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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Changes of Vine Water Status and Growth Parameters Under Different Canopy Management on cv. Merlot (*Vitis vinifera* L.)

Farklı Taç Yönetimi Uygulamalarının Merlot Üzüm Çeşidinde (*Vitis vinifera* L.) Asma Su Durumu Değişimine Etkileri

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Abstract

The climate is the dominant regulator that determines the cultivation in a viticulture region as it strongly controls vine physiology, vine growth, canopy microclimate, berry quality and finally wine components. However, the effects of climate change force vine producers to find solutions that will facilitate their adaptation processes. The importance of water management in vineyards is becoming more important every day for sustainable viticulture and winemaking. Efficient use of water in vineyards is an important issue to control the yield and to provide the targeted berry quality at the desired level. This experiment was carried out during the 2013-2014 and 2015 growing seasons to evaluate the effects of green pruning practices on water leaf potentials of 12-14 years old grapevines of cv. Merlot (*Vitis vinifera* L.) grafted onto Kober 5BB in the experimental vineyard of Tekirdag Viticulture Research Institute in Turkey. A completely randomized block design was used: $LRMS_1$, $LRMS_2$, $LRMS_3$ represent three levels of leaf removal treatments on main shoots and $LRLS_1$, $LRLS_2$, $LRLS_3$ represent three levels of leaf removal treatments on lateral shoots. Due to the relatively high soil moisture in vineyard conditions, no extreme and high-water stress levels was observed in experiment years. The main factor controlling the water status in cv. Merlot vines was largely dependent on the meso-climatic conditions and soil water availability during the growing season. However it was observed that increasing of main shoot length give rise to tendency to water stress. It was determined that leaf removal treatments on lateral shoots caused changes in shoot weight, pruning weight and Ravaz index (RI), especially in 2014 whereas the leaf removal treatments on main shoots caused changes in mentioned parameters in 2015. In conclusion, the results show that plant water condition can be managed with summer pruning taking into account of different climatic conditions and different phenological stages. Planning of canopy management practices should be done by considering long- and medium-term meteorological evaluations while short-term planning within vegetation period should be done in relation to weekly and monthly meteorological data.

Keywords: Climate, Leaf removal, Leaf water potential (Ψ_{leaf}), Precipitation, Water stress

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Öz

İklim, asma fizyolojisi, asma büyümesi, taç mikrokliması, meyve kalitesi ve son olarak şarap bileşenlerini güçlü bir şekilde kontrol ettiği için bir bağcılık bölgesindeki yetiştiricilik yöntemini belirleyen baskın düzenleyicidir. Diğer yandan iklim değişikliğinin etkileri, üreticileri bu değişikliklere uyum sağlamak konusunda yeni çözümler üretmeye zorlamaktadır. Bağlarda su yönetiminin önemi, sürdürülebilir bağcılık ve şarapçılık için her geçen gün daha da artmaktadır. Suyun verimli kullanılması, verimin kontrol altına alınması ve hedeflenen tane kalitesinin istenilen düzeyde sağlanması için önemli bir konudur. Bu deneme, yeşil budama uygulamalarının 12-14 yaşındaki, Kober 5BB anacı üzerine aşılanmış Merlot (*Vitis vinifera* L.) çeşidi asmalarda yaprak su potansiyellerine etkilerinin belirlenmesi amacıyla 2013-2014 ve 2015 yıllarında Tekirdağ Bağcılık Araştırma Enstitüsü, Türkiye' de yürütülmüştür. Tesadüf blokları deneme deseninde yürütülen araştırmada $LRMS_1$, $LRMS_2$, $LRMS_3$ uygulamaları ana sürgünler üzerinde uygulanmış üç farklı yaprak alımı seviyesini, $LRLS_1$, $LRLS_2$, $LRLS_3$ uygulamaları koltuk sürgünleri üzerinde uygulanmış üç farklı yaprak alımı seviyesini ifade etmektedir. Bağ şartlarındaki nispeten yüksek toprak nemi nedeniyle deneme yıllarında aşırı ve yüksek su stresi seviyeleri gözlenmemiştir. Merlot asmalarında su durumu kontrolünün büyük ölçüde yetiştirme dönemindeki mezoklimatik koşullar ve toprak su potansiyeline bağlı olduğu belirlenmiştir. Bununla birlikte ana sürgün boyundaki artışın su stresini artırdığı gözlenmiştir. Koltuk sürgünlerinde yapılan yaprak alma uygulamalarının özellikle 2014 yılında sürgün ağırlığı, budama ağırlığı ve Ravaz indeksinde (RI) değişikliklere neden olduğu, 2015 yılında ise ana sürgünlerde yapılan yaprak alma uygulamalarının aynı parametrelerdeki değişikliklerde etkili olduğu belirlenmiştir. Taç yönetimi uygulamaları planlamasının yıllar ölçeğinde uzun ve orta vadeli meteorolojik değerlendirmeler dikkate alınarak, kısa vadeli planlamanın ise vejetasyon dönemi içinde haftalık ve aylık meteorolojik veriler dikkate alınarak yapılması gerektiği değerlendirilmektedir.

Anahtar Kelimeler: İklim, Yaprak alma, Yaprak su potansiyeli (Ψ_{yaprak}), Yağış, Su stresi

1. Introduction

Climate change persists as one of the most complex and major problems facing humanity. In addition to being an environmental threat, it also poses great challenges for sustainable development (Kadıoğlu, 2012). Estimates indicate that if the increase in the atmospheric CO_2 continues at current rates, temperatures will increase by 1.5°C between 2030 and 2052 years (IPCC, 2018). The calculated viticulture climate indicators reveal the rise of temperatures in Thrace Region of Turkey as in most Mediterranean climate regions. Although the total amount of precipitation has not changed significantly, the rainfall in the vegetation period deviates undecidedly from the long-term averages (Candar et al., 2019).

