Research in Plain English

Modeling the Impacts of Weather and Cultural Factors on Rotundone Concentration in Cool-Climate Noiret Wine Grapes

Research in Plain English provides brief, non-technical summaries of journal articles by Cornell faculty, students, and staff.

Authors: Andrew D. Harner, Justine E. Vanden Heuvel, Richard P. Marini, Ryan J. Elias, and Michela Centinari
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Summary by Rebecca Wiepz.

The Takeaway.

- Rotundone contributes the desirable 'black pepper' aroma found in many wine grapes and is commonly associated with Shiraz wine grapes.
- Previous studies have assessed how climate or viticultural practice affect rotundone accumulation, but none assessed both climate and viticultural factors together.
- This study evaluated the joint contribution of 21 viticultural, mesoclimate and microclimate variables on resulting rotundone concentration in seven vineyards over two years.
- The authors used these measurements to construct a predictive and a descriptive model using multiple regression.
- Vineyard growing degree-days and the cumulative amount of solar radiation were the variables that were best correlated with rotundone concentrations.
- Within-canopy microclimate (as influenced by fruiting zone leaf removal) was more weakly correlated with rotundone.
- Low (<15 C) and high (>30 C) berry temperatures were correlated with low rotundone concentrations.
- A four-variable model incorporating 1) GDD during ripening, 2) crop load (Ravaz index), and 3) leaf petiole concentrations of phosphorus and 4) calcium explained 80% of the variation in rotundone concentrations.
- Understanding the way the environment affects accumulation of this compound can help growers to manipulate its content in their wines.
- Multiple regression is a great tool to understand which of a variety of factors impacts the variable in question. Its use in this study allowed the development of a simple model that growers can potentially use to inform their planting and management decisions and also explained which factors have a significant influence on rotundone concentration.

Background.

The surroundings in which a grape is grown have a strong influence on the final flavor of a wine. In part, this is due to the accumulation of secondary flavor compounds from the grape variety and local climate. One of the most recently discovered flavor compounds, rotundone, is responsible for creating the “peppery” flavor for which Shiraz is famous. While Shiraz is the wine most commonly associated with rotundone, it has also been extracted from a variety of red wines, including Noiret, a Cornell variety released in 2006.

Multiple regression is a statistical technique designed to analyze the impact of a set of variables on a single response variable. To utilize this technique, multiple influencing factors have to be introduced to the analysis for potential use in the resulting model. For example, how fast a cup of coffee cools down could be modeled using multiple regression. The impacting factors could include characteristics of the container (size, insulation, surface area), the surroundings (air temperature, wind), and the coffee itself (volume, initial temperature). By measuring lots of these factors and introducing them into the analysis, we can describe the relationships they have with our response variable (coffee temperature) and each other. The model with the best fit can not only tell us which of the environmental factors to manipulate to keep our coffee warm but can potentially predict our coffee’s temperature at a given time.

Experiment.

The focus The authors measured 21 different factors (Table 1), including production metrics, nutrient and water status, meso climate (weather at the site), and microclimate (within canopy) in seven vineyards in NY and PA in 2016 and 2017(Figure 1), and used multiple regression statistical analysis to determine which combinations of variables influenced rotundone concentration in Noiret grapes.

Table 1 | Vine and climate measurements recorded at seven Noiret Vineyards during 2016 and 2
predict rotundone concentration in the fruit at harvest.

Vine Metrics		**Climate**	
Production Metrics	**Nutrient and Water Status**[a]	**Mesoclimate**[b]	**Microclimate**[c]
Yield	Nitrogen	Temperature	Air temperature
Cluster number	Phosphorous	GDD	Berry temperat
Cluster weight	Potassium	GDD_v	CEFA
Berry weight	Magnesium	Rainfall	LEFA
Pruning weight	Calcium	$Rainfall_v$	DH10
Crop load	Berry $\delta^{13}C$	Solar radiation	DH15
Juice soluble solids		CSE	DH20
Juice pH		CSE_v	DH25
Juice titratable acidity			DH30
			DH35
			DH40

[a] Berry $\delta^{13}C$, Ratio of ^{13}C:^{12}C measured in grape berries at harvest.

[b]GDD, Seasonal growing degree days; GDD_v, Veraison-to-harvest growing degree days; $Rainfall_v$, Veraison-to-harvest CSE, Seasonal cumulative solar exposure (MJ/m^2); CSE_v, Veraison-to-harvest cumulative solar exposure (MJ/m^2).

