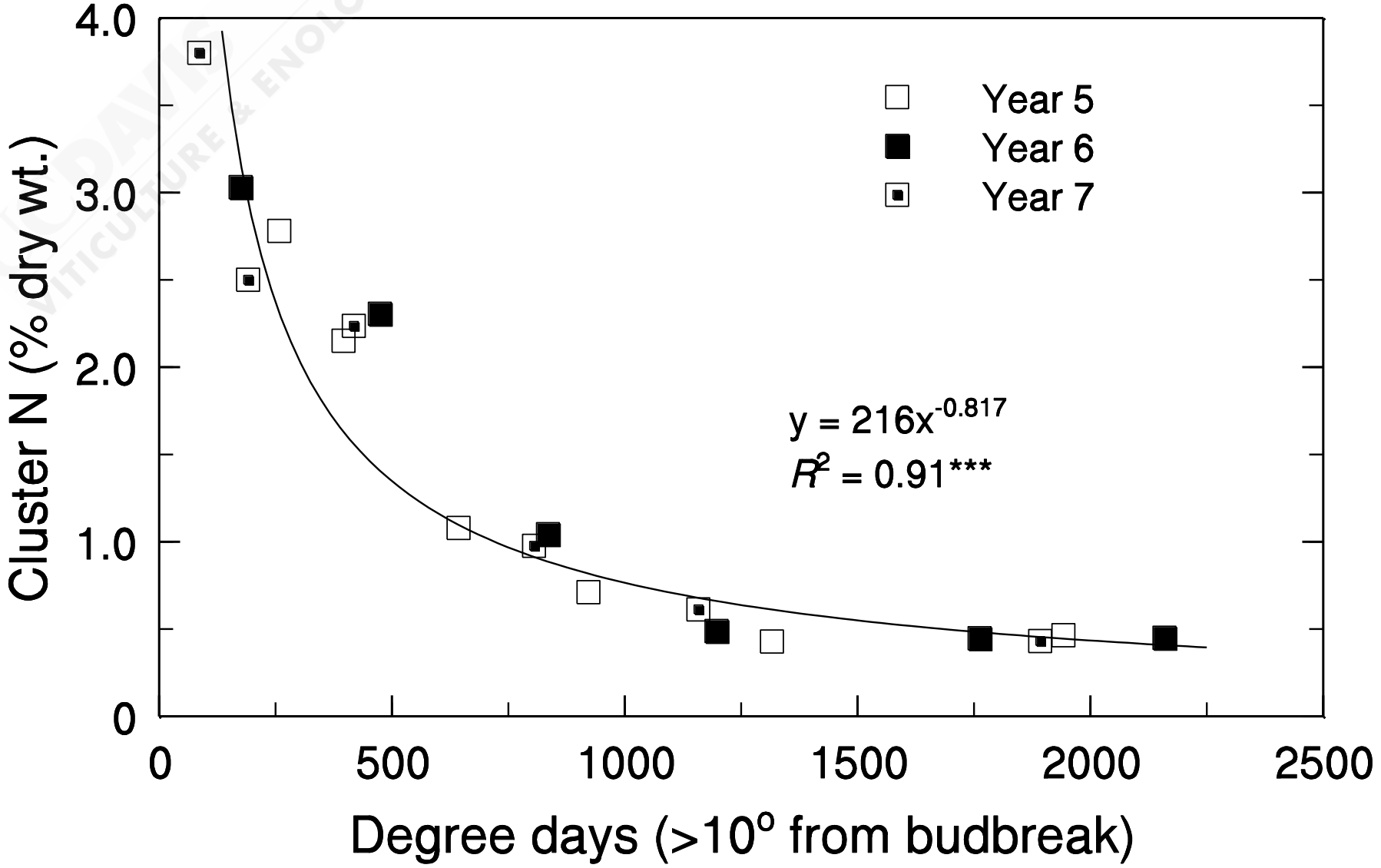


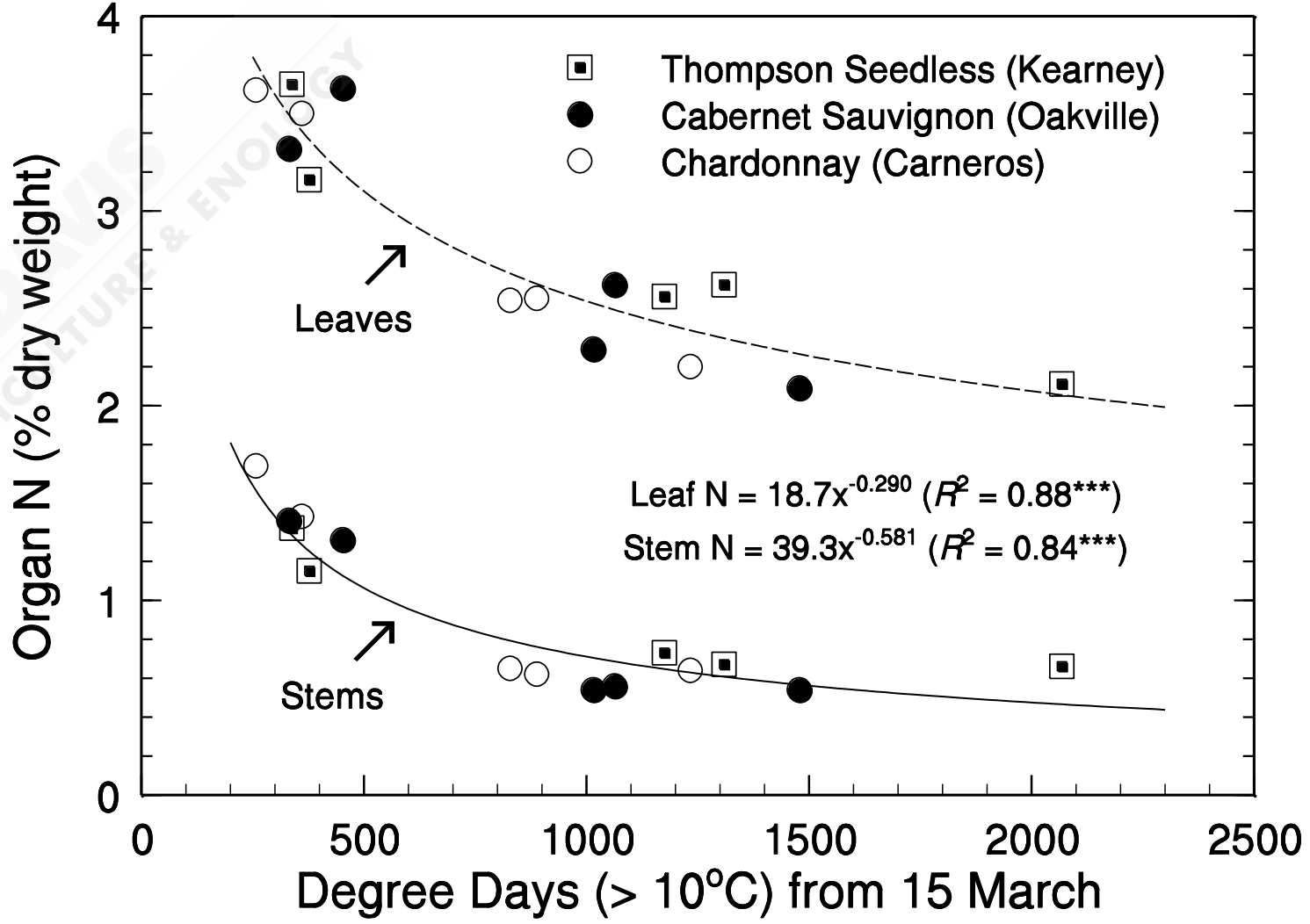
The concentrations of N and K in the fruit decrease as fruit dry biomass increases.

What happens to the concentration of N during the growing season?

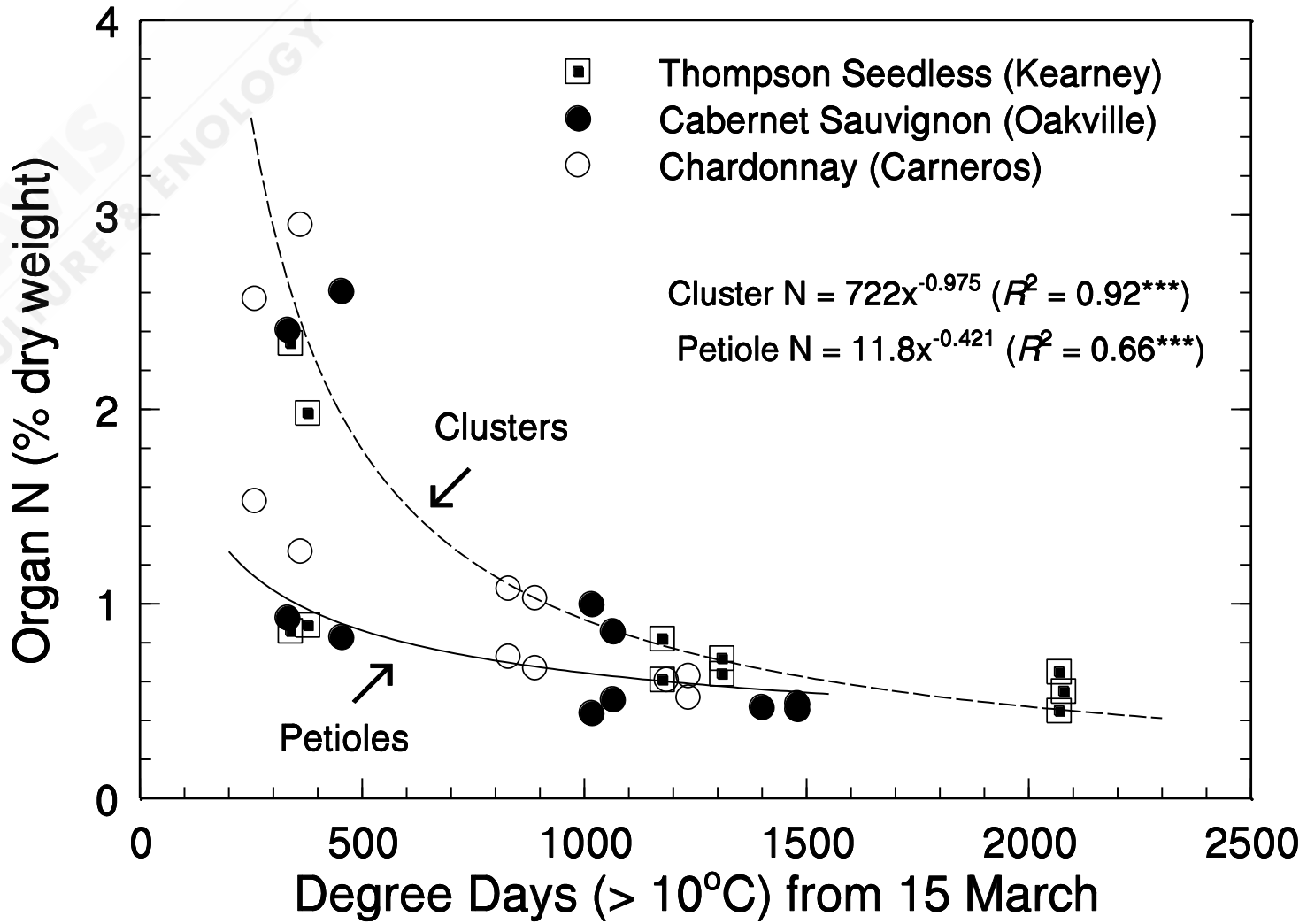





4.0
3.0
2.0
1.0
0
Cluster N (% dry wt.)
0
500
1000
1500
2000
2500
Degree days (>10° from budbreak)
Year 5
Year 6
Year 7
y = 216x-0.817
R2 = 0.91***



The relationship between leaf and stem N concentration and the accumulation of degree-days for 3 cultivars grown at different locations. Data were collected at bloom, veraison and close to harvest across two years.



