

Soil pH, Nutrient Availability, and Vine Productivity

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Experimental Design

An experimental vineyard block was planted in 1999 to investigate the effect of mineral nutrient availability on Concord growth and productivity. Three factors (soil pH, commercial fertilizers, and irrigation) are being used alone and in combination to manipulate soil nutrient availability (figure 1). At planting, four soil pH treatments were randomly established in four experimental blocks with lime and sulfur soil amendments. In 2003, each block was split in two equal sub-blocks where one sub-block received additional fertilizers based on soil and petiole tests and the other sub-block received no additional fertilizers. In addition, each block was again split into sub-block for irrigation or no irrigation; however, sufficient precipitation in 2003 and 2004 prohibited the need for additional soil moisture through irrigation.

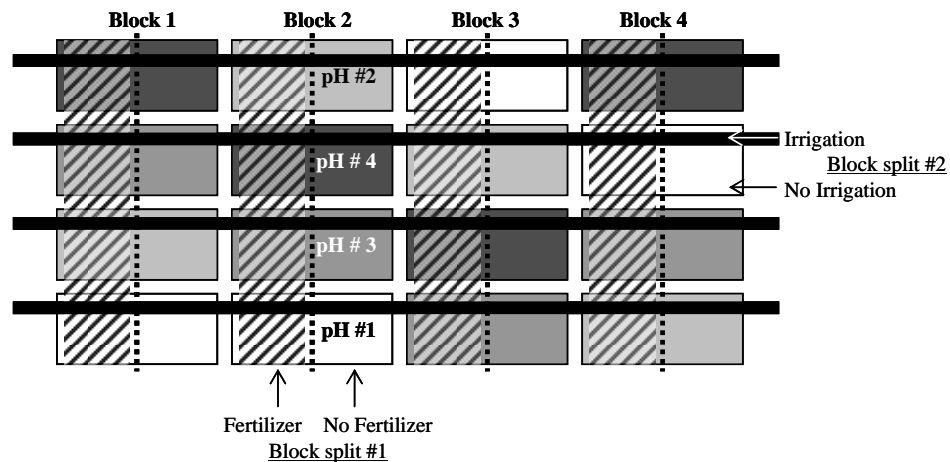


Figure 1: Diagram of the Concord/Soil pH block at the Cornell Vineyard Laboratory in Fredonia. Each soil pH plot is split for fertilizer and irrigation. Therefore, each block has 16 treatment combinations (4 soil pH x 2 fertilizer x 2 irrigation) replicated in four blocks.

Effect of soil amendments on soil pH and cation balance:

The starting soil pH of the experimental vineyard at planting was between 5.0 and 5.2. Ground sulfur was used to lower the soil pH and dolomitic limestone was used to raise the soil pH. Sulfur was used in 1999 and 2000 to establish soil pH around 4.5 and no additional sulfur has been needed to maintain the desired treatment (table 1). A

total of 3.9 equivalent tons/acre of limestone was applied over three years to target a soil pH around 6.5. No additional limestone was applied in 2003 or 2004 to monitor soil pH, which dropped to 6.0 or below. For the highest soil pH treatment, 8.9 equivalent tons/acre of limestone was applied over four years and this failed to increase the soil pH to the desired target. Similar to treatment number 3, a lack of limestone application in 2003 and 2004 resulted in a decrease in soil pH. A maintenance application of ammonium nitrate fertilizer is applied to the entire vineyard each year and the acidic soil reaction of this nitrogen fertilizer may explain the decrease in soil pH when limestone applications are discontinued.

Table 1: Growing season soil amendments and the following spring soil pH measurements of the four target soil pH treatments.

Soil pH Treatment	1999	soil pH	2000	soil pH	2001	soil pH	2002	soil pH	2003	soil pH	2004
1 (target pH=4.5)	0.26 t/a sulfur	4.6-5.0	0.25 t/a sulfur	4.0-4.3		4.5-4.6		4.2-4.3		4.3-4.4	
2 (target pH=5.5)		5.2-5.5		5.3-5.5		5.2-5.6		5.0-5.3		4.8-5.2	
3 (target pH=6.5)	1.9 t/a lime	6.1-6.5	1.0 t/a lime	6.2-6.4		6.0-6.2	1.0 t/a lime	5.7-6.0		5.7-6.0	
4 (target pH>7.0)	2.9 t/a lime	6.4-6.6	2.0 t/a lime	6.4-6.6	2.0 t/a lime	6.3-6.5	2.0 t/a lime	6.3-6.4		6.0-6.2	

As expected, the soil amendments of lime and sulfur with the corresponding change in soil pH influenced the balance of available cations (Al, H, Ca, Mg, K, and Na) in the soil. Lowering soil pH increased the amount of Al and H and decreased the amount of Ca, Mg, and K in the soil (figure 2A). Veraison petiole sampling indicated lower K and Mg uptake at soil pH treatment #1 and values for both nutrients were below recommended values (table 2). For Concord, veraison petiole target values for K and Mg are 2.0% and 0.5%, respectively. In 2004, veraison petiole K was measured at 1.45% and Mg was measured at 0.26%.

