

The Effects of Lallemand LaVigne™ Mature on Syrah Grapevines in the Gimblett

By:

Fran Creighton
2018000138

Supervised by:
Chandre Honeth

A report submitted in partial fulfillment of the requirements for the degree:

BACHELOR OF WINE SCIENCE and BACHELOR OF VITICULTURE

Eastern Institute of Technology – Hawke's Bay

October 2020

Abstract

LalVigne Lallemand Mature was designed to aid in the ripening problem NZ is facing due to the increasing temperatures of climate change, it was designed to increase and develop phenolics in grapes, all while keeping brix, pH and TA the same. In this investigation, a uniform trial and a uniform control area were arranged on Syrah grapevines in a vineyard in the Gimblett Gravels of Hawkes Bay, the product, Lallemand Mature was applied twice, with one application at the beginning of veraison, and another 9 days later. The aim of this experiment was to determine the effect of Lalvigne Lallemand Mature on Syrah grapevines in the Gimblett Gravels, specifically phenolic content. Fortnightly samples were taken and analyzed, resulting in berry weight, brix, pH, TA, and phenolic data being recorded and studied, the findings of this investigation were; there were no significant differences between the Lallemand Mature treated vines and control vines for berry weight, brix, and anthocyanins. It was found that for phenolic content, pH, and TA there was some significant difference between the Lallemand Mature treated samples and control samples, however, these differences were each only recorded for one date and was rather small, leaving the rest of the data with no significant differences. It was concluded that Lallemand Mature did not have a significant affect on any berry parameters in this investigation and more investigation into this product will be needed.

Introduction

Climate change is becoming a big problem for viticulture in NZ and all over the world, as the increasing temperatures are creating ripening problems, particularly in reds. These ripening problems are because the increasing temperatures are causing the sugar levels in the berries to increase rapidly, faster than other important parameters in grapes. This leads to unbalanced wines, with poor colour, poor acids, and high alcohol, creating problems for both the viticulturist and the winemaker. Furthermore, high temperatures for long durations can cause anthocyanin accumulation to become inhibited, further deteriorating the wines balance and quality. A product developed by LalVigne, was created to battle this problem - Lallemand Mature. Lallemand Mature is a yeast derived foliar spray, designed to increase phenolic content and maturity, while brix, pH and TA remain unaffected. In this investigation, Lallemand Mature is applied to Syrah grapes in the Gimblett Gravels to test the products ability to improve phenolics, a trial area and a control area are sprayed and analyzed to determine Lallemand Matures' working ability.

Literature Review

Introduction

Hawkes Bay is New Zealand's second-biggest wine region, and the history of wine dates back to 1851 when the first vines were planted. The vineyard area is 4678 ha in this region and is used to produce 10% of NZ wine. This region has a good reputation internationally and is recognized mainly for its high-quality reds and some aromatics whites. An important area within this region is called Bridge Pa and produces many fine reds, it is found inland and was formed over thousands of years by the forever changing Ngaruroro River which has left red metal, free-draining alluvial soils as well as gravel and stony terraces - desirable land for a viticulturist. (*Hawke's Bay - New Zealand Wine, 2020*).

The Climate of the Hawkes Bay region is very sunny and hot, which results in a long growing season, the surrounding hills provide protection from the wind, however, frost can be an issue in some areas. There is an average of 2188 annual sunshine hours and an average of 803mm of annual rainfall. (*Hawke's Bay - New Zealand Wine, 2020*).

The soil of Hawkes Bay, in particular Bridge Pa, consists of old soil that is free-draining, has low fertility, alluvium deposits or eroded ash, loess, and underlying sediments. (*Hawke's Bay - New Zealand Wine, 2020*).

Syrah is a cultivar that is well suited to this region because it requires hot, long, sunny days to grow and ripen its thick skin, it also tends to grow well with the bridge pa styled soil types, this makes it potentially unique and premier wine for Hawkes Bay. (*Syrah - New Zealand Wine, 2020*).

NZ Syrah

The NZ Syrah tends to have bright, spicy flavors with elegant textures, and the wine is packed with strong, beautiful plum and savory black pepper flavors. The ideal NZ Syrah has no noticeable herbaceous characters so full, proper ripening is important. (*Syrah - New Zealand Wine, 2020*).

However, viticulturists are struggling with the uneven and lengthy-time required for proper ripening of the fruit, Syrah grapes require hot days and warm nights, as well as enough berry development time to be adequately ripened, and have the desired level of brix, pH, and TA. (*Syrah - New Zealand Wine, 2020*). Viticulturists are forced to choose between harvesting fruit that is higher than the desired brix, with optimum acids, color development, and phenolic maturity or fruit that has the optimum amount of sugar but has undesirable acids and underdeveloped color and phenolics. (Pastore et al., 2020). This is because of the ever-changing climate due to climate change, the warming weather accelerates ripening, increasing sugars and therefore alcohol, leading to unbalanced wines having low acid, poor

color, and high alcohol, as well as uncompleted phenolic maturity. This is the problem that LaVigne Lallemand Mature is designed to overcome - aiding and assisting the development and maturation of phenolics to keep up with the quickening of berry ripening due to increasing temperatures of climate change. (Pastore et al., 2020).

Ripening stages

There are three main stages of berry ripening, stage 1 - berry formation, stage 2 - lag phase, stage 3 - veraison, and ripening. (Urska, 2017)

Stage 1 - berry formation: (Duration of 40 - 60 days) In this stage berry size increases due to cell division and enlargement, the berries remain green and hard and have very low sugar content. Organic acids accumulate, with tartaric acid forming mainly in the skin and malic acid forming mainly in the flesh, tannins accumulate in this stage too and form in the skins and seeds. (Urska, 2017)

Stage 2 - lag phase: (Duration of 7-40 days) In this stage berry growth slows or completely stops so that all the vines energy can focus on seed development, seed embryos rapidly grow and will reach full size. Berries have low sugar content still but the acids and tannins reach their peak. (Urska, 2017).

Stage 3 - Veraison and berry maturation: (Duration of 35-55 days) This is the third and final stage of berry development, in this stage the berries ripen and begin to soften, the color pigments in red varieties accumulate in the skin, sugar content builds, aroma and flavors become apparent. The concentration of organic acids decreases and berry size increases due to the enlargement of cells. When the sugar content (brix), pH, and aroma and flavors are at their desired level, the harvest will begin. (Urska, 2017).

Ripening problems are typically found during the third development stage. (LaVigne, 2017)

