How does vine density affect Pinot Noir Grape quality and price?

By: Luis Martinez-Salinas

Oregon State University

Table of Contents

Abstract

With the wine economy in Oregon consistently growing every year, more research is being done to help increase efficiency of the different components of the wine economy. One of those components is the vineyard itself and the business of growing wine grapes, specifically for this paper Pinot noir grapes. Pinot noir makes up the largest portion of Oregon wine grapes that are grown and bring in the most in terms of economic revenue from output. The purpose of this paper is to assess vineyard spacing or plant density, which is the distance in between vines and in between rows, and how it affects the quality of wine grape produced to try and increase efficiency in the number of high-quality grapes produced while trying to keep maintenance costs low. The approach in the paper will be to read the most applicable and up-to-date articles on vine spacing, how it affects wine grape composition, and then to summarize the results in a way that can be of benefit to potential and current growers trying to maximize their wine grape revenue and reduce possible costs. Some of the major findings related to how the different spacings affected plant growth, canopy density, grape composition, water stress, and that too close of spacings were not a viable proposition due to maintenance costs and that the wider spacings were not as effective either because of how long production would take and the quality was not at the same level as the more median and median-closer spacings.

My interest in this topic comes from an interest in a related industry, the craft beer industry. My interest in craft beer led me to trying out wines and becoming more interesting in learning about its production. My professor then suggested this topic and it became quite fascinating due to me not even realizing the economic impact it had on the state of Oregon and how many different parts it had as well as how many similarities it had with the beer industry including the hops growers and problems they face regarding growing hops efficiently.

Introduction

In 2017, the wine industry had an economic impact of $219.9 billion dollars in the United States [1] Of the direct economic impact from vineyards and grape production, the output was at $3.49 billion dollars [1]. In Oregon alone, the total output from the Wine industry was $6.5 billion dollars with $117 million of that coming from vineyard output. The 2017 Oregon Vineyard and Winery Report [2] saw increases across the board in acreage of vineyard grown for all regions and for the different varieties of wine in sales, revenue, and production. The variety that led in planted acreage and production continues to be Pinot Noir with 58% of all planted acreage and 59% of production. The price per ton change from 2016-2017 for Pinot Noir, as the weighted average of price received by Oregon grape growers, went from $2,422 to $2,375 while the yield per harvested acre in tons increased from 2.58 to 2.89. The production increased in tons from 45,851 to 53,457 from 2016-2017 with the value increasing from $111 million to $117 million. From these numbers, we can see that the supply has increased which can be a reason why the price per ton for the grapes has decreased by $47 per ton.

With Pinot Noir continuing its reign atop the production numbers for Oregon wine grapes, research into finding the most productive and cost effective growing and production strategies are of the utmost importance for new growers and already established vineyards. Vineyard profit can be increased by cutting costs, increased yield and/or grape quality to fetch higher prices, and/or both. In this paper, we will focus on one aspect of the grape production process which is finding the optimal spacing between each vine plants and between each planted row in a vineyard. Finding this spacing would help reduce maintenance costs, and possibly increase yield and/or quality to help get higher prices thus increasing revenue. Research, some of which will be further covered in this paper, has shown that vineyard spacing, or planting density

of vineyards, has some effects on the quality and yield of grapes due to different effects of the planting space. There are different factors which affect this as well like soil type, rainfall, exposure to sunlight and direction the plants face and are planted, among others.

In the early 2000s, the common practice was to keep the spacing narrower [3]. This allowed for more grape vines to be planted in a limited amount of area. This allows for a thicker canopy to develop and interplant shading because of how close they are to each other. With denser planting, the idea was to increase yield due to more plants and increase revenue with more product sold. In more recent years, other spacing options have been looked at more carefully to find more cost-effective ways to produce quality grapes while managing or reducing costs associated with canopy maintenance and management. In this paper I will go into more detail the different spacing options, how they affect the vine growth, and how this affects the overall quality and therefore price that growers can get for their grapes because the goal is to increase the price per ton for the Pinot Noir grapes grown while maintaining or reducing the costs of maintenance for the plants.

