IMPACT OF ORGANIC MULCH ON VINEYARD SOIL MOISTURE RETENTION, GRAPEVINE GROWTH AND NUTRITION

An Undergraduate Research Scholars Thesis

by

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ABSTRACT

Impact of Organic Mulch on Vineyard Soil Moisture Retention. (May 2015)

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Drought and irrigation water quality are major concerns for vineyards in Texas. Drought results in a higher demand for irrigation water which may not be available to some grape growers. A field study was conducted in a commercial *Vitis spp.*cv Lenior vineyard to evaluate the use of organic hardwood mulch as a potential water conservation tool for wine grape vineyards. Treatments consisted of applying hardwood mulch directly beneath grapevinesat 40 days after anthesis at a depth of 8 cm and widths of 0.6 m, 0.9m, and 1.2 m. Significant reductions in weed coveragewere observed at 90 days after harvest in the 0.9 m and 1.2 m mulch treatments compared to unmulched vines. Fluctuations in volumetric water content in the soil directly beneath treated vines were lower in the 1.2 m treatment compared to unmulched vines. Concentrations of calcium and zinc, and the sodium absorption ratio in the soil beneath the 0.9 m and 1.2 m mulch treatments were significantly reduced by mulching. Applying hardwood mulch did not affect grapevine yield or juice chemistry. Further research into the use of hardwood mulch in vineyards is recommended to determine if it is a viable tool for vineyard operators.

CHAPTER I

INTRODUCTION

Literature review

The Texas wine industry has experienced rapid growth over the past decade. In 2013, Texas produced 1.3 million cases of wine, a 108% increase from 2005 (MFK Research et al., 2005). Vineyard acreage also increased during that period from 3,300 acres in 2005 (USDA-NASS, 2011) to 7,092 in 2012 (USDA-NASS, 2012). However, grape growers in Texas face challenges related to climate and disease.

Although grapes have a lower water requirement than many other crops (Food and Agriculture Organization of the United Nations, 2015), irrigation water low in salts is needed for successful production. A study on Thompson Seedless grapevines in California reportedvine water use of up to 7 mm of water a day(Williamset al., 2013). In areas of Texas where natural rainfall cannot meet vineyard water requirements, supplemental water is usually supplied through a drip irrigation system fed by a well, a pond, or the local city water supply. However, growers with coarse textured or shallow soil may struggle to maintain satisfactory soil moisture in dry seasons. Some growers may resort to a daily watering schedule which can result in inefficient use of water resources. Furthermore, frequent irrigation with saline water increases the potential for salt accumulation in the soil profile which can negatively impact soil structure, vine health, and vine performance (Hasegawa et al., 2000).

Irrigation Water Quality

Irrigation water commonly contains salts such as magnesium ($MgSO_4$), sodium chloride (NaCl), calcium sulfate ($CaSO_4$), and sodium bicarbonate ($NaHCO_3$)(Grattan, 2002). When soil has a high salt concentration, the osmotic potential of the soil solution decreases (becomes more negative). This results in plants having to use more energy to pull water out of the soil (Ayers and Wescot, 1994). If the salt levels are extremely high, plants can die from drought stress, although the soil may be saturated with water. (Ayers and Wescot, 1994).

Negatively charged ions in salty water such as sodium can be toxic to grapevines. The symptoms of salt toxicity include small leaves, distorted fruit, and an overall stunted plant growth (Ramoliya, 2003).The use of sodic irrigation water can also result in problems related to soil structure. Sodium binds with fine soil particles causing them to disperse. The dispersion of clay soil particles can result in reduced infiltration, hydraulic conductivity, gas exchange and surface crusting (Rengasamy, 1991). To prevent damage, growers with sodic irrigation water must take steps to prevent the accumulation of sodium in the soil.

Salts may be removed from the rooting depth of the soil by leaching with water that is low in salts such as rain water and snow melt. However, the water required to leach highly saline soil may be as much as 1.2 m of water per acre (Provin and Pitt, 2014). In drier climates with insufficient rainfall to perform natural leaching, additional irrigation water beyond the needs of the crop may be applied to leach salts below the root zone (Ayers and Wescot, 1994). Other techniques such as reducing soil water evaporation, improving drainage, and applying gypsum to the soil may also aid in reducing salt accumulation (Ayers and Wescot, 1994).