The relationship between climate and grapevine cultivation make viticulture vulnerable to the detrimental effects of the climate change. Numerous studies about the effects of global warming on grapevine cultivation, phenology, berry and wine quality have been published in the last decades (Webb et al., 2008; Fraga et al., 2012; Vrsic and Vodovnik, 2012; Donat et al., 2013; Rogiers et al., 2015; Kurtural et al., 2016; Bahar et al., 2017a; Korkutal et al., 2019). It is widely accepted that weather factors such as temperature, solar radiation and water availability affect grapevine growth and development, ultimately altering yield and wine quality (Jones, 2018).

Generally, higher temperatures during the vegetation period results in a decrease in the total acidity content (Schulz and Jones, 2010; Leolini et al., 2019) and an increase in the amount of sugar. It also increases the possible alcohol content (Jones and Davis, 2000), and destabilize the technological maturity, phenolic and aromatic compositions (Petrie and Sadras, 2008).

Soil is one of the component of wine production as it provides water and nutrients. It also determines the limits of the root system and root rhizosphere (Deloire et al., 2004). Soil variability and climate interactions are the most important identifiers of viticultural efficiency (Fraga et al., 2014; Priori et al., 2019).

Water availability can be considered the major source of climatic variation in vegetation period which shows itself in the intensity and timing of precipitation and also in soil physical properties (Santos et al., 2020). Severe water deficits during the vegetation period can restrict photosynthesis. Thus, shoot growth, yield and berry composition are negatively affected (Keller et al., 2016). Impacts of the climate change on the soil moisture hence on agricultural production should be well evaluated (Deveci et al., 2019). A more efficient use of water is necessary for sustainability in viticulture.

Vine water status causes a wide range of effects in grapevine, depending on the vine's phenological developmental status. During inflorescences and floral differentiation stages, enough water availability is vital to provide a favourable yield (Guilpart et al., 2014). Along with the developmental stage water-scarce may result a reduction in shoot growth and canopy development, poor flower development and low berry set (Ojeda et al., 2002; Roby et al., 2004; Junquera et al., 2012; Keller et al., 2016). On the contrary, excessive water availability encourages uncontrolled vegetative growth, resulting in undesirable dense canopies, increase the risk of fungal diseases, manipulate harvest time and complicate quality management (Cook et al., 2015; Molitor et al., 2016; Balint and Reynolds, 2017). The relative increase of water stress in the harvest period positively affects the production and distribution of carbohydrates, increases fruit quality and regulates unwanted vegetative development (van Leeuwen et al., 2009; Bahar et al., 2017b). Dry weather conditions towards the harvest are generally preferred to achieve the goal of high-quality wine (Ramos et al., 2008). Appropriate water deficit affects grape berry and wine composition positively by promoting higher water use efficiency with slower leaf growth (Savoi et al., 2016; Vilanova et al., 2019). These positive effects are usually explained by the smaller berries having a higher skin to pulp ratio. A relatively high skin ratio results in high tannins, anthocyanins, total phenolics and organoleptic properties. The effects of water stress on the physiological and metabolic pathways lead to the formation of secondary metabolites in the berries.

At the end of vegetation period, pruning weight is directly affected by water availability during the vegetation period (Intrigliolo and Castel, 2010; Uriarte et al., 2015). Long-term lack of water causes reductions in shoot weight (Junquera et al., 2012). Water deficit has a cumulative reducing effect on starch and sucrose accumulation in trunks and roots. (Rogiers et al., 2011; Rossouw et al., 2017). This may be important since the carbohydrate reserves in perennial vine organs are the primer sugars to be used during the following vegetation period (Baeza et al., 2019). Responses to vine water status can be modified synergistically or antagonistically with the effects of other stresses under field conditions. These responses may be related to physiological and molecular variations such as stoma activity, genetic potential, hormonal regulation as well as human effects (Flexas et al., 2002; Chaves et al., 2010; Walker et al., 2014; Medrano et al., 2015; van Leeuwen et al., 2019; Mirás-Avalos and Araujo, 2021).

Many studies report that climate change will increase drought events and the need for irrigation will arise. But many others report that irrigation will not be a sustainable solution (Gambetta et al., 2020). The short term human agronomic practices, like canopy management, are as important as any others and can significantly modify vineyard performance (Olsen et al., 2011; Garcia et al., 2018; Fayolle et al., 2019; Mirás-Avalos et al., 2020) and provide sustainability. The purpose of green pruning, which is a part of canopy management, is to remove excess shoots to balance the vegetative growth and the yield in the grapevine. Timing and method of green pruning can be used to modulate water dynamics in an intermediate scale in the period from beginning of the bud burst to harvest.

Optimization of water use by means of green pruning rationalize the use of nutrients thus reduce the cultivation costs while avoiding environmental pollution and fertilizer losses (Martínez et al., 2016).

Since, monitoring and managing vine water potential are very important for achieving production targets, it is necessary to determine the grapevine water status by using an accurate estimation method and optimizing water management in vineyards. In this context, leaf water potential (Ψ_{leaf}) is a reliable indicator of the water stress experienced by grapevines (Scholander et al., 1965). Water potential (Ψ) is the suction pressure that a plant needs to extract water from the soil. When the amount of soil water available decreases, plant Ψ would also decrease.

In this research, the role of different canopy management practices, in terms of controlling water status of cv. Merlot (*Vitis vinifera* L.) vines and their effects on berry, cluster and growth parameters were investigated.

2. Materials and Methods

2.1. Vineyard

The experiment was conducted during the 2013-2014-2015 vegetation periods on cv. Merlot grapevines (*Vitis vinifera* L.) grafted onto Kober 5BB, in the coordinates 40.969184 °N – 40.973562 °N latitudes and 27.461911 °E – 27.477504 °E longitudes and, 30-35 m altitude in Tekirdag, Turkey.