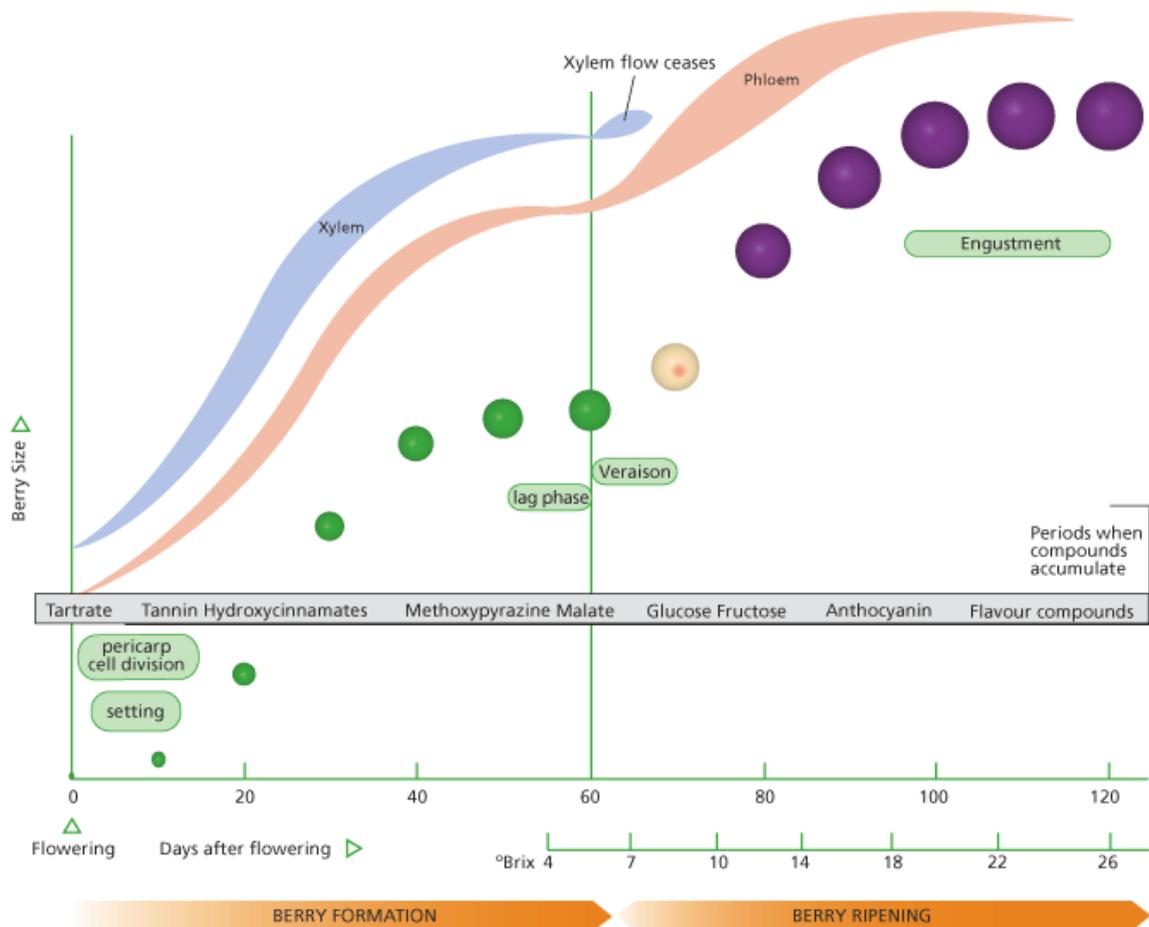


Figure 2: Diagram showing relative size and color of berries at 10-day intervals after flowering, passing through major developmental events (rounded boxes). Also shown are the periods when compounds accumulate, the levels of juice 'brix', and an indication of the rate of inflow of xylem and phloem vascular saps into the berry. Illustration by Jordan Koutroumanidis, Winetitles.

Figure 1 - Berry formation & ripening (Urska, 2017)

Brix

Grape sugar content (mainly sucrose) is measured in brix and indicates the degree of ripeness so the winemaker knows when to harvest, as ripeness increases, brix increases. (*Brix – Grapes*, 2019). Each degree of brix equals 1 gram of sugar per 100 grams of grape juice. To measure brix a refractometer is used - a handheld instrument that measures dissolved sugar in a small grape juice sample. Most Syrah grapes are harvested between 23 and 26 brix. (*Brix – Grapes*, 2019).

pH

pH in winemaking is a measure of the strength and concentration of acid in the juice or wine,

and this can be measured throughout the grape-growing season (ripening in particular) and winemaking. (*Acidity and PH*, 2017) It has effects on wine stability, tartrate salts, sulfur dioxide, proteins, color, and oxidation. As ripening increases, the pH increases because the berries become less acidic, the optimum pH for harvesting syrah is between 3.3 - 3.8. (*Acidity and PH*, 2017)

TA

The titratable acid (TA) in wine/grape juice is a measure of all organic acids, mainly tartaric and malic. (Fawkes, 2015). There is a specific level that winemakers desire to get the flavor combination they are searching for, so during ripening TA is a parameter that is constantly observed. Typically, as ripening increases, TA decreases. The desired TA level for Syrah is 5-6.5 g/L. (Fawkes, 2015).

Phenolics

Phenolic compounds consist of a phenyl ring backbone with a hydroxyl group attached and in wine affect the taste, color, mouthfeel, and produce antioxidant properties. Plants produce phenolics because they have important roles in making color pigments, antioxidants, and lignan, and have roles in plant processes such as signaling, electron transport, communication, and defense mechanisms. (Girelli et al., 2015, p. 1879) Phenolics can be broadly separated into two categories; flavonoids and non-flavonoids. Non-flavonoids include the stilbenoids such as resveratrol and phenolic acids, and flavonoids include anthocyanins and tannins which contribute to the color and mouthfeel; (Girelli et al., 2015, p. 1879)

Anthocyanins

Anthocyanins are responsible for the colour in Syrah, and develop during stage three of ripening, as ripening increases, anthocyanins increases. Anthocyanins are found in the skins which is why to get colour pigmentation in the overall wine, skin contact is essential (Girelli et al., 2015, p. 1879). Anthocyanin compounds are sensitive to thermal increases, therefore, high temperatures for long periods of time can cause a reduction in the accumulation of anthocyanins, thus why climate change has caused ripening problems. (Pastore et al., 2019). High temperatures for long periods of time decrease the synthesis that triggers anthocyanin development and accumulation, Lallemand Mature aids this problem by inducing synthesis of anthocyanins, diminishing this problem. (Pastore et al., 2019)

Tannins

Tannins are chemical compounds that are originally found in the skin, seeds, and stems of grapes and can be introduced into the wine during winemaking procedures that include the

addition of oak. (Girelli et al., 2015, p. 1879). Tannins affect the colour, aging ability, and the texture/mouthfeel of the wine, and have no smell or taste but add a drying sensation in the mouth and a sense of bitterness - this is because the tannins react with the proteins in your mouth, and have a direct relationship with the astringency of wine, as tannin levels in wine increase, so do astringency. The amount of tannins found in wine depends on the variety, with Syrah being among the most tannic grape varieties. (Girelli et al., 2015, p. 1879)

How Phenolics increase in grapevines

To understand how phenolics increase naturally in grapevines, it is important to understand the basic biosynthesis of phenolics and why plants produce them in the first place. Phenolics are produced via the shikimate pathway, localized in the chloroplast, this pathway is responsible for producing amino acids such as phenylalanine, tyrosine, and tryptophan. (Francenia Santos-Sánchez et al., 2019). These aromatic amino acids are precursors for secondary metabolites such as phenolic compounds. This pathway is triggered by the plant so phenolic compounds can be synthesized when they are needed. (Francenia Santos-Sánchez et al., 2019).

Factors that induce synthesis

- Biotic stress (stress caused by herbivores or pathogens) (Francenia Santos-Sánchez et al., 2019).
- Abiotic stress (unfavorable temperatures and pH, saline, high levels of UV) (Francenia Santos-Sánchez et al., 2019).

Elicitors (molecules that trigger a physiological response) cause abiotic or biotic stress to the vine through a release of a reactive oxygen species, thereby inducing synthesis that stimulates the activation of secondary metabolism compounds, most importantly, phenolics - this is how LalVigne Lallemand Mature works, it acts as an elicitor. (Pastore et al., 2019). The product is exogenously applied to the vine, the vine perceives this applied product as a pathogen attack which triggers a plant stress response, inducing phenolic production. (Pastore et al., 2019). The Lallemand Mature induced stress causes a number of defense genes to activate and/or inhibits the activation of non-defense related genes which affect proteins and enzymes involved in many different biosynthetic pathways of secondary metabolites, stimulating a variety of plant responses, the main response being, phenolic accumulation. (Pastore et al., 2019).

Lallemand Mature:

LalVigne Lallemand Mature is an organic foliar spray for grapevines, in which a natural inactive yeast from the *Saccharomyces Cerevisiae* Lallemand yeast collection is used.

(LaVigne, 2017). Two applications are required, one at 5% veraison, and a second 10-12 days later. (LaVigne, 2017). The purpose of this spray is to improve and enhance phenolic maturity in grapes, it does this by; increasing the concentrations of extractable anthocyanins, increasing skin tannin, increasing the degree of polymerization, increasing skin thickness, reduction of herbaceous/aggressive character, while unaffected other berry parameters such as brix, pH and TA. (LaVigne, 2017).

Lallemand mature has been developed to assist with ripening problems, in particular, the Syrah ripening problems explained above. In vineyards that are prone to inadequate ripening, Lallemand mature can be applied to assist with veraison so that the grapes will ripen as desired. (LaVigne, 2017). Lallemand Matures' mode of action is that it acts as an elicitor (explained above).

There have been a small number of previous trials in which Lallemand Mature has been used to address this ripening problem, some having positive results where phenolics have increased, and some had negative results, where phenolics have not increased. Research papers that have found success with this specific product include; a study performed by (Villangó, Pásti, Kállay et al., 2015)., In which Lallemand Mature was applied on Syrah vines over two vintages (2012 and 2013) in a cool-climate wine region (Eger, Hungary), the conclusion of this study was that the phenolic potential was greatly improved by Lallemand Mature. Another study by (Crupi et al., 2021) experimented with Lallemand Mature on red table grapes in the Mediterranean basin and found that all grapes treated with Lallemand Mature had increased phenolics and anthocyanins.

Some examples of research papers which have had unsuccessful or varied results include a study from Pastore et al. (2019) in which LaVigne Lallemand Mature was applied to potted Sangiovese vines over two years (2016 and 2017) in Italy, the product was applied as per the instructions and it was found that in one of the years Lallemand Mature had increased anthocyanins in some of the results, however in the other year (which had similar climate and no significant new variables) there was no difference between the trial and control samples. This study also found (in agreement with other studies and LaVigne) Lallemand Mature had no effect on other berry parameters such as; brix, pH, and TA. Another study by (Kogkou et al., 2017, p. 29) applied LaVigne Lallemand Mature on Agiorgitiko grapes in southern Greece and found that it had not affected any berry parameters, nor phenolics or anthocyanins in their investigation.

There is a lot of varied, contradicting research on Lallemand Mature as a foliar spray when applied to improve phenolic and anthocyanin concentration and maturity.

