VITICULTURE STUDIES

Viticulture Studies (VIS)
2024, 4(1): 1-8
https://doi.org/10.52001/vis.2024.23.1.8

Research Paper

Impact of Varied Soil Tillage and Shoot Lengths on Vegetative Development, Water Stress, and Yield in Cabernet Sauvignon Grapevines (*Vitis vinifera* L.)

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How to cite: Yasasın, A. S., Coşkun, Z., Zobar, D., Açıkbaş, B. (2024). Impact of Varied Soil Tillage and Shoot Lengths on Vegetative Development, Water Stress, and Yield in Cabernet Sauvignon Grapevines (Vitis vinifera L.). Viticulture Studies (VIS), 4(1): 1 – 8. https://doi.org/10.52001/vis.2024.23.1.8

Article History:
Received: 17.01.2024
Accepted: 30.01.2024
First online: 31.01.2024

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Keywords
Cabernet sauvignon
Abiotic stress
Leaf area
Conservation tillage

Abstract

This research was carried out from 2010 to 2012 at the Tekirdag Viticulture Research Institute, focusing on the Cabernet Sauvignon grape variety, which was grafted onto Kober 5BB rootstock. The climate in the region, particularly during the winter and spring, was characterized by significant rainfall, which contributed to the swift vegetative growth of grape varieties from bud burst to bloom. The primary objective of this study was to ascertain the most effective soil tillage technique. This involved evaluating the impact of various soil tillage methods (conventional, minimized, conservation) and shoot lengths (1.0 m and 1.5 m) on the vegetative growth and water stress levels in Cabernet Sauvignon, with an emphasis on controlling vegetative growth. The findings indicated that conservation tillage resulted in the most favorable outcomes, with the lowest pruning weight (1.58 kg.vine^{-1}), leaf area (142.38 cm^2), and yield (3.2 kg.vine^{-1}). When considering different shoot lengths, the shortest shoot length (1.0 m) led to a minimal pruning weight of 1.69 kg per vine. The study concludes that, under the conditions in Tekirdag, conservation soil tillage, alongside conventional methods, is advisable for Cabernet Sauvignon cultivation due to its beneficial impact on leaf water potentials.

Introduction

Grapevines encounter various stress conditions throughout their lifespan. These conditions negatively affect plant growth, plant metabolites and yield. Abiotic stresses such as drought, insufficient nutrition, salinity, extreme temperatures (both low and high) as well as soil &atmospheric pollution and radiation, collectively contribute to the limitation of yield in plant production.

Among the abiotic stresses, drought is the most significant factor, which limits plant production. It occurs when plants fail to acquire the water they need, often intensifying during the summer months due to inadequate precipitation and problems related to drought stress are able to emerge (Yasasin, 2010). Despite varying drought tolerance levels among vine varieties (Yağmur, 2008), their growth is impeded. Drought stress can lead to a reduction in berry size and weight, shrinkage, shelling, looseness in cluster and delayed maturation (Keller et al., 2016, Kizildeniz et al., 2018, Keller et al., 2023). These problems contribute to a decline in berry quality and a decrease in vine yield (Yasasin, 2010; Deloire et al., 2005).

In this regard, it has been indicated that cover crop tillage can be employed in regions with rainfall in winter and spring to reduce vine growth (Olmstead, 2006). Consequently, the application of cover crop tillage resulted in a decrease in pruning weight, yield, vine growth, and leaf area per vine as determined by various studies. (Hua et al., 2005; Mattii et al., 2005; Palma et al. 2007; Tesic et al., 2007; Lopes et al., 2008; Bahar and Yasasin, 2010).

This study was conducted to determine the effects of suppressing rapid vegetative growth in the Cabernet Sauvignon variety through different soil tillage and shoot length applications, spanning from bud burst to the berry set stage. The research focused on stress levels, vegetative growth and yield in a region characterized as rainy during winter and spring.

Material and Methods

This experiment was carried out during the 2010–2012 growing seasons using the Cabernet Sauvignon/5BB graft combination. The research was carried out in the main experimental vineyard located at the Tekirdag Viticulture Research Institute, situated at an elevation of 27 meters above sea level, with geographical coordinates of 40°58'10.71" North and 27°28'21.71" East, in Turkey. The vine spacing was set at 2.5 x 1.5 meters. The vines, which were ten years old, were pruned in a bilateral cordon style. During the pruning process, each vine was left with eight spurs, each having 2 to 3 buds, totaling 16 to 18 buds per vine. An additional adjustment was made to equalize the number of clusters (26 to 28 per vine) and shoots (16 to 18 per vine) when the shoot length reached 20 to 25 cm. The rows in the vineyard were oriented in a north-south direction.