Three leaf removal treatments on the main shoots and three leaf removal treatments on the lateral shoots were applied to the plants of 12-14 years old grapevines in a N-S oriented vineyard located approximately 3 km away from the sea border. Vine spacing was 2.5 to 1.5 m and the vines were pruned as double Guyot. Shoot and cluster number were balanced to density of 13-14 and 24-26 in-pre bloom. The experimental design consisted of three replications in which plots for each leaf removal strategies contained four grapevines. Vines that disrupt uniformity were excluded from the trial.

Soil type was clay loam with high groundwater. The wilting point of 0 to 180 cm horizon was 12.40-16.44% moisture, and the field capacity was 24.90-29.77% moisture by volumetric analysis. Some other soil properties of the vineyard are given in *Table 1*. Standard pest control and cultural practices were applied to all treatments during three trial years.

Table 1. Soil properties of vineyard in the year 2013

Soil depth (cm)	Water holding capacity (%)	pH	Salt (%)	Lime ($CaCO_3$, %)	Organic matter (%)	N (%)	P (ppm)	K (ppm)
0-30	58.00	7.88	0.06	1.70	1.01	0.05	5.49	301.57
30-60	51.00	7.80	0.06	1.62	1.07	0.05	6.95	287.99
60-90	51.00	7.84	0.06	3.24	0.79	0.04	3.81	211.54

Descriptive meso-climatic weather data such as temperature, light intensity and total precipitation at two meters high from ground were monitored during for three consecutive years with a weather station installed within the experimental area.

2.2. Leaf removal treatments

Leaf removal treatments on main shoots (LRMS) were performed at preverasion when main shoots reached approximately 175 cm in height (EL 31-33), by cutting back the shoots from shoots to three different heights, leaving behind about 100, 125 and 150 cm of the shoots. Leaf removal treatments on lateral shoots (LRLS) were performed at veraison (EL 33-35) either by removing the entire shoots or leaving 3-4 and 6-7 leaves on basal end of the shoots, counting from the basal end of the lateral shoots. All leaf removals were applied in the same phenological periods for three consecutive years according to Lorenz et al. (1995). All main and lateral shoot lengths kept at the applied levels until the harvest period with additional green prunings *(Table 2).*

Table 2. The description of LRMS and LRLS treatments

Treatment	**Description**	**Treatment time**
LRMS$_1$	Cutting back the main shoots to maintain 100 cm shoot lenght	prior to veraison
LRMS$_2$	Cutting back the main shoots to maintain 125 cm shoot lenght	prior to veraison
LRMS$_3$	Cutting back the main shoots to maintain 150 cm shoot lenght	prior to veraison
LRLS$_1$	Removing of lateral shoots	veraison
LRLS$_2$	Removing leaves on the distal end of the lateral shoots, leaving 3-4 leaves on the basal end	veraison
LRLS$_3$	Removing leaves on the distal end of the lateral shoots, leaving 6-7 leaves on the basal end	veraison

2.3. Soil moisture status (%)

Soil moisture measurements were carried out with gravimetric method according to Blake and Hartge (1986). Measurements were taken during the hours of 06:00 to 08:00 AM, in the days leaf water potential measurements were made in all experimental years. Data were collected in the rows at 25 cm from the base of each vine in each treatment from 0-30 cm, 30-60 cm and 60-90 cm soil depths and average values were calculated.

2.4. Vine water status (Ψ)

The plant water status, as an indicator of stress level, was determined by observing the predawn and midday leaf water potentials. Water stress [as Predawn Leaf Water Potential (Ψ_{pd}) and as Midday Leaf Water Potential (Ψ_{md})] measurements were held with console type pressure chamber (Scholander Pressure Chamber) before dawn and at noon. Predawn measurements (Ψ_{pd}) were started 2 hours before sunrise and continued until sunrise. Midday measurements (Ψ_{md}) were performed between 12:00 and 14:00. Measurements were performed on 3 fully developed leaves in the middle region of the main shoots of each vine (Scholander et al., 1965). In each application, one leaf water potential measurement was performed on three leaves of each of the four grapevines, and these measurements were used as the average of replications. Leaf water potential measurements were evaluated according to the class intervals in *Table 3.*

Table 3. Leaf water potential values and expected water stress levels according to the phenological stages for wine grape cultivars (Deloire et al. 2004; van Leeuwen et al., 2009; Martínez et al., 2013)

Ψ_{pd}(MPa)	**Ψ_{md}(MPa)**	**Stress level**	**The phenological stage for expected stress level**
≥ -0.2	≥ -1.0	No stress	Bud burst-Fruit set
-0.2 to -0.3	-1.0 to -1.2	Weak stress	Fruit set-Veraison
-0.3 to -0.5	-1.2 to -1.4	Mild-moderate stress	Veraison-Maturity
-0.5 to -0.8	-1.4 to -1.6	Moderate-severe stress	
≤ -0.8	≤ -1.6	Severe stress	

Ψ_{pd}= pre-dawn leaf water potential, **Ψ_{md}=** midday leaf water potential

2.5. Berry, cluster and vigour parameters.

Representative random samples of 24 clusters from four vines from each replications were taken to the laboratory to determine the cluster weight at harvest. Randomly selected 250 berries from all parts of these clusters were weighted to determine berry weight (Carbonneau et al., 1991). The pruning weight (kg/vine) was determined by weighing the pruned shoots with a digital hand scale. Shoot weight (g/vine) was determined by dividing the total pruning weight by the number of main shoots. The ratio between vine yield and pruning weight (RI) was calculated according to Ravaz (1903).