Other trials using yeast derivative foliar sprays with the same/similar mode of action have also been explored;

Many studies have shown that the addition of yeast to soil/plants have increased nitrogen and phosphorus content, (Lonhienne et al., 2014, p. 788) applied yeast to tomato and sugar cane plants and found that 'The addition of live or dead yeast to fertilized soil substantially increased the nitrogen (N) and phosphorus (P) content of roots and shoots of tomato (*Solanum Lycopersicum*) and young sugarcane plants.' Many other reports have similar findings, with various plants - including grapevines. (Portu, López, Baroja, Santamaría, & Garde-Cerdán, 2016), Studied the effects of a foliar treatment containing methyl jasmonate and a yeast extract and found that grape and wine anthocyanin content increased, and an application of yeast increased grape stilbene content. A study from (Giacosa, Ossola, Botto, Segade, Paissoni, Pollon, & Rolle, 2019). Showed that grapevines treated with an application of inactive dried yeast had increased berry thickness making grapes more resistant to skin damage (physical and/or pathogenic attacks), in some cases but not all, the accumulation of anthocyanins increased. A study by (Pastore et al., 2020) was performed in which a commercial yeast foliar spray was applied to potted Sangiovese vines at the beginning and at the end of veraison over three consecutive years, in this study they found that there was no significant difference between any berry parameters, including brix, pH, TA, and phenolic content.

Much the same as Lallemand Mature, there is a lot of varied, contradicting research on yeast-derived foliar spray when applied to improve phenolic and anthocyanin concentration and maturity.

The objectives of this study are to determine the effects of Lallemand Mature on Syrah grapevines, by investigation the effects on berry weight, brix, pH, TA, anthocyanins and phenolics.

Materials and Methods

Aim & Hypothesis

The aim of this experiment is to determine the effect of Lalvigne Lallemand Mature on Syrah grapevines in the Gimblett Gravels, specifically phenolic content.

- NULL Hypothesis - Lallemand mature will not affect berry parameters such as; berry weight, pH, TA, Brix, and phenolics.

- ALTERNATIVE Hypothesis - Lallemand mature will affect berry parameters such as; berry weight, pH, TA, Brix, and phenolics.

Site Information

The samples were taken from Syrah grapes in a vineyard in the Bridge Pa area in Hawkes Bay New Zealand, see map below.

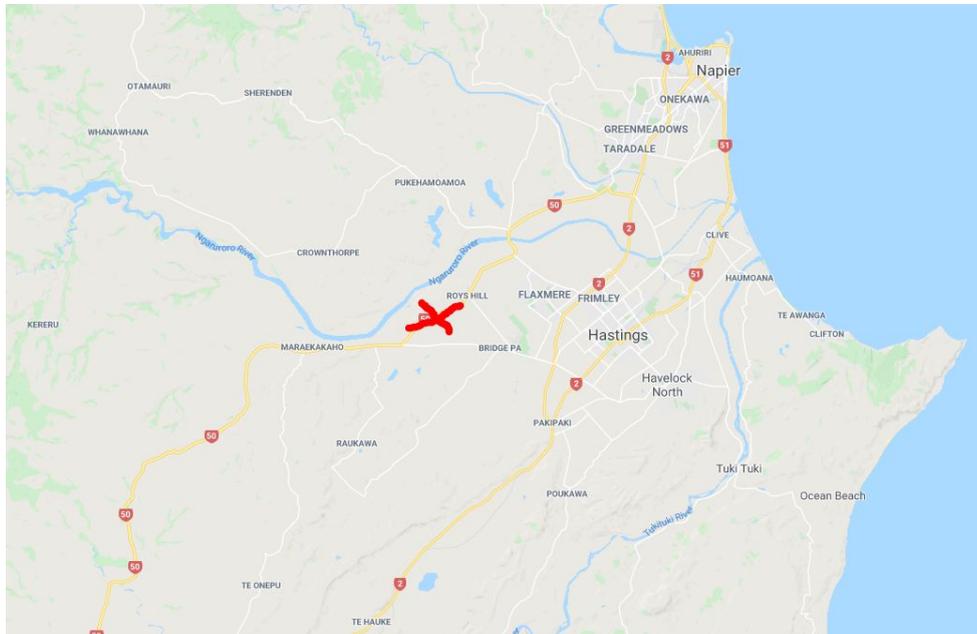


Figure 2 - Map of Hawkes Bay



Figure 3 - Map of site

This site has uniform grounding with the same soil type (alluvial gravel soil), same vine age (7 years), clone (Syrah clone 470), irrigation zone, rootstock (Schwartzman), and vine healthiness - minimizing error due to potential variables.

Sampling information

Set up:

There are 4 rows of trial and 4 rows of control separated by 1 row to ensure there is no cross-contamination (see diagram below). These rows have been selected because they are in a uniform area with the same soil type, same vine age, clone, irrigation zone, rootstock, and healthiness. Sampling is carried out in the middle 2 rows to ensure the full application of the trial product in the trial area, and no contamination from the product in the control area. Other than the differing treatments, these two areas have been treated the exact same way viticulturally before and after spray trials.

Spraying:

Lallemand Mature spray was applied at a rate of 2 x 1 Kg/ha, it was diluted to about 10 times its weight in water to put in suspension. It was applied firstly on the 4/2/2020, and then a second application was applied in the afternoon of the 13/02/2020. The first samples were taken on the morning of 13/02/2020.

Sampling:

Berry samples were taken randomly from 5 bays tagged in the trial area, and 5 bays tagged in the control area (see diagram), 100 berries are taken from each bay and bagged separately. This is a total of 1000 berries, 500 from the control area, and 500 from the trial area.

The first berry sample was taken approximately 1 week after the first application on the 13/02/2020, then once a fortnight following until the 19/03/2020.

Immediately after the samples were taken, they were taken to the lab where half of the berry samples were used to test berry weight, brix, pH, TA, and sensory characteristics and recorded. The other half of the berries were labeled and frozen in the -80 degree chiller until all berry samples had been completed, then they were used in a detailed phenolics analysis.

At harvest, 150 berries were meant to be taken from each bay and brix, TA, pH, phenolics, total anthocyanins, organic acids, and yield to be recorded - This did not happen due to coronavirus, so the last berry sample took place on the 19/03/2020.

Lallemand Mature Spray Trials Map

Treatment - PINK

494

495 - Bay 2 (yield - Vine 1 & 3), Bay 7 (yield - Vine - 2 & 3)

496 - Bay 3 (yield - Vine 1 & 4), Bay 4 (yield - Vine 1 & 3), Bay 9 (yield - Vine 1 & 2),

497

Control - ORANGE

499

500 - Bay 2 (yield - Vine 1 & 3), Bay 4 (yield - Vine 2 & 4), Bay 6 (yield - Vine 2 & 3)

501 - Bay 3 (yield - Vine 1 & 3), Bay 7 (yield - Vine 2 & 3)

502

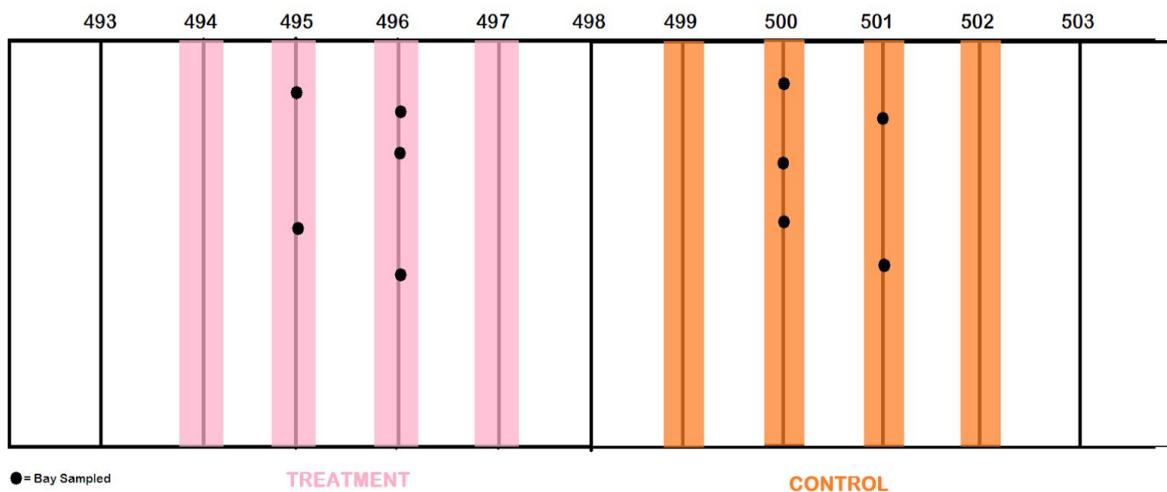


Figure 4 - Diagram of setup.

