Research Project Title: Foliar Nitrogen Application in Wine Grapes to Enhance Wine Quality

Research Progress Report: Grant Code 2015-09

Name, Mailing and Email Address of Principal Investigator(s):
John Havlin, Josh Heitman, Rob Austin
Dep. Soil Science, NC State University, Raleigh, NC 27695
jlhavlin@ncsu.edu *jlheitman@ncsu.edu* rob_austin@ncsu.edu

Objectives:
Evaluate late season foliar nitrogen (N) application on plant N concentration and yeast assimilable N (YAN) in the fruit.

Justification:
Although adequate N availability is required to support optimum grape yield and fruit quality, elevated N increases canopy leaf area, which increases disease pressure (Poling, 2007). In addition, extensive shoot growth requires additional thinning to optimize canopy microclimate for fruit and wood maturation (Christensen, 2005). In the southeast, where excessive plant available water accelerates vine growth, little or no N is applied to avoid the potential negative effects of excessive N (Jackson and Lombard, 1993; Keller, 2005). Consequently, YAN in grape musts is frequently below the minimum threshold (140 mg N/L) required to avoid stuck fermentation and atypical aging (Monteiro and Bisson, 1991; Spayd et al., 1995; Hannam et al., 2014).

One potential solution to increase YAN, while minimizing vine growth and disease potential, is through late-season foliar N. Grape leaves readily absorb urea-N, which is translocated to the clusters (Conradie, 1986; Dong et al., 2002). In contrast, late-season soil applied N is not effective due to low surface soil moisture (Howard, 2014). Lacroux et al. (2008) demonstrated soil applied N increased vigor and *Botrytis* incidence, whereas foliar N improved vine N status and enhanced aroma characteristics of Sauvignon Blanc without increasing vigor or *Botrytis* susceptibility. Other studies confirm the positive effects of foliar N on increased YAN and wine aromatics (Garde-Cerdan et al., 2014; Ancín-Azpilicueta et al., 2013; Lasa et al., 2012; Dufourcq et al., 2009).

Methodologies
The original proposed treatments were adjusted after further discussion with Dr. Gill Giese (Manager, Shelton Vineyards). Instead of fewer N rates applied to two varieties, we expanded the N rate treatments applied to one variety. We determined it was critical to evaluate split N applications in addition to the N rates as originally proposed (Table 1).

Table 1. Treatments used in the 2015 foliar N study.

N treatment designation	**N Treatment description**	
	Total N applied (lb N/a)	***N application times***[1]
0	check	
10	10	10 d pre-veraison
10 x 2	20 (2 - 10 lb/a)	10 d pre-veraison; veraison
20	20	10 d pre-veraison
20 x 2	40 (2 - 20 lb/a)	10 d pre-veraison; veraison
40	40	10 d pre-veraison
10 x 4	40 (4 - 10 lb/a)	10 d pre-veraison; veraison; 4 & 14 d post-veraison
Soil N	80	pre- bud break

[1]full bloom = May 20; veraison = July 20

Each treatment was applied to 48 ft of row on ~10 ft row spacing. Four replications of each treatments were applied with a CO_2 backpack sprayer equipped with 4-80° flat spray nozzles equally spaced on a 4 ft. boom (R&D Sprayers, Inc.). The sprayer boom was held vertically along each side of the row to facilitate optimum canopy coverage. Urea solution (20% N) was diluted with variable amounts of distilled H_2O to prepare 1650 mL of final N solution applied to each treatment. Treatments were single applications of 10, 20, 40 lb N a^{-1}; 20 and 40 lb N a^{-1} split applied at 10 and 20 lb N a^{-1}, respectively; and 40 lb N a^{-1} split applied at 10 (4 splits) and 20 (2 splits) lb N a^{-1}, respectively (see Table 1 for application times). For the soil N treatment, 90 lb N a^{-1} as urea was broadcast applied in late March.