2.6. Trial design and statistical analyzes

The experiment was laid out in a completely randomized block design with each treatment comprising three replications. JMP 13.2.0 statistical program was used for determining differences in applications. Significant differences were grouped with the LSD test at 5% significance level.

3.1. Climate

Some climatic data obtained from the experiment vineyard in 2013, 2014 and 2015 years were presented in *Figure 1*. The average temperature and precipitation values for a long-term period (1939-2019) are estimated as 14.00°C and 589.50 mm, respectively (MGM 2019). The rainfall in 2013 was below the seasonal norms with 443.80 mm. The precipitation in the vegetation period was 165.60 mm and slightly lower than the long-term averages of 196.70 mm. The average temperature was recorded as 16.24°C. The average light intensity values for the months of the study and for the year 2013 were 1046.33 µmol s^{-1} m^2 and 1018.09 µmol s^{-1} m^2, respectively.

Annual rainfall (770.50 mm) and vegetation period rainfall (611.30 mm) values in 2014 were much higher than the average of long-term. The average temperature values for the year 2014 and months of the study were 16.08°C and 19.88°C, respectively. The average light intensity values for the months of the study and for the year were 581.39 µmol s^{-1} m^2 and 772.74 µmol s^{-1} m^2, respectively. Both values were considerably low compared to the previous year.

The yearly precipitation was 507.90 mm and the vegetation period precipitation was 267.80 mm in year 2015. The average temperature values for the year 2015 and months of the study were 16.00°C and 20.20°C, respectively. The average light intensity was recorded as 924.47 µmol s^{-1} m^2 for the year 2015 and was recorded as 1154.70 µmol s^{-1} m^2 during the vegetation period. According to the data recorded over three experimental years, 2014 differed from the other two years in terms of rainfall, light intensity and relative humidity *(Figure 1).*

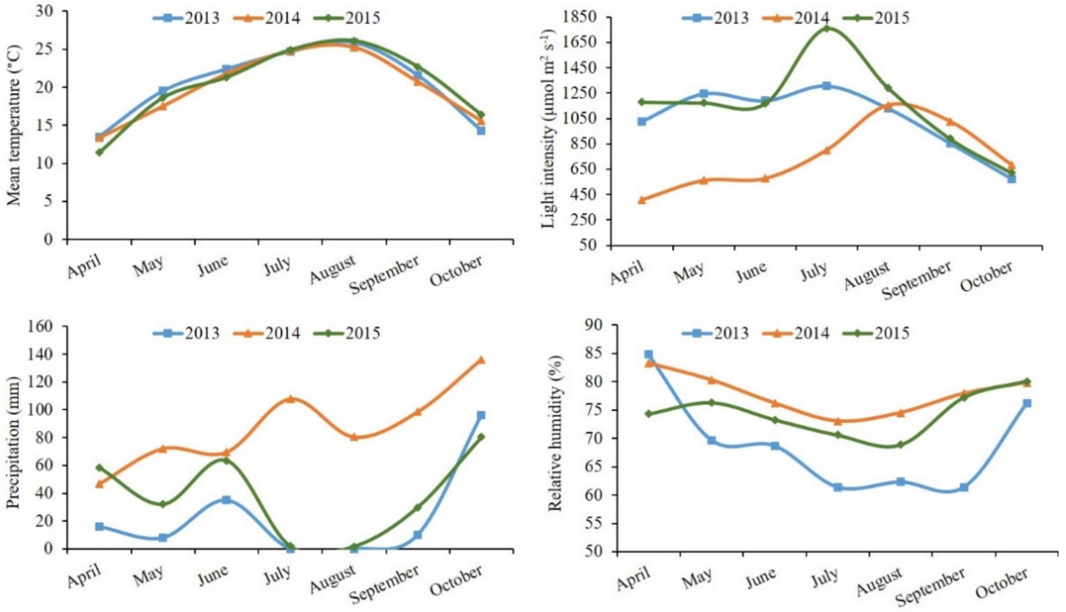

Figure 1. Climatic data of experimental vineyard in vegetation periods of 2013, 2014 and 2015 years

Climatic data obtained from the days of midday leaf water potential (Ψ_{md}) measurements were made over three years were taken during the hours of 12:00 to 14:00 across the vineyard *(Figure 2).*

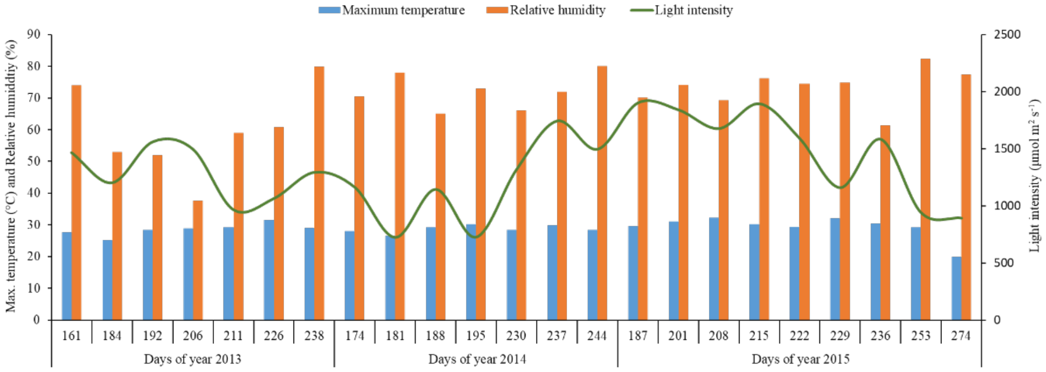

Figure 2. Climatic data of experimental vineyard in leaf water potential measurement days during the experimental years

3.2. Phenology

The results of phenological observations are presented in *Table 4*. Harvest was done at 22-23% TSS (Total Soluble Solids) except for the year 2014 due to the unusual heavy precipitation *(Table 4).* Taking into account the physical condition of the berries, the harvest in 2014 was carried out with a lower TSS percentage to avoid berry rot due to excessive rainfall.