Chemical Analysis

Each week half of the berries were analyzed and the other half was frozen in the -80 degree chiller. The half that was analyzed arrived at the lab immediately after the samples were picked, and the analyzing procedure was as follows;

BERRY WEIGHT:

Each bag was weighed and counted to ensure the bag contained 50 berries. This weight was recorded and divided by 50 to get the average berry weight.

BRUX:

The berries were crushed in their individual bags and strained into a clean beaker to remove large solids. A drip from each bag was placed on a clean, calibrated digital refractometer using a dripper, and brix was recorded

pH & TA:

Juice from each bag was put into a centrifugal tube, labeled, and put into the centrifuge for 4 minutes at 100% RPM. The juice was poured off solids into test tubes and placed into a labeled test tube rack that went into the autotitrator. This measured pH and TA which were then recorded.

Phenolics:

The berries were counted to ensure there were 50 berries, rebagged and labeled with trial/control and bay number then immediately placed in -80 degree chiller until all berry samples have been collected to analyze.

Once all berries have been collected, they were removed from the freezer the night before the phenolic analysis. Phenolics were analyzed according to the method from (Iland et al., 2013)

Statistical analysis

All raw data was put into excel, the average and standard deviation were found for each set of data, using excel's technology. Line graphs with error bars were created in excel for each parameter, these graphs used the raw data and the calculated standard deviation for the error bars - the graphs were titled; 'The Effects of Lallemand Mature on Berry Weight', 'The Effects of Lallemand Mature on pH, TA & Brix', 'The Effects of Lallemand Mature on Anthocyanins and Total Phenolics', all graphs were given axis labels, and formatted to produce easy-reading, logical graphs.

T-tests were performed in excel for all the phenolic data, a table summarizing this was made, and any significance was highlighted. The berry weight, pH, TA, and brix data were put into Jasp (version 0.9.2) and an ANOVA and post hoc test was performed, and any significance was highlighted, added to the excel graphs as stars above the respective date, and then discussed in the results section. All relevant graphs/tables/tests were copied over & included in the results section and discussed.

Results

An ANOVA and Post Hoc test was performed on the berry weight to test if there was any significant difference between the trial and control samples. It was found that there was no

significant difference between the berry weight of trial and control samples. Lallemand Mature did not significantly affect berry weight in this investigation.

An ANOVA and Post Hoc test was performed on the brix to test if there was any significant difference between the trial and control samples. It was found that there was no significant difference between the brix of trial and control samples. A T-test was also performed on the brix and found there was a slight significant difference, in which the treated berries had a higher brix - this difference is so small that one test picked it up and the other didn't. Lallemand Mature had a varied affect on brix in this investigation.

An ANOVA and Post Hoc test was performed on the pH to test if there was any significant difference between the trial and control samples. It was found that there was a significant difference (* p < .05) on the 12/03/2020 between the pH of the trial samples and the pH of the control samples, however, on the remaining dates there was no significant difference between the pH of the trial and control samples. The effect of Lallemand Mature was variable on pH in this investigation.

An ANOVA and Post Hoc test was performed on the TA to test if there was any significant difference between the trial and control samples. It was found that there was a significant difference (* p < .05) on the 14/02/2020, between the TA of the trial samples and the TA of the control samples, however, on the remaining dates there was no significant difference between the TA of the trial and control samples. The effect of Lallemand Mature was variable on TA in this investigation.

Table 1 - T-Test on the total phenolics per gram berry weight, and Color per gram berry weight

Date	Color per gram berry weight	Total phenolics per gram berry weight
27/02/2020	0.7916615317	0.03327923887
12/03/2020	0.7425077683	0.724459814

A T-Test was performed on the total phenolics per gram berry weight to test if there was any significant difference between the trial and control samples. It was found that there was a significant difference (T = 0.03327923887) on the 27/02/2020, between the total phenolics per gram berry weight of the trial samples and the total phenolics per gram berry weight of

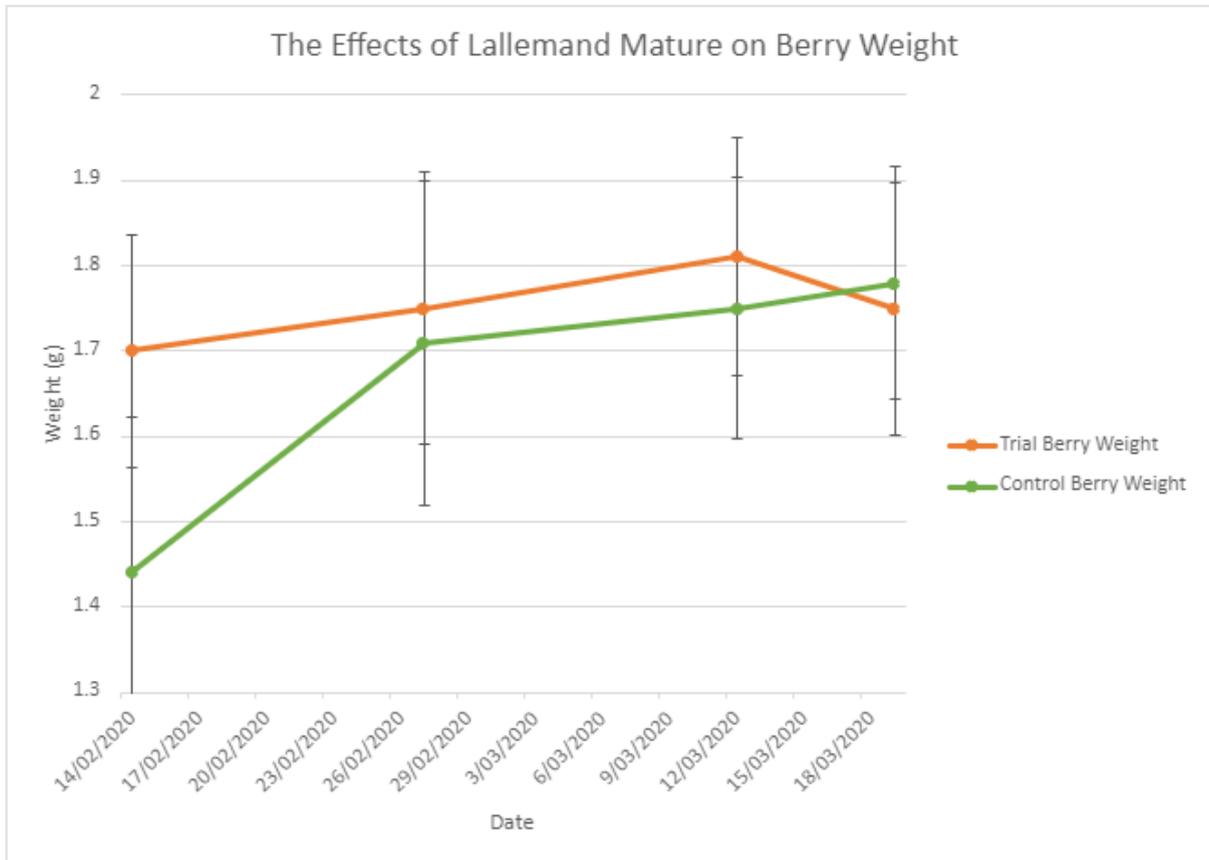
the control samples, however, on the remaining dates, there was no significant difference between the total phenolics per gram berry weight of trial and control samples. Lallemand Mature was variable on total phenolics per gram berry weight in this investigation.

A T-Test was performed on the Colour per gram berry weight to test if there was any significant difference between the trial and control samples. It was found that there was no significant difference between the Colour per gram berry weight of trial and Colour per gram berry weight control samples. Lallemand Mature did not significantly affect Colour per gram berry weight in this investigation.