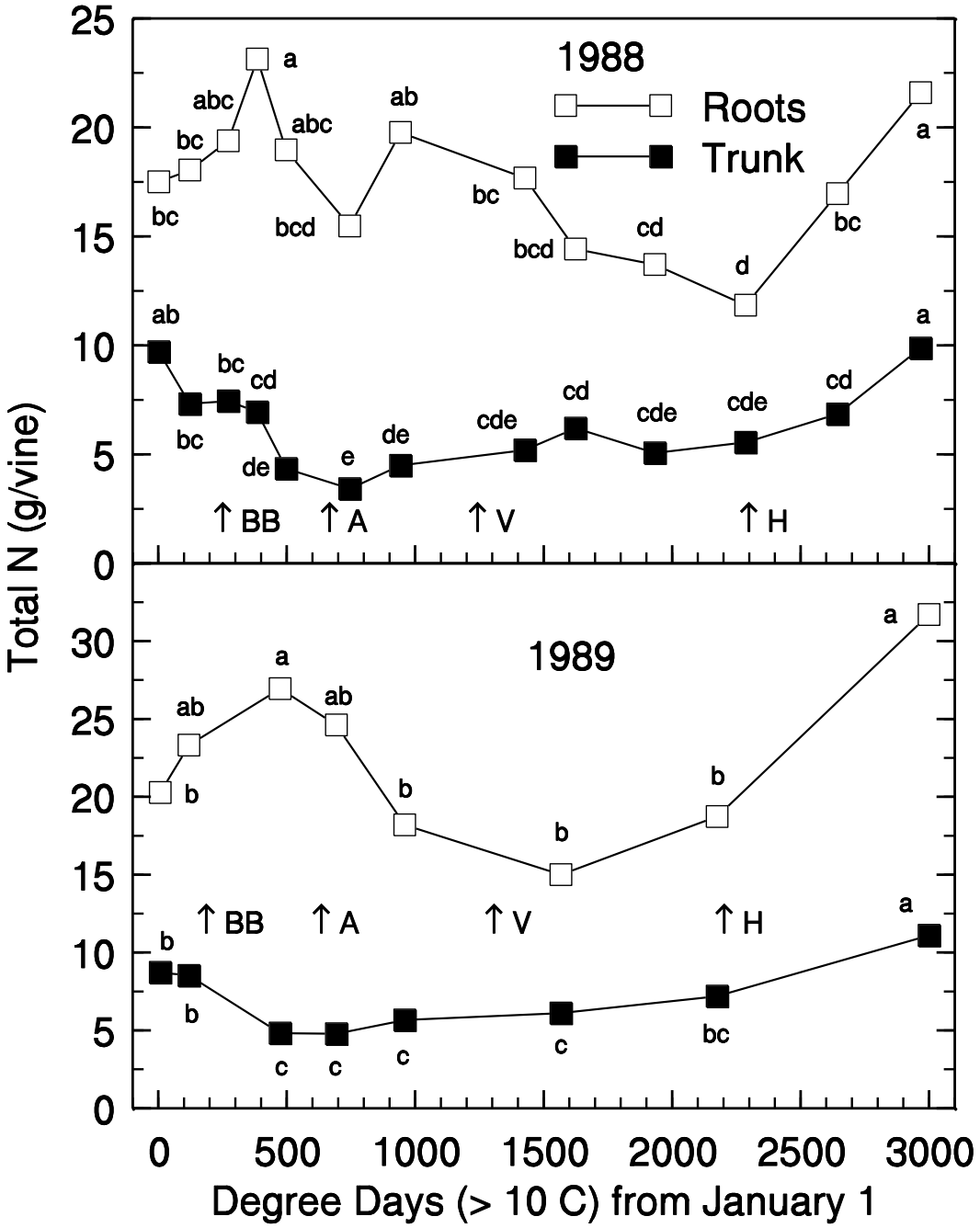
The relationship between cluster and petiole N concentration as a function of degree days. Other information as found in previous slide.

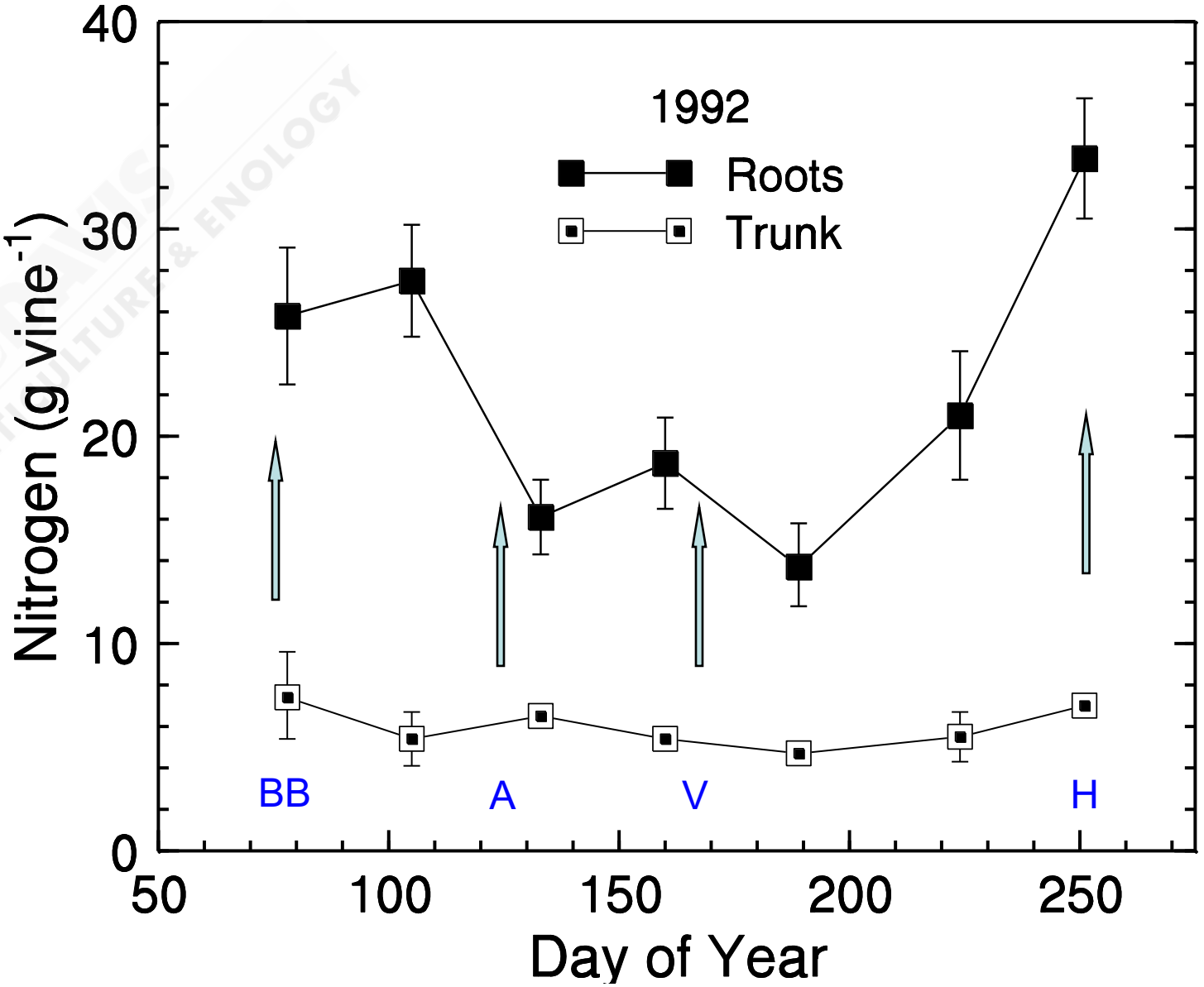
Summary:

- Nitrogen and K uptake are curvilinearly related to both seasonal vine water use and biomass accumulation of Thompson Seedless grapevines.
- The curvilinear relationship was more than likely due to the separation of vegetative and reproductive growth demands of N and K during the season.
- It is unknown whether the greater N and K uptake during the early portion of the growing season was due to an active uptake of both mineral nutrients or redistribution of N and K from the permanent structures of the vine.
- The concentration of N in the organs of grapevines decreases as the season progresses and is a function of the accumulation of degree days.

Dynamics of N Reserves in the Roots and Trunk and their utilization to support current season's growth of shoots (leaves, stems and clusters). How important is the post-harvest period for the replenishment of N reserves?

Total N in the roots and trunk of Thompson Seedless grapevines across two seasons. BB, A, V and H refer to budbreak, anthesis (bloom), veraison and harvest, respectively. An increase in N indicates the accumulation of N while a decrease indicates the loss of N from the root or trunk. Vines were 4 and 5 years old in 1988 and 1989, respectively.





Total N in the trunk and roots of 6 year old Thompson Seedless grapevines from budbreak (BB), through anthesis (A), veraison (V) and harvest (H).