Organic matter

The use of organic mulch in vineyards has shown to provide a range of benefits including soil moisture preservation, increased vine growth and yield, improved nutrient status, improved soil structure, decreased soil compaction, soil insulation from extreme temperatures, and weed control comparable to cultivation (Guerra and Steenworth, 2012).A study in Oregon compared young grapevines with and without mulch beneath them. The study revealed that in-row mulch treatments maintained higher soil moisture concentrations than those without mulch. Soil moisture beneath the mulch was reportedto be 12% higher thanthe unmulched soil (Frederickson, 2011). As a result, the mulched vines had 43% higher pruning weights than the unmulched vines. Guerra and Steenworth (2012) also observed an increase in vine growth with the use of organic mulch, in addition to higher yields and reduced pathogens and pests.Tiquia et al. (1989) conducted a field study to compare organic mulch and bare soil, and they reported significant increases in soil organic matter content, soil respiration, microbial biomass N, soil pH, cation-exchange capacity, and concentrations of essential plant nutrients from the use organic mulch.These effects could also contribute to higher grapevine growth and vigor.

Mulch has a long history of use for weed suppression by smothering the weed seedlings.Depending on the texture of mulch, applications at depths of 5 to 15 cm can provide effective weed control (Elmore, 1997). By serving as a barrier between falling rain and the soil, mulch has also been shown to reduce soil erosion and water run-off in vineyards (Gril et al., 1989).

Frederickson(2011)compared soil compaction beneath mulched and unmulched grapevines, and depending on the sample depth, the soil beneath unmulched vines had 48 to 218% more soil compaction than the mulched treatments. Covering the soil with mulch has also been shown to reduce soil temperature fluctuations throughout the day. Agnew et al. (2002) reported that bare soil temperatures fluctuated as high as 10° C throughout the day in the winter and in contrast, soil covered by organic mulch fluctuated by less than 0.5° C.

The objective of this study is to evaluate the impact of organic mulch on soil moisture retention, grapevine growth and yield, and soil nutrient composition. In hot climates such as Texas, grape growers use irrigation to supplement the water needs of their vineyards, but this may be a challenge for growers who do not have access to adequate volumes of salt-free irrigation water.Identifying an effective, economic means of preserving soil moisture would benefit vineyard operators that struggle with drought and poor irrigation water quality.

CHAPTER II

METHODS

Experimental design

A commercial wine grape vineyard in College Station, Texas (30.62° N, 96.33° W) was used in this study. The soil is classified by the USDA as a Gredge fine sandy loam with a 0 to 5 percent slope. Vines were four year old *Vitis spp*., cv. Lenoir grapevines trained to a low wire bilateral cordon system. Cordons were at 1 meter height and shoots were vertically positioned. Vines were spaced at 3 meters between rows by 2.44 meters between vines. Row orientation was east to west. Vine management was performed according to the standard viticultural practices for Lenoir grapes in the College Station area. The experimental design was a randomized complete block with four replications. The experimental plot consisted of four rows and each experimental unit consisted of three consecutive vines in each row.

Treatments consisted of an untreated control (no mulch) and hardwood mulch applied directly beneath vines at a depth of 8cm and widths of 0.6, 0.9, and 1.2 meters. The mulch used was composed of hardwood trees from the College Station area. Mulch treatments were applied at 40 days after anthesis. Irrigation was withheld from the mulch treatments, but the control treatment was irrigated as needed, according to the vineyard manager.

Soil moisture

Volumetric soil moisture was monitored over the growing season in the control and 1.2 m treatment using WatchDog 1525 data loggers and WaterScout SM100 Soil Moisture Sensors

(Spectrum Technologies Inc., USA). Sensors were placed in the soil at depths of 15 cm and 30 cm directly beneath vines. In the 1.2 m mulch treatment, the sensors were placed in the soil beneath the mulch. Volumetric water content (VWC) of the soil was monitored over the course of the study in three replications of the control and the 1.21 m treatment (Fig 1). However, a data logger malfunctioned and data for one replication was discarded. Thus, statistical analysis was not performed on the soil moisture data.

Soil Analysis

At 120 days after harvest, soil samples were collected in the control, and the 0.9 m and 1.2 m mulch treatments for soil chemical analysis. A composite sample consisting of ten soil cores per treatment, representing a soil depth of 0 to 20 cm, were taken directly beneath vines and a subsample was collected for analysis at the Texas A&M AgriLife Extension Service, Soil, Water, and Forage Testing Laboratory..

Vine characteristics

During the winter, dormant pruning was conducted and cane pruning weights were measured with a Pelouze 7710 Hanging Scale (Newell Rubermaid, Atlanta, Georgia). Crop load was calculated as yield divided by pruning weight and average cane weight was determined by dividing the cane weight by the number of canes. Pruning weight data was not collected for the untreated control vines.