Table 2 - Change in average color per gram berry weight for trial and control over time and the change in average total phenolics per gram berry weight for trial and control over time

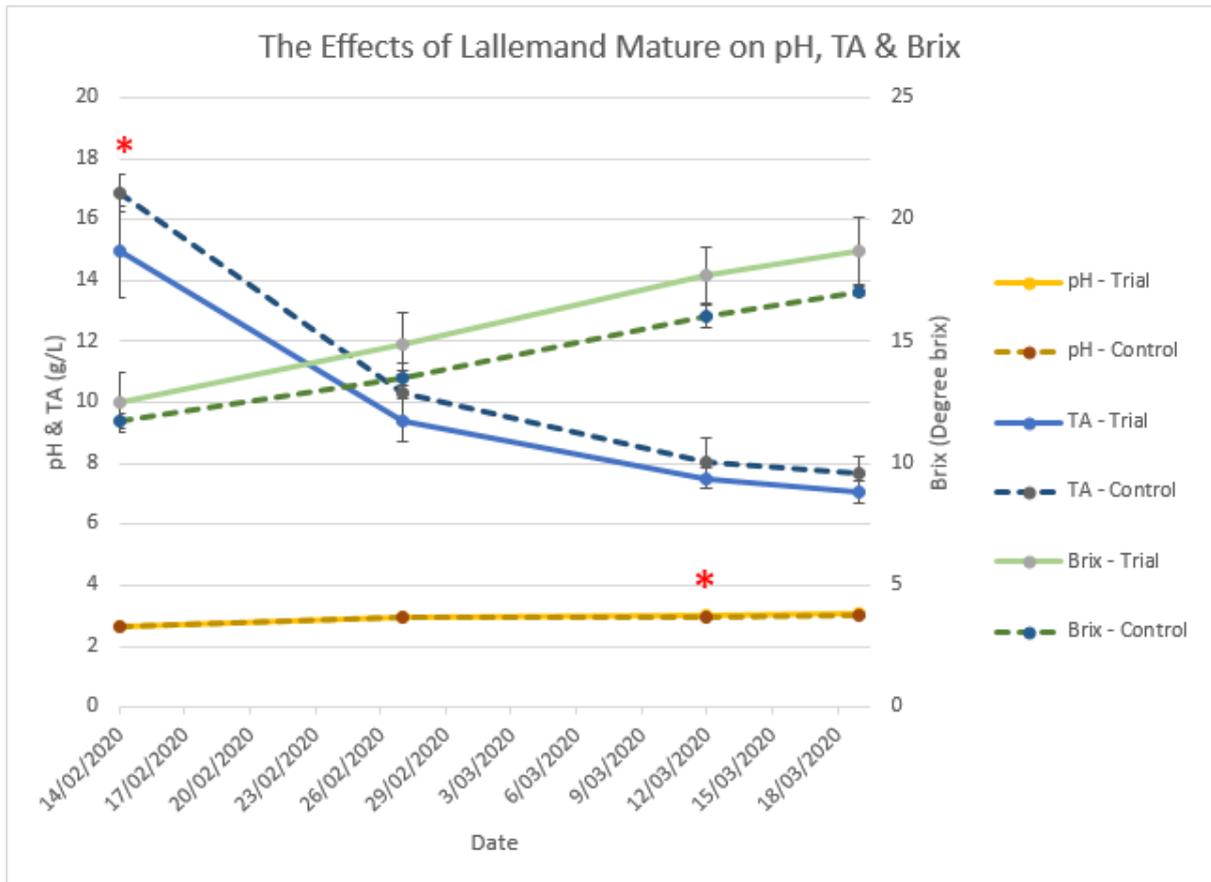
<i>Change over time</i>	<i>Average colour per gram</i> (mg anthocyanins/g berry weight)	<i>Average Total phenolics per gram</i> (au/g berry weight)
Trial	0.311592947	0.148915003
Control	0.264964923	0.066348129

This table shows the change in average color per gram berry weight for trial and control over time and the change in average total phenolics per gram berry weight for trial and control over time. For both 'average color per gram berry weight' and 'average total phenolics per gram berry weight' the trial had a larger change over time, meaning it increased more and had a steeper gradient.



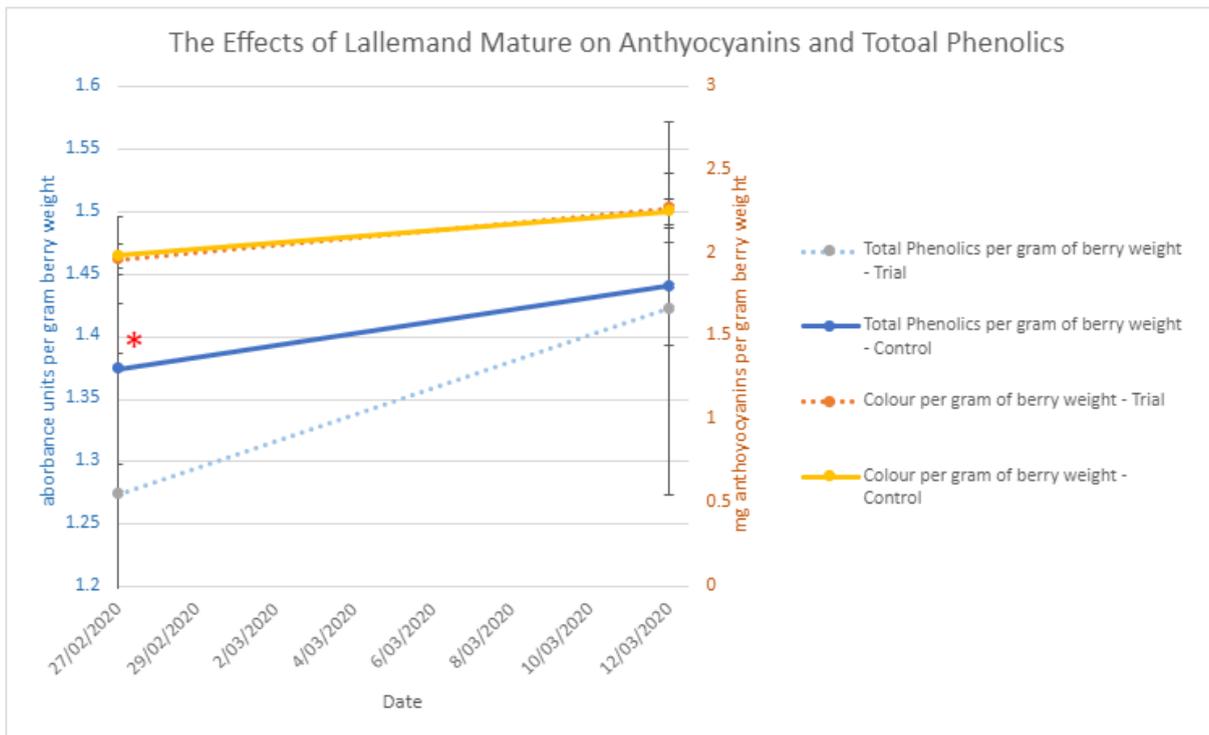
Graph 1 - The Effects of Lallemand Mature on Berry Weight.

The graph 'The Effects of Lallemand Mature on Berry Weight' shows that berry weight varies both for control and trial, however, they both increase over time, with no real trends.



Graph 2 - The Effects of Lallemand Mature on pH, TA & Brix.

The graph 'The Effects of Lallemand Mature on pH, TA & Brix' shows that for pH, they (control and trial) increase over time at similar rates. The graph also shows that for TA, they both decrease over time with similar gradients. The graph also shows for brix, they both increase over time at similar gradients. This was all expected as these are common trends for the ripening of Syrah.



Graph 3 - The Effects of Lallemand Mature on Anthocyanins and Total Phenolics.

The graph 'The Effects of Lallemand Mature on Anthocyanins and Total Phenolics' shows that for color per gram of berry weight, both the trial and control increase overtime with similar gradients. For total Phenolics per gram of berry weight control and trial begin being far apart, then over time get closer together. Control begins with having a higher total Phenolics per gram of berry weight than the trial, and then increases slightly, and trial increases dramatically over time.

Discussion

Berry Weight:

It was found that there was no significant difference between the berry weight of trial and control samples. Lallemand Mature did not significantly affect berry weight in this investigation. This was expected as in the Lallemand Mature catalog (LaVigne, 2017) it was stated that it would not affect berry weight. There were little to no studies correlating berry weight and Lallemand mature. The null hypothesis is accepted - Lallemand Mature had no significant effect on berry weight or the development of the berry.

Berry Primary Metabolism

Brix:

It was found that there was no significant difference between the brix of trial and control samples in the ANOVA and a slight significant difference in the T-test, in which the treated

berries had a higher brix - this difference is so small that one test picked it up and the other didn't. Lallemand Mature had a varied affect on brix in this investigation.

It was also stated in the Lalvigne catalog (LalVigne, 2017) that brix will be unaffected by the product. A study by (Pastore et al., 2020) was performed in which a commercial yeast foliar spray was applied to potted Sangiovese vines at the beginning and at the end of veraison over three consecutive years, in this study they found that there was no significant difference between the brix of the control and brix of the trial - supporting the results in this investigation. There were no found studies correlating brix and Lallemand mature or any yeast-derived foliar spray. Based on the ANOVA the null hypothesis is accepted - Lallemand Mature had no significant effect on brix, however the T-test showed some difference so overall it was inconclusive.

pH:

It was found that there was a significant difference on 12/03/2020 between the pH of the trial samples and the pH of the control samples, however, on the remaining dates, there was no significant difference between the pH of the trial and control samples. On 12/03/2020 it was found that trial samples had an average pH of 3.05, and the control samples had an average pH of 2.98, an ANOVA and post hoc test was carried out to show that there was a statistically significant difference between these results - showing that the trial samples had a significantly higher pH than the control sample. It is stated in the Lalvigne catalog (LalVigne, 2017) that pH will be unaffected by Lallemand Mature, so these results were unexpected. In a study by (Pastore et al., 2020) that is explained above, they found that there was also no significant difference between the pH of the control and pH of the trial. These results could be because of random error or chance - as this is only for one date, this is only one year worth of trials and through research, found literature does not support the claim that pH and Lallemand mature are correlated, therefore, there is not enough information or data to prove that pH is affected by Lallemand Mature. The null hypothesis is accepted - Lallemand Mature did not significantly affect pH in this investigation.