Project Statement and Approach

The purpose of this research paper is to try and find and answer the question “How does vineyard density affect Pinot noir grape quality and price?” Density consists of the spacing between vines and between rows when planting a vineyard. In this paper we will try and find the spacing distance that will produce grapes of the highest quality that will fetch the highest price per ton of wine grapes.

The focus of the paper is how vineyard density affects grape quality which in turn affects prices. I will be researching the effects of vineyard spacing or planting density to determine what

the best possible distance will be in between vines and in between rows that will have the highest probability of producing high quality Pinot Noir grapes.

My approach will be as follows:

1. First, I will determine how various grape qualities affect their price. I will then go into more detail on the actual spacing and how narrow spacing versus wider spacing or more median spacing affects the grape vine in terms of growth, canopy, micro and macroclimate, shoot growth, vigor, crop yield, bunch yield, water needs, sunlight needs, and other factors that will determine the results of the overall grape quality, which is determined by °Brix, SS levels, phenols, TA, and anthocyanins.
2. I will be referencing tables that I have found in my research that have data from different spacings that were common across different studies that I found. An important measure I will be looking for will be the Brix measure to try and compare the TSS or Total Soluble Solids in the grapes depending on the different spacings because that will help us gauge the sugar content in the grapes which will be a factor when the grapes are used for actual wine production.
3. Using the table with the Brix measures and related spacings, I will determine what spacing results with the highest °Brix levels and which spacing provides the highest levels while also factoring in density which affects costs and the other grape quality measures.

By following this approach, my goal is to have data and results that will help provide some guidance for new growers and possibly update some existing practices of established growers to achieve higher vineyard profit.

Literature Review

I will start off by going into more detail regarding the composition of grapes and what are characteristics of high-quality grapes. From there, I will go into different vineyard spacing methods and how they affect the vine growth which in turn will lead us back to the grape composition results.

Characteristics of high-quality grapes:

To assess grape quality, growers, scientists, and winemakers look at different indicators. The first indicator they look at is Soluble Solids (SS), as expressed or measured by Brix levels, or °Brix. "At, or close to maturity (18°Brix), SS levels are within 1% of actual sugar content (glucose and fructose) [4]. The sugar levels tell us the possible alcohol yield after fermentation. As the grapes mature, we can look at the SS level to tell us the state of ripeness. In areas with shorter seasons, like Oregon for example, the SS level can be a "useful indicator of ripeness and quality [4]." Prices can be adjusted to the SS level of the harvested grapes. They go on to mention that in warmer regions with lower rainfall that the SS is a less reliable indicator of future wine quality unless other factors are taken into consideration. They go on to say, "Grapes of high °Brix may produce high alcohol wines which mask other quality components… an upper limit of 24° Brix is often used to indicate the proper maturity for quality white and red table wines in warmer regions [5]."

Another factor that is looked at is organic acids, which are made up of tartaric, malic, and citric acids. These acids are measured by titration and are expressed as total titratable acids (TA). Of these, Malic acid is the acid most influenced by respiration and warmer and cooler climates affect malates. Malates in cool climates decline more slowly and stays more acidic versus

warmer climates where the malates decline faster, possibly producing blander wines from the grapes. The range mentioned in the article states that “wine with too much acid (10 g/L TA equivalents and above) is tart to the taste and deacidification may be required. In warm/hot climates acid may be too low (below 6-7 g/L), producing a bland wine [5].” So, the optimal range appears to be between 6-7 and 10 g/L TA so as to not need deacidification or addition of tartaric or citric acid.

Another important factor that is looked at are the phenolics and anthocyanin. Phenolics are the tannic component of wine “which imparts bitterness and astringency.” The Phenolics are “extracted from the skins, seeds, and rachis during crushing, pressing, and fermentation.” They are a major piece of what gives red wine its color. They are also a determinant of the flavor of the wine depending on their concentration and the phenolics present. Red wines have much higher flavonoids and phenolic content and are generally aged longer than white wines due the changes that happen in content and nature of phenols during the aging process [5]. Berry development also plays a factor as far as location of the berry. Berries that are more exposed will be “more advanced in SS and have higher phenols than those on the shaded side of the cluster [5].”

