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Title: Identifying optimal nutrient concentrations for premium winegrape production based on physiological needs and fruit quality.

Principal Investigator:

R. Paul Schreiner, Research Plant Physiologist, USDA-ARS-HCRL, Corvallis, OR 97330.

Cooperators:

Jungmin Lee, USDA-ARS-HCRL, Parma, ID.

James Kennedy, Department of Food Science, Oregon State University.

Michael Qian, Department of Food Science, Oregon State University.

Objectives of Proposed Research:

The goals of this project for the next few years are: 1) to develop optimal tissue nutrient levels for N, P, and K in winegrapes that are based on physiological performance and fruit quality, 2) to identify the best tissue (leaf vs. petiole) and time of growing season to collect samples for specific nutrients (N,P,K) to diagnose sub-optimal concentrations, and 3) to identify indicators (physiological or visual) of sub-optimal nutrient levels that growers can utilize to better manage winegrape nutrition.

Specific Objectives for 2006:

- 1) Apply different levels of N, P, and K to 4 year-old vines and monitor growth, nutrient status, gas exchange and photochemistry responses to treatments.
- 2) Assess impact of nutrient status on fruit quality.

Experimental Procedures:

The experimental pot-n-pot, sand culture vineyard was constructed at the Lewis Brown Research Farm (Oregon State University) in 2003. Self-rooted Pinot noir (clone UCD2A, Pommard) vines were grown in a coarse, sand medium supplied with complete mineral nutrient solution for 3 years (2003-2005). A small crop was carried on vines in 2005, by thinning fruit to one cluster per shoot. Root systems were examined in the winter of 2006 and we discovered that roots in some pots had blocked the drain holes resulting in waterlogged (anoxic) conditions in the bottom of pots. We therefore removed the bottom fourth of all roots and sand from each pot, replaced our original screens with copper screen (to inhibit root growth on pot bottoms), and added new sand to the bottom of all pots. Beginning in May 2006, different nutrient treatments were applied to vines by fertigating 1-3 times per week. Eleven treatments applied were: Complete Nutrition Control (1/2 strength Hoagland's solution), 50% Complete Nutrition Control (1/4 strength Hoagland's), and three decreasing levels of each N, P or K at 50%, 20%, and 10% in an otherwise 1/2 strength solution. Each treatment was applied to 4 replicate sets of five vines arranged in a randomized block design (11 treatments x 4 reps x 5 vines = 220 vines). Vines were pruned to 8 buds in February 2005 and 2006 on a single cane with a renewal spur. After the threat of frost had passed (May 16), vines were thinned to 6 shoots on each fruiting cane.

Vine measurements made in 2005 and 2006 included; dormant pruning weights, spring and early summer shoot lengths, leaf area, leaf and petiole nutrient concentrations at bloom and veraison, SPAD readings at bloom and veraison (2006), and numerous measurements of chlorophyll fluorescence (FMS-2), leaf water potential (pressure bomb), stomatal conductance (steady state porometer), and soil moisture (TDR). We also determined the wilting point of the sand culture medium on two separate days in August, 2005 based on stomatal conductance and leaf water potential measurements using extra vines in the vineyard that are not included in the trial.

Vines were developing normally in 2006 up until the end of the bloom period, when we noticed a high degree of inflorescence necrosis (IN) in the vineyard. On July 2, ~ 2 weeks after

bloom, we assessed the percentage of primary and secondary clusters showing IN symptoms (dieback of part or all of the rachis) for all vines in the experiment. Because IN was both highly variable from vine to vine and affected by nutrient treatment, we chose to remove all clusters from experimental vines to preserve uniformity and start all over again next year. However, we did not remove the clusters on the extra vines in this vineyard in order to monitor the impact of IN on final fruit yield and quality.