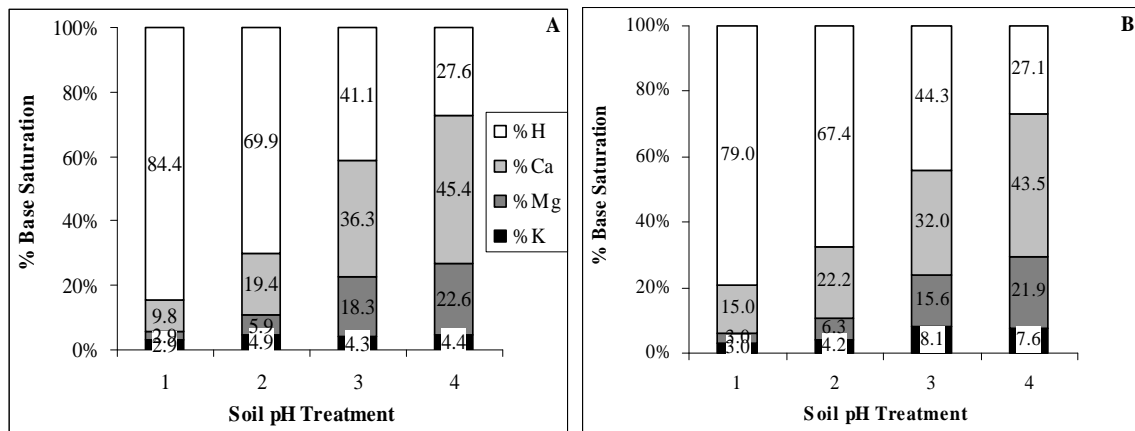


Figure 2A and B: Relative amounts of H, Ca, Mg, K in 2004 spring soil samples in the four soil pH treatment plots without additional fertilizer (A) and with additional fertilizer applied in the 2003 growing season (B). For additional fertilizer, soil pH treatment 1 received 250#/acre calcium and soil pH treatments 3 and 4 each received 200#/acre potassium. The same fertilizer treatments were applied in the 2004 growing season.

In 2003, Calcium fertilizer was added to the low pH block in an effort to add cation competition to the excessive H and Al ions. Calcium fertilizer increased % base

saturation of Ca from 9.85 to 15.0% and decreased H from 84.4% to 79.0%; however, this minor change did not translate into improved mineral nutrition for Concord vines (figure 2A and table 2).

Increasing the soil pH with lime in treatments 3 and 4 greatly increased the amount of available Ca and Mg, decreased the amount of H and Al, and did not change the amount of available K in the soil (figure 2A). In unfertilized plots, the change in soil pH and available nutrients led to an increase in tissue Mg to above the recommended veraison value of 0.5% and a decrease in tissue K to below the recommended value of 2.0%.

In 2003 and 2004, potassium fertilizer was added to the soil pH treatments 3 and 4. The relative amount of available potassium doubled in the soil because of the fertilizer application even though K represented only 8% of the total % base saturation. The increase in soil available K led to an increase in veraison tissue values to over 2.0% and brought tissue Mg down to approximately 0.5%.

Table 2: Tissue nutrient concentrations from bloom and veraison Concord petioles in the 2004 growing season from soil pH plots with and without additional fertilizers. In 2003 and 2004, additional fertilizers and soil amendments were applied after bloom; therefore, the bloom tissue values are reflective of soil pH and fertilizer application in 2003 and veraison values are reflective of soil pH and fertilizer application in 2004. Means with different letters are separated by Duncan's multiple range test at the 0.05% level.