Sample and harvest parameters

At harvest, 100 berries were collected at random from each treatment for chemical analysis. The berries were pressed by hand, and the juice was strained through cheese cloth. The juice samples were then frozen at -17 °C until analyses were performed.

Berry analysis of °Brix, TA, and pH

Juice samples were removed from the freezer and heated at 65 °C for one hour in a water bath to redissolve tartrates before analysis. Soluble solids were measured with a digital refractometer (model PAL series, Atago,-Tokyo, Japan) with temperature correction. Titratable acidity (TA) was measured with a 5.0 mL aliquot of juice by titration against 0.1 N NaOH to pH 8.2 and expressed as tartaric acid equivalents. Juice pH was measured with a digital pH meter (model Ion 6, Oakton Instruments, Vernon Hill, Illinois).

Weed coverage

Weed coverage was assessed visually at 90 days after harvest as the percent area covered by weeds in a 1.2 meter strip directly beneath the vines.

Statistical analysis

Statistical analyses were conducted with SAS®statistical software (SAS Institute, Cary, North Carolina). Data was subjected to the Proc GLM procedure and means were separated using the Fischer's protected least significant difference (LSD) at the 5% significance level.

CHAPTER III

RESULTS

Vine characterization

Pruning weights of the unmulched vines were not collected for comparison to the mulch treatments (Table 1). The range in the number of canes per vine across the mulch treatments was 60.3 to 75.0 with no significant differences observed between treatments. There were no significant differences between treatments for pruning weight, average cane weight, and crop load.

Table 1 Effect of organic mulch treatments on vine characteristics and crop load for Lenoir.

Treatment	Canes/vine	Pruning weight (kg)	Average cane weight (g)	Crop load (yield/pruning weight)
CON	.	.	.	.
0.6 m	60.3	1.72	28.68	3.69
0.9 m	63.8	1.61	25.40	4.40
1.2 m	75.0	2.08	27.67	4.37
Significance[a]	ns	ns	ns	ns

[a]ns indicates not significant and statistically significant at the 0.05 level of probability.

Yield components

The number of clusters per vine and yield per vine ranged from 31.5 to 42.8 and 6.23 kg to 9.06 kg, respectively with no significant differences between treatments. Mulching did not affect average cluster weight or average berry weight.

Table 2 Effect of organic mulch onyield components of Lenoir.

Treatment	Clusters/vine	Yield/vine (kg)	Average cluster weight (g)	Average berry weight (g)
CON	31.5	6.23	441.6	2.44
0.6 m	32.8	6.37	438.1	2.58
0.9 m	36.3	7.06	435.5	2.54
1.2 m	42.8	9.06	482.5	2.47
Significance[a]	ns	ns	ns	ns

[a]ns indicates not significant and statistically significant at the 0.05 level of probability.

Juice chemistry

Mulching did not influence juice chemistry at harvest (Table 3). The range in total soluble solids across the treatments was 20.3 to 21.5 °Brix. Titratable acidity and pH ranged from 10.9 to 11.6 g/L and 3.69 to 3.72, respectively.

Table 3 Effect of organic mulch on juice chemistry of Lenoir.

Treatment	TSS (°Brix)	TA (g/L)	pH
CON	20.9	10.9	3.69
0.6 m	21.5	10.7	3.79
0.9 m	20.5	11.4	3.74
1.2 m	20.3	11.6	3.72
Significance[a]	ns	ns	ns

[a]nsindicates not significant and statistically significant at the 0.05 level of probability.

Weed coverage

The untreated control had a significantly higher weed coverage beneath the grapevinesthan the 0.9 m and 1.2 m treatments (Table 5). The range in weed coverage between treatments was 2% to 61%. The lowest weed coverage was observed beneath the 1.2 m mulch treatment followed by the 0.9 m treatment.

