The unique ripening kinetics and grape chemistry of Petit Manseng

A producer focused summary of results and applications

Adapted from: Beverages, 2025, 11(4), 108

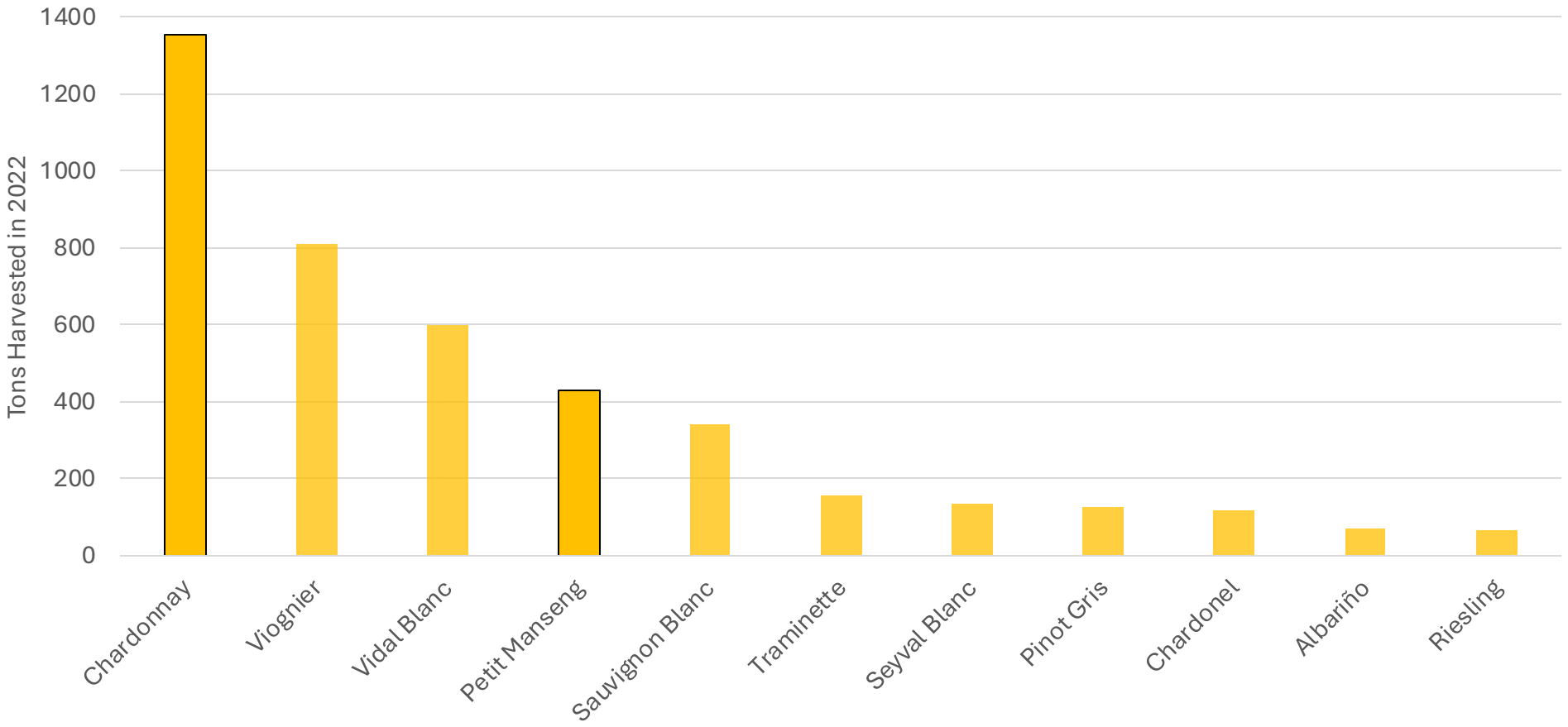
Authors: Joy Ting, Alicia Surratt, Lauren Moccio, Ann Sandbrook, Beth Chang, Dennis Cladis

Special thanks to: Jenna Barazi, Mac Mason, Vineyard Partners

This work was produced as a joint project of the Winemakers Research Exchange and
The Virginia Tech Food Sciences Department
Funding was provided by The Virginia Wine Board

Clickable Table of Contents

Introduction



Over the past 20 years, Petit Manseng has gained popularity in Virginia vineyards. Although traditionally used for off-dry or dessert style wines[1], some Virginia winemakers produce dry table wines from this variety. However, Petit Manseng's naturally high sugar and acid levels pose significant challenges to producing a balanced dry style wine. **This study characterized the ripening kinetics of Petit Manseng to inform harvest timing and winemaking decisions for production of dry Petit Manseng**. Chardonnay was used as a reference variety because it is the most widely planted white grape in Virginia[2], providing a familiar benchmark for ripening kinetics among growers and winemakers.