Metrics of the utilization of N reserves:

- N in the trunk is used to support root growth early on.
- Very little N reserves are used to support initial shoot growth (up to mid to late April)
- ~ 20% of the N reserves were used through fruit harvest one year, 17% used through July 24th another year and 28% through July 7th another year.
- If one calculates from budbreak to fruit harvest, reserves contributed 11 and 4% of shoot N requirements during two of the growing seasons.
- During the 6th growing season, N reserves in the roots and trunks had been completely replenished by fruit harvest.

The amount of N in the vine at harvest (9/5) and that at the end of the growing season (all leaves have fallen from the vine). The bottom row is the change in N from harvest to the end of the season. EOS stands for end of season.

Date	Clusters	Leaves	Stems	New Total	Fruiting canes	Trunk	Roots
	---------- (g N / vine) ----------						
9/5	32.0	30.0	11.1	73.1	2.2	7.0	18.8
EOS	31.1	15.6	12.1		2.5	11.1	31.7
Δ 9/5	---	**-14.4**	+1.0		+0.3	**+4.1**	**+12.9**

Values above are equivalent to lbs. per acre.

Approximately 50% of the N in the leaves at harvest will remain in the leaves that fall from the vine.

The loss of N from the leaves between harvest and EOS account for **85%** of the N accumulated in the trunk and roots after harvest.

Comparison of 28 year-old Thompson Seedless grapevines that were fertilized with 34 g N per vine and those not fertilized and harvested at fruit maturity.

Treatment	Organ	Dry Bio. (g/vine)	N conc. (% dry wt.)	Total N (g/vine)	Woody N (g/vine)
'-N'	Leaves	1370	1.620	22.2	---
Current years	Fruit	6324	0.437	27.7	---
58.9 g/vine	Stems	1438	0.502	7.2	7.2
78.0 kg/ha	F.C.	411	0.448	1.8	1.8
69 lbs/acre	Trunk	8730	0.364	**31.8**	31.8
	Roots	5240	0.962	**50.4**	50.4
'+N'	Leaves	1592	1.746	27.8	---
Current years	Fruit	6175	0.550	34.0	---
73.5 g/vine	Stems	1623	0.604	9.8	9.8
97.3 kg/ha	F.C.	368	0.522	1.9	1.9
87 lbs/acre	Trunk	8650	0.394	**34.1**	34.1
	Roots	5300	1.318	**69.8**	69.8

Root N reserves (those found in the roots and trunk) can be refilled with N fertilizer applied during the growing season (fertilized 1 month after budbreak and after berry set).

Utilization of Nitrogenous and Potassium Reserves

- N may be translocated from the permanent structures of the vine (the trunk early on and roots later) to the shoots. The reserves may supply 10 to 25% of the total N needed for shoot/fruit growth at some point during the season.
- The vine's N reserves can be restored with N from the leaves as they senesce. This occurs from harvest through the end of leaf fall. They can also be restored with N taken up from the soil or fertilizer prior to or after harvest.
- Potassium is primarily derived from the soil with little coming from the permanent organs.

Uptake of ^{15}N labeled grapevine leaves and canes the year after incorporation into the vineyard's soil. Below data indicate that the N in the leaves and prunings can be taken up the following year.

Irrigation Treatment	Applied Tissue N (g vine^{-1})	Total Vine Biomass (kg vine^{-1})	Recovered ^{15}N labeled tissue (%)[a]
Drip Irr.			
Leaves	18.5 ± 1.6	14.1 ± 1.0	4.73 ± 0.92
Canes	18.9 ± 2.1	16.6 ± 1.1	1.46 ± 0.43
Furrow Irr.			
Leaves	18.1 ± 2.1	16.7 ± 0.9	4.95 ± 0.45
Canes	24.1 ± 2.3	16.7 ± 0.5	2.05 ± 0.92

[a] The scientific literature values range from 6 to 29% (based mostly on agronomic crops) the year following incorporation into the soil.

N budget of vines across cultivars, grape production techniques and locations.

The average, high and low amounts of several mineral nutrients in one ton of fruit from grapevines (from Biology of the Grapevine).

Mineral Nutrient	Average	High	Low
	----------(lbs. / t)----------		
N	2.92	4.12	1.80
P	0.56	0.78	0.44
K	4.94	7.38	3.18
Ca	1.00	1.86	1.08
Mg	0.20	0.32	0.10

N BUDGET OF THOMPSON SEEDLESS GRAPEVINES

Growth Period

Leaves	~35 g/vine
Shoots	~10 g/vine
Clusters	~30 g/vine
	75 g/vine

After Harvest

Fallen leaves	~10 -15 g/vine
Prunings	~15 g/vine
Remolilization	~ 10 -15 g/vine
	35 - 45 g/vine

g per vine are equivalent to lbs per acre with these vine and row spacings

Effects of Irrigation treatment on total vine % N and K and the amounts of those two nutrients per unit area at harvest of **5 year-old** Thompson Seedless vines.

	Irrigation treatment (fraction of applied H_2O amts)			
Total vine	0.2	0.6	1.0	1.4
N (% dry wt)	0.81 a	0.70 b	0.75 ab	0.73 ab
K (% dry wt)	0.72 bc	0.63 c	0.82 b	0.95 a
lbs. N/ ton	2.36	2.14	2.44	2.40
lbs. K/ ton	3.28	2.56	3.30	4.42
lbs. N/acre	52	79	95	97
lbs. K/acre	46	72	104	125

Comparison of 28 year-old Thompson Seedless grapevines that were fertilized with 34 g N per vine and those not fertilized.

Treatment	Organ	Dry Bio. (g/vine)	N conc. (% dry wt.)	Total N (g/vine)	Woody N (g/vine)
'-N'	Leaves	1370	1.620	22.2	---
Current years	Fruit	6324	0.437	27.7	---
58.9 g/vine	Stems	1438	0.502	7.2	7.2
78.0 kg/ha	F.C.	411	0.448	1.8	1.8
69 lbs/acre	Trunk	8730	0.364	31.8	31.8
	Roots	5240	0.962	50.4	50.4
	Total	23,513		141.1	91.2
'+N'	Leaves	1592	1.746	27.8	---
Current years	Fruit	6175	0.550	34.0	---
73.5 g/vine	Stems	1623	0.604	9.8	9.8
97.3 kg/ha	F.C.	368	0.522	1.9	1.9
87 lbs/acre	Trunk	8650	0.394	34.1	34.1
	Roots	5300	1.318	69.8	69.8
	Total	23,708		177.4	115.6

Effect of vineyard location, cultivar and year on the amount of N found in the fruit and that needed to produce a crop.

The amount of N per ton of fruit at four vineyard locations across three years.

Location	Total N ----- (pounds per ton of fruit) -------		
Year	1997	1998	1999
Carneros (Chardonnay)	2.68	2.50	2.58
Gonzales (Chardonnay)	2.48	2.56	2.88
Oakville (Cab. Sauvignon)	1.96	2.48	2.70
Paso Robles (C.S.)	3.16	3.02	2.76

The amount of N in the fruit at harvest, leaves as they fell from the vines and prunings taken during the winter at four locations and across years.

Location	Total N (clusters, leaves and prunings) ---------- (pounds per acre) ----------		
Year	1997	1998	1999
Carneros	52.2	37.9	42.5
Gonzales	42.0	23.5	36.7
Oakville	39.8	38.2	36.8
Paso Robles	38.9	41.0	32.6

Values would be greater if the N in leaves had been determined at harvest.

The effect of cultivar and year on total fruit fresh biomass 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
2016	35.2	28.1	68.3	2.41	131	1528 / 842
Sheegene						
2016	30.1	24.0	61.6	2.57	165	2020 / 1747
				2.86		

The effect of N treatments on total fruit fresh biomass 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

Grapevine N Fertilizer Program

1.) Assessing vineyard/vine N status
2.) Determination of N fertilizer amounts
3.) Kinds of N fertilizers
4.) Timing of fertilization events
5.) Effects of N on vegetative and reproductive growth

1.) Assessing vine nutrient status

a.) deficiency symptoms

b.) soil analysis

c.) tissue analysis

1.) Assessing vine nutrient status

a.) deficiency symptoms –
by the time this is observed
vine growth may already be
adversely affected.

1.) Assessing vine nutrient status

b) Soil analysis

"Soil Analysis is of no value in determining N needs. This is due to the transient nature of its main available form (NO_3) in the soil profile and the unavailability of organic-N fraction until it is mineralized."

L.P. Christensen, UCCE Specialist
Raisin Production Manual

1.) Assessing vine nutrient status

c.) Tissue Analysis – criteria for usefulness

- The tissue used and the mineral nutrient measured should be related to the mineral nutrient status or its concentration in other organs of the vine.
- The tissue used and the mineral nutrient measured should be related to vegetative and reproductive growth of the vine.
- A critical value or its range for the mineral nutrient in the organ measured should be robust enough to cover a wide range of vineyard or grapevine situations.

1.) Assessing vine nutrient status

c.) Tissue Analysis

- Time of Sampling
- Type of Tissue Sampled
- Form of Nitrogen

Time of Sampling

Bloom and/or Veraison

- Definite Growth Stage
- Repeatable
- Convenient

Type of Tissue Sampled

- Petioles of mature leaves or those from opposite the cluster at bloom
- Petioles of mature leaves at veraison
- Leaf blades
- Fruit at harvest
- Canes during dormancy

Form of Nitrogen

Petioles – NO_3-N, NH_4-N, total N

Leaf Blades – total N

Fruit – total N, arginine, YANC

Canes – total N, arginine

NITRATE-NITROGEN
Bloom Petiole Levels (ppm)

	Nitrate-Nitrogen (ppm)
Deficient	Less than 350
Questionable	350 - 500
Adequate	500 – 1,200
Excessive	Over 2,000
Possibly toxic	Over 3,000

The next slides show the relationships among petiole NO_3-N and petiole and grapevine organ (leaves, stems and cluster) N concentrations, total vine N, cluster number per vine and yield.