Table 4. Phenological development stages of Merlot variety during the experimental years

Budburst (EL 04-07)	**Flowering (EL 23-25)**	**Veraison (EL 35)**	**Harvest (EL 38)**
05.04.2013; 95th day	29.05.2013; 149th day	22.07.2013; 203th day	26.08.2013; 238th day
02.04.2014; 92nd day	29.05.2014; 149th day	30.07.2014; 211st day	16.09.2014; 259th day
12.04.2015; 102nd day	28.05.2015; 148th day	01.08.2015; 213rd day	05.10.2015; 278th day

The changes in berry maturation between verasion and harvest over the years were largely due to fluctuations in the precipitation regime. The calculated Winkler Indexes (WI, GDD) were determined as 2157.00, 2074.64 and 2142.00 respectively in three consecutive years. The amount of precipitation during the vegetation period was 165.60 mm in 2013 and was 267.80 mm in 2015.

3.3. Changes of soil moisture

In 2013, soil moisture was ranged between 19.58% and 15.78%. Minor fluctuations were caused by precipitations that fall before the measurement days. The precipitation in the vegetation period of 2014 was 611.30 mm approximately 2.5 times higher than the vegetation period average of long-term (1939-2019). The highest soil moisture was measured as 28.90% and the lowest soil moisture as 18.64%. In the measurement days of 2015, soil moisture fluctuated between 15.53% and 20.21% *(Figure 3).*

Soil moisture content ranged between 15.53% and 28.90% during the experimental years. Soil moisture did not fall below the wilting point which was calculated as 14.42% on average in any of the measurements carried out for three consecutive years. This was due to the fact that the vineyard is predominantly clayey at depths of 60-90 cm.

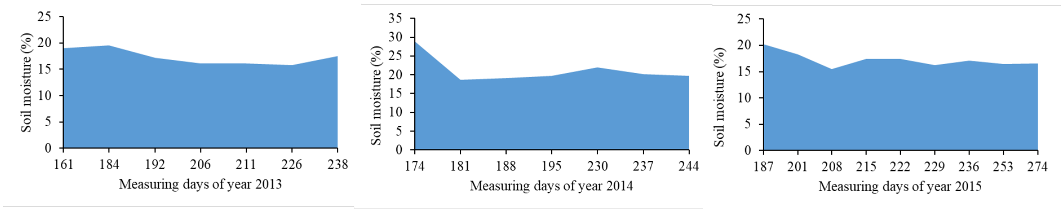

Figure 3. Soil moisture status of experimental vineyard in leaf water potential measurement days during the experimental years

Data were presented as the means of 0-30 cm, 30-60 cm and 60-90 cm of soil depths.

3.4. Changes of predawn leaf water potential (Ψ_{pd}) and midday leaf water potential (Ψ_{md})

The lowest predawn leaf water potentials were measured on the 226th day with value of -0.28 MPa in $LRLS_1$ and $LRMS_1$ treatments in the year 2013. Predawn leaf water potentials on day 238th also indicated low stress levels. These two were the only days when predawn stress was detected in 2013 *(Figure 4)*.