Return to Table of Contents

Experimental Design

The study included systematic sampling of Chardonnay and Petit Manseng from five vineyard sites across Virginia:

- 2 in Northern Virginia
- 2 in Central Virginia
- 1 in the Shenandoah Valley

Each site grew both varieties in the same vineyard and utilized farming operations considered standard to Virginia. Sampling was conducted weekly from veraison until harvest in 2021 and 2022 (for a total of 74 samples)

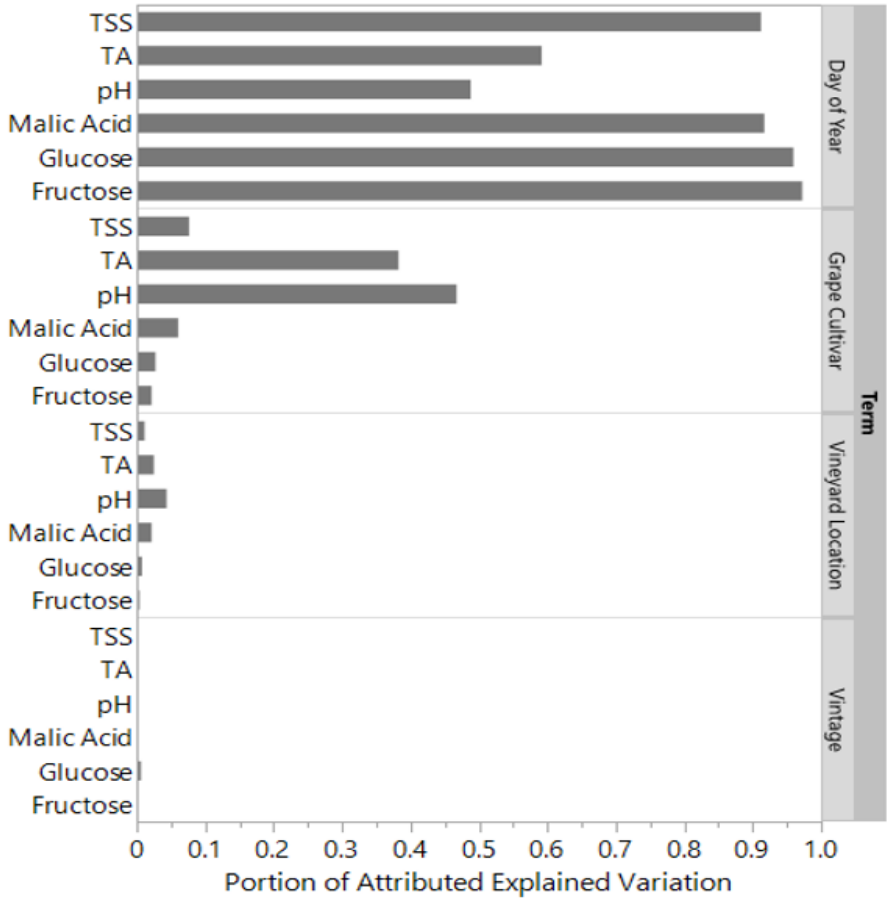
Each sample was analyzed for:

- berry weight
- total soluble solids (TSS)(Brix)
- pH
- titratable acidity (TA)
- glucose
- fructose
- malic acid
- yeast assimilable nitrogen (YAN)

Return to Table of Contents

Most variation in the set was due to grape variety, not vineyard or vintage

A boosted tree statistical model was used to measure the relative importance of time, grape variety, vineyard location, and vintage for each chemistry variable.



The models were a good fit. They explained > 95% of the variation.

As expected, the most important factor was day of year. Grape variety explained the second most variation.

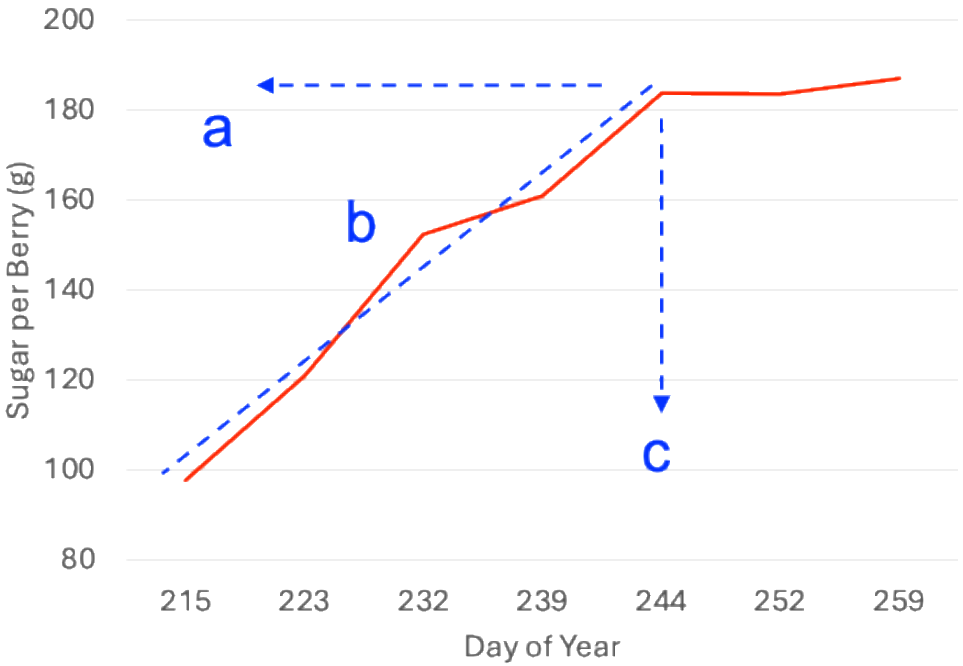
Although vineyard location and vintage are important factors to consider, they explained a very small portion of the variation in ripening kinetics of grapes in the current sample set.