Effects of climate on grape quality:

Now we will look at how climate can affect the quality of the grapes. Temperature can affect the coloration of the grapes and for Pinot noir, cooler night temperatures between 15°C to 20°C promoted good skin color when compared to range from 25°C to 30°C. Daytime temperatures of 20°C instead of 30°C enhanced color [5]. Water stress can be a factor in both the yield and composition of the grapes but the “magnitude of changes in berry composition due to water stress were much less than the changes in vegetative growth and yield. [5]” Studies show

excessive irrigation slows ripening, increases yield, increases juice pH and lowering acid content, and reduces anthocyanins from shading due to increases shoot growth [6]. pH levels above 3.60 in wine may increase relative bacteria activity, "lower the color intensity in red wines, bind more Sulphur dioxide and reduce the free $S0_2$ content, and can shorten the ability wine to age [5]." We will look at water more when we talk about the spacing and the how it affects the micro-climate of the vine, or the climate within the canopy of the vine.

Effects of vineyard spacing on grape quality:

Next, we will look at the soils and planting techniques and how they affect quality, specifically the plant density. In these studies, they use the metric system, but I will be converting to imperial measures using the following table in my significance/policy implications and conclusions:

Meters	Feet
1	3.28
1.5	4.92
2	6.56
2.5	8.20
3	9.84
3.5	11.48

According to Lombard and Jackson, European regions that have a reputation for quality wine have the common practice of planting 1 m X 1 m, or closer. This practice is used because closer planting is said to provide a larger area of foliage to spread over, enabling roots to more efficiently use the soil volume. Champagnol [7] promotes the narrower spacing and believes that "a high density of (necessarily) small plants "helps control congestion in a vineyard and produce quality wine. This is not the case across the board though as other researches like Carbonneau [8], and in the United States, Smart [9], say that wider spacing can achieve adequate foliage distribution and receive the benefit of good light penetration. The narrower spacing, as mentioned above, is used to help the roots maximize growth in the given soil volume but in moist soils, like during the rainier seasons in OR or with irrigation, the vines can still exploit the large soil volume even widely spaced.

One aspect of vineyard spacing that needs to be taken into consideration is water stress. When we cover the vine spacing numbers, the first distance measure is between row spacing and the second is between vine spacing. Studies have shown that "increased density encouraged more effective use of nutrients and water but caused increased drought stress in very dry conditions." They go on to say that earlier in the season, closer spaced vines receive better sunlight penetration but that the same plants suffered from water stress later in the season. Of Pinot noir grapes, in Lombard and Jackson's paper, they said that close spaced planting (1 m X .5 m, 1 m X 1 m, 2 m X 1 m) produced grapes that matured earlier and with higher skin color that made higher-colored quality wines versus wider spacing (2 m X 2 m, 3 m X 1 m, 3 m X 2 m, 3 m X 3 m).

Other things to keep in mind is that high density planting in a vigorous site can lead to uncontrollable growth, which can increase maintenance costs and create unfavorable microclimates, and in areas were moisture stress can be severe, wider spacing is needed to conserve the available water supply.

When looking at how vine spacing, or plant density, affects the grapevine and grape production, we can start by looking at how it affects microclimate. Microclimate is a term that can be used to encompass the different environmental factors that affect the plant and leaves in the canopy. The microclimate is affected by environmental factors such as light, temperature, and humidity. These all have roles in how they affect photosynthesis, which is one of the most important physiological processes in vines [10]. Photosynthesis is affected by the light that reaches the leaves which depends on how the canopy is structured. The arrangement of the leaves themselves within the canopy is managed through training and trellising.