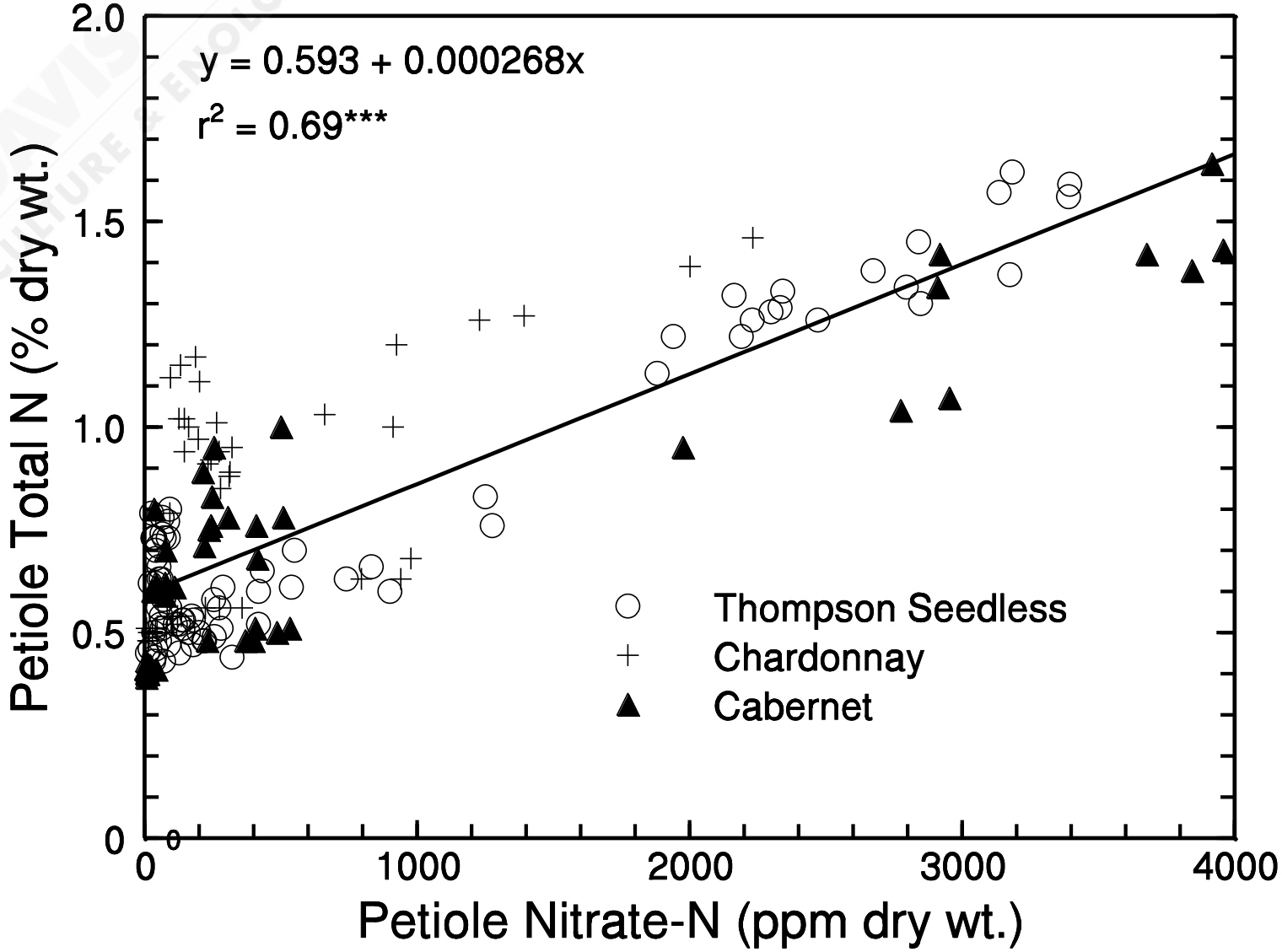
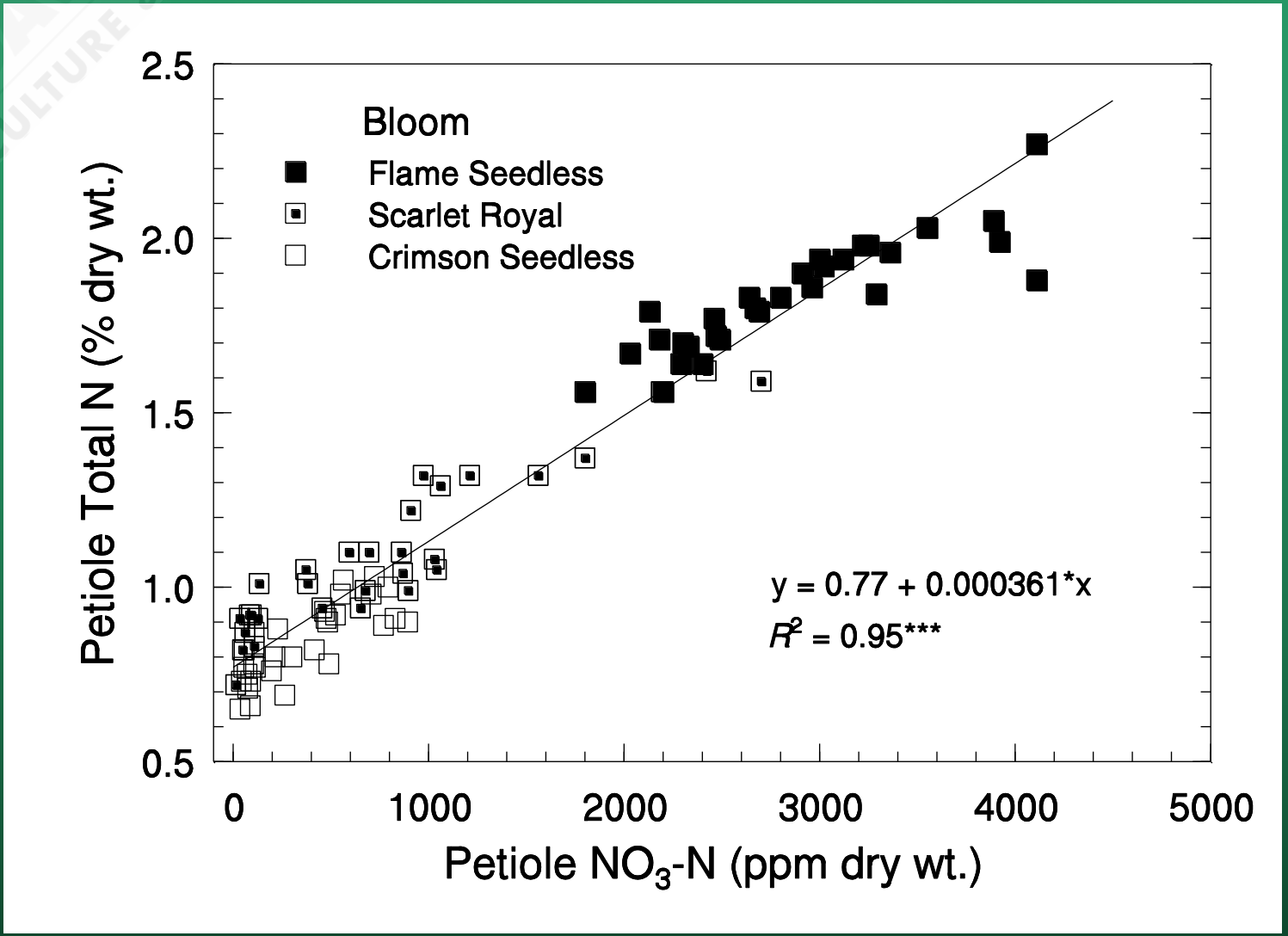
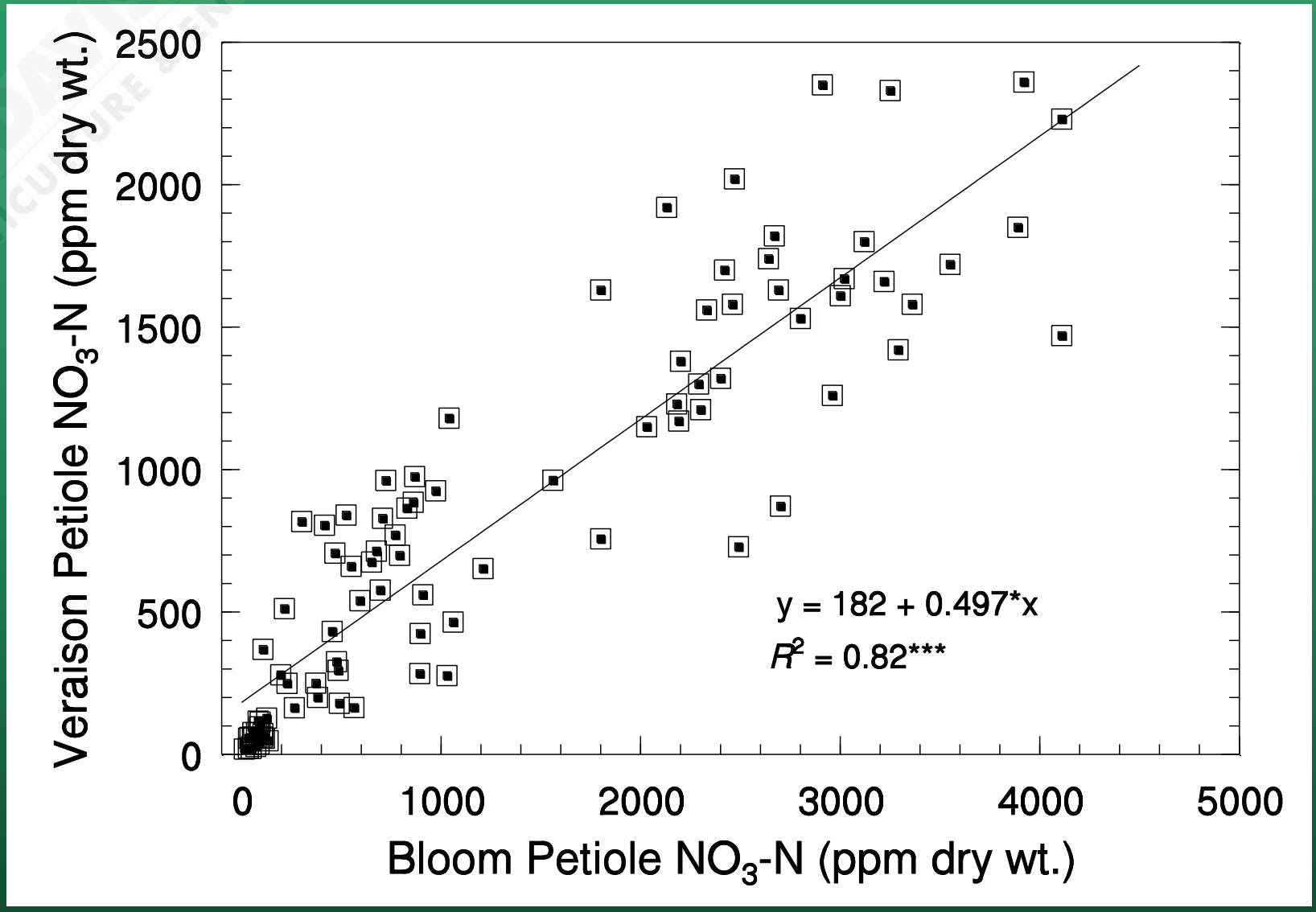