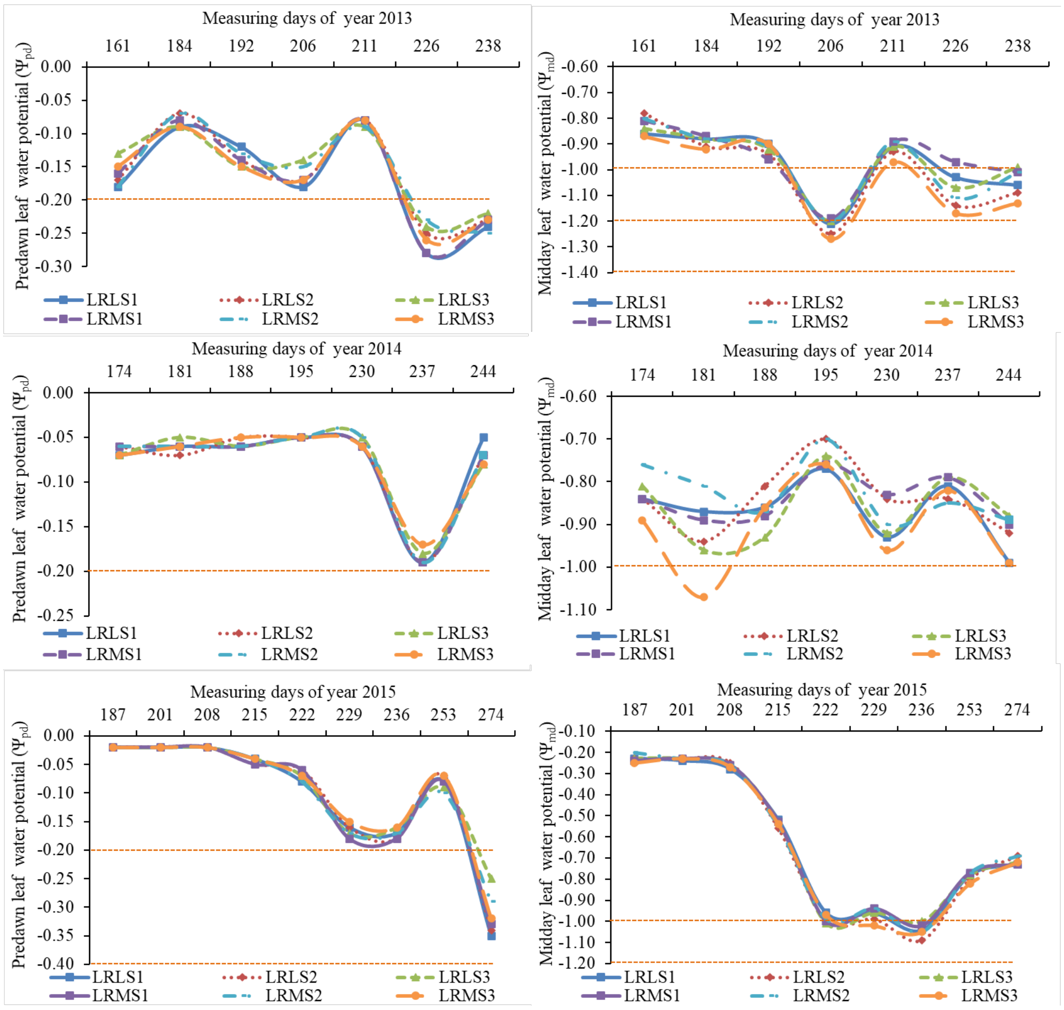

Figure 4. Predawn and midday leaf water potentials according to different leaf removal treatments
$LRMS_1$, $LRMS_2$ and $LRMS_3$ represents 100 cm, 125 cm and 150 cm main shoot lengths, $LRLS_1$ represents removing of all lateral shoots, $LRLS_2$ and $LRLS_3$ represents leaving 3-4 and 6-7 leaves on the basal end of the lateral shoots. Red dotted lines along the horizontal axis represent the water stress levels of vines (Deloire et al. 2004; van Leeuwen et al., 2009; Martínez et al., 2013).

In 2014, measurement did not reflect any sign of stress mainly due to the effect of extraordinary rainfall during the vegetation period. The lowest Ψ_{pd} value, -0.19 MPa, was measured on day 237th. $LRMS_3$ and $LRLS_3$ treatments were represented slightly higher Ψ_{pd} values. All treatments formed similar curves *(Figure 4)*.

When periodically examined, predawn leaf water potential [Ψ_{pd} (-MPa)] measurements of 2015, started to show stress signs during the period between veraison and maturity but disappeared towards the harvest in September. However, just before harvest, medium stress sings in all treatments was observed. Further examinations showed similar tendencies in all leaf removal applications and there were no significant differences between the applications *(Figure 4)*.

Measurements of predawn leaf water potential [Ψ_{pd} (-MPa)] over three years revealed changes in soil moisture content due to the general climate conditions, especially precipitation and climatic conditions were found to be more effective on manipulation of leaf water potentials than canopy management treatments.

A relative increase of midday water stress is expected to during the time from veraison to harvest, which vary between $-1.2 \leq \Psi_{md} \geq -1.6$ MPa (Deloire et al., 2004). In 2013, when the average of the measured days was taken into consideration, regardless of the practices, moderate stress was observed for the first time on the 206th day (after veraison) with a value of -1.22 MPa. Although the differences among the treatments are very little, the highest values were recorded in $LRMS_3$ with -1.03 MPa and $LSLR_2$ with -1.01 MPa *(Figure 4)*.

In 2014, apart from $LRMS_3$ treatment none of the midday leaf water potential [Ψ_{md} (-MPa)] measurements indicated any signs of stress. This may be due to the extraordinary rainfall especially during the vegetation period. The lowest value of Ψ_{md} (-1.08 MPa) recorded on the 181st day in treatment $LRMS_3$ indicated weak stress level *(Figure 4)*.

It was observed that the midday leaf water potential tended to increase slightly until the 236th day (after veraison) of the 2015 year. The lowest value was measured on the same day with -1.09 MPa in $LRLS_2$ treatment.

The fact that there were no significant decrease in Ψ_{md} values in 2013 and also in 2014 which had the highest rainfall in vegetation period and the whole year may be the indication of midday water stress is not only under the control of soil moisture and seasonal precipitation, but also daytime temperature values and the cultivation preferences *(Table 5)*. There are also studies indicating that Ψ_{md} values are in high correlation with daily water use and can be used reliably in vineyard irrigation programs (Mata et al., 1999; Shackel, 2007; Williams and Baeza, 2007; Williams et al., 2012).

Table 5. Seasonal means of predawn and midday leaf water potentials according to different leaf removal treatments

	2013		2014		2015	
Treatment	**Ψ_{pd} (MPa)**	**Ψ_{md} (MPa)**	**Ψ_{pd} (MPa)**	**Ψ_{md} (MPa)**	**Ψ_{pd} (MPa)**	**Ψ_{md} (MPa)**
$LRMS_1$	-0.17	-0.98a	-0.14	-0.85a	-0.14	-0.87
$LRMS_2$	-0.16	-1.00a	-0.15	-0.85a	-0.14	-0.86
$LRMS_3$	-0.17	-1.06b	-0.13	-0.92b	-0.13	-0.89
$LSD_{0.05}$	*ns*	*0.048*	*ns*	*0.062*	*ns*	*ns*
$LRLS_1$	-0.17	-1.00	-0.14	-0.89	-0.14	-0.86
$LRLS_2$	-0.16	-1.05	-0.14	-0.85	-0.13	-0.86
$LRLS_3$	-0.17	-1.05	-0.14	-0.88	-0.14	-0.89
$LSD_{0.05}$	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Values expressed with different letters in the same column are statistically significant at the $P < 0.05$ level according to LSD multiple comparison test. LRMS; Represents leaf removal treatments on main shoots, LRLS; Indicates leaf removal treatments on lateral shoots. Ψ_{pd}= pre-dawn leaf water potential, Ψ_{md}= midday leaf water potential, ns= not significant.

When the mean values of Ψ_{pd} in 2013 were evaluated according to the leaf removal treatments, the variation was very small but the highest values were observed with -0.17 MPa. In 2014 the lowest value of Ψ_{pd} was observed in $LRMS_2$ with -0.15 MPa. All of these values indicate low stress according to *Table 3*. As in the previous two years there were no significant differences between applications in 2015. In general, all applications followed a parallel course *(Table 5)*.