These results allowed data from both years and all locations to be combined for investigation of differences due to grape variety.

Return to Table of Contents

Statistical models of grape ripening provided metrics for comparison

Many grape chemistry parameters, including sugar accumulation and acid depletion, increase or decrease at a relatively steady state until ripe, then level off[3]. The characteristics of ripening can be mathematically described with linear plateau regression, a type of broken line regression. Assigning numbers to these trends allows direct comparison of characteristics between varieties.



a = The maximum (or minimum) value at ripeness (the average value when the line plateaus)

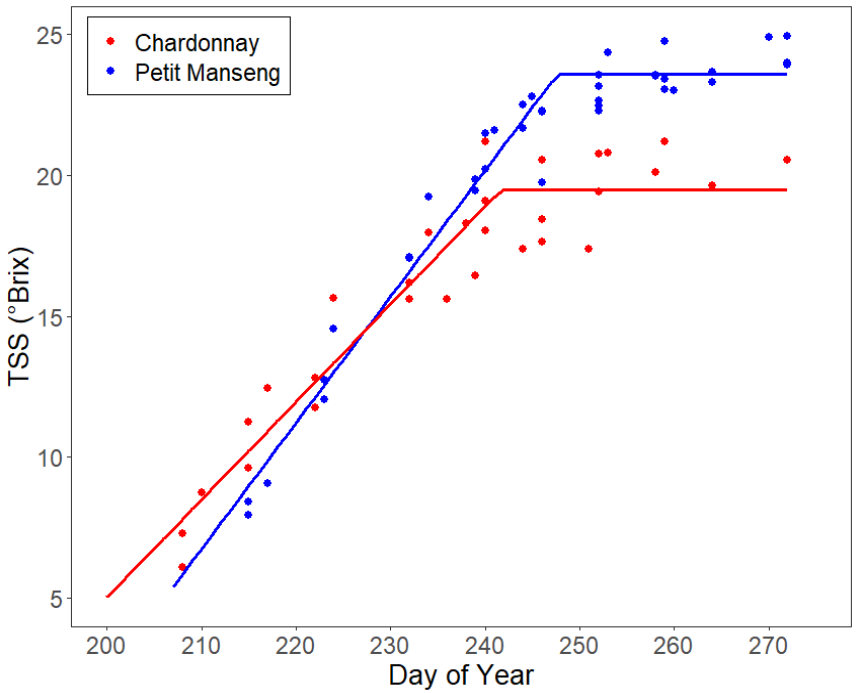
b = The rate of change during ripening (the slope of the line)

c = The timepoint when grapes reach physiological maturity (value on the x axis when the slope plateaus)

This analysis was not meant to identify an exact value, since a, b, and c will vary by vintage and vineyard, but rather to compare the average values between varieties at each vineyard/vintage combination. Comparisons led to several insights into the sugar and acid chemistry of Petit Manseng.

Return to Table of Contents

Petit Manseng had rapid sugar accumulation and high potential alcohol



R^2 = 0.95	Chardonnay	Petit Manseng	p-value
Plateau (°Brix)	19.49±0.40	23.58±0.22	<0.0001
Change per day	0.35±0.03	0.45±0.02	0.0037
Plateau day of year	242±1.9 (Aug 29)	248±0.9 (Sept 4)	0.0037

Sugar accumulated 33- 45% faster in Petit Manseng than in Chardonnay

Petit Manseng grapes may need to be sampled more frequently than in other varieties.

Brix plateaued at an average of 23.5° Brix in Petit Manseng vs.19.5° Brix in Chardonnay, leading to an average potential alcohol of 14.3% in Petit Manseng compared to 12.2% in Chardonnay. Anecdotally, these values can be much higher in dry vintages.

- High alcohol impacts yeast cell membrane proteins, causing stress, loss of function, and cell death[4].
- Stressed yeast also produce acetic acid which decreases the quality of the wine, and in high enough concentration, can be a stress factor of its own[4].
- When coupled with other stress factors (such as low pH and excess fructose), high ethanol may contribute to stuck fermentations[4].