Soil samples were collected prior to bud-break from each treatment area at 0-10 and 10-20 cm depths. Four cores were randomly collected from each treatment and composited, from which a subsample was air dried and sent to the NC Department of Agriculture & Consumer Services Laboratory for analysis (Hardy et al., 2003).

Plant tissue (petiole and leaf) samples were collected at full bloom (pre-treatment). At full bloom, 40-50 petiole/leaf samples were collected from opposite the first or second cluster from the bottom of the shoot in each treatment. Petioles and leaves were analyzed separately and total N (and other macro- and micronutrients) was determined in each sample (Hardy et al., 2003).

To test the potential to remotely quantify plant N status, both ground-based and low-altitude aerial sensors were evaluated. The hand-held active sensor (Trimble Greenseeker) emits light at two wavelengths and measures light reflected off the canopy surface. The proportion of reflected light at the two wavelengths is used to determine the normalized difference vegetative index (NDVI), which is related to plant N content and vigor. The sensor was run 20" above the canopy pointed directly down and 12" from the row pointed toward the canopy (middle guidewire). These two sensor arrangements were used because of the observed difference between the light-green young leaves on the canopy top, and the darker, more mature leaves toward the bottom. In additional to the Trimble sensor, a multispectral camera mounted on an Unmanned Aerial Vehicle (UAV) was used to measure canopy reflectance. A Tetracam ADC micro camera was mounted in a gimbal attached to the bottom of a custom quadcopter. Flights were performed at 30 and 50 m altitudes, traversing along vineyard rows. Over 60 multispectral images were post-processed to remove vine row shadows, grass, and soil before the final NDVI value was calculated. The remote sensing data were collected on May 20^{th} (full-bloom) in conjunction with the timing of tissue collection.

Grape clusters were collected at harvest from each treatment, sent to the Enology Services Laboratory (Appalachian State Univ.), and analyzed for pH, total acidity (TA), Brix, Malic acid, YAN (yeast assimilable N), and FAN (free amino acid N). Grape juice samples were also sent to the Enology Analytical Services Lab. (Virginia Tech), where additional aromatic compound analyses are being conducted.

Plant N measurements and harvest fruit quality data were analyzed using Analysis of Variance (ANOVA) as the plot design is a randomized complete block design.

Results

The research site was located on a Fairview sandy clay loam (fine, kaolinitic, mesic Typic Kanhapludults) located on Shelton Vineyards in Surry Co., NC (Fig. 1). Soil properties were typical of vineyard soils (high P, K, micronutrients) in the Yadkin Valley appellation with a previous history of manure applications (old dairy farm; Table 2). Soil pH (0-20 cm) was optimum for vinifera wine grape production.

Figure 1. Aerial view of field research site at Shelton Vineyards (Dobson, NC)

Table 2. Selected soil properties from the research plot area.

Depth	OM	CEC	BS	pH	Ca	Mg	P	K	S	Mn	Zn	Cu
cm	*%*	*meq* $100g^{-1}$	*%*		------- *%* -------		---------------------------- *ppm* --------------------------					
0-10	0.48	9.0	77.0	5.9	0.94	0.23	746	1170	177	239	185	84
10-20	0.38	7.5	84.5	6.4	0.87	0.22	182	647	161	195	85	29

Leaf and petiole N analysis at full-bloom (prior to foliar N application) was necessary to establish background plant N levels that could be used to assess foliar N need. Table 3 shows that petiole N content at full bloom was below the established critical level of 1.2-1.6% N (Poling, 2007). No significant differences in plant N or NDVI were detected between treatment areas since foliar N applications did not begin until July 9. Despite 90 lb N a^{-1} soil applied at bud break, plant N /NDVI was not affected. Higher soil N rates will be used in 2016.

Table 3. Full bloom (May 20) plant N content and NDVI using Greenseeker (GS) and UAV sensor platforms.