Canopy density, which is what the arrangement of leaves and shoots in a canopy is referred to, is affected by vine vigor, which means any factors that affect vine vigor will also affect canopy density. High canopy densities are “obtained when the available area per vine (dictated by vine spacing and the size of the trellising system) is too small to accommodate the shoot growth of the vine [10].” On the other hand, low canopy densities arise from too big of an area available for the vegetative capacity of the vine. Archer and Strauss mention that “ideal canopy densities are procured when the available space can accommodate vegetative growth without necessitating intensive canopy management techniques,” which also helps cut down on maintenance costs [10].

Returning to microclimate, canopy density affects leaf temperature through air movement and controlling the sunlight penetration. Leaf temperature also affects photosynthesis and heavily vegetative canopies provide more shade and lower temperatures in the leaves with less light reaching interior leaves. Leaves in sparser canopies receive more radiant energy which increases photosynthesis in the leaves and creates a better microclimate. According to the paper by Archer and Strauss, they mention that studies have shown that sparser canopies produce more ventilated leaves and clusters and increased canopy shading in more vegetative canopies decreased the sugar concentration and negatively affected bud fertility. Grape quality can be affected through “photosynthetic, thermal, or phytochrome effects” [10], which can enhance the quality but at the same time, the quality can be adversely affected by high temperatures in “well-exposed bunches in sparse canopies with little or no air movement.” Archer and Strauss reported “negative morphological and grape compositional effects in shaded Cabernet Sauvignon fruit.” They said that increase shade inside of the canopy cause a decline in berry set, sugar, skin anthocyanins and phenols, while malic acid, K-concentration and pH increased. While they reported that about

Cabernet Sauvignon, the article is focused on effects on Pinot noir, so it could be assumed that it would have similar effects on Pinot noir grapes.

Archer and Strauss also wrote about the effects of vine spacing on the vegetative and reproductive performance of Pinot noir on top of the physiological effects mentioned above. In their study on vine spacing and vine performance through five seasons they found that, regarding shoot growth, growth per vine of the closer spaced vines was less than that of the wider spaced vines. The shoot mass per hectare was higher in the closer spaced vines [10]. They said that no difference could be found "between either percentage of budburst or fertility of buds in different spacings" and that all phenological stages occurred earlier in the closer spacings.

As far as berry yield, or grape yield, Archer and Strauss found that yield per vine decreased and yield per hectare increased with closer vine spacing. In the study, vines in the treatment plot with spacing of 1 m X .5 m, 1 m X 1 m, and 2 m X 1 m reached full production one year faster than those in the treatment plot of 2 m X 2 m and 3 m X 1.5 m. They reached full production two years earlier than those in the 3 m X 3 m treatment plots. While the production took longer in the wider spacings, it is also stated that the material costs for a trellising system and grafted vines for the closer spacing treatment plots was more than double than the ones who took a year longer to produce and more than 4 times than the ones that took two years longer to produce. They said that the "higher costs ruled out the highest planting density in this experiment as a viable proposition."

The wider spacing on the treatment plots resulted in increased bunch mass, which was a result of more berries per bunch and could be related to "better fruit set as well as differentiation of bigger cluster primordia [10]." The following graph was presented regarding spacing and bunch mass (g), berry mass (g), yield/vine (kg), yield/m^2 leaf area (kg), and yield/ha (t):

Table 1: Effect of vine spacing on the bunch mass, berry mass, and yield of Pinot noir/99 Richter. Stellenbosch, South Africa. No irrigation applied. [10]

Spacing (m)	Bunch mass (g)	Berry mass (g)	Yield/vine (kg)	Yield/m^2 leaf area (kg)	Yield/ha (t)
1.0 X 0.5	94.62	1.18	0.633	0.459	12.66
1.0 X 1.0	115.13	1.18	1.090	0.423	10.90
2.0 X 1.0	126.80	1.23	1.842	0.436	9.21
2.0 X 2.0	124.05	1.24	2.975	0.696	7.44
3.0 X 1.5	130.55	1.24	3.485	0.650	7.75
3.0 X 3.0	134.89	1.24	5.701	0.793	6.33

The next graph they presented used the same measurements for spacing but gave more data on sugar concentration in °Brix, acid concentration, pH levels, and the acid concentration and pH levels for the delayed harvests.

