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RE: Potential impact of terpene and odor neutralizer drift on grape and wine composition

Introduction

I am a faculty member in the Department of Viticulture and Enology at the University of California, Davis California. I have more than 15 years of experience in the field of grape and wine chemistry. My research is multidisciplinary and focusses on factors that impact grape and wine characters so that the winemaking processes could be tailored by individual winemakers to achieve the desired flavor and aroma profiles in the finished wine. Grape and wine-related research has allowed the industry to move beyond mere commercial acceptability to the production of intricately crafted fine wines. My research has a strong emphasis on the sensory evaluation of wines and has contributed to the body of work that has made descriptive analysis of wines a standard procedure for wine evaluation and has had the added benefit of making wines less intimidating for the consumer.

Currently, there are considerable concerns regarding the adverse effect that high concentrations of certain terpenes can have on wine flavor, including terpenes commonly emitted from cannabis plants. Some common cannabis terpenes are associated with other plants that have been demonstrated to adversely affect wine quality. It is and continues to be my opinion that the concentration of proposed and existing cannabis facilities in close proximity to and upwind of winegrape-producing vineyards in the Santa Ynez Valley, have a reasonable potential to alter the terpene composition of grapes grown in adjacent vineyards. These changes in winegrape terpene composition and concentration could potentially change wine characteristics and result in wines considered tainted. If wines are tainted, it will have an adverse effect on the reputation and marketability of these wines and thus the viability of the wine industry in Santa Barbara County.

The California grape and wine industry is a $31.9 billion dollar industry, with 637,000 acres of winegrapes planted. Based on a Stonebridge Research report published in December 2015, the Santa Barbara County wine industry has a $1.7 billion dollar economic impact on the region. Recent legislation adopted by the Santa Barbara County Board of Supervisors established regulations for the cultivation of recreational cannabis within the unincorporated regions of the Santa Barbara County. In part, these regulations permit outdoor cultivation of cannabis, including in regions where the primary agriculture are vineyards.

Santa Barbara County wine industry stakeholders have expressed concern regarding the potential impacts that outdoor cannabis cultivation may have on vineyards, winegrapes, and the resulting wines. Concerns focus on the extent that a concentration of terpenes emitted from outdoor cannabis cultivation and proposed odor abatement systems that utilize odor neutralizing essential oils (namely, the system marketed by Byers Scientific & Manufacturing) will be absorbed by winegrapes and ultimately impact resulting wine style and quality. Despite these changes in local policy regarding cannabis cultivation, the federal government continues to enforce restrictive policies and regulations on research into the impacts of marijuana (cannabis) on both health and public welfare. As a result, research on marijuana (cannabis) generally has been limited in the United States. The effects of cannabis on adjacent crops, including crops with sensitive characteristics like grapes, has also been limited, leaving grape and wine industry stakeholders and policy makers without the evidence they need to make sound decisions regarding the permitting of outdoor cannabis cultivation and odor abatement systems that utilize essential oils near vineyards and in designated American Viticultural Areas.

This lack of evidence-based information on the potential impacts of the cannabis industry on established vineyards creates a very real risk to the future viability of the grape and wine industry in Santa Barbara County and other counties that have or may adopt regulations allowing outdoor cannabis cultivation and/or odor abatement systems that use vaporized essential oils sited near vineyards. Santa Barbara County is currently considering permits for outdoor cannabis cultivation that rely upon vaporized essential oil odor abatement systems which individually and cumulatively could have potential significant impacts if sited near established vineyards. Until further research can be conducted, the wine industry and policymakers must rely on previously conducted research into how winegrapes react to volatile compounds from the atmosphere to draw conclusions about potential impacts of cannabis and essential oil vapors to existing vineyards and resulting wine quality.

Research has conclusively shown that winegrapes have porous skins and can absorb volatile compounds from the atmosphere. Well-known examples are volatile phenols from wildfire smoke (Kennison et al., 2009; Krstic et al., 2015) and Eucalyptol (1,8 cineole) from *Eucalyptus* trees (Capone et al., 2012). New research also indicates Eucalyptol absorption on to grapes from the invasive plant *Artemisia verlotiorum* (Poitou et al., 2017) and α-pinene absorption from nearby Monterey cypress (Capone 2017). Research has further shown that cannabis emits volatile terpenes into the atmosphere (Wang et al., 2019). As such, we may use this existing research to analogize and draw conclusions regarding the potential impacts of cannabis terpenes and essential oils on winegrapes. My conclusion, based on my background and familiarity with how winegrapes react to volatile phenols transmitted in air and what we know of terpenes such as 1,8-cineole and α-pinene, is that terpenes in the atmosphere will absorb on to grapes and, depending on the concentration and frequency of exposure, can potentially pose a threat to the grape and wine industry.