N treatment	Plant N		NDVI[1]		
	Petiole	Leaf	GS top	GS side	UAV
	------------ *%* --------------				
0	0.97	3.53	0.53	0.84	0.84
10	0.95	3.59	0.58	0.86	0.84
20	0.93	3.59	0.52	0.84	0.83
10x2	0.97	3.63	0.51	0.85	0.86
40	0.92	3.65	0.59	0.87	0.83
20x2	0.88	3.61	0.55	0.85	0.84
10x4	0.93	3.74	0.58	0.82	0.86
Soil N	0.96	3.57	0.58	0.85	0.85
p = 0.05	ns	ns	ns	ns	ns

[1]NDVI = normalized difference vegetative index

Use of the Greenseeker and UAV remote sensing platforms was included to evaluate their ability in detecting plant N levels too low to support adequate production of YAN in grapes. An example multispectral and color image of the plot area collected using the UAV is shown in Figure 2.

Figure 2. Multispectral Image (*left*) and color image (*right*) collected by unmanned aerial vehicle (UAV). Heathier vegetation appears brighter red in the multispectral image.

The multispectral image (Fig. 2) must be post-processed to removed interferences from vegetation other than grape plants (row middles) or bare soil (Fig. 3). From the corrected images, the NDVI is calculated (Fig. 3; Table 3).

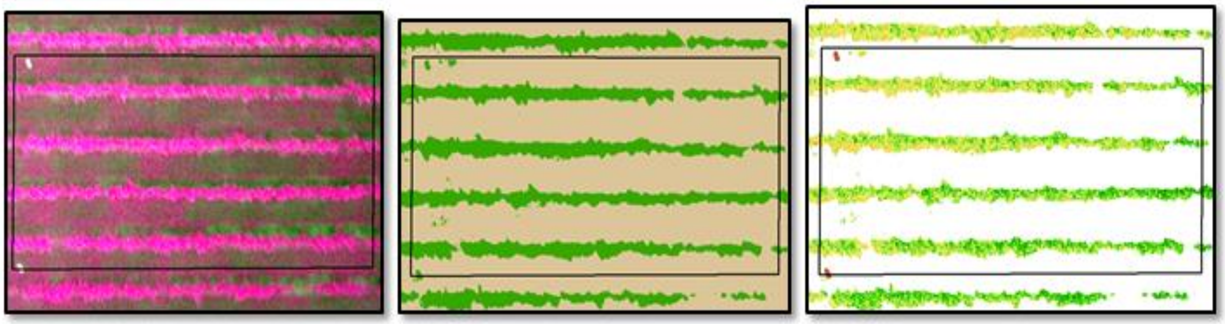

Figure 3. Multispectral Image (*left*), classified imaged used to differentiate vineyard canopy and soil (middle), and NDVI calculated values (right) with soil masked out ; darker green represent higher NDVI values.

Regardless of the orientation (top or side), Greenseeker determined NDVI was not correlated with %N in the leaf (Fig. 4) or in the petiole (data not shown). In contrast, there was a weak correlation between leaf N and the UAV derived NDVI, indicating some promise in the use of multispectral remote sensing using an UAV platform. There was no correlation between petiole N and UAV NDVI (data not shown).