For production of dry Petit Manseng, yeast strains with high ethanol tolerance may be needed to complete fermentation.

Return to Table of Contents

Petit Manseng had an unfavorable ratio of glucose:fructose at harvest

The ratio of glucose to fructose at harvest followed a similar pattern as the other metrics, however, it did not plateau. Instead, the model had two slopes. Initially, the ratio declined quickly, then more slowly, but **it never stopped declining**. On average, Chardonnay was harvested as soon as physiological maturity was reached but Petit Manseng was harvested 21 days after sugar loading stopped.

Because Chardonnay was harvested earlier in its ripening cycle, the glucose:fructose at harvest averaged 1.04. However, for Petit Manseng, this ratio fell to 0.97 before fruit was harvested.

Ratio of Glucose:Fructose	Chardonnay	Petit Manseng
Ratio at Rate Change	1.11	1.09
Day Pre-Harvest at Rate Change	-25.0	-36.9
Change Per Day (Fast Phase)	0.06	0.03
Change Per Day (Slow Phase)	0.003	0.003

Though yeast sugar transporters can accommodate both glucose and fructose, they prefer glucose[5], which leaves leftover fructose, even when fermentation begins with equal amounts. Starting a fermentation with a glucose:fructose < 1.0 increases this imbalance, increasing the chance of stuck fermentation[5].

Fructophilic yeast strains may be needed to complete fermentation of dry Petit Manseng.

Return to Table of Contents

Later harvest of Petit Manseng may lead to very ripe tropical aromas

Although sugar accumulation does not directly correlate with the accumulation of grape berry flavors, varietal aromas develop as grapes ripen. The onset of physiological maturity (the time point when sugar accumulation ends) can provide a benchmark for aromatic development.

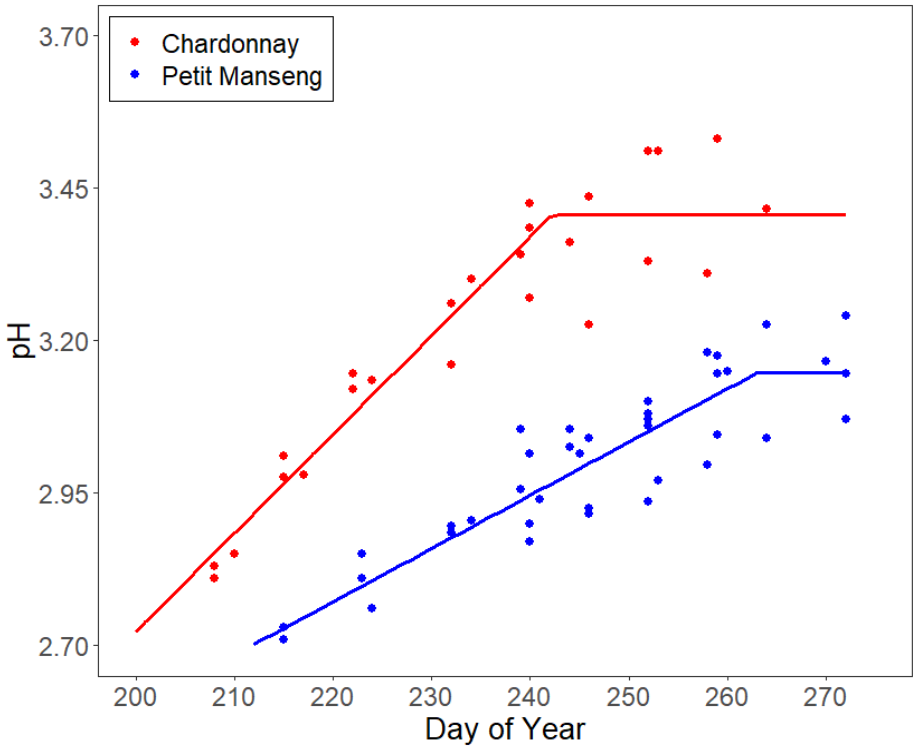
Aroma development is thought to follow a "berry aromatic sequence" that occurs after grapes reach physiological maturity[3]. In this sequence, aromas develop from the fresh flavors found soon after physiological maturity to the mature fruit flavors found after longer hang time. Different grape varieties may follow a different evolution of aromas, but several have been described. In Cabernet Sauvignon, this includes the development from herbaceous through red fruits all the way to stewed or dried fruit[11]. A similar progression for Sauvignon Blanc moves from vegetal through citrus to tropical fruit[7].

In Petit Manseng, harvesting long after the onset of physiological maturity may amplify the (potentially overwhelming) tropical aromas in these wines.