In the experimental vineyard, soil tillage was conducted in autumn, followed by leaving it for natural grassing. Soil tillage was performed superficially with a cultivator. The initial weed mowing between rows occurred after berry set in conservation (CST) and minimized tillage (MIT), and it was subsequently repeated regularly every 15 days. Soil tillage within the rows was regularly performed for all treatments. The experiment adopted a randomized split block design, incorporating three soil tillage techniques: conventional tillage (CVT), minimized tillage (MIT), and conservation tillage (CST). Additionally, two different shoot length treatments, namely 1.0 m and 1.5 m, were employed, each with five repetitions. The experimental setup encompassed a total of 90 vines, as detailed in Table 1.

Soil tillage treatments:

Conventional tillage (CVT): Soil tillage was performed superficially with a cultivator once in autumn. After the start of the vegetation period, soil tillage was conducted using conventional methods at 15-20 day intervals until the end of veraison.

Minimized tillage (MIT): In autumn, soil tillage was performed superficially with a cultivator and then left for natural grassing. The minimum tillage treatment started at the pea size stage of berries and was conducted at 15-20 day intervals until the end of veraison. Weed mowing between rows was carried out regularly every 15 days.

Conservation tillage (CST): Throughout the conservation tillage treatment, natural grassing occurred and no tillage was performed. Weed mowing between rows was carried out regularly every 15 days.

Shoot lenght treatments:

1.0 m shoot lenght: Limiting shoot lenght to 1.0 m by topping after berry set.

1.5 m shoot lenght: Limiting shoot lenght to 1.5 m by topping after berry set.

Table 1. Experimental Design

Soil tillage Treatments	Shoot lenght treatments	Vine number.plot^{-1}	Total vine number (plot x 5 repetition)
CVT	1.0 m	3	15
	1.5 m	3	15
MIT	1.0 m	3	15
	1.5 m	3	15
CST	1.0 m	3	15
	1.5 m	3	15
Total vine number in experiment area			90

(CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservation tillage)

All data analyses were performed with SPSS (PASW® Statistics 18 for Windows) software. LSD tests were used to assess the significant differences of measured traits between groups at the $P<0,05$ level.

Examined parameters:

Leaf water potential (Ψ_{leaf}): Leaf water potentials (Ψ_{leaf}) for each vine were assessed using a Scholander Pressure Chamber (Scholander et al., 1965). Measurements of both predawn (Ψ_{pd}) and midday (Ψ_{md}) leaf water potentials were conducted approximately six times over a span of 14 days, beginning from the onset of flowering and continuing until harvest. These measurements were performed on fresh, healthy, and fully mature leaves selected from each vine, covering all soil tillage and shoot length treatments.

Yield (kg vine^{-1}): During the harvest, clusters from each vine representing the different treatments were collected in the early morning hours, between 08:00 and 10:00 am. These clusters were then weighed, with the results expressed in kilograms per vine (kg.vine^{-1}).

Leaf area (cm^2): In the second half of July, 50 leaves from the medial zone of shoots (from the third to the tenth node) were collected from each treatment and the leaf area was measured with a laser area meter (CID, Inc) (Mattii et al., 2005).

Pruning weight (kg.vine^{-1}): The weight of the pruning wood was determined by weighing vine canes taken from 2 vines per treatment and carried out in February.

Statistical analysis: All data analyses were performed with SPSS (PASW® Statistics 18 for Windows) software. LSD tests were used to assess the significant differences of measured traits between groups at the $P<0{,}05$ level. The experimental design is given in Table 1.

RESULTS AND DISCUSSION

Total precipitations in 2011 (788.8 mm) were higher than in 2010 (734.9 mm) and 2012 (670.8 mm). Similar situations were observed during the vegetation periods of 2010 (156.0 mm), 2011 (390.9 mm), and 2012 (155.6 mm) years. Additionally, precipitation in the spring period (March, April, and May sum) was 95.0 mm (2010), 153.7 mm (2011) and 152.9 mm (2012). However, in the summer of 2011, precipitation (147.8 mm) and leaf water potential values (Ψl_{eaf}) were higher than in the other years. Annual average temperatures were 14.5°C, 12.9°C, and 15.4°C in 2010, 2011, and 2012, respectively. Maximum temperatures were 34.8°C, 33.8°C, and 35.8°C while minimum temperatures were -12.5°C, -5.2°C, and -9.9°C in 2010, 2011, and 2012, respectively. The warmest month was August (average temperature: 26.5°C) in 2010, while in 2011 (average temperature: 24.4°C) and 2012 (average temperature: 27°C) was July (Figure 1). As observed, 2011 was cooler and rainier than the other years.