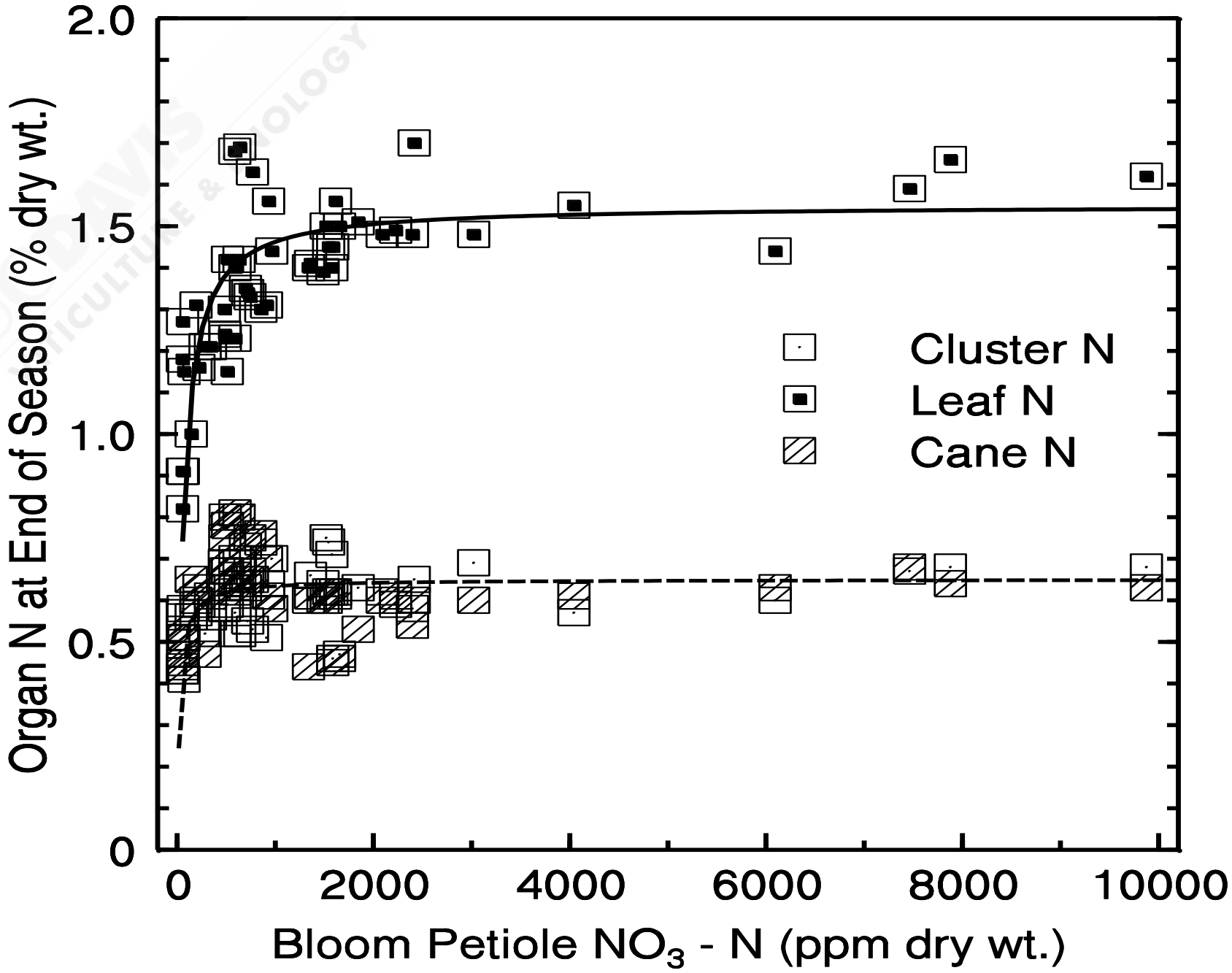
Figure 1. The relationship between petiole nitrate-N and petiole total N for three cultivars.

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

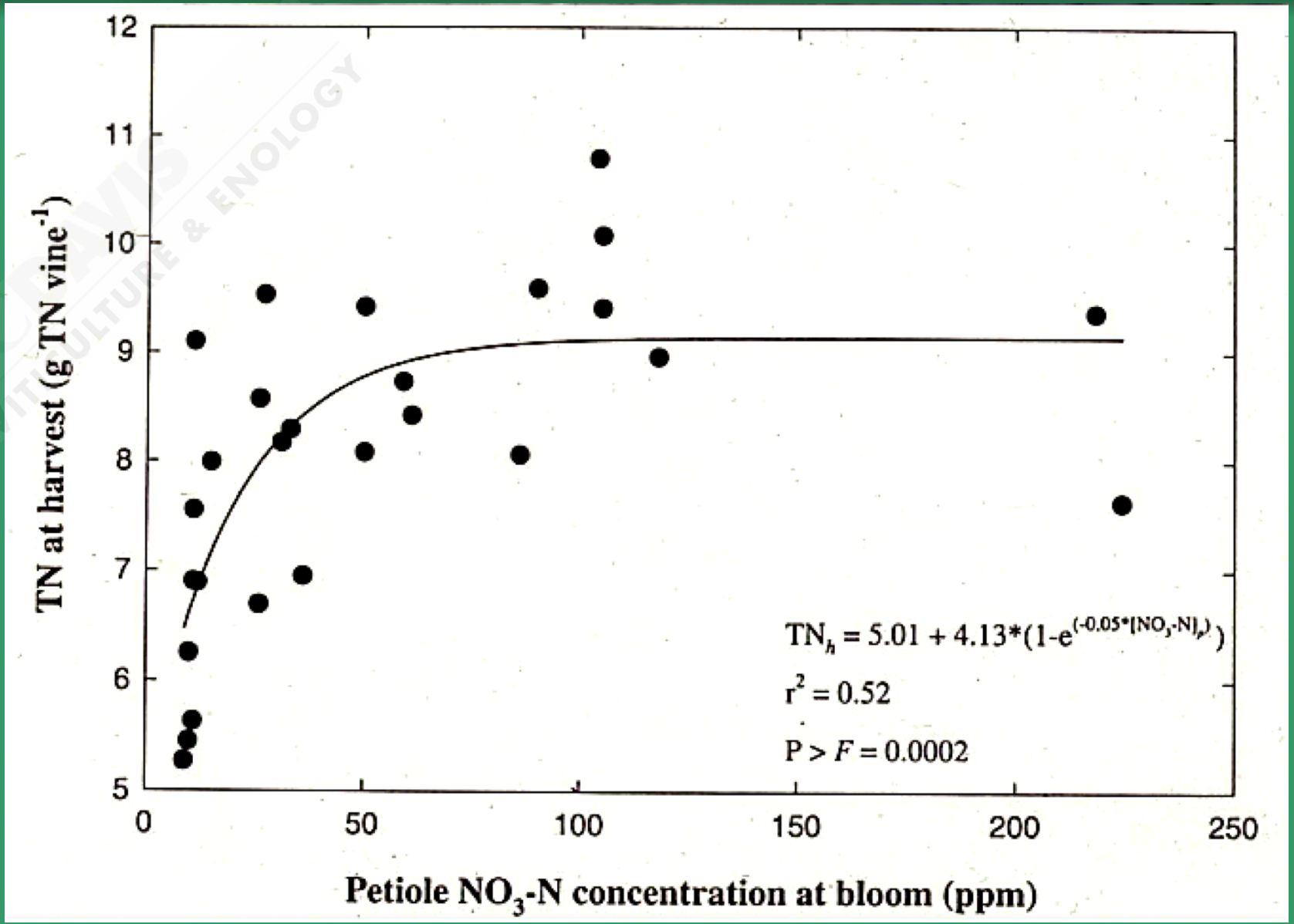


Relationship between veraison petiole NO_3-N and bloom petiole NO_3-N of all three cultivars.