Results and Discussion:

2005 Season

2004 season pruning weights averaged 94 g per vine, but this value does not account for large losses from the summer 2004 prunings to establish the trunk and head. Growth of vines in 2005 was vigorous and vines were hedged 3 times since early July. Leaf and petiole nutrient concentrations collected at bloom and veraison in 2005 were within “adequate” ranges for all nutrients, except copper was a little low (Table 1). Other nutrient concentrations were comparable to field-grown Pinot noir vines in Oregon at both bloom and veraison. Leaf fluorescence measurements conducted in mid-July were nearly identical to data collected in 2004 with a maximum quantum efficiency of photosystem 2 (predawn Fv/Fm) averaging 0.827, and actual quantum efficiency of photosystem 2 at midday (1800-2000 PAR) averaging 0.427. The wilting point of the sand medium determined on August 5 and 9 on our extra vines occurred at a moisture content of 6.7 % volumetric water (Table 2). At this moisture level, stomatal conductance was $15 \text{ mmol m}^{-2} \text{ s}^{-1}$ and leaf water potential was -1.54 MPa. These same measures in the experimental vines measured at the same time as the wilted vines were above $300 \text{ mmol m}^{-2} \text{ s}^{-1}$ and -1.00 MPa, respectively. The crop yield in 2005 averaged 439 g vine^{-1} .

2006 Season

Pruning weights corresponding to the 2005 season were assessed in the different treatment plots (even though treatments had not yet been applied) to ensure that vines were uniform. Pruning weights were not affected by treatment and averaged 499 g vine^{-1} . Shoot growth of Pinot noir was affected by nutrient treatment, with differences becoming apparent around the time of bloom. Near the end of the bloom period (June 21) the 20% N treatment had significantly shorter shoots than the control, and after another 2 weeks (July 6) both the 20% and 10% N treatments were significantly lower than the control (Table 2). Reduced rates of P or K did not affect shoot lengths of vines. The leaf area of vines showed a similar trend as shoot lengths, with the two lowest N treatments having least area per vine, but this was not statistically significant. SPAD measurements, which indicates leaf chlorophyll and hence N concentrations, taken at bloom and veraison were also lower in the 20% and 10% N treatments compared to the control, but SPAD was unaffected by the P or K treatments (Table 2). Leaf N concentrations at bloom confirmed SPAD readings showing lower N in the 50%, 20%, and 10% N treatments compared to the control. Other nutrients will be examined this winter by ICP. Chlorophyll fluorescence measurements taken in June, July, and August of 2006 were not affected by nutrient treatment. Likewise, nutrient treatments did not affect the stomatal conductance of vines or soil moisture on any given sampling dates. If differences in water use by vines were occurring in the different nutrient treatments, we were unable to detect these differences using fairly sophisticated equipment.

The incidence of inflorescence necrosis (IN) was significantly affected by nutrient treatments. The percentage of clusters with IN was significantly reduced in the two lowest N treatments (20% and 10% N), but the P and K treatments were the same as the control (Table 2). However, symptoms of IN were highly variable, often ranging from 0% to 70% within the 5 continuous vines of a single replicate. IN is believed to be caused by an inability to assimilate ammonium in the rachis tissues of fruit clusters, leading to toxic ammonium concentrations in these tissues and eventual necrosis. High ammonium and/or a lack of available carbon

substrates in developing clusters gives rise to IN, such that low light levels or vigorous shoot growth can cause necrosis, due to the competing sink of new shoots for carbon substrates. We had 4 days cloudy weather during the bloom period, which probably limited carbon available to assimilate ammonium in rachis tissues. While the effect of N was clear in our study, we only supplied vines with nitrate-N and our leaf and petiole N concentrations at bloom in 2006 were not high. Indeed, N concentrations in these vines at bloom were lower than typical Pinot noir vineyards from Oregon where IN has not occurred. The problem was unique to the sand culture vines in 2006. These observations suggest that the drainage problems we had in the winter (due to excessive root growth on pot bottoms) probably contributed to the development of IN in our sand culture vines. High levels of ammonium in the sand could have occurred as a result of the waterlogged conditions (denitrification) and from the eventual rotting of roots that were compromised last winter. The high vine to vine variability of IN symptoms that we observed may be explained by this, since the drainage problem was also quite variable from pot to pot.

The impact that IN had on fruit yield and quality in our extra vines in 2006 was striking (Table 3). The range in yield per vine was very large, and cluster size was more important than cluster number per vine in predicting yield. In addition, yield was positively correlated to soluble solids ($r = 0.94$), indicating that the small clusters affected by IN could not ripen properly. Our decision to remove the crop from the experimental vines and assess effects of nutrients on fruit quality beginning in 2007 appears to be justified.