Vegetation ↔ Herbaceous ↔ Citrus ↔ Melon ↔ Tropical Fruit

Return to Table of Contents

pH remained very low throughout ripening in Petit Manseng



R^2 = 0.90	Chardonnay	Petit Manseng	p-value
Plateau	3.44±0.02	3.15±0.03	<0.0001
Change per day	0.016±0.001	o.oo9±0.001	<0.0001
Plateau day of year	244±2.3 (Sept 1)	263±3.8 (Sept 19)	0.0002

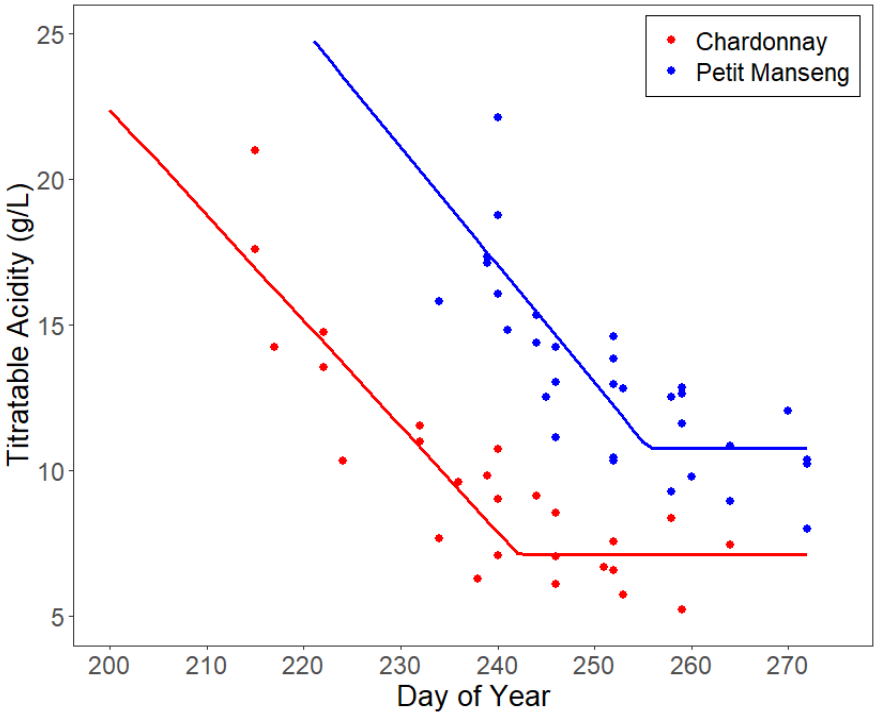
Low pH (< 3.5) imparts microbial stability[8] and amplifies the impact of SO_2 in finished wines, however, **pH < 3.0 may lead to yeast stress,** causing a longer lag phase, lower overall cell mass, change in sugar conversion, and higher acetic acid production[9].

In Chardonnay, pH increased quickly, reaching a comparatively high maximum (3.44) within 3 days of the sugar plateau. In Petit Manseng, the rise in pH was 1.8 times slower, reaching plateau at a pH of 3.11. The pH was prohibitively low (<3.0) at the time of sugar maximum, and continued to rise for an additional 21 days post sugar maximum before leveling off.

Petit Manseng grapes maintain lower pH overall but need to be harvested later in ripening to allow microbially permissive pH for healthy fermentation.

Return to Table of Contents

Titratable acidity was prohibitively high in Petit Manseng



R^2 = 0.78	Chardonnay	Petit Manseng	p-value
Plateau	7.13±0.53	10.76±0.63	<0.0001
Change per day	-0.362±0.049	-0.404±0.036	0.867
Plateau day of year	242±2.6 (Aug 30)	256±2.4 (Sept 12)	0.001

Titratable acidity (TA) is the acid measure most closely associated with the perception of tartness in wine. While quality white wines rely on a certain level of acidity to provide freshness and balance, excessive TA can overwhelm other wine characteristics and result in a harsh profile.

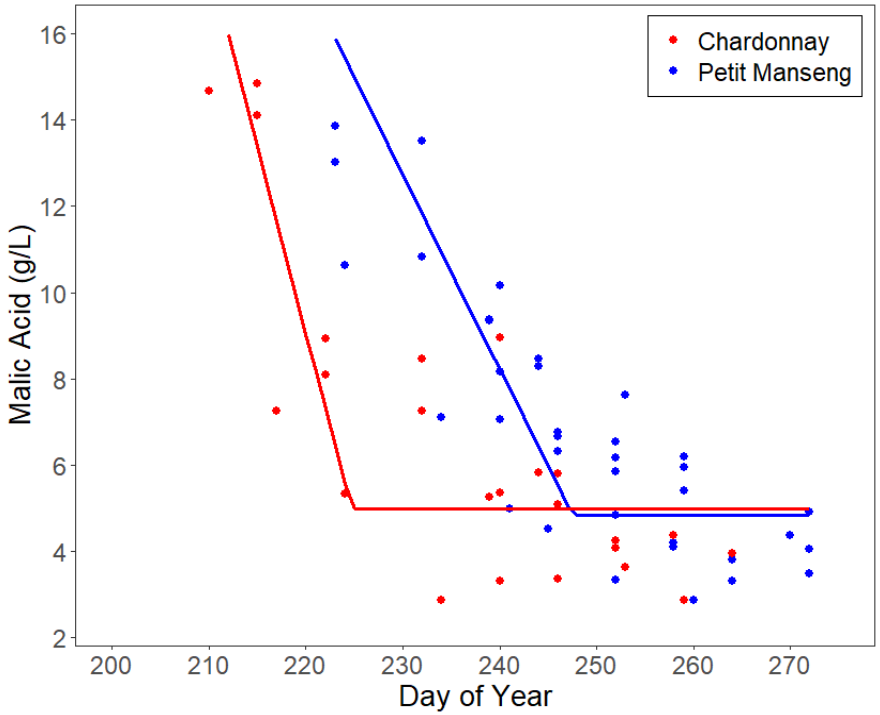
For white table wines, a TA of 7.0 – 9.0 g/L at harvest is considered optimal[10,11].