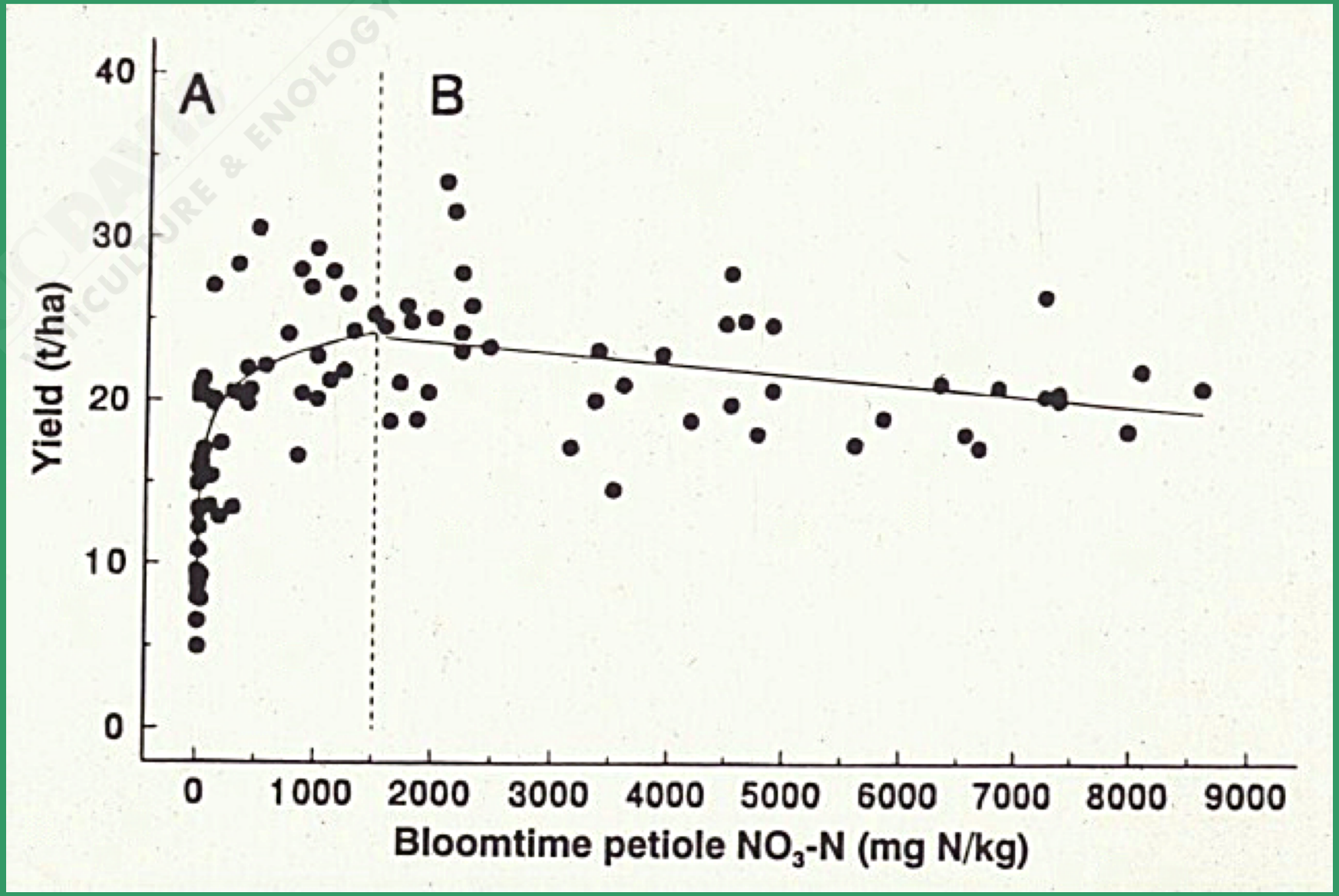



2.0
1.5
1.0
0.5
0
Organ N at End of Season (% dry wt.)
0
2000
4000
6000
8000
10000
Bloom Petiole NO3 - N (ppm dry wt.)
Cluster N
Leaf N
Cane N

The previous slide shows that the concentration of N in the leaves, stems and clusters of Cabernet Sauvignon and Chardonnay on 5 different rootstocks does not decrease significantly until petiole NO_3-N decreases to very low values.



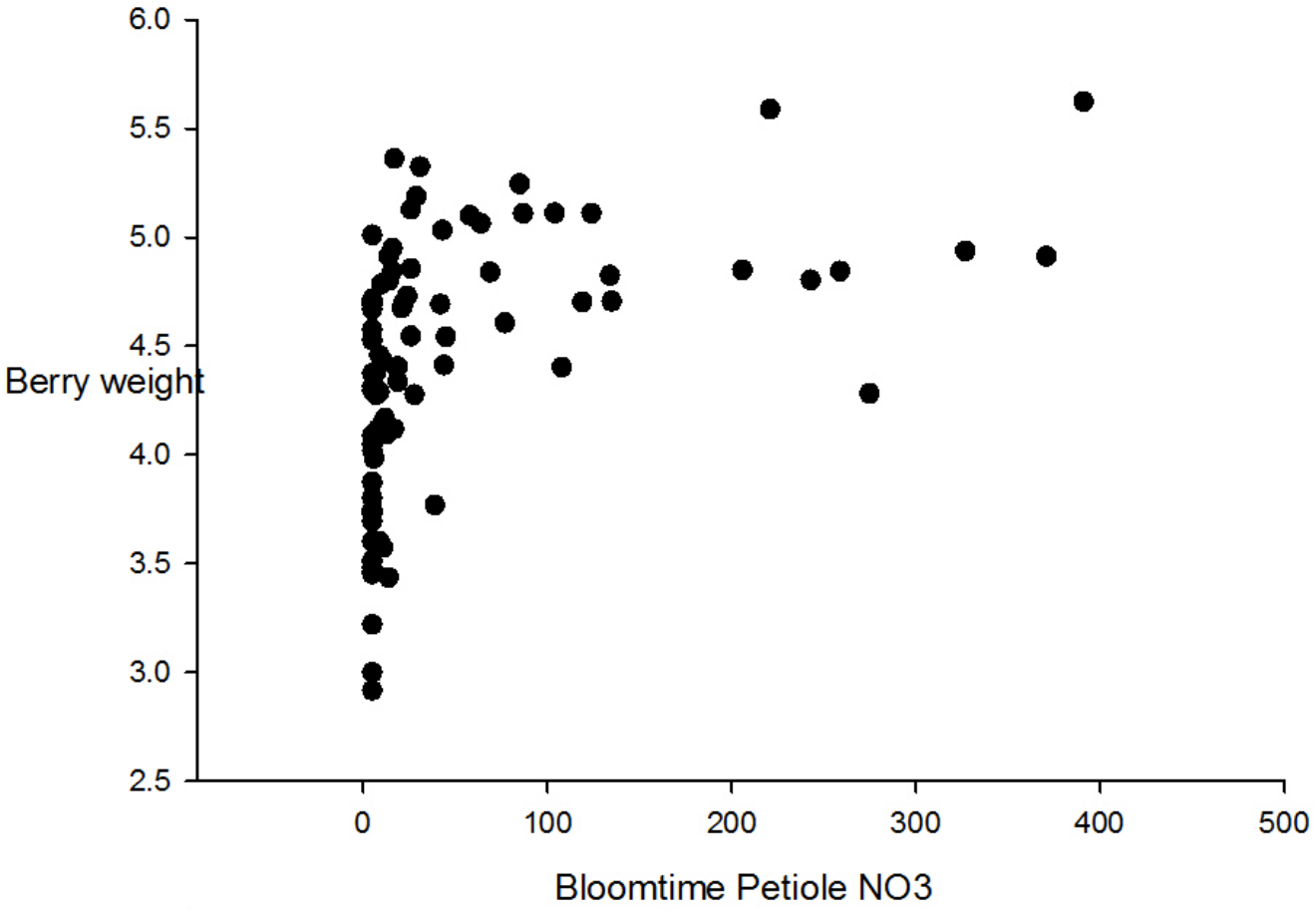
Under the conditions of this study, total N in Cabernet Sauvignon vines at harvest was maximum at a petiole nitrate N concentration of 100 ppm at bloom. (Iandolino, MS Thesis, UC-Davis, 2001)



Study by Spayd et al. (1993) on White Riesling

The study by Spayd et al. (1993) found that yield of White Riesling increased almost five-fold when petiole nitrate-N values increased from 7 to approximately 200 ppm and then leveled off after that.

Relationship between bloom petiole NO_3-N and berry weight (g) of Flame Seedless vines grown near Selma, CA.



The effect of different irrigation and applied N treatments on return bud fruitfulness of **Thompson Seedless** grapevines.

Treatment in 2001	Bloom 2001 Nitrate-N (ppm dry wt.)	Bloom 2001 Total N (% dry wt.)	Shoot # 2002 (# / 4 vines)	Cluster # 2002 (# / 4 vines)
No Irr./No N	64	0.72	365	159 b
Irrigated/No N	42	0.70	333	157 b
Irrigated/50 lbs. N	2450	1.33	359	200 a
Irrigated/100 lbs. N	2804	1.39	380	215 a

The effect of different irrigation and applied N treatments on return bud fruitfulness of Chardonnay and Cabernet Sauvignon grapevines.

Treatment in 2001	Bloom 2001 Nitrate-N (ppm dry wt.)	Bloom 2001 Total N (% dry wt.)	Cluster # 2002 (#/6 vines)
Chardonnay			
No Irr./No N	262	0.94	123
Irrigated/No N	152	1.02	171
Irrigated/80 lbs	1979	1.32	151
Cabernet Sauvignon			
No Irr./No N	145	0.73	144
Irrigated/No N	299	0.76	142
Irrigated/40 lbs	--	--	148
Irrigated/80 lbs	3215	1.30	144

The effect of three applied N treatments in 2014 on bloom petiole nitrate-N and total N of **Scarlett Royal** grapevines and return fruitfulness in 2015. Applied N is that removed in the crop the previous year.

Treatment in 2014	Bloom 2014 Nitrate-N (ppm dry wt.)	Bloom 2014 Total N (% dry wt.)	Cluster # 2015 (# / 4 vines)
No N	107 c	0.90 c	212 b
1.0 N	836 b	1.14 b	220 ab
2.5 N	1460 a	1.26 a	229 a

Conclusions:

- The relationship between petiole nitrate-nitrogen and N concentration in the leaves, fruit and canes in several studies, total N in the vine at harvest and bud fruitfulness in response to N fertilizers indicates that a bloom-time petiole NO_3-N value of 200 ppm would be “adequate.” Nitrate values in the petioles at bloom below 100 ppm decreased percent N in those organs only slightly.
- A bloom-time petiole NO_3-N value less than 100 ppm one year may significantly reduce return fruitfulness the next. It is unsure whether is would adversely affect yields. If values less than 100 ppm occurred several years in a row one should assume its time to fertilize with N.

Grapevine Fertilization Program

2.) **Determination of fertilizer amounts**

It will depend upon whether it is a maintenance program or one to correct a deficiency

a.) for a maintenance program one needs to determine how much of the mineral nutrient is removed from the vineyard (i.e. develop a N budget)

b.) determine the efficiency with which fertilizer is taken up.

The average, high and low amounts of several mineral nutrients in one ton of fruit from grapevines.

Mineral Nutrient	Average	High	Low
	----------(lbs. / t)----------		
N	2.92	4.12	1.80
P	0.56	0.78	0.44
K	4.94	7.38	3.18
Ca	1.00	1.86	1.08
Mg	0.20	0.32	0.10

Grapevine Fertilization Program

3.) Kinds of N fertilizers

"Generally the choice of the formulation of nitrogen can be based mostly upon cost."

L.P. Christensen, UCCE Specialist

Applied water amounts (via drip or flood irrigation), nitrate N (NO_3-N) in the irrigation water (and equivalents) and applied N in the fertilizer treatments (x or 2.5x amounts) for the Scarlet Royal and Crimson Seedless vineyards during the **2015** growing season. No fertilizer N was applied to the Flame Seedless vines in **2015**.