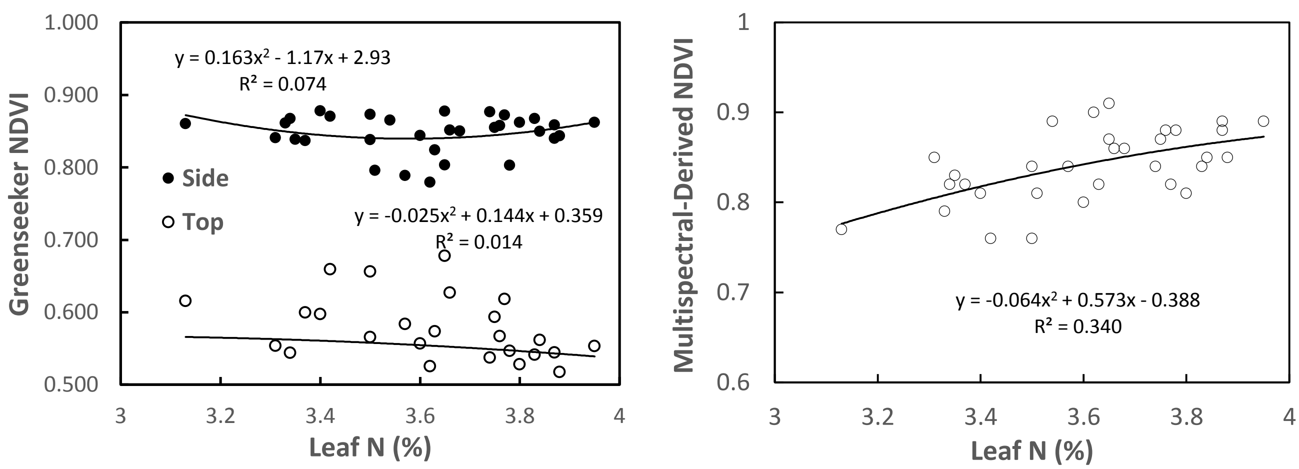

Figure 4. Leaf N % versus Greenseeker (left) or UAV (right) derived NDVI at full bloom.

Soil applied N (pre-bud break) had little effect on wine grape quality parameters (Table 4). In contrast, foliar N significantly increased YAN, malic acid, and FAN in grapes at harvest. A small increase in juice pH was also observed. These parameters generally increased with increasing N rate (0→40 lb N a^{-1}); however, the two treatments that resulted in the highest YAN levels were the 20 lb N a^{-1} and 40 lb N a^{-1} (10 lb/a x 4 split applications). The 40 lb N a^{-1} (single application) resulted in some leaf edge burn and will be discontinued in 2016.

Conclusions

These preliminary results suggest that foliar N applied pre- and post-veraison can significantly improve grape N content and other parameters critical to enhancing flavor compound concentrations, without increasing vine vigor. These preliminary data also demonstrate the potential use of remote sensing (UAV) in assessing N status in the vineyard.

Table 4. Foliar and soil applied N effects on selected wine grape quality parameters.

TRT	Brix	Titratable Acidity	pH	Malic Acid	YAN	FAN
		g L⁻¹		*g L⁻¹*	*ppm*	*ppm*
0	21.2 a	4.14 a	3.37 a	2.24 a	143.7 a[1]	70.6 a
10	21.4 a	4.22 a	3.41 a	2.41 b	170.6 b	85.0 b
10 x 2	21.5 a	4.10 a	3.52 b	2.60 c	187.7 b	95.5 bc
20	21.4 a	4.36 a	3.60 b	2.83 d	217.5 c	117.7 c
20 x 2	21.7 a	4.19 a	3.48 a	2.51 bc	187.9 b	94.5 bc
10x4	21.0 a	4.13 a	3.63 b	2.91 d	221.1 c	125.6 d
40	21.1 a	4.25 a	3.46 a	2.56 c	194.5 bc	100.1 c
soil N	21.3 a	4.09 a	3.44 a	2.30 a	149.3 a	77.7 a
P > f	**0.9310**	**0.6624**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

[1]means followed by the same letter are not significantly different (p=0.01)

Impact Statement

To reduce vine vigor and leaf disease pressure, wine grape growers in the southeastern U.S. minimize or avoid use of soil applied N. As a result, wine makers frequently add N (DAP) to the must to complete the fermentation process. Low N plants result in low YAN in the must, potentially reducing flavor in the final wine product. This research will establish the value of foliar N applied through grape maturation (pre → post veraison) to enhance the flavor profile of *vinifera* grapes.

References:

Ancín-Azpilicueta, C., Nieto-Rojo, R., Gómez-Cordón, J. 2013. Effect of foliar urea fertilization on volatile compounds in Tempranillo wines. *J. Sci. Food Agri.* 93:1481-1485.