Table 5 Percent of Treated Area Covered by Weeds

Mulch Treatment	Weed coverage (%)
Control	61c[b]
0.6 m	54c
0.9 m	30b
1.2 m	2a
Signifcance[a]	**

[a]nsand ** indicate not significant and statistically significant at the 0.01 level of probability.
[b]Means followed by different letters are significantly different at the 95% level (Fisher's LSD

Soil chemical composition

Therewere no significant differences between treatments in soil nitrate and potassium concentration(Table 4). Phosphorus concentrations ranged widely from 88 to 370 mg/kg, but were not significantly different. The untreated control had a significantly higher calcium concentration than the 0.9 m and 1.2 m treatments, by 108 and 31%, respectively. Mulching did not have a significant impact on soil concentrations of magnesium, sulfur, iron, manganese, boron, and sodium. Zinc concentrations ranged from 0.22 mg/kg to 0.52 mg/kg with the 0.9 m and 1.2 m treatments having significantly lower zinc concentrations than the untreated control. Copper concentrations in the soil of the 0.9 m treatment was significantly lower than both the untreated control and 1.2 m mulch treatment. Soil pH and organic matter were not significantly impacted by the mulch treatments. Sodium absorption ratio (SAR) ranged from 4.9 to 7.0.The 0.9 m and 1.2 m treatments had a significantly lower SAR than the untreated control.

Table 4 Effect of organic mulch on soil chemistry.

Treatment	NO_3^-N	P	K	Ca	Mg	S	Fe	Zn	Mn	Cu	B	Na	pH	OM (%)	SAR
	———	———	———	———	———	———	mg kg^{-1}	———	———	———	———	———			
CON	13	370	113	867a[b]	104	13	18.3	0.52a	11	0.11a	0.30	134	6.4	0.78	7.0a
0.9 m	5	79	115	416b	101	7	10	0.22b	2.4	0.06b	0.57	103	6.5	0.69	5.0b
1.2 m	1	88	130	658b	92	9	21	0.28b	8	0.09ab	0.13	94	6.0	0.66	4.9b
Significance[a]	ns	ns	ns	**	ns	ns	ns	*	ns	*	ns	ns	ns	ns	**

[a]ns, * and ** indicate not significant and statistically significant at the 0.05 and 0.01 levels of probability, respectively.
[b]Means followed by different letters are significantly different at the 95% level (Fisher’s LSD).

Volumetric water content

Volumetric water content (VWC) ranged from 2% to 43% over the growing season. During the months of June, July, September, and October the VWC remained the highest in the 1.2 m mulch treatment at the 30 cm depth. Similarly, the 1.2 m treatment maintained a higher VWC in the soil than the untreated control at 15 cm deep over the same period. Greater fluctuations in VWC can be observed at 15 cm in the 1.2 m treatment compared to 30 cm. On June 20, an irrigation event can be observed in the untreated control vines. VWC increased over a two-day period from less than 10% to greater than 25%. The mulched treatments did not receive irrigation thus no response in soil moisture can be seen. However, on July 2 a rainfall event increased soil moisture in all treatments, followed by a decline over the next two weeks. In comparison, the 1.2 m mulch treatment experienced a slower decline in volumetric water content at 30 cm compared to the untreated control. During the last week of July and first two weeks of August four irrigation events can be observed in the untreated control vines. After harvest, VWC remained above 10% at 30 cm for both the 1.2 m treatment and untreated control.