		Irrigation Type	Flame Seedless	Scarlet Royal	Crimson Seedless
Applied water	L/vine	Drip	2279	4051	4327
		Flood	2432	549	2472
		Total	4711	4600	6799
	Gal./vine	Drip	603	1072	1145
		Flood	643	145	654
		Total	1246	1217	1799
	mm	Total	844	824	761
	inches	Total	33.2	32.4	30.0
NO_3-N	mean (ppm)	---	7.82 (8.11)	5.02 (4.39)	3.80 (3.78)
N equivalents		g N/vine	36.8	23.1	25.8
		kg N/ha	65.9	41.4	28.9
N amount in the water →		**lbs. N/acre**	**58.7**	**36.9**	**25.8**
Applied N	x treatment	g N/vine	---	31.3	42.3
	2.5x treatment	g N/vine	---	78.3	105.8

Applied water amounts (via drip or flood irrigation), nitrate N (NO_3-N) in the irrigation water (and equivalents) and applied N in the fertilizer treatments (x or 2.5x amounts) for the Scarlet Royal and Crimson Seedless vineyards (Goshen) and Flame Seedless and Autumn King vineyard (Selma) during the **2016** growing season.

		Irrigation Type	Scarlet Royal	Crimson Seedless	Flame Seedless	Autumn King
Applied water	L/vine	Drip	5023	5277	4910	4252
		Flood	----	1168	---	---
		Total	5023	6445	4910	4252
	Gal./vine	Drip	1329	1396	1299	1125
		Flood	0	309	0	0
		Total	1329	1705	1299	1125
	mm	Total	900	721	733	635
	inches	Total	32.4	30.0	28.9	25.0
NO_3-N	mean (ppm)	---	4.27 (5.02)	5.37 (3.80)	1.97	3.23
N equivalents		g N/vine	21.4	34.6	9.7	13.7
		kg N/ha	38.4	38.8	14.4	20.4
N amount in the water →		**lbs. N/acre**	**34.2**	**34.6**	**12.9**	**18.2**
Applied N	x trtmnt	**lbs. N/acre**	79.4	49.4	25.7	34.2
	2.5x trtmnt	**lbs. N/acre**	198	123.5	64.3	85.5

Scarlet Royal (2016 soil N data) (vine x row = 6 x 10 ft. (1.83 x 3.05 m), area = 5.58 m^2, depth = 1.52 m, volume = 8.43 m^3, bulk density = 1.49 g/cm^3, wt./vine = 12,635 kg/volume)
Resolution: NO_3-N = 1.0 mg/kg; NH_4 = 0.2 mg/kg. Grams N/vine x 1.6 = lbs. N/acre (15.7 and 20 g N/vine = 25 and 32 lbs./acre, respectively)

	------ 0 N -------		1.0x (slg) N		2.5x (slg) N		2.5x (sf) N	
Block	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N	NO_3-N	NH_4-N
I	0.36	1.02	0.62	1.59	3.89	0.76	0.58	3.64
III	0.36	0.78	0.47	0.38	0.56	1.00	2.05	6.98
V	0.42	0.78	0.55	1.11	0.77	2.59	1.29	2.61
mean	0.38	0.86	0.55	1.03	1.74	1.45	1.31	4.41
g N/vine	4.80	10.9	6.96	13.0	22.0	18.3	16.4	55.8
soil total	---	15.7	---	20.0	---	40.3	---	72.2
Soil Δ N	---	---	---	+4.3	---	+24.6	---	+56.5
Vine Δ N	---	---	---	+89.6[b]	---	+99.0[b]	---	+93.5[b]
Acct. N				+93.9	---	+123.6	---	+150.0
Applied N[b]	---	---	---	123	---	306.8	---	286.5
Unacct. N[a]	---	---	---	-30.0	---	-183.2	---	-136.5

[a] Unaccounted-for N = Applied N - Accounted (Acct.) for N.
[b] These values are added across the three year study

Grapevine Fertilization Program

4.) Timing of fertilization events

One must know when the N is being utilized by the vine to choose the appropriate date to apply the fertilizer.

L.E. Williams' recommendation for N fertilization application timing

Split applications[a]

1st application – one month after BB

2nd application – just after berry set.

[a] apply one half the total fertilizer to be used each time.

When do you not want to apply an inorganic nitrogen fertilizer?

1.) Avoid applying N in winter/early spring if the fertilizer is susceptible to leaching during this season.

2.) An application of N fertilizer just prior to or at bloom may increase the amount of berries that fail to set.

3.) A post-harvest application of an N fertilizer is probably not as efficient as some thought. For one to consider this time as appropriate, one needs to assess vine health, length of season remaining and soil type.

Values of fertilizer recovery efficiency (RE_N)

- 7 – 11% on Concord (dry-farmed in New York State (US)).
- 24 to 27% on Thompson Seedless (two fertilizer forms, nitrate and ammonia, drip irrigated)
- 4 – 11% Cabernet and Chardonnay drip irrigated vineyards (on different rootstocks)
- 24 – 29% using two amounts of ammonium nitrate fertilizer. Drip irrigated Cabernet Sauvignon.
- 70% on 50 year-old Sultana (Thompson Seedless) vines grown in Australia.

Effect of irrigation type and form of nitrogen on N fertilizer recovery efficiency (RE_N) and NDF.

Treatment	Recovery of ^{15}N Fertilizer ($g\ ^{15}N$ fert. $vine^{1}$)	RE_N ($g\ ^{15}N\ vine^{-1}/g\ ^{15}N$ fert.)*100	NDF ($g\ ^{15}N\ vine^{-1}/g\ N\ vine^{-1}$)*100
Drip Irr.			
NO_3	10.6	42.4%	10.4%
NH_4	9.3	37.3%	8.2%
NO_3/Cont.	11.1	40.3%	11.4%
Furrow Irr.			
NO_3	3.3 a	13.3% a	4.9% a
NH_4	2.6 b	10.4% b	3.2% b

Petiole NO_3-N at bloom was 1011 ppm (dry weight basis)

Comparison of 28 year-old Thompson Seedless grapevines that were fertilized with 34 g N per vine and those not fertilized.

Bloom petiole NO_3-N for '-N' treatment was 94 ppm (dry wt. basis).

Treatment	Organ	Dry Bio. (g/vine)	N conc. (% dry wt.)	Total N (g/vine)	Woody N (g/vine)
'-N'	Leaves	1370	1.620	22.2	---
Current years	Fruit	6324	0.437	27.7	---
58.9 g/vine	Stems	1438	0.502	7.2	7.2
78.0 kg/ha	F.C.	411	0.448	1.8	1.8
69 lbs/acre	Trunk	8730	0.364	31.8	31.8
Petiole	Roots	5240	0.962	50.4	50.4
	Total	23,513		**141.1**	91.2
'+N'	Leaves	1592	1.746	27.8	---
Current years	Fruit	6175	0.550	34.0	---
73.5 g/vine	Stems	1623	0.604	9.8	9.8
97.3 kg/ha	F.C.	368	0.522	1.9	1.9
87 lbs/acre	Trunk	8650	0.394	34.1	34.1
RE_N =	Roots	5300	1.318	69.8	69.8
>100%	Total	23,708		**177.4**	115.6

The amount of N measured in the vine after leaf fall of 28 year-old Thompson Seedless grapevines as a function of three N fertilizer treatments and removing ½ of the leaves on the vine after fruit harvest ('PH Def'). The N treatments were no applied N (-N), the application of 34 g/vine (40 lbs N/acre) during the growing season in two slug applications (1/2 each time)(+N) and a post-harvest application of N (25 g N/vine; 30 lbs N/acre) after harvest (PH + N). The PH + N treatment received no applied N during the growing season.

N Trtmnt	Total N*	Δ N From Harvest**	Leaf N Remobilized	N Uptake	RE_N
	(g/vine)	(g/vine)	(g/vine)	(g/vine)	(%)
'-N'	128.2	37.0	11.0	26.0	---
'+N'	142.0	26.4	13.7	12.7	---
'PH + N'	134.0	42.8	9.7	33.1	28.4*
'PH Def'	111.2	20.0	6.8	13.2	---

*RE_N of 'PH + N' = (N uptake ('PH + N') – N uptake ('-N')/ 25.0) x 100

*Sum of N in the stems, fruiting canes, trunk and roots after leaf fall

**Δ N = N in stems, fruiting canes, trunk and roots at leaf fall minus N in those organs at harvest. Control for –N, PH+N and PH Def was the –N treatment at harvest.

The effect of cultivar (Crimson Seedless 'Old'), year and N treatment on total N at harvest. Total N is the sum of the N in the leaves, stems and clusters at fruit harvest. Delta (Δ) N refers to the total amount of N (summed across years) in the treatment vines minus the total N in the 0 controls. Applied N is the sum of N applied across the three years. N fertilizer use efficiency (RE_N) is ΔN / applied N x 100.

Cultivar/ Treatment	2014	2015	2016	Total	Δ 0 N trt.	Applied N	RE_N
CS 'Old'	----------	----------	g N/vine	----------	----------	----------	
0	88.9	121.6	107.5	318.0	---	---	---
x	86.4	141.2	138.0	365.6	47.6	138.5	34.4%
2.5x	98.7	143.3	150.9	392.9	74.9	343.7	21.8%
0-s	90.7	108.0	107.3	mean ↓	---	---	---
0-ma	87.1	135.2	107.7	318.0	---	---	---
x-s	89.3	157.0	135.8	382.1	64.1	137.5	47.3%
x-ma	83.5	125.0	140.1	348.6	30.6	137.5	22.3%
2.5x-s	98.9	137.1	141.0	377.0	59.0	343.7	17.2%
2.5x-ma	98.5	149.5	163.2	411.2	93.2	343.7	27.1%

Combination of drip and furrow irrigation.

The effect of cultivar (Scarlet Royal 'Old'), year and N treatment on total N at harvest. Total N is the sum of the N in the leaves, stems and clusters at fruit harvest. Delta (Δ) N refers to the total amount of N (summed across years) in the treatment vines minus the total N in the 0 controls. Applied N is the sum of N applied across the three years. N fertilizer use efficiency (RE_N) is ΔN / applied N x 100.

Cultivar/ Treatment	2014	2015	2016	Total	Δ 0 N trt.	Applied N	RE_N
SR 'Old'	---------- g N/vine ----------						
0	86.6	119.2	108.4	314.2	---	---	---
x	106.7	151.9	145.2	403.8	89.6	118.7	75.6%
2.5x	107.1	155.5	147.8	410.4	96.2	296.7	32.5%
0-s	85.2	130.7	102.4	mean ↓	---	---	---
0-ma	88.0	107.6	114.2	314.1	---	---	---
x-s	105.1	142.3	138.7	386.1	72.0	122.7	58.7%
x-ma	108.2	161.4	151.6	421.2	107.1	114.6	93.4%
2.5x-s	107.2	153.8	152.2	413.1	99.0	306.8	32.3%
2.5x-ma	107.1	157.2	143.3	407.6	93.5	286.5	32.6%

Vineyard predominately drip irrigated.