The most suitable water stress levels were obtained during vegetation periods of 2010, 2011 and 2012 for yield and quality parameters. During the research period, the lowest pre-dawn leaf water potential value was obtained from conservation tillage application (-0.54 MPa) in 2010. In 2011 which had more rainfall compared

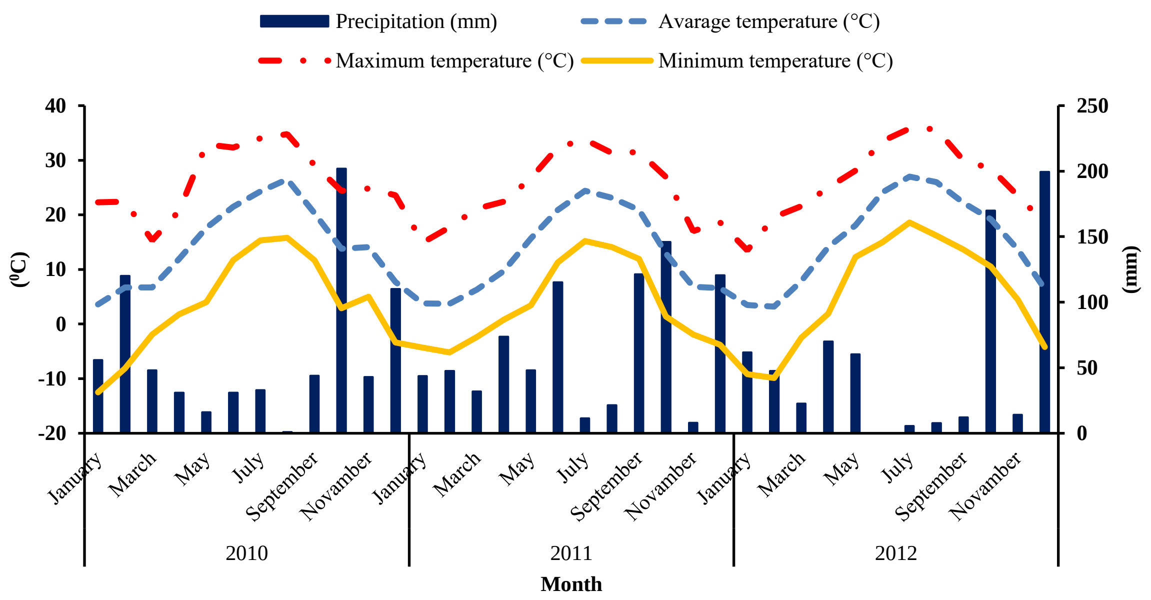

Figure 1. Temperature (°C) and precipitations (mm) in 2010–2012

to other years and the highest pre-dawn leaf water potential value was determined in the minimized tillage application (-0.38 MPa). Conservation tillage and minimized tillage applications did not cause excessive stress compared to conventional soil tillage. The obtained values were at the level that should be in the period of phenological stages. However, conservation soil tillage has slightly lowered pre-dawn leaf water potential compared to other soil