Known Impacts of Smoke Taint

Volatile phenols are naturally synthesized in winegrapes and are also released into wine during barrel aging, as toasting of the oak barrels will release the same compounds. However, when the amount of volatile phenols absorbed by the grape berry as well as vine leaves are excessive, this could result in an undesirable taint in the wine called "smoke taint". This taint can greatly impact

the salability of the impacted winegrapes and can make the resulting wine unmarketable.

There is already a body of research that studied the impacts that wildfires have on wines produced with grapes that have been affected by wildfires. In the case of wildfires specifically, large amounts of volatile phenols are released into the air during the fires due to the thermal degradation of lignin in wood. When volatile phenols are emitted into the air and absorbed by the grape berry and vine leaves in sufficient quantities, this results in an undesirable effect called "smoke taint" in the wine. Smoke taint is characterized as a wine with excessive smoky aroma and an ashtray-like aftertaste. It is generally accepted as an undesirable characteristic of wines, rendering affected wines unsaleable.

It has been shown that the risk of smoke taint increases with repeated and continual exposure to the volatile phenols released from the thermal degradation of lignin in wood. These compounds are absorbed continually by the exposed grapes with each exposure and are stable within the grapes until harvest and processing when these compounds are released within the fermenting must (crushed grapes undergoing alcoholic fermentation). The grape and wine industry have been significantly impacted by smoke exposure in the last three years.

Based on the foregoing, there is significant evidence that winegrapes absorb volatile phenols emitted into the surrounding atmosphere, and such absorption has resulted in significant impacts to the characteristics of the resulting wines, including making such wines unsaleable.

Known Impacts of Eucalyptus Taint

In addition to the absorption of volatile phenols released during wildfires, winegrapes are known to absorb ambient terpenes. Terpenes are a large and diverse class of volatile organic compounds, produced by a variety of plants, including cannabis. They often have a strong odor and their function in the plant can be to protect the plant against herbivores or attract pollinators. Because these terpene compounds are volatile, at ambient temperature they can be released in the air (can evaporate from the plant oils where they are present) and travel with atmospheric conditions.

The most studied impact of terpene emissions on winegrapes and resulting wines is Eucalyptus taint, which is mainly caused by a terpene called 1,8-cineole or Eucalyptol. Capone and coworkers showed during a three-year vineyard study that the Eucalyptus taint in wine was not only caused by 1,8-cineole but also that this terpene originated from *Eucalyptus* trees nearby vineyards (Capone et al., 2012). Eucalyptus oils consist mostly of 1,8-cineole, although depending on the species this can vary from a 60% to 90% contribution. Eucalyptol in wine is described as a medicinal, camphoraceous, fresh/minty/cool character. In high concentrations this is seen as a "taint" as it overpowers the wines' other inherent characteristics and is not a winegrape varietal characteristic. Another study by Capone (Capone et al., 2011) showed that Eucalyptol can also be present in grape skins and MOG (materials other than grapes such as the stems and leaves) through absorption of the terpene in grapevine tissues. Eucalyptol, or 1,8-cineole, is present at significant concentrations in the emissions from some strains of cannabis. To clarify, this study found Eucalyptol concentrations above odor detection levels in wines which was caused by airborne transmission of terpenes and the absorption of such terpenes by both the winegrape berries and surrounding vine tissues from the air. This is separate from Capone's observations where *Eucalyptus* stems and leaves were present in the grapevine canopy and subsequently harvested

with the winegrapes which resulted in even higher levels of Eucalyptol in the resulting wines. More recently, Poitou et al. (2017) showed that green character observed in French Cabernet Sauvignon and Merlot wines was related to the absorption of 1,8-cineole from an invasive plant (*Artemisia verlotiurum*) present in some vineyards.

Terpenes present in wines have very low aroma detection threshold levels and ETS Laboratories determined that the aroma (odor) detection threshold level for California Merlot is 1.1 µg/L. Herve et al., (2003) reported a recognition threshold of 3.2 µg/L in red wine. Irrespective, these are detection threshold levels in the parts per billion range. In other words, very low levels of terpenes are detectable in wines and thus low levels of terpene absorption can potentially impact wine characteristics and thus wine quality.