The effect of cultivar (Flame Seedless – Selma 'Old'), year and N treatment on total N at harvest. Total N is the sum of the N in the leaves, stems and clusters at fruit harvest. Delta (Δ) N refers to the total amount of N (summed across years) in the treatment vines minus the total N in the 0 controls. Applied N is the sum of N applied across the three years. N fertilizer use efficiency (RE_N) is ΔN/applied N x 100.

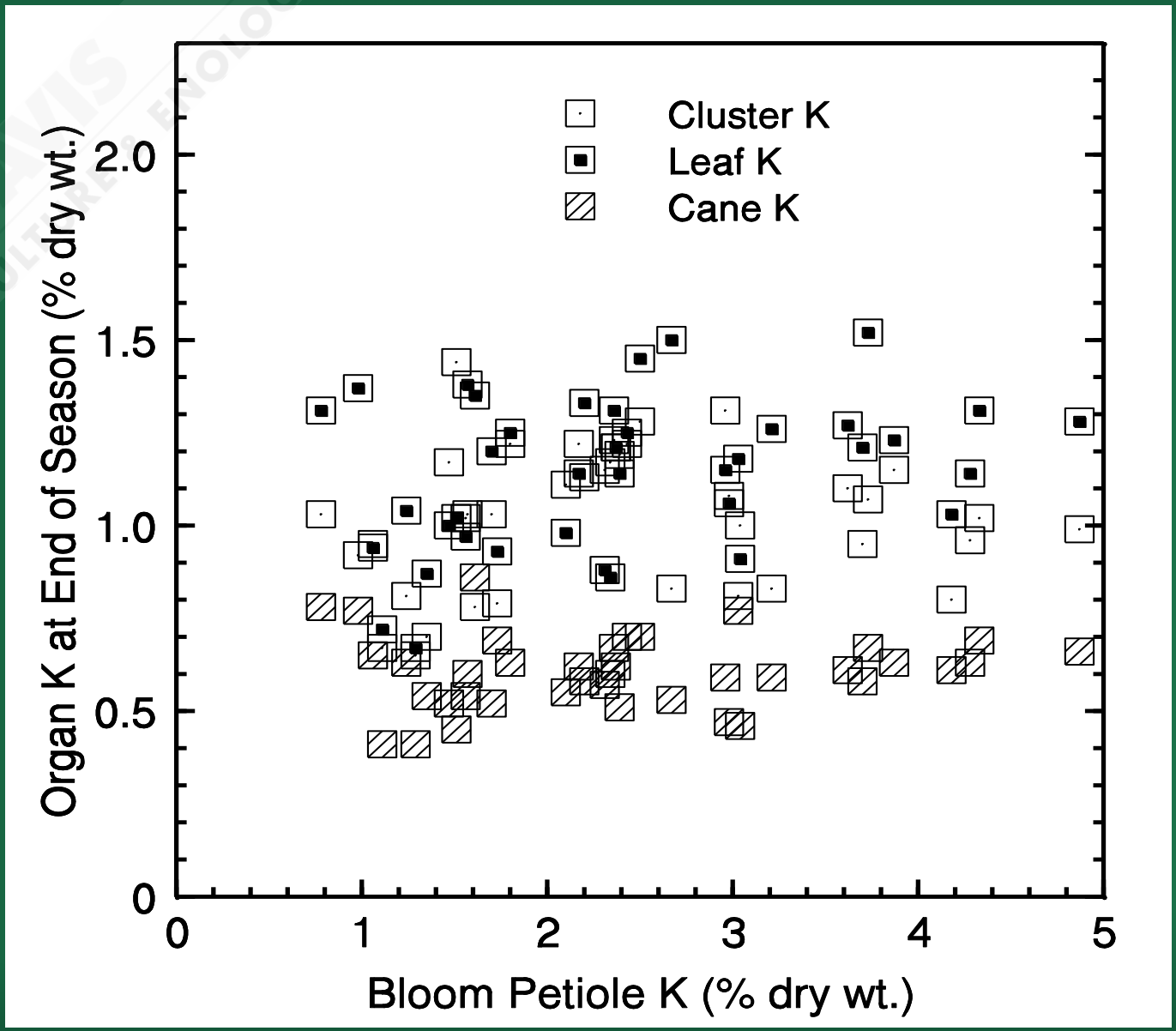
Cultivar/ Treatment	2016	2017	2018	Total	Δ 0 N trt.	Applied N	RE_N
FS 'Old'	----------	----------	g N/vine	----------	----------	----------	**%**
0	34.4	38.2	30.3	102.8	---	---	---
x	46.2	61.0	46.2	153.4	50.6	72.9	69.4
2.5x	62.4	72.5	56.3	191.2	88.4	181.5	48.7
0-s	33.9	37.1	30.3	mean ↓	---	---	---
0-ma	34.7	39.3	30.3	102.8	---	---	---
x-s	42.6	59.7	45.5	147.1	44.3	73.5	60.3
x-ma	50.4	62.3	46.5	159.2	56.4	71.5	78.9
2.5x-s	55.4	78.9	60.8	195.1	92.3	183.9	50.2
2.5x-ma	69.4	66.0	51.9	187.3	84.5	179.0	47.2

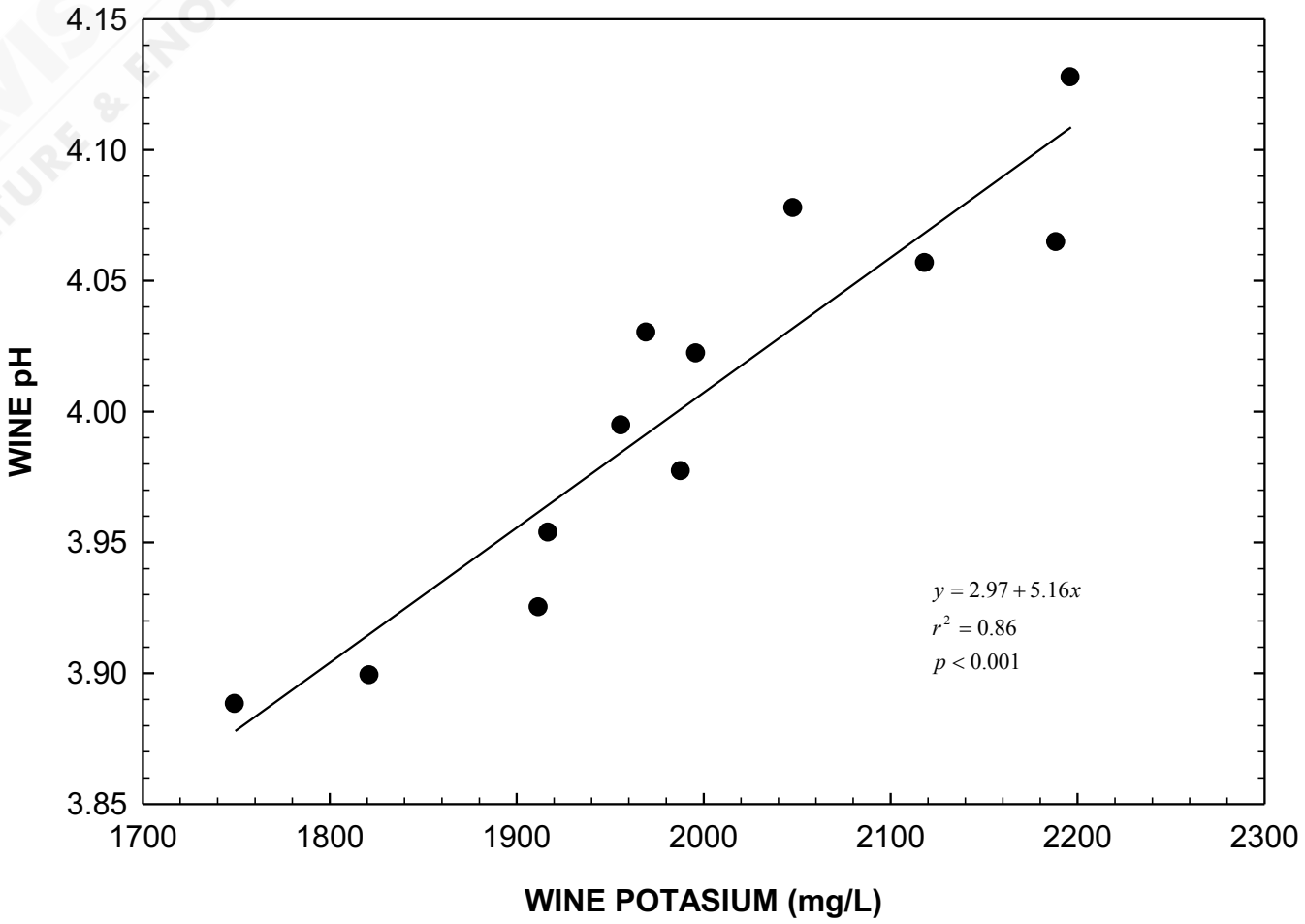
POTASSIUM

	Potassium (%)
Bloom Petiole Levels	
Deficient	Less than 1.0
Questionable	1.0 to 1.5
Adequate	Over 1.5
Midsummer Petiole Levels	
Deficient	Below 0.5
Adequate	Above 0.8

The amount of K per vine per year and K in a ton of fruit at four vineyard locations across three years and from two to five rootstocks.

Location	Total Vine K Lbs. / acre	Fruit K Lbs. / ton
Carneros	57.0	4.06
Gonzales	36.3	3.72
Oakville	65.0	5.78
Paso Robles	45.9	5.16


Cluster K
Leaf K
Cane K
Organ K at End of Season (% dry wt.)
Bloom Petiole K (% dry wt.)
0
0.5
1.0
1.5
2.0
0
1
2
3
4
5



The relationship between wine potassium and wine pH

Recommendations:

- Take petiole samples every year at bloom and possibly at veraison.
- Set up procedure for their collection and location within each vineyard.
- Decide on form of N to analyze and repeat every year.
- Get reliable counts of clusters each year prior to any cluster removal procedures.
- Have must analyzed for N at the winery and relate to petiole values measured at bloom or veraison.
- Come up with value for the amount of N per ton of fruit removed from your vineyard.
- Analyze soil for nitrates at some point to determine background amount of N present.
- Monitor irrigation water for N.