In terms of predawn leaf water potential, our findings are in accordance with the studies conducted with Syrah (Korkutal et al., 2018) and Cabernet-Sauvignon (Bahar et al., 2018) varieties in Tekirdağ. In both studies, it was reported that leaf removal practices did not have significant effects on predawn leaf water potentials.

The midday leaf water potential measurements were found to be statistically significant in 2013 and 2014. In 2013, although midday measurements showed only weak signs of stress, the lowest value was measured at -1.06 MPa in the $LRMS_3$ application in seasonal means of Ψ_{md}. In 2014, results were similar to the previous year; $LRMS_3$ treatment had the lowest value with -0.92 MPa and was statistically differed from the other two main shoot applications. While there was no statistical significance among the main shoot applications in 2015, the $LRMS_3$ application again showed the lowest value with little difference *(Table 5)*.

Although there were no considerable differences in results in terms of water stress measurements in experimental years, it can be said that stress tends to increase as the length of the main shoot increases especially for Ψ_{md} as suggested by Yasasin et al. (2017).

3.5. Berry, cluster and vigour parameters

In all experimental years, shoots and clusters were balanced to retaining 13-14 shoots and 24-26 clusters in pre-bloom. Thus, the differences between the yield values were not statistically significant. Yields means from three experimental years were ranged between 5.20 kg/vine and 5.39 kg/vine.

Effects of the main shoot and lateral shoot treatments on berry, cluster and vigour parameters are shared in *Table 6*. In 2013, no statistically significant differences were observed in terms of berry weight, cluster weight, shoot weight, pruning weight and RI data. However cluster, shoot and pruning weights were found to be slightly higher in LRMS$_3$ application, while RI data were lower.

Table 6. Effects of the main shoot and lateral shoot treatments on berry, cluster and vigour parameters.

Treatment	Berry wt. (g/100pieces)	Cluster wt. (g)	Shoot wt. (g/shoot)	Pruning wt. (kg/vine)	Ravaz index
2013					
LRMS$_1$	150.86	291.65	72.77	0.98	6.66
LRMS$_2$	149.18	275.94	70.82	0.97	6.79
LRMS$_3$	150.54	306.64	81.44	1.13	5.96
LSD $_{0.05}$	*ns*	*ns*	*ns*	*ns*	*ns*
LRLS$_1$	149.55	266.07	72.23	0.98	7.04
LRLS$_2$	148.00	322.14	72.64	1.00	6.32
LRLS$_3$	153.03	285.43	80.16	1.10	6.05
LSD $_{0.05}$	*ns*	*ns*	*ns*	*ns*	*ns*
2014					
LRMS$_1$	145.00	136.66	88.33	1.21	0.64
LRMS$_2$	141.15	110.90	95.59	1.31	0.52
LRMS$_3$	143.96	118.49	122.72	1.70	0.36
LSD $_{0.05}$	*ns*	*ns*	*ns*	*ns*	*ns*
LRLS$_1$	140.04	119.07	80.11b	1.12b	0.64a
LRLS$_2$	137.31	120.24	118.11a	1.61a	0.43b
LRLS$_3$	152.75	126.74	108.41a	1.50a	0.45b
LSD $_{0.05}$	*ns*	*ns*	*22.72*	*0.27*	*0.15*
2015					
LRMS$_1$	180.25	288.96	60.61b	0.83b	10.86a
LRMS$_2$	179.82	290.59	76.36ab	1.04ab	9.06ab
LRMS$_3$	177.13	301.32	93.66a	1.29a	7.12b
LSD $_{0.05}$	*ns*	*ns*	*23.01*	*0.29*	*2.55*
LRLS$_1$	174.03	277.58	67.26	0.93b	9.80
LRLS$_2$	184.84	293.25	82.99	1.13a	8.12
LRLS$_3$	178.32	310.04	80.38	1.10ab	9.12
LSD $_{0.05}$	*ns*	*ns*	*ns*	*0.16*	*ns*

Values expressed with different letters in the same column are statistically significant at the P <0.05 level according to LSD multiple comparison test. LRMS; Represents leaf removal treatments on main shoots, LRLS; Indicates leaf removal treatments on lateral shoots. Ψ_{pd}= pre-dawn leaf water potential, Ψ_{md}= midday leaf water potential, ns= not significant.

In 2014, the effect of leaf removal treatments on lateral shoots on shoot weight, pruning weight and RI was non-significant. While LRLS$_1$ application resulted the lowest shoot and pruning weights and the highest RI values, the other two leaf removal treatments on lateral shoots were in the same statistical group. The unexpected low values in cluster weight and RI in 2014 may be attributed to rotting resulting from heavy rainfall which also gave rise to yield loss *(Table 6).*

Effects of main shoot treatments on shoot weight, pruning weight and RI parameters were found to be significant in 2015. The higher shoot and pruning weights were observed in LRMS$_3$ treatment. LRMS$_3$ resulted in the lowest RI. While the effect of LRLS$_2$ on pruning weight was significant, leaf removal treatments on lateral shoots had no significant effect on weight parameters in 2015 *(Table 6).* Although statistically non-significant, lower values in berry and cluster characteristics, especially in the years of low rainfall (2013 and 2015), were observed in the $LRLS_1$ application. Low values with the $LRLS_1$ may have been due to the relative decrease in total leaf area, and not the changes in predawn or midday leaf water potentials. However this consideration may not be applied to berry chemical quality components.