[c]CEFA, Cluster exposure flux availability; LEFA, Leaf exposure flux availability; Degree-hour (DH) indexes calculated a percentage of hours the fruit temperature was within pre-defined intervals from veraison to harvest. Temperature rang 10-15ºC(DH_{10}), 15.1-20ºC(DH_{15}), 20.1-25ºC(DH_{20}), 25.1-30ºC(DH_{25}), 30.1-35ºC(DH_{30}), 35.1-40ºC(DH_{35}), and >40.00º

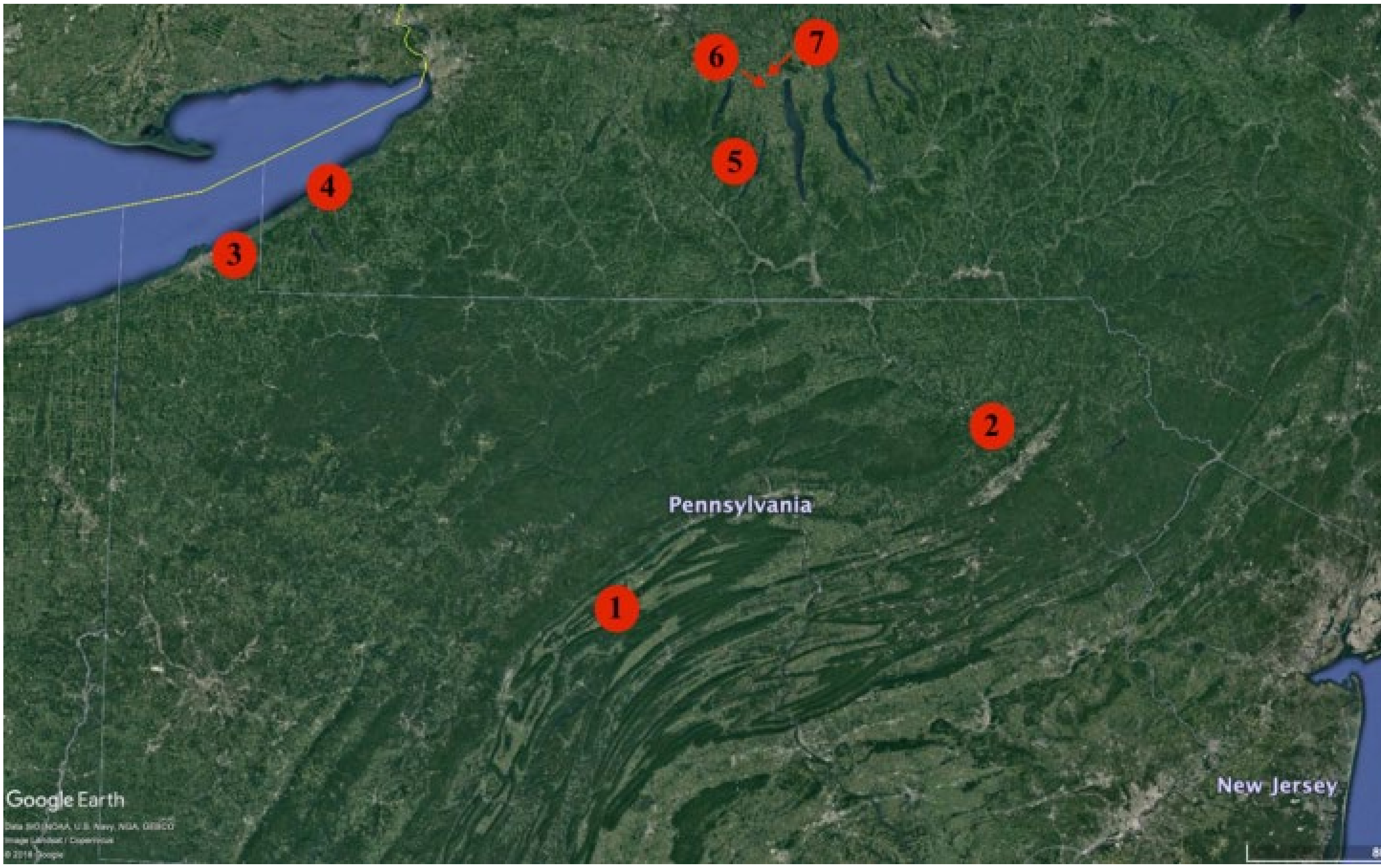

FIGURE 1 | Map of Noiret vineyards selected for the study. (Image and caption credit A. Harner)

The outline In each of the seven Noiret vineyards, two treatments (leaf removal or no leaf removal) were applied to single panel experimental units (3-4 vines per panel). The leaf removal treatment was used to maximize the range of temperature and sunlight within the canopy, rather than to create a direct comparison between the two treatments. Leaves were removed when berries were approximately pea size from basal node to above the distal cluster, and the cluster zone was kept free of vegetative growth for the entire season.