	pH treatment	fertilizer	N%		P%		K%		Mg%		Ca%	
Bloom	1	no	1.47	a	0.44	cde	3.69	a	0.23	f	0.78	e
	1	yes	1.47	a	0.45	cd	3.77	a	0.23	f	0.83	de
	2	no	1.39	ab	0.42	def	3.73	a	0.32	e	0.87	de
	2	yes	1.38	ab	0.42	def	3.73	a	0.33	e	0.90	d
	3	no	1.30	b	0.51	abc	2.88	bc	0.44	cd	0.85	de
	3	yes	1.35	b	0.49	bcd	3.00	bc	0.41	d	0.81	de
	4	no	1.40	ab	0.54	ab	3.11	b	0.48	bcd	0.87	de
	4	yes	1.40	ab	0.58	a	3.55	a	0.46	cd	0.87	de
Target Values			1.2-2.2		0.17-0.30		1.5-2.5		0.3-0.5		1.0-3.0	
Veraison	1	no	0.79	d	0.22	h	1.45	h	0.26	ef	1.24	c
	1	yes	0.78	d	0.23	h	1.77	gh	0.23	f	1.28	bc
	2	no	0.87	cd	0.23	h	2.19	defg	0.32	e	1.32	abc
	2	yes	0.90	cd	0.25	h	2.38	de	0.32	e	1.36	ab
	3	no	0.90	cd	0.36	efg	1.84	fgh	0.61	a	1.40	a
	3	yes	0.89	cd	0.30	gh	2.31	de	0.50	bc	1.33	ab
	4	no	0.87	cd	0.40	def	1.94	efg	0.55	ab	1.35	ab
	4	yes	0.91	c	0.35	fg	2.56	cd	0.48	bcd	1.33	ab
Target Values			0.8-1.2		0.14-0.30		1.2-2.0		0.35-0.75		1.0-2.0	

Vine Growth and Productivity:

Similar to many other plant species' response to soil acidity, there appears to be a distinction between vines growing in soil pH above and below 5.0. Below soil pH 5.0, aluminum toxicity, beneficial cation deficiency, and reduced root growth can lead to decreased growth and productivity. In this study, pH treatment 1 vines have lower vine size and yield (table 3 and figure 3), lower cation uptake (table 2) and lower berry weight (data not shown). Lower yield and lower berry weight have also resulted in these vines having higher juice soluble solids (table 3).

Table 3: Vine size, yield, and juice soluble solids of soil pH and fertilizer treatments in 2002, 2003, and 2004. Means with different letters are separated by Duncan's multiple range test at the 0.05% level.

pH treatment	fertilizer	2002			2003			2004							
		pruning weight (pounds/vine)	yield (tons/acre)	jss (obrix)	pruning weight (pounds/vine)	yield (tons/acre)	jss (obrix)	pruning weight (pounds/vine)	yield (tons/acre)	jss (obrix)					
1	no	2.0	4.7	18.4 a	1.5	b	5.3	b	17.3	a	2.0	b	6.1	17.9	a
1	yes	2.1	4.6	18.6 a	1.7	ab	6.0	ab	17.0	a	2.0	ab	5.9	17.9	a
2	no	2.3	4.8	17.5 b	2.0	ab	7.0	a	15.7	b	2.2	ab	6.0	16.7	b
2	yes	2.4	5.6	17.4 b	2.1	a	7.4	a	15.8	b	2.5	a	6.6	16.6	b
3	no	2.3	4.8	17.3 b	2.0	ab	7.1	a	15.7	b	2.1	ab	5.9	16.6	b
3	yes	2.1	4.6	17.6 b	2.0	ab	7.4	a	15.8	b	2.1	ab	5.6	16.7	b
4	no	2.3	4.9	17.2 b	1.9	ab	7.1	a	15.5	b	1.9	b	5.3	16.7	b
4	yes	2.2	4.9	17.2 b	1.9	ab	6.9	ab	15.6	b	1.8	b	5.2	16.7	b

In soil pH treatments 2, 3, and 4, where the soil pH is above 5.0, aluminum toxicity is no longer an issue and the focus turns to proper cation balance between Ca, Mg, and K. In high producing Concord vineyards, K is of special concern because plant demand can increase based on crop size and K supply can decrease because of competition with Mg. As discussed earlier, soil and tissue K and Mg has been successfully manipulated with soil amendments and fertilizer applications. However, this has led to little statistical difference in vine performance in terms of vine size, yield, and juice soluble solids.

In 2004, soil pH treatments 2 and 3 tended to have higher pruning weight and yield and lower juice soluble solids than soil pH treatment 4. There was no additional effect of fertilizer application other than on tissue nutrient concentration (table 2). As with other root management experiments, this soil pH/nutrient availability trial remains an experiment concerning vine size. The effect of soil pH on vine size in this experiment is shown in figure 3. The low soil pH treatment is showing greater year to year variation than the other three treatments. In addition, there appears to be a trend toward greater separation between treatments 2, 3, and 4 in 2003. As expected, there has been a direct relationship between vine size and yield as well as yield and juice soluble solids (figure 4 A and B).