TA:

It was found that there was a significant difference on 14/02/2020, between the TA of the trial samples and the TA of the control samples, however, on the remaining dates, there was no significant difference between the TA of the trial and control samples. On 14/02/2020 it was found that trial samples had an average TA of 14.965 g/L, and the control samples had an average TA of 16.875 g/L, an ANOVA and post hoc test was carried out to show that there was a statistically significant difference between these results - showing that the trial samples had a significantly lower TA than the control sample. It is stated in the Lalvigne catalog (LalVigne, 2017) that TA will be unaffected by Lallemand Mature, so these results were unexpected. In a study by (Pastore et al., 2020) that is explained above, they found

that there was also no significant difference between the TA of the control and TA of the trial. Again, these results could be because of random error or chance - as this is only for one date and this is only one year's worth of trials, there is not enough information, data, or other research to prove that TA is affected by Lallemand Mature. The null hypothesis is accepted - Lallemand Mature did not significantly affect TA in this investigation.

Total phenolics per gram berry weight:

It was found that there was a significant difference on the 27/02/2020, between the total phenolics per gram berry weight of the trial samples and the total phenolics per gram berry weight of the control samples, however, on the remaining dates, there was no significant difference between the total phenolics per gram berry weight of trial and control samples. On 27/02/2020 it was found that trial samples had an average total phenolics per gram berry weight of 1.27 au/g berry weight, and the control samples had an average total phenolics per gram berry weight of 1.37 au/g berry weight. An ANOVA and post hoc test was carried out to show that there was a statistically significant difference between these results - showing that the trial samples had a significantly lower total phenolics per gram berry weight than the control sample. It was also found that the trial had a larger change/increase in total phenolics per gram berry weight over time, meaning it increased more and had a steeper gradient - this could indicate that perhaps more applications of the product would show better results, as the trial phenolics could keep increasing and as a result be significantly higher than control samples. It would have been useful to start sampling earlier as the control and trial areas may have begun this far apart for some reason, in which case the product has been successful in increasing phenolics, or perhaps the product caused this initial difference, which would be a negative impact of this product. It is stated in the Lalvigne catalog (LalVigne, 2017) that total phenolics per gram berry weight will be increased by Lallemand Mature, so these results were unexpected, and indicate that the product did not work in this investigation. A study by (Pastore et al., 2020) that is explained above, found that there was also no significant difference between the phenolics of the control and phenolics of the trial - this supports my results. However, a study was performed by (Villangó, Pásti, Kállay et al., 2015),. In which Lallemand Mature was applied on Syrah vines over two vintages (2012 and 2013) in a cool-climate wine region (Eger, Hungary), the conclusion of this study was that the phenolic potential was greatly improved by Lallemand Mature. There is a lot of varied, contradicting research on both Lallemand mature and yeast derived foliar spray when applied to improve phenolic concentration and maturity, and in this investigation, Lallemand Mature did not increase phenolics remarkably, this could be because of random error, methods of application, variety or other variables specific to this investigation, the season

(which was already inducing stress) or, this product does not work. More trials are needed to come to a reliable conclusion. The null hypothesis is accepted - Lallemand Mature did not significantly affect phenolics in this investigation.

Colour per gram berry weight:

It was found that there was no significant difference between the Colour per gram berry weight of trial and Colour per gram berry weight control samples. It is stated in the LalVigne catalog (LalVigne, 2017) that anthocyanins will be increased by Lallemand Mature, so these results were unexpected and contradict this. In a study by (Pastore et al., 2020) that is explained above, it was found that there was also no significant difference between the anthocyanins of the control and anthocyanins of the trial, and several other papers have similar findings. However, there were also several papers that have documented a positive effect of yeast derived foliar sprays on the anthocyanins of grapevines, such as (Villangó, Pásti, Kállay et al., 2015). In this study (explained above) the conclusion was that the anthocyanin concentration and extractability were greatly improved by Lallemand Mature. Another study had similar findings; (Portu, López, Baroja, Santamaría, & Garde-Cerdán, 2016). Studied the effects of a foliar treatment containing methyl jasmonate and a yeast extract and found that grape and wine anthocyanin content increased. There is a lot of varied, contradicting research on both Lallemand mature and yeast derived foliar spray when applied to improve anthocyanin concentration, for example, A study from (Giacosa, Ossola, Botto, Segade, Paissoni, Pollon, & Rolle, 2019). showed that grapevines treated with an application of inactive dried yeast had in some cases but not all, an increase of the accumulation of anthocyanins. In this investigation, however, Lallemand Mature did not increase anthocyanins, this could be because of random error, methods of application, variety, or other variables specific to this investigation, or, this product simply does not work. More trials are needed to come to a reliable conclusion.

Even though there was no statistical difference between the anthocyanins of the trial and control samples, It was found that the trial had a larger change/increase in color per gram berry weight over time, meaning it increased more and had a steeper gradient. As said above, this could indicate that perhaps more applications of the product would show better results, as the anthocyanins of the trial samples could keep increasing and as a result be significantly higher than control samples.

The null hypothesis is accepted - Lallemand Mature did not significantly affect anthocyanins in this investigation.

Difficulties

During the data collection of this investigation, COVID-19 began, this caused a halt to the collection of data - stopping it a week short. This meant that harvest data was not collected and analyzed, narrowing the amount of data, and perhaps limiting results. There is a possibility that results and conclusions would be different if all data was collected and analyzed, however, the potential degree of difference is unknown. This season was a dry season - maybe elicitors did not work as well because the vines were already stressed.

Conclusions and Recommendation

In conclusion, the effects of Lalvigne Lallemand Mature on Syrah grapevines in the Gimblett Gravels of Hawkes Bay were determined and were found to have no significant differences between the Lallemand Mature treated vines and the control vines for berry weight, brix, and anthocyanins. It was found that for phenolic content, pH, and TA there was some significant difference between the Lallemand Mature treated samples and control samples, however, these differences were each only recorded for one date, leaving the rest of the data with no significant differences. This product has varied effects on grapevines, as it can be very successful, however, it can also be very unsuccessful like what has been found in this investigation. It is recommended that more trials should be done, with potentially more applications or earlier spraying to see if this results in a more successful outcome. Berry samples should be taken earlier with a bigger sample size than what was undertaken in this experiment, to give a deeper, more comprehensive data set and results, so better trend lines could be made.

References

- Acidity and pH.* (2017, May 22). The Australian Wine Research Institute.
https://www.awri.com.au/industry_support/winemaking_resources/frequently_asked_questions/acidity_and_ph/
- Brix – Grapes.* (2019, June 20). New Technologies for Agriculture Extension.
<https://grapes.extension.org/brix/>
- Crupi, P., Palattella, D., Corbo, F., Clodoveo, M. L., Masi, G., Caputo, A. R., Battista, F., & Tarricone, L. (2021). Effect of pre-harvest inactivated yeast treatment on the anthocyanin content and quality of table grapes. *Food Chemistry*, 337, 128006. <https://doi.org/10.1016/j.foodchem.2020.128006>
- Fawkes, H. (2015). *Syrah and Shiraz Grapes – Climatic, Winery Influence, Most important regions – WSET Level.* Decanter.
<https://www.decanter.com/learn/wset/syrah-and-shiraz-grapes-climatic-winery-influence-most-important-regions-wset-level-2-285043/#:~:text=The%20Grape,tannin%20and%20medium%20acidity%20levels.&text=In%20moderate%20climates%2C%20you%20may,spice%2C%20herbaceousness%20and%20smokey%20characteristics>
- Francenia Santos-Sánchez, N., Salas-Coronado, R., Hernández-Carlos, B., & Villanueva-Cañongo, C. (2019). Shikimic Acid Pathway in Biosynthesis of Phenolic Compounds. Plant Physiological Aspects of Phenolic Compounds, 0–9. https://doi.org/10.5772/intechopen.83815*
- Giacosa, S., Ossola, C., Botto, R., Segade, S. R., Paissoni, M. A., Pollon, M., ... & Rolle, L. (2019). Impact of specific inactive dry yeast application on grape skin mechanical properties, phenolic compounds extractability, and wine composition. *Food Research International*, 116, 1084-1093.
- Girelli, A. M., Mele, C., Salvagni, L., & Tarola, A. M. (2015). Polyphenol Content and Antioxidant Activity of Merlot and Shiraz Wine. *Analytical Letters*, 48(12), 1865–1880. <https://doi.org/10.1080/00032719.2014.1003429>
- Hawke's Bay - New Zealand Wine.* (2020). New Zealand Wine.
<https://www.nzwine.com/en/region/hawkes-bay>