The first part of the Capone study focused on making wines from grapes from two different vineyards harvested at set distances from the *Eucalyptus* trees. Their results clearly indicated a large impact due to distance from the terpene source, which in this case are the *Eucalyptus* trees. Above aroma threshold levels of 1,8-cineole were present in the wines made from grapes up to 50 meters from the *Eucalyptus* trees. An important fact to remember is that diffusion of volatile compounds depends on several factors including temperature, air pressure and movement. It will diffuse until the environment is in equilibrium. Thus, the distance of travel will depend on initial concentration as well as the listed environmental conditions which will be unique for each site.

In the Capone study, only two sites were utilized, which resulted in different levels of 1,8-cineole in the wines (9.5 – 15.5 µg/L). The study confirmed the airborne transfer of volatile organic compounds as found by other studies (Kennison et al., 2009). The study also showed that even higher concentrations of 1,8-cineole were present in winegrape stems and leaves, potentially due to their larger surface area or difference in exposure to the atmosphere or epidermis (outer layer of tissue in a plant). Thus MOG (material other than grapes, including winegrape stems and leaves that were exposed to and absorbed airborne terpenes) can also be a source of 1,8-cineole. This is particularly concerning due to labor costs and shortage which often necessitates the use of mechanical harvesters where more MOG are included.

Capone also found that *Eucalyptus* leaves and bark can lodge in the grapevines and be included during harvest which made a significant contribution to the 1,8-cineole composition of the wine when included in the must. However, even wines made from hand-picked grapes with no MOG or *Eucalyptus* leaves and/or bark, produced wines with above aroma threshold levels of 1,8- cineole if made from winegrapes grown within the first 50 meters from *Eucalyptus* trees. Including grape stems and some grape leaves (which, as described above, also were shown to absorb airborne terpenes), as will be normal during most fermentations, will result in even higher levels of 1,8-cineole.

This study confirmed that terpenes can become airborne and absorb on to other plant surfaces such as grape berries, leaves and stems, and that such absorption has resulted in significant impacts to the composition, quality, and flavor profiles of the resulting wines. Terpenes could potentially similar to smoke taint development, continually absorb on to grapes with continued exposure to terpenes. However, this needs to be investigated. New research by Capone (2017) showed that α-

pinene can also absorb on to grapes in close proximity to Monterey cypress trees and alter the sensory profiles of the wines.

Based on scientific evidence, it is reasonable to conclude that other terpenes present in cannabis will also absorb on to grapes. Absorption of external terpenes onto winegrapes can impact the character of the resulting wines.

Terpene Drift and Potential Impact

Cannabis plants are known for their strong smell due to high concentrations of a range of different terpenes. The chemotype, growing time, and canopy area effects the concentration of terpenes emitted into the air (mostly monoterpenes, C_{10} compounds, and sesquiterpenes, C_{15} compounds). Terpene concentrations in *Cannabis* plants are in the range of g/kg quantities, whereas the threshold levels of these compounds are in the µg/kg range (Aizpurua-Olaizola et al., 2016). This is a 10^6 order difference between the cannabis terpene concentration and terpene odor detection levels. Research has shown terpene emission rates of up to 8.7 $\mu gC\ g^{-1}\ hr^{-1}$ depending on the strain of *Cannabis spp* (Wang et al., 2019). Additionally, β-myrcene, eucalyptol and d-limonene were the most dominant terpenes in the emissions for the four strains evaluated. Other important terpenes in cannabis plants are α-pinene, β-pinene, linalool, α-terpineol, β-caryophyllene, hashishene, α-humulene and more. New terpenes are continually being identified in cannabis plants. A more recent report by Vizuete (2019) confirmed detectable emissions of terpene biogenic volatile organic compounds and that such emissions are dependent upon the strain of *Cannabis spp*.

Terpenes native to winegrapes are biosynthesized in winegrapes and can play an important role in the varietal character of a winegrape variety. Additionally, during the winemaking process, yeast and bacteria can also synthesize small amounts of terpenes (Carrau et al., 2016). The specific combination of terpenes present in winegrapes depends on the variety, but the total terpene levels will be in the order of µg/kg and µg/L amounts in winegrapes and wines respectively (Waterhouse et al., 2017). As evidenced by the studies of 1,8-cineole referenced above, it is clear that changing the level, relative ratio, and combination of terpenes within winegrapes and thus the resulting wines, could change the character of the wine significantly. Such changes could be a result of proximity to plants emitting 1,8-cineole, or other terpenes, including those emitted by *Cannabis* plants.