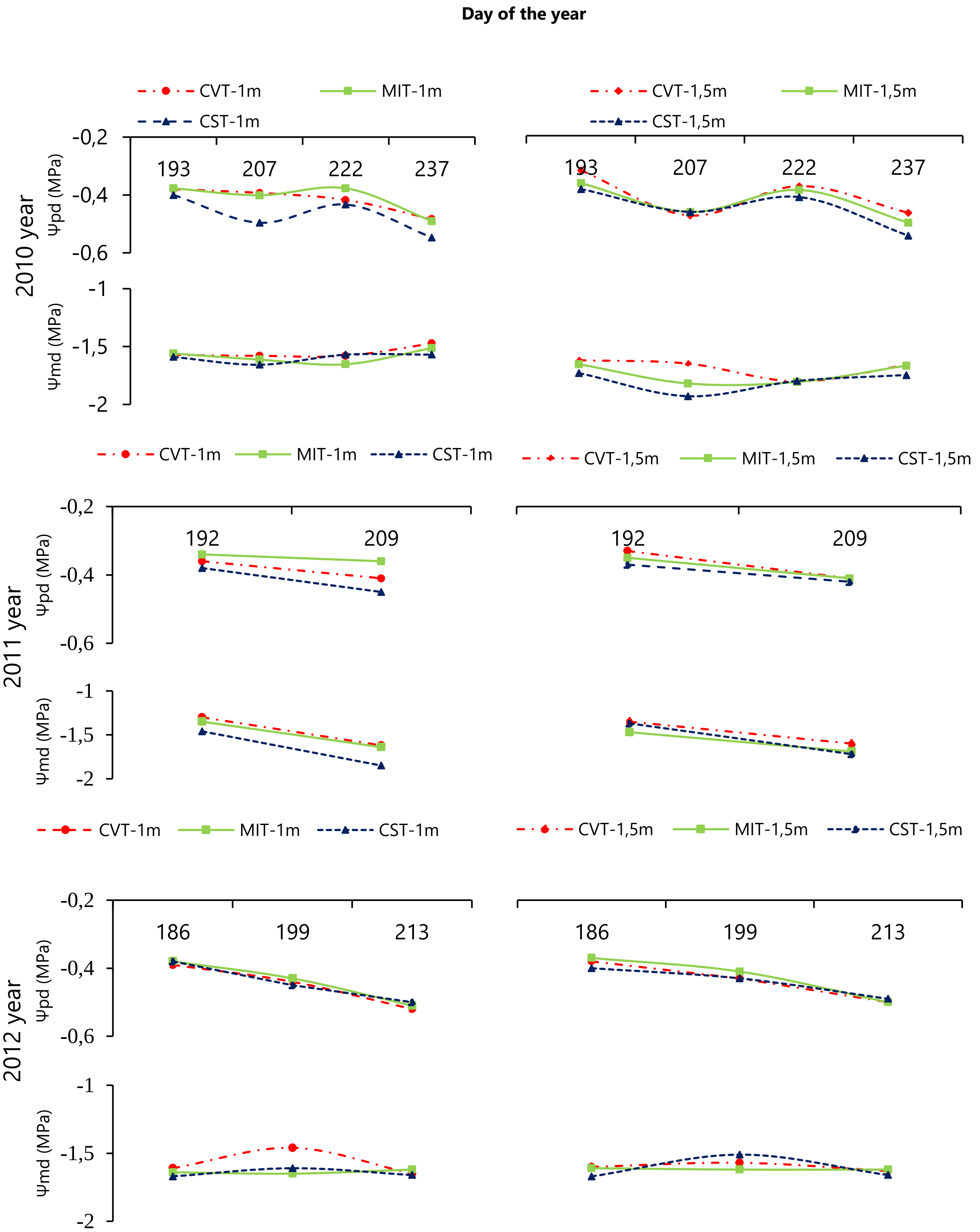

Figure 2. Ψ_{pd} and Ψ_{md} values depending on treatments in 2010-2012 vegetation period. (CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservation tillage)

tillage treatments, thus increased water stress. This had a positive effect in terms of quality improvement (data not shown). Regarding shoot length, the highest pre-dawn leaf water potential value was also measured in both 1m and 1.5m shoot length applications (-0.41 MPa) in 2011. Whereas the lowest pre-dawn leaf water potential (Ψ_{pd}) value was measured in 1.0 m shoot length (-0.51 MPa) in 2010 and 2012. There were no significant differences in Ψ_{pd} depending on different shoot lengths. Therefore, in this region, the length of the shoots can be regulated between 1m and 1.5m depending on the climatic conditions of the year. The results

Table 2. The effect of different soil tillage and shoot length treatments on yield (kg.vine^{-1}) in cv. Cabernet Sauvignon (*Vitis vinifera* L.)

Soil tillage	Shoot lenght	Years			Mean effect of soil tillage	Mean effect of shoot lenght
		2010	2011	2012		
CVT	1.0 m	3.5	3.7	3.7	3.7a	3.4 (1.0 m)
	1.5 m	3.8	3.8	3.8		
MIT	1.0 m	3.5	3.1	3.1	3.4b	
	1.5 m	3.9	3.2	3.2		3.5 (1.5 m)
CST	1.0 m	3.7	3.1	3.1	3.2b	
	1.5 m	4.0	2.8	2.8		
Mean effect of years		3.7a	3.3b	3.3b	0.26	N.S.

(CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservation tillage). *Main effect of soil tillage $LSD_{p<0.05}$: 0,26

Table 3. The effect of different soil tillage and shoot length treatments on leaf area in cv. Cabernet Sauvignon (*Vitis vinifera* L.).

Soil tillage	Shoot lenght	Years			Mean effect of soil tillage	Mean effect of shoot lenght
		2010	2011	2012		
CVT	1.0 m	153.09	160.85	144.48	151.35a	146.12 (1.0 m)
	1.5 m	152.61	155.40	141.67		
MIT	1.0 m	143.89	147.95	135.50	144.56b	
	1.5 m	148.62	153.37	138.05		146.07 (1.5 m)
CST	1.0 m	141.78	147.74	139.82	142.38b	
	1.5 m	148.57	150.95	125.42		
Mean effect of years		148.09a	152.71a	137.49b	5.92	N.S.

(CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservation tillage). *Main effect of soil tillage $LSD_{p<0.05}$: 5.92

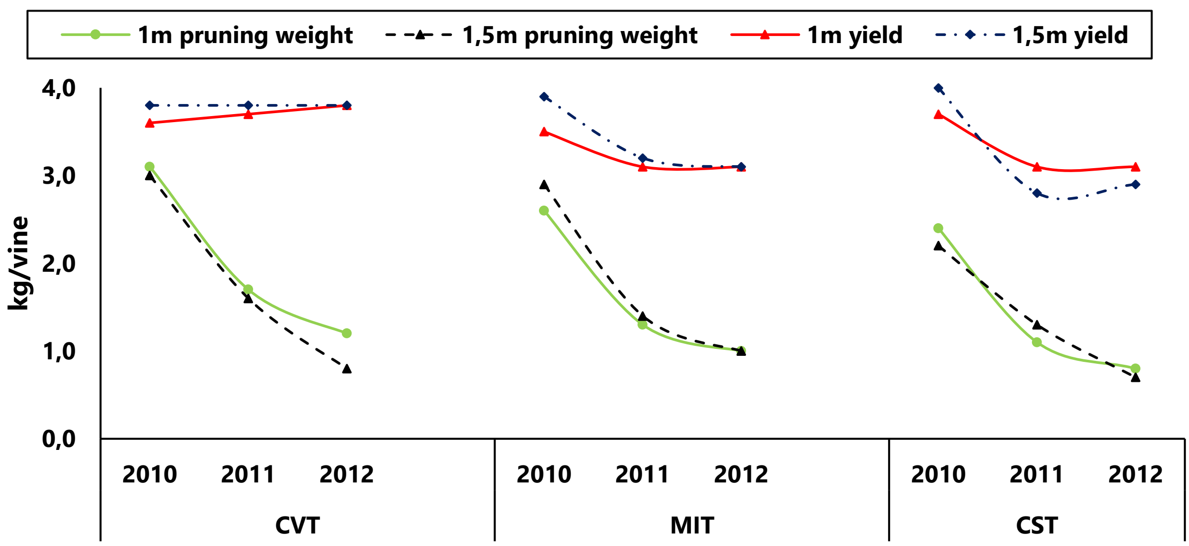

Figure 3. The effect of different soil tillage and shoot length treatments on pruning weight in cv. Cabernet Sauvignon (*Vitis vinifera* L.) (CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservation tillage)

showed that predawn leaf water potential (Ψ_{pd}) values obtained at the maturation stage were compatible with many studies (Deloire et al., 2004; Yasasin, 2010; Bahar and Kurt, 2015; Rogiers et al., 2015).

In terms of soil tillage, the lowest midday leaf water potential (Ψ_{md}) value was measured in the conservation tillage application in 2011 (-1.78 MPa). The highest midday leaf water potential was -1.48 MPa in the minimized tillage application in 2010. The highest midday leaf water potential value was measured in the 1.0 m shoot length in 2011 (-1.70 MPa). Colak (2010) stated that midday leaf water potential values (Ψ_{md}) in high water stress should be between -1.4 MPa and -1.6 MPa at this stage. Our findings were compatible with these values (Figure 2).