In Petit Manseng, titratable acidity plateaued at 10.3 g/L, a level that may lead to overly sour wine if fermented dry. That plateau was not reached until 6 days prior to harvest; at the end of sugar loading, the TA was prohibitively high (14 g/L).

This measure showed greater variability between vineyards/vintages than other metrics, with some sites and years producing less prohibitive values than others.

Return to Table of Contents

Malic acid was not higher in Petit Manseng than Chardonnay



R^2 = 0.90	Chardonnay	Petit Manseng	p-value
Plateau	4.99±0.52	4.84±0.51	0.882
Change per day	-0.821±0.08	-0.470±0.03	0.0004
Plateau day of year	Aug 13	Sept 4	<0.0001

Grapes contain several organic acids that contribute to TA, but the most important acids for wine quality are tartaric and malic acid. Both are formed early in berry development, then decrease after veraison, but depletion depends on different processes for each acid[6,12].

Determining if Petit Manseng acidity is driven by tartaric acid or malic acid (or both) may help producers adopt targeted strategies to mitigate the high acidity of Petit Manseng.

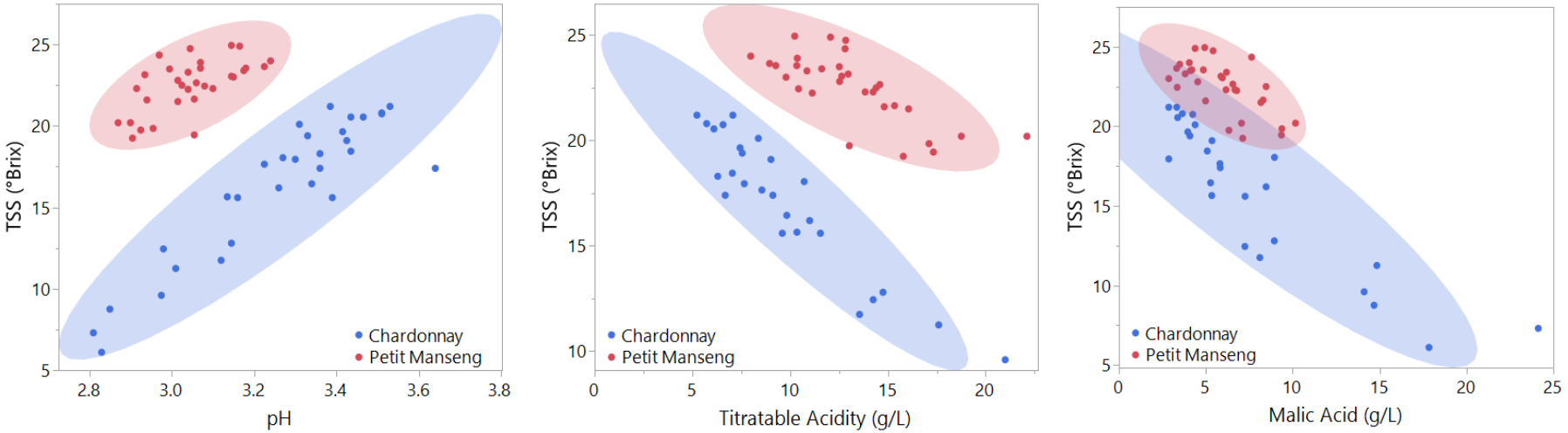
Though malic acid decreased at a faster rate in Chardonnay than Petit Manseng, both varieties reached a very similar minimum.

In Chardonnay, this minimum was reached 17 days prior to sugar plateau. For Petit Manseng, malic acid minimum was reached the same day as sugar plateau.

Return to Table of Contents

The difference in acidity was probably due to tartaric acid

Linear Discriminant Analysis (LDA) sorts combinations of variables to form groups. LDA correctly predicted grape variety with 100% certainty using only Brix & pH or Brix & TA, indicating acidity is definitely different between these two varieties. However, varieties could not be discriminated using Brix & malic acid. **This indicates that another acid (likely tartaric) is heavily influencing the separation.**



There are several characteristics of Petit Manseng that support the idea that tartaric acid heavily contributes to its high relative acidity.