- Iland, P., Bruer, N., Edwards, G., Caloghris, S., & Wilkes, E. (2013). *Chemical Analysis of Grapes and Wine: Techniques and Concepts* (2nd edition). Patrick Iland Wine Promotions; 2nd edition (2013).
- Kogkou, C., Chorti, E., Kyraleou, M., Kallithraka, S., Koundouras, S., Logan, G., Kanakis, I., & Kotseridis, Y. (2017). Effects of foliar application of inactivated yeast on the phenolic composition of *Vitis vinifera* L. cv. Agiorgitiko grapes under different irrigation levels. *International Journal of Wine Research*, *Volume 9*, 23–33. <https://doi.org/10.2147/ijwr.s136698>
- LalVigne. (2017). *Lallemand*. https://www.lallemandwine.com/en/new-zealand/?utm_source=google-ad-nz&utm_medium=cpc&utm_campaign=main-adLonhienne, T., Mason, M. G., Ragan, M. A., Hugenholtz, P., Schmidt, S., & Paungfoo-Lonhienne, C. (2014). Yeast as a Biofertilizer Alters Plant Growth and Morphology. *Crop Science*, *54*(2), 785–790. <https://doi.org/10.2135/cropsci2013.07.0488>
- Pastore, C., Allegro, G., Valentini, G., Colucci, E., Battista, F., & Filippetti, I. (2019). Biochemical and molecular effects of yeast extract applications on anthocyanin accumulation in cv. Sangiovese. *BIO Web of Conferences*, *13*, 03005. <https://doi.org/10.1051/bioconf/20191303005>
- Pastore, C., Allegro, G., Valentini, G., Pizziolo, A., Battista, F., Spinelli, F., & Filippetti, I. (2020). Foliar application of specific yeast derivative enhances anthocyanins accumulation and gene expression in Sangiovese cv (*Vitis vinifera* L.). *Scientific Reports*, *10*(1), 1–20. <https://doi.org/10.1038/s41598-020-68479-0>
- Portu, J., López, R., Baroja, E., Santamaría, P., & Garde-Cerdán, T. (2016). Improvement of grape and wine phenolic content by foliar application to grapevine of three different elicitors: Methyl jasmonate, chitosan, and yeast extract. *Food Chemistry*, *201*, 213-221. (Portu, López, Baroja, Santamaría, & Garde-Cerdán, 2016).
- Syrah - New Zealand Wine*. (2020). New Zealand Wine. <https://www.nzwine.com/en/winestyle/syrah/>
- Teixeira, A., Eiras-Dias, J., Castellarin, S., & Gerós, H. (2013). Berry Phenolics of Grapevine under Challenging Environments. *International Journal of Molecular Sciences*, *14*(9), 18711–18739. <https://doi.org/10.3390/ijms140918711>
- Urška, U. (2017, November 14). *Grape berry growth and maturing*. EVineyard Blog. <https://www.evineyardapp.com/blog/2017/11/14/grape-berry-growth-and-maturing/>
- Villangó, Sz., Pásti, Gy., Kállay, M., Leskó, A., Balga, I., Donkó, A., Ladányi, M., Pálfi, Z., & Zsófi, Zs.. (2015). Enhancing phenolic maturity of Syrah with the application of a new foliar spray. *South African Journal of Enology and Viticulture*, *36*(3), 304-315. Retrieved September 21, 2020, from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2224-7904201500300005&lng=en&tlng=en.

Appendices

ANOVA

ANOVA - Berry Weight (g)

Cases	Sum of Squares	df	Mean Square	F	p
Date	0.277	3	0.092	3.75	0.02
Treatment	0.071	1	0.071	2.899	0.098
Date * Treatment	0.114	3	0.038	1.546	0.222
Residuals	0.788	32	0.025		

Note. Type III Sum of Squares

Post Hoc Tests

Standard

Post Hoc Comparisons - Date * Treatment

		Mean Difference	SE	t	p _{tukey}
12/03/2020 , Control	14/02/2020 , Control	0.308	0.099	3.103	0.068
	19/03/2020 , Control	-0.03	0.099	-0.302	1
	27/02/2020 , Control	0.042	0.099	0.423	1
	12/03/2020 , Trial	-0.064	0.099	-0.645	0.998
	14/02/2020 , Trial	0.048	0.099	0.484	1
	19/03/2020 , Trial	-0.002	0.099	-0.02	1
	27/02/2020 , Trial	1.041e-16	0.099	1.049e-15	1

14/02/2020 , Control	19/03/2020 , Control	-0.338	0.09 9	-3.406	0.03 4	*
	27/02/2020 , Control	-0.266	0.09 9	-2.68	0.16 6	
	12/03/2020 , Trial	-0.372	0.09 9	-3.748	0.01 4	*
	14/02/2020 , Trial	-0.26	0.09 9	-2.62	0.18 6	
	19/03/2020 , Trial	-0.31	0.09 9	-3.123	0.06 5	
	27/02/2020 , Trial	-0.308	0.09 9	-3.103	0.06 8	
19/03/2020 , Control	27/02/2020 , Control	0.072	0.09 9	0.725	0.99 6	
	12/03/2020 , Trial	-0.034	0.09 9	-0.343	1	
	14/02/2020 , Trial	0.078	0.09 9	0.786	0.99 3	
	19/03/2020 , Trial	0.028	0.09 9	0.282	1	
	27/02/2020 , Trial	0.03	0.09 9	0.302	1	
27/02/2020 , Control	12/03/2020 , Trial	-0.106	0.09 9	-1.068	0.95 9	
	14/02/2020 , Trial	0.006	0.09 9	0.06	1	
	19/03/2020 , Trial	-0.044	0.09 9	-0.443	1	
	27/02/2020 , Trial	-0.042	0.09 9	-0.423	1	
12/03/2020 , Trial	14/02/2020 , Trial	0.112	0.09 9	1.128	0.94 5	
	19/03/2020 , Trial	0.062	0.09 9	0.625	0.99 8	
	27/02/2020 , Trial	0.064	0.09 9	0.645	0.99 8	
14/02/2020 , Trial	19/03/2020 , Trial	-0.05	0.09 9	-0.504	1	
	27/02/2020 , Trial	-0.048	0.09 9	-0.484	1	
19/03/2020 , Trial	27/02/2020 , Trial	0.002	0.09 9	0.02	1	

* p < .05

Note. P-value adjusted for comparing a family of 8

ANOVA

ANOVA - Brix

Cases	Sum of Squares	df	Mean Square	F	p
Date	205.035	3	68.345	81.315	< .001
Treatment	18.906	1	18.906	22.494	< .001
Date *					
Treatment	1.453	3	0.484	0.576	0.635
Residuals	26.896	32	0.840		

Note. Type III Sum of Squares

Post Hoc Tests

Standard

Post Hoc Comparisons - Date * Treatment

		Mean Difference	SE	t	p _{tukey}
12/03/2020, Control	14/02/2020, Control	4.300	0.580	7.416	< .001 ***
	19/03/2020, Control	-1.020	0.580	-1.759	0.650
	27/02/2020, Control	2.520	0.580	4.346	0.003 **
	12/03/2020, Trial	-1.700	0.580	-2.932	0.099
	14/02/2020, Trial	3.560	0.580	6.140	< .001 ***
	19/03/2020, Trial	-2.660	0.580	-4.588	0.002 **
	27/02/2020, Trial	1.100	0.580	1.897	0.563
14/02/2020, Control	19/03/2020, Control	-5.320	0.580	-9.175	< .001 ***
	27/02/2020, Control	-1.780	0.580	-3.070	0.073
	12/03/2020, Trial	-6.000	0.580	-10.348	< .001 ***
	14/02/2020, Trial	-0.740	0.580	-1.276	0.901
	19/03/2020, Trial	-6.960	0.580	-12.004	< .001 ***
	27/02/2020, Trial	-3.200	0.580	-5.519	< .001 ***

19/03/2020, Control	27/02/2020, Control	3.540	0.580	6.105	< .001	***
	12/03/2020, Trial	-0.680	0.580	-1.173	0.934	
	14/02/2020, Trial	4.580	0.580	7.899	< .001	***
	19/03/2020, Trial	-1.640	0.580	-2.828	0.123	
	27/02/2020, Trial	2.120	0.580	3.656	0.018	*
27/02/2020, Control	12/03/2020, Trial	-4.220	0.580	-7.278	< .001	***
	14/02/2020, Trial	1.040	0.580	1.794	0.629	
	19/03/2020, Trial	-5.180	0.580	-8.934	< .001	***
	27/02/2020, Trial	-1.420	0.580	-2.449	0.253	
12/03/2020, Trial	14/02/2020, Trial	5.260	0.580	9.072	< .001	***
	19/03/2020, Trial	-0.960	0.580	-1.656	0.714	
	27/02/2020, Trial	2.800	0.580	4.829	< .001	***
14/02/2020, Trial	19/03/2020, Trial	-6.220	0.580	-10.727	< .001	***
	27/02/2020, Trial	-2.460	0.580	-4.243	0.004	**
19/03/2020, Trial	27/02/2020, Trial	3.760	0.580	6.485	< .001	***