Table 1: Effect of vine spacing on grape composition of Pinot noir/99 Richter. Stellenbosch, South Africa. No irrigation applied. [10]

Spacing (m)	Sugar concentration (°B)	Acid concentration TTA (g/l)	pH	Delayed harvest*	
				TTA (g/l)	pH
1.0 X 0.5	23.92	8.60	3.04	-	-
1.0 X 1.0	24.03	8.65	3.08	-	-
2.0 X 1.0	23.60	8.84	3.09	-	-
2.0 X 2.0	22.42	9.49	3.09	7.92	3.29

3.0 X 1.5	22.48	9.44	3.10	7.81	3.32
3.0 X 3.0	22.06	9.41	3.09	7.57	3.37

In the above graph, the sugar concentration, pH levels, and acid concentration were measured when the grapes from the closer spaced treatment plots reached optimum maturity which is about 23°B. The wider spaced grapes at this time had lower sugar concentrations and higher acid concentrations. The wider spaced grapes were left until they reached 23.5°B and then the TTA and pH was measured again which are the delayed harvest measurements.

Significance and Policy/Business Implications

The significance of this research paper is that the data and information that was summarized will be able to provide some insight to growers, new and established, as to what the optimal spacing distance is when planting Pinot noir vineyards. As I read through the literature, there were a couple of things that stood out to me that I think are important. I started with determining some of the factors that affect grape quality, because the overall goal of the information presented is to provide a vine spacing distance which will lead to the overall best quality of grape which will fetch the highest selling price per ton. In the enterprise budget analysis that was created by Professor Olen and Dr. Skinkis, they used the spacing of 4’ X 8’. In the studies that I looked at, they had spacings that measured narrower at 3.28 ft to wider at 9.84 ft. In the two articles that I looked at by Archer and Strauss, they mentioned that due to the high trellising costs and prices for the grafted vines at the very narrow spacings from 3.28 ft X 1.64 ft, 3.28 ft X 3.28 ft, and 6.56 ft x 3.28 ft that they were ruled out as a viable proposition. The narrower measures though, also produced in the first year. When move towards the next treatment plots, the distances are 6.56 ft X 6.56 ft and 9.84 ft X 4.92 ft. At these distances the

production starts a year later than the closer spacings but at half the costs. I think that the widest spacing they looked at, which was 9.84 ft X 9.84 ft, would not be feasible either due to the two additional years wait until production, even the costs are less than a quarter of the closest spacing, due to the negative effects the wider spacing has on the grape quality.

In the graphs that I used from the articles that compared °Brix, acid concentration and pH between the spacings, data showed that °Brix was highest in the closer spacings but still within the optimal range in the spacings from 6.56 ft X 3.28 ft and 6.56 ft X 6.56 ft. The acid concentration jumps up a bit from 8.84 to 9.49 in the shift from the same spacing of 6.56 ft X 3.28 ft to 6.56 ft X 6.56 ft. From the data gathered regarding the spacing options and how they affect bunch mass, berry mass, °Brix, acid concentration, and the information summarized in the literature review, I would say that the best spacing distance would be from 4 ft to 6 ft in between the vines and 4ft to 6ft in between rows as well because while bunch mass decreases slightly from 3.28 ft between rows to 6.56 ft between rows, keeping between vine distance the same, the berry mass is larger, the yield/vine is larger. One reason to have denser spacing between rows might be that the °Brix levels go down in the biggest jump any of the categories have from 23.60 to 22.42 at the 6.56 ft between rows. Overall, I tend to agree with the spacing listed on the enterprise budget analysis because irrigation is present so there will not be as much water stress and the wider in between row spacings will cut down on the cost much more than the closer.