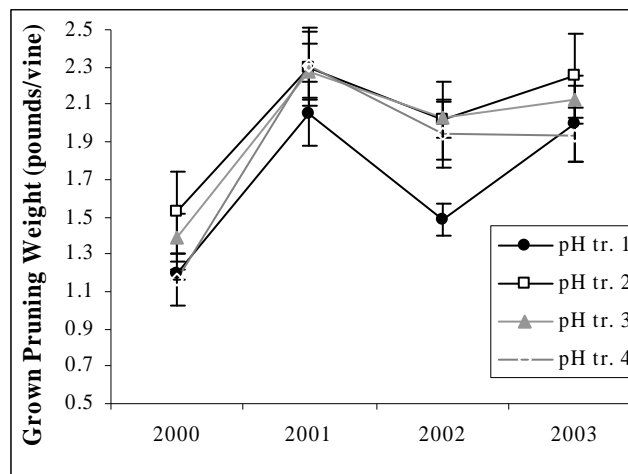


Figure 3: Vine size (pounds of dormant cane prunings per vine) of the four soil pH treatments from 2000-2003. Each point is the mean of four blocks with standard error.

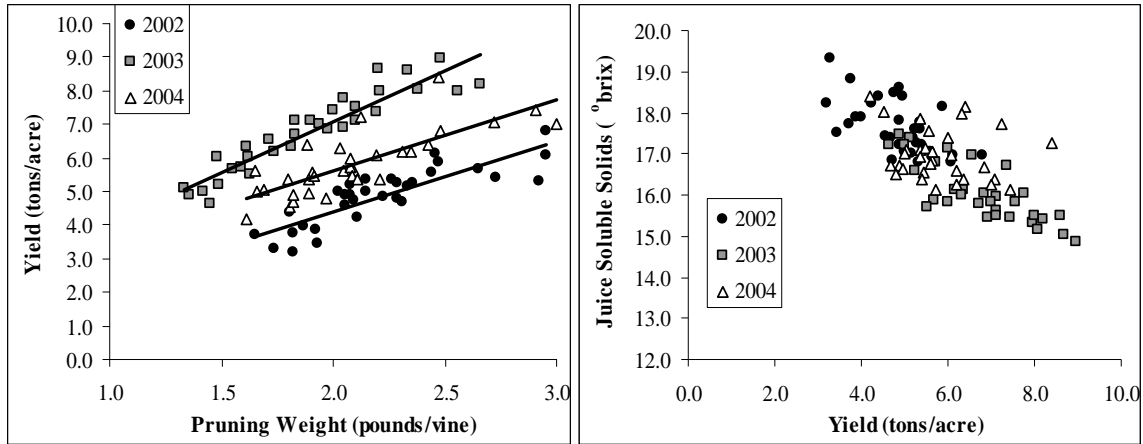


Figure 4 A and B: The relationship between pruning weight and yield (A) and the relationship between yield and juice soluble solids (B) of all soil pH treatment vines in 2002-2004.

Conclusions and Future Directions

Soil pH below 5.0:

Soil pH treatment #1 vines are suffering from typical acid soil problems and the addition of supplemental Ca, P, and Mg fertilizers are doing little to help vine nutrition, growth, or productivity. Increasing soil pH with lime is the obvious solution but the slow soil mobility of carbonate in established vineyards can make this an inefficient management practice. In other crops, gypsum has been used to decrease sub-soil aluminum toxicity in acid soils. We would like to test this practice in our experimental plot.

Soil pH above 5.0:

In higher lime content vineyard soils, the management issue focuses on the balance of K and Mg. As the soil pH increases, the availability and uptake of Mg increases and the uptake of K decreases. In addition, K availability and uptake is influenced by soil moisture (more available in wet years) and fertilizer application. Vine K demand will also increase with vine size and yield. Two major issues that have not yet been addressed in this study are the effect of differential soil moisture on K/Mg balance and the effect of large crop size on vine K demand. This study is poised to answer the soil moisture question with irrigation in the event of a dry growing season where soil moisture can be controlled experimentally. Larger crop size (8-10 tons/acre) can be addressed by growing larger vines and continuing balanced pruning or by selecting a higher bud number or pruning formula to increase yield and crop stress on these vines.