- Tartaric acid is less impacted by environmental conditions than malic acid[13]. Petit Manseng has high acidity in both cold and warm vintages.
- The amount of tartaric acid per berry remains relatively constant post veraison, but the overall concentration decreases due to enlargement of the berry itself[12]. Because Petit Manseng berries are smaller (1.28 g/berry vs. 1.89 g/berry in Chardonnay), they remain at a higher concentration of tartaric acid.

Return to Table of Contents

Factors that contribute to balance in white wine

It is clear from these data that Petit Manseng will not produce a wine with the same chemical balance as Chardonnay, however, can it produce a balanced dry table wine? While it is difficult to define balance strictly in chemical terms, enologists and winemakers generally agree on certain guidelines.

Qualitatively, Zoecklein (2005)[14] described palate balance in an equation that expresses the inverse relationship between the perception of sweetness and the perception of acidity.

Sweetness ⟷ Acids + Phenols

Even in a dry wine, moderate ethanol and intense tropical fruit character add to perception of sweetness and body. When ethanol is present in excess, it can be "pungent" and bitter[15], offsetting this effect. Ripe fruit or spicy aromas also shift the balance to the left.

Acid balances sweetness, which keeps the wine from seeming too heavy or cloying. Both herbaceous/green aromas from less ripe fruit and acetic acid due to spoilage will also shift the balance to the right[14].

Petit Manseng contains high levels of components from both sides of the equation. While these components may balance one another, the equilibrium is delicate and easily tipped.

Return to Table of Contents

An equation for balance between acid and alcohol

Balancing the high sugar (and resulting alcohol) with the high acidity of Petit Manseng makes harvest decisions particularly challenging. Should fruit be picked early to avoid excessive alcohol, or left on the vine to allow acidity to decrease? In practice, a trade-off is often required.

Although fruit sampling numbers cannot directly predict whether Petit Manseng will yield a balanced dry wine, several guidelines can help. Metrics of sugar/acid balance have been defined as indicators of maturity for quality wine production, though caution is warranted when interpreting these values: ranges associated with quality vary across regions and are not always reliable indicators of varietal character[11,16]. Still, these measures provide useful benchmarks that can be assessed from fruit chemistry data and compared across vintages and sites.

Two of these metrics can be readily calculated from common fruit and juice analyses:

Brix × pH
Optimal Range: 220-260

Brix ÷ TA*
Optimal Range: 30-32
**TA is expressed in g/100mL*

Other guidelines to keep in mind when deciding when to pick Petit Manseng:

- Alcohol concentration above 13.5% can be perceived as hot/pungent or bitter, though this threshold is different in different wines[17]
- pH lower than 3.0 can stress yeast[8]
- Optimal TA for white wine is usually 7-9 g/L[9,10]

Unfortunately, Petit Manseng fruit chemistry in a given vintage or vineyard may never meet all these criteria. Additional interventions may be needed in the cellar to balance the wine.

Return to TOC

Predicting quality potential for Chardonnay and Petit Manseng

	Chardonnay		Petit Manseng	
	Physiol. Maturity	Plateau	Physiol. Maturity	Plateau
Day of year	241 (Aug 29)	244 (Sept 1)	247 (Sept 4)	262 (Sept 19)
°Brix	19.5	19.5	23.6	23.6
pH	3.33	3.44	3.00	3.16
TA (g/L)	7.49	7.13	13.99	10.76
°Brix * pH^2	224	231	212	236
°Brix / TA	26.0	27.3	16.9	22.0

This table shows the average value for acid and sugar balance (1) at the moment when sugar loading ended and (2) after all the values had reached a plateau. Neither Chardonnay nor Petit Manseng met all the criteria all the time. Chardonnay had lower sugar and higher pH than optimal. (The low values for °Brix / TA were likely due to low Brix.) On average, Petit Manseng had too low a pH at physiological maturity and too high of a TA at both timepoints.

Simply waiting it out will not fully address the high acidity of Petit Manseng, though some waiting time does improve pH and TA.

Return to Table of Contents

Some sites and vintages of Petit Manseng can produce quality dry wine

Taken together, these data indicate that not all vintages or vineyards may be appropriate for production of dry style Petit Manseng that meets traditional standards of wine balance.

However, some do.

Throughout the sampling periods:

- There were 9 occurrences of Chardonnay within the desired range of Brix*pH^2 while there were 11 occurrences of Petit Manseng in this range, with at least one occurrence per vineyard. **Petit Manseng provides better pH balance than Chardonnay.**
- There were only 4 sampling events that met the more stringent criteria based on TA. Three of these four were in Chardonnay. **Titratable acidity is a significant challenge for balanced Petit Manseng.**

To produce dry style wines, grapes may be harvested based on balance of Brix and pH, with winemakers employing cellar operations to mitigate high TA values.