Note. P-value adjusted for comparing a family of 8

* $p < .05$, ** $p < .01$, *** $p < .001$

ANOVA

ANOVA - pH

Cases	Sum of Squares	df	Mean Square	F	p
Date	0.895	3	0.298	275.293	< .001
Treatment	0.023	1	0.023	20.819	< .001
Date *	0.002	3	6.692e -4	0.617	0.609
Treatment					
Residuals	0.035	32	0.001		

Note. Type III Sum of Squares

Post Hoc Tests

Standard

Post Hoc Comparisons - Date * Treatment

		Mean Difference	SE	t	P _{tukey}
12/03/2020, Control	14/02/2020, Control	0.326	0.021	15.658	< .001 ***
	19/03/2020, Control	-0.042	0.021	-2.017	0.487
	27/02/2020, Control	0.044	0.021	2.113	0.428
	12/03/2020, Trial	-0.068	0.021	-3.266	0.047 *
	14/02/2020, Trial	0.296	0.021	14.217	< .001 ***
	19/03/2020, Trial	-0.094	0.021	-4.515	0.002 **
	27/02/2020, Trial	0.004	0.021	0.192	1.000
14/02/2020, Control	19/03/2020, Control	-0.368	0.021	-17.675	< .001 ***
	27/02/2020, Control	-0.282	0.021	-13.544	< .001 ***
	12/03/2020, Trial	-0.394	0.021	-18.924	< .001 ***
	14/02/2020, Trial	-0.030	0.021	-1.441	0.831
	19/03/2020, Trial	-0.420	0.021	-20.172	< .001 ***
	27/02/2020, Trial	-0.322	0.021	-15.465	< .001 ***
19/03/2020, Control	27/02/2020, Control	0.086	0.021	4.131	0.005 **
	12/03/2020, Trial	-0.026	0.021	-1.249	0.911
	14/02/2020, Trial	0.338	0.021	16.234	< .001 ***
	19/03/2020, Trial	-0.052	0.021	-2.498	0.233
	27/02/2020, Trial	0.046	0.021	2.209	0.373
27/02/2020, Control	12/03/2020, Trial	-0.112	0.021	-5.379	< .001 ***
	14/02/2020, Trial	0.252	0.021	12.103	< .001 ***
	19/03/2020, Trial	-0.138	0.021	-6.628	< .001 ***
	27/02/2020, Trial	-0.040	0.021	-1.921	0.547
12/03/2020, Trial	14/02/2020, Trial	0.364	0.021	17.483	< .001 ***
	19/03/2020, Trial	-0.026	0.021	-1.249	0.911
	27/02/2020, Trial	0.072	0.021	3.458	0.030 *
14/02/2020, Trial	19/03/2020, Trial	-0.390	0.021	-18.731	< .001 ***
	27/02/2020, Trial	-0.292	0.021	-14.025	< .001 ***
19/03/2020, Trial	27/02/2020, Trial	0.098	0.021	4.707	0.001 **

Note. P-value adjusted for comparing a family of 8

* p < .05, ** p < .01, *** p < .001

ANOVA

ANOVA - TA (g/L)

Cases	Sum of Squares	df	Mean Square	F	p
Date	466.850	3	155.617	229.543	< .001
Treatment	9.411	1	9.411	13.882	< .001
Date * Treatment	3.145	3	1.048	1.546	0.222
Residuals	21.694	32	0.678		

Note. Type III Sum of Squares

Post Hoc Tests

Standard

Post Hoc Comparisons - Date * Treatment

		Mean Difference	SE	t	P _{tukey}
12/03/2020, Control	14/02/2020, Control	-8.847	0.521	-16.989	< .001 ***
	19/03/2020, Control	0.362	0.521	0.695	0.997
	27/02/2020, Control	-2.278	0.521	-4.374	0.003 **
	12/03/2020, Trial	0.506	0.521	0.972	0.975
	14/02/2020, Trial	-6.937	0.521	-13.321	< .001 ***
	19/03/2020, Trial	0.944	0.521	1.813	0.616
	27/02/2020, Trial	-1.396	0.521	-2.681	0.165
	14/02/2020, Control	19/03/2020, Control	9.209	0.521	17.684
27/02/2020, Control		6.569	0.521	12.615	< .001 ***
12/03/2020, Trial		9.353	0.521	17.961	< .001 ***
14/02/2020, Trial		1.910	0.521	3.669	0.018 *
19/03/2020, Trial		9.791	0.521	18.802	< .001 ***
27/02/2020, Trial		7.451	0.521	14.308	< .001 ***

19/03/2020, Control	27/02/2020, Control	-2.640	0.521	-5.070	< .001	***
	12/03/2020, Trial	0.144	0.521	0.277	1.000	
	14/02/2020, Trial	-7.299	0.521	-14.016	< .001	***
	19/03/2020, Trial	0.582	0.521	1.118	0.948	
	27/02/2020, Trial	-1.758	0.521	-3.376	0.036	*
27/02/2020, Control	12/03/2020, Trial	2.784	0.521	5.346	< .001	***
	14/02/2020, Trial	-4.659	0.521	-8.946	< .001	***
	19/03/2020, Trial	3.222	0.521	6.187	< .001	***
	27/02/2020, Trial	0.882	0.521	1.694	0.691	
12/03/2020, Trial	14/02/2020, Trial	-7.443	0.521	-14.292	< .001	***
	19/03/2020, Trial	0.438	0.521	0.841	0.989	
	27/02/2020, Trial	-1.902	0.521	-3.652	0.018	*
14/02/2020, Trial	19/03/2020, Trial	7.881	0.521	15.133	< .001	***
	27/02/2020, Trial	5.541	0.521	10.640	< .001	***
19/03/2020, Trial	27/02/2020, Trial	-2.340	0.521	-4.494	0.002	**

Note. P-value adjusted for comparing a family of 8

* $p < .05$, ** $p < .01$, *** $p < .001$

ANOVA

ANOVA - Berry Weight (g)

Cases	Sum of Squares	df	Mean Square	F	p
Date	0.277	3	0.092	3.750	0.020
Treatment	0.071	1	0.071	2.899	0.098
Date *	0.114	3	0.038	1.546	0.222
Treatment					
Residuals	0.788	32	0.025		

Note. Type III Sum of Squares

Post Hoc Tests

Standard

Post Hoc Comparisons - Date * Treatment

		Mean Difference	SE	t	p _{tukey}
12/03/2020, Control	14/02/2020, Control	0.308	0.099	3.103	0.068
	19/03/2020, Control	-0.030	0.099	-0.302	1.000
	27/02/2020, Control	0.042	0.099	0.423	1.000
	12/03/2020, Trial	-0.064	0.099	-0.645	0.998
	14/02/2020, Trial	0.048	0.099	0.484	1.000
	19/03/2020, Trial	-0.002	0.099	-0.020	1.000
	27/02/2020, Trial	1.041e -16	0.099	1.049e -15	1.000
14/02/2020, Control	19/03/2020, Control	-0.338	0.099	-3.406	0.034*
	27/02/2020, Control	-0.266	0.099	-2.680	0.166
	12/03/2020, Trial	-0.372	0.099	-3.748	0.014*
	14/02/2020, Trial	-0.260	0.099	-2.620	0.186
	19/03/2020, Trial	-0.310	0.099	-3.123	0.065
	27/02/2020, Trial	-0.308	0.099	-3.103	0.068
19/03/2020, Control	27/02/2020, Control	0.072	0.099	0.725	0.996
	12/03/2020, Trial	-0.034	0.099	-0.343	1.000
	14/02/2020, Trial	0.078	0.099	0.786	0.993
	19/03/2020, Trial	0.028	0.099	0.282	1.000
	27/02/2020, Trial	0.030	0.099	0.302	1.000
27/02/2020, Control	12/03/2020, Trial	-0.106	0.099	-1.068	0.959
	14/02/2020, Trial	0.006	0.099	0.060	1.000
	19/03/2020, Trial	-0.044	0.099	-0.443	1.000
	27/02/2020, Trial	-0.042	0.099	-0.423	1.000
12/03/2020, Trial	14/02/2020, Trial	0.112	0.099	1.128	0.945
	19/03/2020, Trial	0.062	0.099	0.625	0.998
	27/02/2020, Trial	0.064	0.099	0.645	0.998
14/02/2020, Trial	19/03/2020, Trial	-0.050	0.099	-0.504	1.000
	27/02/2020, Trial	-0.048	0.099	-0.484	1.000
19/03/2020, Trial	27/02/2020, Trial	0.002	0.099	0.020	1.000

* p < .05

Note. P-value adjusted for comparing a family of 8

T-Test (Excel)	Brix
Lallemand Mature	0.028412