Components of the model.

Selection. The multiple regression procedure in the statistical analysis software was first used to analyze correlations between rotundone concentration and the potential influencing variables. After observing which variables were highly correlated on their own, multiple approaches were used to determine the best model for the meso- and micro-climate datasets. Each model was analyzed on the amount of variation it accounted for in the dataset. A model was chosen based on this, as well as a lack of collinearity and its potential predictive ability based on estimated error. Based on all of these criteria, a model with high explanation and the fewest necessary variables was selected.

Meso-climate: Weather parameters during the ripening season (from veraison to harvest) were better correlated with rotundone than those from the entire season. While cumulative sun exposure from veraison to harvest (CSEv) and growing degree days from veraison to harvest (GDDv) both had high correlations independently with rotundone concentration, only one was in the final model due to the high collinearity between the two variables. Generally, high sun and high temperatures go hand in hand.

The final model was chosen based on a predictive ability and diminishing return in variation explained for variables added beyond the four chosen. The selected model showed rotundone was positively influenced by phosphorous, crop load, and GDDv, while calcium had a negative impact on rotundone concentrations.

To validate the model, the data was split into two randomized sets, where the first one was used to determine the model, which was then used to calculate predicted rotundone concentrations for the second data set. Based on the similarity between predicted and actual rotundone concentrations, this is a good and accurate predictive model.

Micro-climate: Very little direct correlation occurred between rotundone concentration and the within canopy variables. Berry temperature was only directly correlated with rotundone when it was between 15 and 20°C, and the amount of sunlight on leaves and clusters was not correlated in either season.

The best model included percentage of degree hours between 10 and 15°C, and 30-35°C (DH10 and DH30, respectively), as well as cluster light exposure when berries are pea-sized (CEFAp) and accounted for slightly more than half of the variation. While none of these factors individually impacted rotundone concentration, their combined interaction accounted for slightly more than half of the variation in the data set.

Conclusions and looking forward.

The high variability, similar to what has been seen in other studies of rotundone, made this data set a good candidate for regression analysis. Additional validation would benefit the four-variable predictive model, but overall it was reliable and predictive. For growers that do regular petiole analysis and have historic pruning weight and cropping data, this model may be useful in predicting rotundone levels.

Solar exposure and temperature influenced rotundone differently in the cooler northeastern climates than they have in previous rotundone studies. It's possible that the length of the ripening period is another factor at play here. The sites with the longest ripening periods in this study had the highest rotundone concentrations, suggesting that a longer ripening period in cool climates might favor rotundone accumulations. Similarly, the influence of calcium and phosphorous might be indicative of environmental influences on the model. Calcium, in particular, can be tied to vine water status. The researchers suggest further investigation is needed to better understand the direct vs. indirect effects of macronutrients.

Microclimate factors are uniquely associated with rotundone accumulation in that the components of the model are not directly correlated and have not been associated with high rotundone concentrations in the past. However, the model tells us that high and low temperatures are not conducive to rotundone accumulation. The positive relationship with light exposure of the clusters was unexpected as it had been deemed a negative influence for rotundone previously. Previous research has suggested that pre-veraison sun exposure could result in accumulation of a rotundone precursor, thus influencing later season concentrations.

The conclusions of this study demonstrate a much higher correlation with site-level factors than fruiting zone factors (ie. aggressive leaf removal to expose clusters). Combined with the developed meso-climatic model, which included GDDv, Ca and P, and crop load, this study provides a new perspective on factors influencing rotundone production. It also potentially acts as a tool for Northeastern Noiret growers to identify sites that are more conducive to rotundone production but does not support the use of horticultural practices to manipulate the canopy. The model does require further validation before it can be used.

Rebecca Wiepz is an extension support specialist in the Section of Horticulture at Cornell AgriTech in Geneva, NY.