Christensen, L.P. 2005. Foliar fertilization in vine mineral nutrient management programs. *In* Proc. Soil Envir. Vine Mineral Nutr. Symp. L.P. Christensen and D.R. Smart (eds.), p. 83-90. Am. Soci. Enol. Vitic., Davis, CA.

Conradie W.J., 1986. Utilisation of nitrogen by grape-vine as affected by time of application and soil type. S. Afr. J. Enol. Vitic. 7:76-83.

Dong, S., L. Cheng, C. Scagel, L. Fuchigami. 2002. Nitrogen absorption, translocation and distribution from urea applied in autumn to leaves of young potted apple (Malus domestica) trees. Tree Physiol. 22:1305–1310

Dufourcq, T., Charrier, F., Poupault, P., Schneider, R., Gontier, L., Serrano, E. 2009. Foliar spraying of nitrogen and sulfur at veraison: a viticultural technique to improve aromatic composition of white and rosés wines. *In* Proc.16th Intern. GiESCO Symposium (pp. 379–383). UC Davis, Dept. Viticulture and Enology.

Garde-Cerdan, T., R. Lopez, J. Portu, L. Gonzalez-Arenzana, I. Lopez-Alfaro, P. Santamaria. 2014. Study of the effects of proline, phenylalanine, and urea foliar application to Tempranillo vineyards on grape amino acid content. Comparison with commercial nitrogen fertilisers. Food Chemistry 163:136-141.

Hannam, K., G. Neilsen, D. Neilsen, W. Rabie, A. Midwood, P. Millard. 2014. Late-Season Foliar Urea Applications Can Increase Berry Yeast-Assimilable Nitrogen in Winegrapes (*Vitis vinifera* L.). Am. J. Enol. Vitic. 65:89-95.

Hardy, D.H., M. R. Tucker, and C. E. Stokes. 2003. Crop Fertilization Based on North Carolina Soil Tests. http://www.ncagr.com/agronomi/obook.htm.

Havlin, J.L., D.H. Hardy, R.J. Gehl, S.E. Spayd. 2012. Survey of Nutrient Status in Vitis vinifera Grapes in North Carolina. Comm. Soil Sci. Plant Anal. 43:299-314.

Howard, A. 2014. Water Dynamics in the Yadkin Valley American Viticultural Area – Observations and Modeling. M.S. Thesis. NC State University. Raleigh, NC.

Jackson, D.I., and P.B. Lombard. 1993. Environmental and management practices affecting grape composition and wine quality-A review. Am. J. Enol. Vitic. 44:409-430.

Keller, M. 2005. Deficit irrigation and vine mineral nutrition. Am. J. Enol. Vitic. 56:267-283.

Lacroux, F., O. Tregoat, C. Van Leeuwen, A. Pons, T. Tominaga, V. Lavigne-Cruege, D. Dubordieu. 2008. Effect of foliar nitrogen and sulphur application on aromatic expression of *Vitis vinifera* L. cv. Sauvignon blanc. International J. Vine and Wine Sci. 42(3):125-132.

Lasa, B., S. Menendez, K. Sagastizabal, M. Cervantes, I. Irigoyen, J. Muro, P. Aparicio-Tejo, I. Ariz. 2012. Foliar application of urea to ‘‘Sauvignon Blanc’’ and ‘‘Merlot’’ vines: doses and time of application. Plant Growth Regul. 67:73–81.

Monteiro, F., and L. Bisson. 1991. Amino acid utilization and urea formation during vinification fermentations. Amer. J. Enol. Vitic. 42:199–208.

Poling, E.B. (ed.). 2007. NC Winegrape Grower's Guide. NC Coop. Ext. Ser. 196p.

Spayd, S.W., C.W. Nagel, and C.G. Edwards. 1995. Yeast growth in Riesling juice as affected by vineyard nitrogen fertilization. Am. J. Enol. Vitic. 46:49-55.