Significant differences were found in tillage treatments [CVT: 3.7 kg.vine^{-1} (a); MIT: 3.4 kg.vine^{-1} (b); CST: 3.2 kg.vine^{-1} (b)] and year effect [2010: 3.7 kg.vine^{-1} (a); 2011: 3.3 kg.vine^{-1} (b); 2012: 3.3 kg.vine^{-1} (b)]. The lowest yield value was obtained in Conservation tillage (CST: 3.2 kg.vine^{-1}) treatment (Table 2). The decrease in yield usually began in the second year and there has not been a decline in yield in the first years because of the influence of internal dynamics. Therefore, this retardant effect should be taken into account in conservation soil tillage and minimized soil tillage treatments for vegetative growth decrease, yield reduction and quality improvement. Monteiro & Lopes (2007) stated that Conservation tillage treatment in Cabernet Sauvignon variety did not cause a stastically significant reduction in the yield parameter. However, many other researchers stated that Conservation tillage treatment caused a stastically significant reduction in yield, as we observed (Tesic et al., 2007; Wheeler et al., 2005; Hua et al., 2005).

Leaf size was measured and significant differences were found in soil tillage treatments and between the 3 years. However in the first year of the study, differences in leaf size according to tillage treatments (CVT: 152.9 cm^2; MIT: 146.3 cm^2; CST: 145.2 cm^2) were not found to be statistically significant (Table 3).

Mattii et al. (2005) stated that, cover crop tillage did not have a stastically significant effect on leaf size. Their results are similar to our findings in the first year. However, Palma et al. (2007) were investigated the physiological and qualitative effects of soil tillage and covered soil tillage in the Sangiovese variety. As a result of covered soil tillage, a 40-60% decrease in leaf area, a 20% decrease in leaf water potential and a 50% decrease in leaf gas exchange were determined. The delayed response in yield decrease was also similarly observed in leaf size and in the third year, it reduced to the lowest level.

In pruning weight, statistically significant differences were found in tillage treatments [CVT: 1.9 kg.vine^{-1} (a); MIT: 1.70 kg.vine^{-1} (ab); CST: 1.58 kg.vine^{-1} (b)] and year effect [2010: 2.86 kg.vine^{-1} (a); 2011: 1.40 kg.vine^{-1} (b); 2012: 0.92 kg.vine^{-1} (c)]. These results are compatible with the findings of Mattii et al. (2007) and Cravero et al. (2002) who stated that conservation tillage caused a statistically significant reduction in pruning weight. Over the three years, yield was reduced in minimized tillage (2010: 2.75 kg.vine^{-1}; 2011: 1.35 kg.vine^{-1}; 2012: 1.0 kg.vine^{-1}) and conservation tillage (2010: 2.80 kg.vine^{-1}; 2011: 1.20 kg.vine^{-1}; 2012: 0.75 kg.vine^{-1}), while it remained at about the same level in traditional soil tillage (2010: 3.05 kg.vine^{-1}; 2011: 1.65 kg vine^{-1}; 2012: 1.0 kg.vine^{-1}) (Figure 3). Vines were weakened in traditional soil tillage and therefore pruning weight decreased in all applications (Bahar and Yasasin, 2010).

Conclusions

The following comments can be made as a result of these 3 years of work in the conditions of Tekirdag:

During the cool and rainy vegetation periods (2011) leaf water potentials increased and stress levels reduced. Contrary to this, in relatively hot and dry years such as 2010 and 2012, leaf water potentials decreased and stress levels increased.

The reducing effect of conservation soil tillage on leaf water potentials (Ψ_{leaf}), yield, pruning weight and leaf size were determined. However the effect of minimized soil tillage was found to be unstable in some criteria. In this case, it is advised that the conservation soil tillage can be implemented in addition to conventional soil tillage for sustainable viticulture.

No significant effect of different shoot length on pruning weight, leaf area, yield, Ψ_{pd} and Ψ_{md} was observed. Therefore both 1.0 m and 1.5 m shoot lengths can be used in these conditions. However, bunch load, water deficiency, sugar accumulation and maturity times should be considered when determining the shoot lengths in the current vegetation period.

In conclusion, for the Cabernet Sauvignon grape variety under the climatic conditions of Tekirdag, it is advisable to consider conservation soil tillage alongside conventional methods. This recommendation is based on its beneficial impacts on various factors including leaf water potentials (Ψ_{leaf}), overall yield, pruning weight, and leaf sizes.

Acknowledgments

The author would like to thank all editors, reviewers who read and contributed to the final version of the text.

Conflicts of Interest

The authors declare that there is no conflict of interest.

Author Contribution

Author ASY compiled the data of statistics and economy. Author made critical revision of the manuscript for intellectual content. Allauthors read and approved the final manuscript.

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