Because TA is driven by tartaric acid in Petit Manseng, approaches such as skin contact, harder pressing, and potassium bitartrate precipitation may have the most impact.

These operations have limits, so grapes with excessively high TA may be better utilized for off dry or dessert wines, allowing residual sugar to balance high acidity.

Return to Table of Contents

A practical winemaking plan for dry Petit Manseng
Vineyard Sampling

Harvesting fruit and managing fermentation of Petit Manseng for dry table wine may feel like a juggling act, but careful winemaking can help overcome some of these challenges, resulting in a quality wine your customers will love.

Following are some practical steps to take based on the unique ripening characteristics of this grape variety.

Before harvest:

- Sample fruit weekly after veraison and compare sample values over time.
    - Because Petit Manseng accumulates sugar quickly, samples may need to be taken more frequently, especially close to harvest time.
    - By tracking changes over time, you can determine when the fruit has reached physiological maturity, and understand how quickly acidity is declining and Brix are rising at your site during the vintage.
- Include titratable acidity in your fruit chemistry measurements. Even if the pH is >3.0, the TA may still be prohibitively high. The WRE website has resources on how to measure TA if you need them.

Return to Table of Contents

A practical winemaking plan for dry Petit Manseng
Harvest & Processing

Harvest Decisions

Ideal harvest targets would be Brix < 24, TA<10, pH >3.0. However, it is very possible these metrics will not all line up. You will need to employ winemaking techniques to foster a healthy fermentation and balance acidity.

Pick as early as the pH and TA will allow.

- Due to rapid increase in Brix , even a few days earlier can make a difference for potential alcohol and yeast stress during fermentation.
- Picking later into physiological ripeness shifts to an unfavorable glucose:fructose ratio and probably leads to more intense tropical aromas.

Processing

- Consider pre-fermentation skin contact. Even a couple of hours of skin contact after de-stemming will release potassium that can remove tartaric acid. This may shift the TA into a more acceptable range. However, be careful to avoid oxidation during contact time.
- This is one time not to be too gentle with the press pressure if you want to maximize potassium found in grape skins. But be careful, as phenolics may also be extracted (and tip the balance again).

Return to Table of Contents

A practical winemaking guide for dry Petit Manseng
Fermentation Conditions

Fermentation Conditions:

Stress is cumulative. Several aspects of Petit Manseng chemistry may add yeast stress, increasing the potential for a difficult fermentation. Higher overall sugar accumulation leads to high potential alcohol. Long hang times lead to high fructose relative to glucose and pH <3.0 leads to yeast stress. Wherever possible, do what you can to moderate these and other stressors to help the yeast succeed.

Recommendations:

- Choose your yeast strain carefully.
  - A fructophilic yeast strain will help finish a fermentation with glucose:fructose < 1.0. Even if this is not your primary yeast, have a restart yeast on hand for a second inoculation if the fermentation slows well before completion.
  - The yeast should also be tolerant to high alcohol and low pH. Each of these conditions can be stressful on its own. Taken together, they need a powerhouse yeast strain.
- Keep the yeast as healthy as possible.
  - Careful nutrient management includes complex nitrogen additions at 2-3° Brix depletion (to increase cell density) and 1/3 Brix depletion (to replenish sugar transporting proteins)[18]
  - Maintain fermentation temperature within the tolerance limit of the yeast strain[4].
- Warmer temperature at the end of fermentation may also increase yeast capacity to uptake fructose[5].

Return to Table of Contents

A practical winemaking guide for dry Petit Manseng
Lessons from Previous WRE Trials

Other lessons learned through WRE Trials:

In addition to understanding ripening kinetics in Petit Manseng, the WRE has sponsored many other practical experiments with this variety, most of which focused on making balanced dry style wine. Following are recommendations from those trials:

- In 2019, three different wineries (Hark Vineyards, Early Mountain Vineyards, and Tarara Winery) harvested Petit Manseng at 2 or 3 different levels of ripeness, making wine from each harvest. Based on chemistry and sensory results, two of the three sites had at least one harvest with balanced acidity and alcohol while one site did not. The window for optimal harvest time may be narrow. (Published in the Grape Press).

- Though the excessive acidity is likely due to tartaric acid, malic acid still contributes.
  - Selected yeast strains have been shown to consume malic acid during fermentation, reducing TA and increasing pH (King Family Vineyards, Walsh Family Wine)
  - To date, experiments seeking to put Petit Manseng through malolactic fermentation have not been successful. Anecdotally, winemakers that have found success with this approach advise using no SO_2 at crush and allowing ambient fermentation to occur. *Be advised, these can be very long fermentations!*

- Hyperoxygenation of juice may improve fermentation kinetics without impacting aromatics.

- If chemistry is too extreme juice dilution is an option for completing fermentation, but diluting sugar also dilutes flavor.

Return to Table of Contents

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Return to Table of Contents