Furthermore, research into the effects of nearby *Eucalyptus* trees on winegrapes showed absorption by winegrapes at 1 µg/kg to 5 µg/kg levels of Eucalyptol, whereas initial preliminary data on winegrapes show increases of 200 µg/kg to 500 µg/kg of key cannabis terpenes in winegrapes grown close to *Cannabis* plants. This could indicate a much larger impact of cannabis then those determined for *Eucalyptus* trees. The Vizuete report (2019) erroneously used this preliminary data as threshold values, determining that with the calculated cannabis terpene emission levels, these thresholds will not be reached in grapes. Odor detection threshold values should be determined according to the ASTM (Designation E679 – 19) standard. The best estimate threshold value is the lowest level at which a consumer can consistently identify a sample spiked with the compound of interest as being different from another.

If one terpene or a combination of terpenes overpowers the wine (due to the introduction of foreign

terpenes), making it one-dimensional or imparting unpleasant characters to the wine, the wine may be considered tainted. Furthermore, absorption of terpenes on to the winegrapes may occur over the full growth period of the winegrapes, which is several months from pea size to maturity. However, it is currently not known whether terpenes, like volatile phenols, will have a build-up effect and should be investigated. With continued exposure, this means that there may be no specific high terpene period needed for potential impact on the winegrape's natural terpene composition.

Further research is needed to quantify cannabis-specific terpene emissions rates from *Cannabis* cultivation, as well as distance of diffusion and absorption on to winegrapes under different environmental conditions. In addition, kinetics and mechanism of absorption on to grapes need to be investigated as well as the impact thereof on the resulting wine character.

Potential Impact of Vaporized Essential Oils

The above is similarly concerning in light of the proposed odor neutralizing essential oils proposed by many of the *Cannabis* cultivation projects, namely the system installed by Byers Scientific & Manufacturing. Such systems emit vaporized essential oils into the air via piping that surrounds the perimeter of *Cannabis* cultivation sites. According to the manufacturer's materials, the efficacy of such systems is predicated on the vapors traveling in the air and making contact in the airstream with the odor compounds emitted from *Cannabis*. Upon contact, the odor molecules are "neutralized". In order for such vapors to make contact with odor compounds, the vapors are pushed through small holes in the perimeter piping away from the *Cannabis* cultivation areas and toward areas that may be negatively affected by malodors, namely neighboring properties.

Essential oils mainly contain terpenes and in reality 'neutralization' is masking of unpleasant smelling terpenes by releasing more pleasant-smelling terpenes. Thus, in effect even more terpenes will be present in the atmosphere surrounding grapes which can potentially absorb and alter the character of the grapes and thus the resulting wines.

Complexity of a Proposed Study

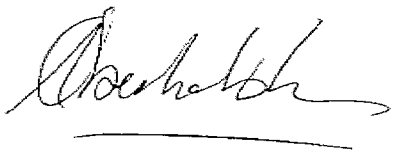
Investigations into the potential impact of *Cannabis* emitted terpenes on winegrapes are complex due to the significant impact of the environment on diffusion of volatile organic compounds. Distance of diffusion will depend on the concentration at the source, as well as environmental conditions. Approximately 80 different terpenes have been identified in different cannabis strains while there are approximately 50 different terpenes in winegrapes. First the presence of atmospheric terpenes at set distances from *Cannabis* cultivation needs to be shown as well as their absorption on to different grape tissues. The impact thereof will be evaluated by producing wines using standard experimental procedures, made from grapes harvested at set distances from *Cannabis* cultivation. These wines will be analyzed both sensorially and chemically to determine their terpene profiles and its relation to sensory characteristics of the wine. Additionally, best estimate thresholds of the identified cannabis terpenes should be determined. However, as compound expression is impacted by the matrix (wine) including other terpenes present, this can become very complex. Marker compounds with their detection threshold levels and their consumer rejection levels should be determined to establish risk analysis. However, due to potential synergistic impacts, this is a very complex process.

Conclusion

Based on the foregoing analysis using the research available to date on the impacts of airborne volatile compounds on winegrapes, outdoor *Cannabis* cultivation could have a potentially significant impact on the terpene composition of winegrapes grown near such *Cannabis* cultivation sites. This impact is even more likely when *Cannabis* is grown on large scale (either as a single project or multiple projects clustered together) with a large canopy area that is collectively emitting *Cannabis* terpenes into the air in regions where vineyards are in close proximity. The impact will be further exacerbated if the proposed Byers systems are used and proactively emit odor neutralizing essential oils into the air, directed toward such vineyards.

Changes to the terpene composition of winegrapes has been shown to impact resulting wine quality in prior studies of 1,8-cineole and now α-pinene. In light of the cultural significance and economic impact of the wine industry in California, it is important that care be taken to avoid adverse impacts while research seeks to provide objective metrics for allowable concentrations of high volatile organic compound releasing plants cultivated close to high quality wine grapes.

Submitted by,



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