The difficult parts of the research, and how they factor into determining optimal planting density distances, are that there are a lot of variables that go into choosing the right vine spacing, or plant density, for the vineyard grower. In Oregon, we have longer seasons and we don’t see as much rainfall during the warmer growing seasons. With irrigation, keeping the plants with the adequate amount of water gives us a little more freedom with spacing and with the variety of

soils available in different regions, some more apt at retaining or distributing water, this helps also. Overall I think the spacing stated above should be a good option for Oregon growers due because the canopies won't become too dense, the grapes will get a good amount of sunlight on the longer summer days here, there won't be too much water stress later in the season for close in between vine spacing, and lesser costs for maintenance of both canopies and in between rows with wider spacing there.

Conclusion

In this research paper, the goal was to find the vine spacing distance, both in between vine and in between row, which would provide us with the highest quality grapes which would fetch the best prices My approach was first to find literature that had information regarding vine spacing, different distances, and how they affected factors that made for high quality grapes. From there I summarized the information and organized in a way where it first addressed the qualities or components of the grape and how it is affected by different factors and then how those factors are then affected by the vine spacing. I then referenced tables from the articles that I read that provided a good visual representation of their results in a way which related to what my objective was in the research. I found that the factors that affect grape composition depend on the region that you are in because that determines the climate, soil, temperature, access to sunlight, and access to water that are huge factors that are affected by the vine spacing. In the end I discussed what I thought would be a distance given the data from the tables and adjusted the range a bit to try and fit in more with what I had learned of the Oregon region of Pinot noir growth.

I think that a good next possible step could be to set up new studies using the treatment plots with different spacings here in Oregon if that is manageable so that we can get first hand

results and data that could be applicable to growers. Another area of interest could be looking more in depth into the same factors I looked at and trying to maintain or set-up the vineyard to maximize grape quality at the beginning of the season and then again make changes that maximize at the end of the season because of the different factors like water stress later depending on spacing and other factors.

References

1. 2017 Oregon Vineyard and Winery Report. (n.d.). Retrieved December 2, 2018, from https://industry.oregonwine.org/resources/reports-studies/2017-oregon-vineyard-and-winery-report/

2. Economic Impact of Wine Industry 2017 Data Oregon. (n.d.). Retrieved December 2, 2018, from http://wineamerica.org/wp-content/themes/wineamerica/pdfs/impact/tables/Oregon-Table.pdf
3. Olen, B., & Skinkis, P. A. (n.d.). *Vineyard Economics: Establishing and Producing Pinot Noir Wine Grapes in Western Oregon* (pp. 1-19, Rep.)
4. Archer, E., & Strauss, H.C. "The Effect of Vine Spacing on Some Physiological Aspects of Vitis Vinifera L. (Cv. Pinot Noir)." *South African Journal of Enology & Viticulture*, vol. 11, no. 2, 2017, doi:10.21548/11-2-2272
5. Jackson, D. I., & Lombard, P. B. (1993). Environmental and Management Practices Affecting Grape Composition and Wine Quality. *Am. J. Enol. Vitic., Vol. 44, No. 4, 1993, 44*(4), 1-22.
6. Smart, R. E., & Coombe, B. G. (1983) *Water relations of grapevines. In: Water Deficits and Plant Growth. Vol. VII. Additional Woody Crop Plants*. T. T. Kozlowski (ed.) pp 137-96 Academic Press. New York.
7. Champagnol, F. (1984) *Elements de Physiologie de la Vigne et de Viticulture Generale*. Pub. The Author, Montpellier.
8. Carbonneau, A. (1982) *Influence des syst~mes de conduite en 'Lyre' sur la physiologie de la vigne.* Prog. Agricole Viticole 99:290-9.
9. Smart, R. E. (1987) *Canopy management to improve yield, fruit composition and vineyard mechanization: A review*. In: Proceedings of the Sixth Australian Wine Industry Technical Conference, Adelaide. T. H. Lee (Ed.) pp. 205- 11.
10. Archer, E., & Strauss, H.C. "The Effect of Vine Spacing on the Vegetative and Reproductive Performance of Vi Tis Vinif Era L. (Cv. Pinot Noir)." *South African Journal of Enology & Viticulture*, vol. 12, no. 2, 2017, doi:10.21548/12-2-2211