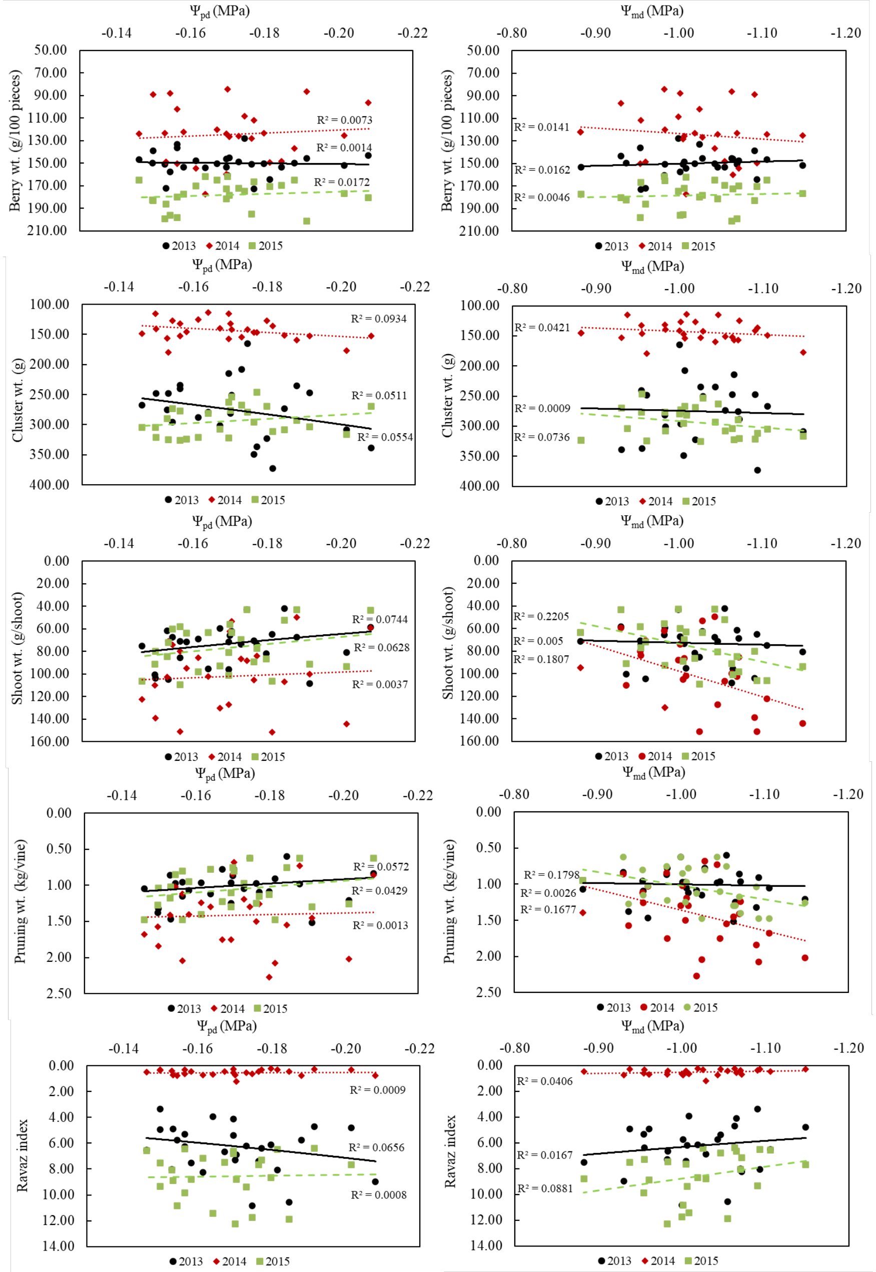

Figure 5. The relationship between predawn and midday leaf water potentials and selected parameters.

Although the pre-dawn and mid-day leaf water potentials were detected only as weak stress levels and only for short periods throughout the entire trial, the trends caused by the decreases and the increases in the examined criteria can be seen in *Figure 5*.

In 2015, both pre-dawn and midday leaf water potential measurements showed that increasing stress slightly decreased berry weight. Similar trend was observed in 2013. In 2014, the increasing mid-day stress increased the berry weight. This situation in 2014 can be explained by the unusual climatic characteristics of the year. It was determined that the increasing stress decreased the cluster weight according to leaf water potential measurements. Adversly Ψ_{pd} measurements inreased cluster weight in 2015. In 2014 and 2015, unexpectedly, shoot and pruning weights showed an increasing trend with increasing Ψ_{md}. However, the results can be evaluated within normal limits, since increasing values indicate the lowest stress level. In addition, the slight increase in Ψ_{pd} also lead to a slight decrease in vigour parameters.

As indicated in many previous studies, increasing and decreasing of leaf water potential can result in changing responses in the vine plant (Uriarte et al., 2015; Rossouw et al., 2017; van Leeuwen et al., 2019; Mirás-Avalos and Araujo, 2021).

4. Conclusions

As a result; the main shoot length increase in the cv. Merlot grape cultivar under the conditions of the trial vineyard caused the stress tendency. This phenomenon can be used as a quality-enhancing tool for canopy management applications in rainy years and high soil moisture conditions. In addition, changes in the growth parameters due to the stress tendency caused by the main shoot length were determined. The removal of lateral shoot leaves had no significant effects on the water status of vines.

Although the applications are manipulative in terms of quality and physiological activity seasonal effects of each vegetation period are the main determining factors. However, the cumulative effect of these small effects becomes more significant when evaluated with phenological periods and whole vegetation periods. In addition, it is thought that the increase and decrease trends observed in the examined criteria can be determined more clearly in drier years. It can be speculate that manipulation of the main shoot length affects yield, berry quality and carbohydrate accumulation by affecting water stress levels.

Therefore, the planning of canopy management practices should be done separately each year by following the long and medium-term meteorological evaluations. Canopy management manipulations should be done according to the phenological period and short term meteorological evaluations.

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