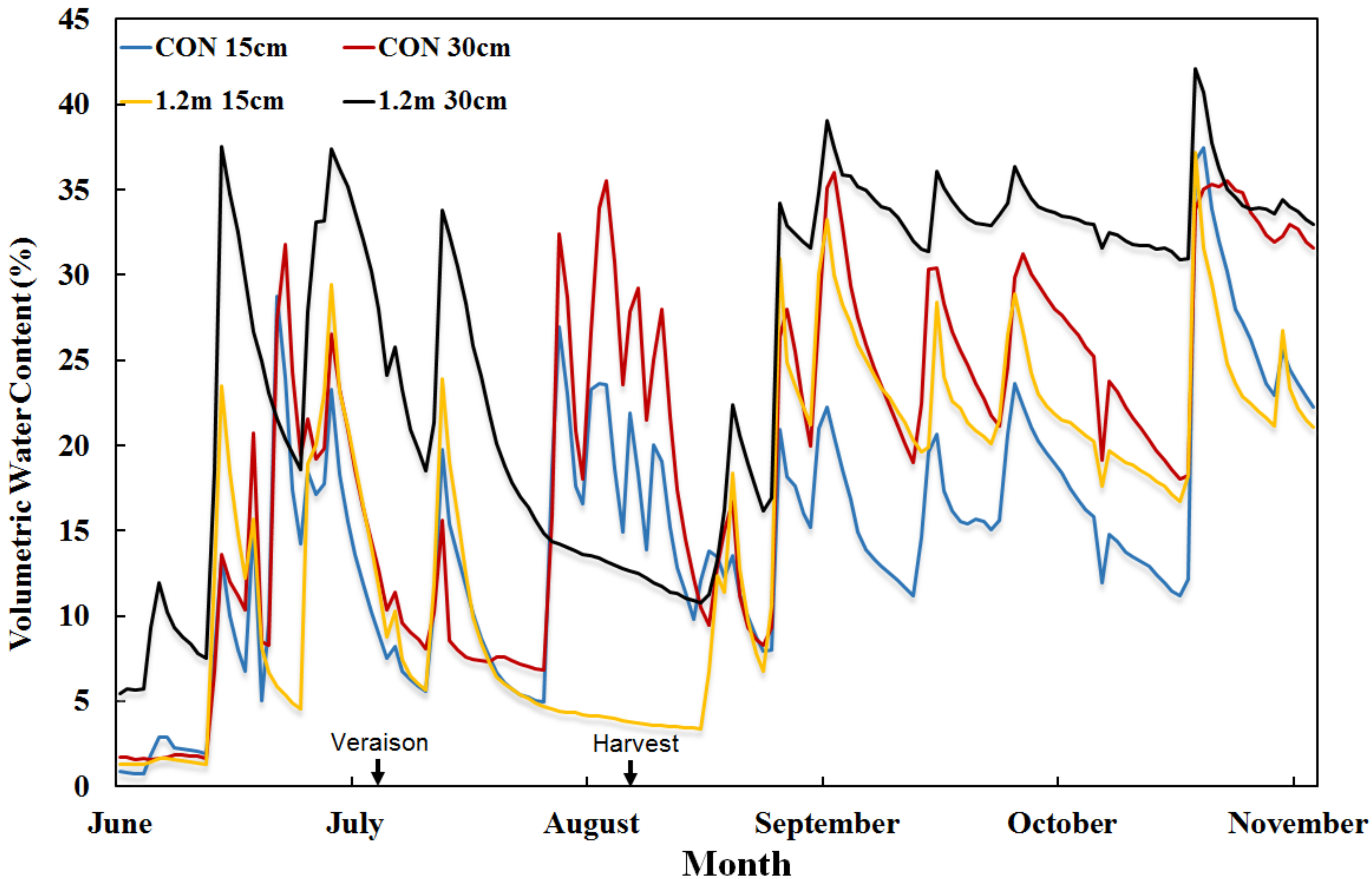

Figure 1 Volumetric watercontent in control and 1.2 m treatment from June to November 2015.

CHAPTER IV

DISCUSSION

In contrast to other research on the use of organic mulch (Guerra and Steenworth, 2012), we did not observe any effect on pruning weight from the use of organic mulch. It may be because vine growth had already begun well before the mulch treatments were applied.It is possible that as the mulch decomposesand nitrogen is releasedin the soil as reported by Tiquia et al. (1989), vine growth and pruning weights could increase.

The soil in the mulch treatments contained significantly lower concentrations ofcalcium, zinc, and copper which has not been previously reported. The higher levels observed in the untreated control could be a result of the irrigation water. The mulched vines did not receive supplemental irrigation, but the untreated control was irrigated five times over the growing season. Depending on the water source, irrigation water can contain calcium, zinc, and copper. However, water samples were not collected in this study for comparison.

The soil sodium absorption ratio was also significantly higher in the control compared to the mulch treatments. Similar observations were reported by Aragues et al., (2014) one year after applying organic mulch in a vineyard. This could be provide a benefit to vineyards at risk of salt accumulation in the soil.

Although other studies have reported increases in yield from the use of organic mulch (Guerra and Steenworth 2012), mulching did not affect fruit yield, cluster weight, or average berry weight in this study. Juice chemistry was also unaffected by the mulching treatments, although the VWC differed greatly between the 1.2 m treatment and the untreated control before harvest.

The VWC in the soil of the 1.2 m treatment experienced a slower decline between rainfall events in comparison to unmulched soil. These findings are in concurrence with others who studied the use of organic mulch on soil moisture retention in vineyards (Cooperative Research Center for Viticulture, 2005, Frederickson, 2011). In situations where excessive vigor is present, additional water retention could be problematic. However, in hot and dry climates increasing water retention could be desirable.

CHAPTER V

CONCLUSION

There are benefits associated with the use of organic mulch in vineyards. The weed suppression and increased water retention observed in this study could be advantageous to growers in hot or arid climates where supplemental irrigation is required for production, and for those who wish to minimize the use of irrigation water. While no improvements in yield and juice chemistry were observed, benefits may be possible with the long term use of mulch. Further testing is recommended to monitor changes in soil chemistry and soil moisture retention over time as organic mulch decomposes or additional applications are made.

CHAPTER VI

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