The copper screen that we installed during the winter of 2006 to inhibit roots from growing on the bottom of pots was successful. Roots were observed growing next to, but not under the copper screen in two vines that were examined in October, 2006. The sand in those pots was also well drained. We plan to examine a number of pots during the dormant season this winter to confirm this.

Potential Significance to Industry:

The goal of this research is to provide winegrape growers with nutrient standards that are based on fruit quality. We propose to develop those guidelines by using the data we collect in this project under controlled nutrient supply conditions along with field data being collected by other PNW research projects in Washington, Oregon, and Idaho. The results obtained in this study will provide a more detailed understanding of how nutrients affect vine growth, various physiological measures of plant performance, and, in turn, fruit quality. In addition, this project will hopefully develop new tools to help in identifying sub-optimal nutrition for use in the vineyard.

Funding Sources:

CRIS base funds, NCSFR 2004-2005

Research Impact:

The development of nutrient standards for winegrapes that are based on plant physiological performance and fruit quality will help growers interpret their routine nutrient test results and better manage vine mineral nutrition. This will enable growers to use fertilizers more efficiently and potentially reduce environmental impact from viticulture. A better understanding of how specific nutrients affect vine performance and fruit quality may also lead to more consistent control of fruit quality and wine style.

Citations:

None at this time.

Table 1. Bloom & Veraison Leaf and Petiole Nutrient Concentrations of Pinot noir grown in sand culture in Oregon, 2005. Data represent mean values (n=4).

Date	Tissue	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	B (ppm)	Zn (ppm)	Cu (ppm)
bloom	Leaf	3.30	0.32	1.02	1.62	0.28	0.24	124	87	37	35	2.5
bloom	Petiole	2.42	0.28	2.43	1.46	0.47	0.10	34	26	61	38	3.9
veraison	Leaf	2.16	0.18	0.95	2.00	0.38	0.20	268	84	28	21	3.1
veraison	Petiole	0.48	0.08	1.40	1.42	0.67	0.08	54	50	23	50	4.0

Table 2. Effect of Nutrient Treatments on Pinot noir grapevines grown in sand culture in Oregon, 2006. Data represent mean values (n=4).

Treatment	Shoot length 6/21 (cm)	Leaf area 6/21 (m ²)	Shoot length 7/6 (cm)	SPAD 6/19	SPAD 8/21	Leaf N 6/19 (%)	Inflorescence necrosis 7/2 (%)
Control Full nutrients	138 a ¹	1.31	191 a	36.0 a	39.6 ab	2.77 a	86 a
50% All nutrients	122 ab	1.18	172 abc	34.4 ab	36.4 bc	2.68 ab	82 a
50% N	129 ab	1.36	181 ab	33.1 ab	38.1 ab	2.60 bc	58 abc
20% N	113 b	1.11	153 c	32.2 b	33.4 c	2.50 c	32 bc
10% N	118 ab	1.05	159 bc	32.2 b	32.9 c	2.48 c	18 c
50% P	133 ab	1.28	187 a	35.7 a	40.9 a	2.79 a	80 a
20% P	124 ab	1.30	176 ab	34.8 ab	40.0 ab	2.78 a	83 a
10% P	125 ab	1.30	178 ab	35.3 ab	39.6 ab	2.74 ab	72 ab
50% K	126 ab	1.23	179 ab	35.5 ab	41.1 a	2.83 a	90 a
20% K	132 ab	1.25	186 a	34.8 ab	38.9 ab	2.79 a	71 ab
10% K	127 ab	1.37	183 ab	34.4 ab	39.4 ab	2.69 ab	87 a
subsamples plot ⁻¹	6	1	6	10	10	5	5

¹ Means followed by the same letter within a column are not significantly different (Tukey's test @ 95% confidence).

Table 3. Range of Fruit Parameters from Pinot noir grapevines allowed to carry a crop in 2006 (n=20).

Variable	Mean	Minimum	Maximum
Yield (kg vine ⁻¹)	0.74	0.04	1.61
Cluster #	12.9	6	19
Cluster weight (g)	52.4	5.0	103.5
Soluble Solids (brix)	20.3	17.0	26.0
pH	3.67	3.55	3.75
T.A. (g L ⁻¹)	5.74	4.63	6.51