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Full Length Research Paper

The yield and berry quality under different soil tillage and clusters thinning treatments in grape (*Vitis vinifera* L.) *cv.* Cabernet-Sauvignon

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The effects of 3 different soil tillage treatments and 2 cluster thinning treatments on leaf water potential ($_{leaf}$), yield and quality parameters of Cabernet- Sauvignon were investigated in this study. The research was conducted (40°58'10.71 N, 27°28'21.71 E) in Tekirdag, Turkey. There were no statistically significant differences among tillage systems. Half of the clusters on a vine were removed at the veraison for cluster thinning treatments. At the result the only significant difference was on the yield, regarding the cluster thinning treatment. Yield/vine values ranged between 2.2 - 2.3 kgvine^{-1} at the cluster thinning treatments and 3.4 - 3.5 kgvine^{-1} at the no cluster thinning treatments. The minimum value for soluble solids in juice was 21.04% at conventional tillage, and the maximum value (21.40%) was at the conservation tillage treatments. The conventional tillage treatment showed the maximum anthocyanin level (463.78 mgkg^{-1}) followed by the conservation tillage treatment (460.14 mgkg^{-1}) and minimum tillage treatment (407.86 mgkg $^{-1}$) respectively regarding the total anthocyanin levels. The lowest phenolic compound values were obtained from CVT-NTH (361.93 mgkg^{-1}) treatment. On the contrary in both conservative soil tillage [CST-NTH (488.36 mgkg^{-1}), CST-CTH (467.79 mgkg^{-1})] applications values were higher. As a result, grape quality parameters were improved by using the conversation tillage treatment with natural grassing in Cabernet Sauvignon.

Key words: Leaf water potential, water stress, soil tillage, cluster thinning, grape yield, berry composition.

INTRODUCTION

During their living period the vines are affected from abiotic stresses; drought, insufficient nutrition, salinity, low and high temperature, soil, atmosphere pollution, radiation and applications of cultivation which are limit the yield and quality. They are highly important factors which affects growth, yield and quality (Patakas and Noitsakis, 2001). Because of high evapotranspiration and water deficit in soil vines are often exposed to water stress (Mahajan and Tuteja, 2005; Patakas et al., 2005). Generally a large proportion of vineyards are located in regions with seasonal drought which correspond to flowering, berry set, veraison or maturity periods (e.g. climate of the Mediterranean type) where soil and atmospheric water deficits, together with high temperatures, exert different effects in yield and berry composition (Agaoglu et al., 2003; Ojeda et al., 2001; Chaves et al., 2007).

In vineyard leaf water potential is considered the most practicable method for the control vine water status. Carbonneau (1998) and Deloire et al. (2004) use both pre-dawn ($_{pd}$) and mid- day ($_{md}$) leaf water potential as a criterion to evaluate vine water status at different developmental stages. Deloire et al. (2005) proposed different levels of $_{pd}$ for various vine styles. Leaf and vine response to water stress depend on both current situation and previous conditions. Levels of water availability, such as the intensity and duration of water stress, affect long-term water stress.

Also different soil tillages in these climates and periods are rather effective on the soil water potential. In recent years because of developing environment and consumption conscience, economic production demands, climatic changes and saving necessity of energy, using

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Table 1. Experimental design

Soil tillage treatments	Cluster thinning treatments	Vine number.plot^{-1}	Total vine number (plot x 5 repetition)
CVT	NTH	3	15
	CTH	3	15
MIT	NTH	3	15
	CTH	3	15
CST	NTH	3	15
	CTH	3	15
Total vine number in experiment area			90

(CVT: Conventional Tillage, MIT: Minimized Tillage, CST: Conservative Tillage, NTH: No Cluster Thinning, CTH: 50% Cluster Thinning)

Figure 1. Different soil tillage treatments in *cv.* Cabernet-Sauvignon (*Vitis vinifera* L.) [a-Conservative (CST) and Minimized (MIT) tillage, b-Conventional tillage (CVT).

drastic changes in soil cultivation are being done. According to these changes conservative soil tillage started to become widespread as an alternative to conventional soil tillage.

Leaf removing, cluster and berry thinning applications have different effects on berry size, cluster compactness, maturity index, precocity, coloring and vegetative growth in viticulture (Ates, 2007). Therefore cluster thinning is applied effectively for the increase of quality of winegrapes variety. Especially 50% cluster thinning is adviced in veraison (Avenard et al., 2003).

This study was carried out to determine the effects and relationships of different soil tillage and cluster thinning treatments on leaf water potential (water stress), yield and berry quality in grape (*Vitis vinifera* L.) cv. Cabernet-Sauvignon.

MATERIALS AND METHODS

Material

This experiment was carried out in 27 m altitude during the 2009 growing season on grape cv. Cabernet Sauvignon grafted onto 5BB in the general experimental vineyard in the campus of Tekirdag Viticultural Research Institute (40°58'10.71 N, 27°28'21.71 E) in Turkey. Spacing was 2.5 - 1.5 m and the 10 years old vines were pruned as bilateral cordon. Eight spurs with 2 - 3 bud and totaly 16 - 18 bud per vine were left at pruning time. Also in berry set second equilibration in the number of clusters (26 - 28 cluster.vine^{-1}) and shoots (16 - 18 shoot.vine^{-1}) was done. Rows were north – south oriented.

The soil of experimental vineyard was cultivated in autumn and then was left for natural grassing. Soil cultivation was performed superficially with a cultivator. The first grass mowing between rows in conservative (CST) and minimized tillage (MIT) treatments were realized in berry set and repeated regularly on each of 15 days. Soil cultivation into rows was regularly done for all the treatments.

A randomized split block design was used with three different soil tillage [conventional tillage (CVT), minimized tillage (MIT) and conservative tillage (CST)], two cluster thinning treatments no cluster thinning (NTH), 50% cluster thinning (CTH) and five replicates. The experimental plot consisted of 90 vines totally (Table 1).

Conventional tillage (CVT)

After the start of vegetation period, soil cultivation was made by using the conventional tillage treatment with 15-20 days interval till the end of veraison (Figure 1).

Minimized tillage (MIT)

The minimum tillage treatment was started at the pea size stage of berries with 15 - 20 days interval till the end of veraison.

Conservative tillage (CST)

During the conservation tillage treatment, natural grassing occurred and no cultivation was done.

No cluster thinning (NTH)

For this treatment any cluster thinning was not done (26 - 28 *cluster.vine*$^{-1}$).

50% cluster thinning (CTH)

Half of the clusters on a vine (13-14 *cluster.vine*$^{-1}$) were removed at the veraison for cluster thinning treatment.

Leaf water potential

The $_{leaf}$ of each vine was determined with a Scholander Pressure Chamber (Scholander et al., 1965) . $_{pd}$ and $_{md}$ leaf water potentials were measured 6 times on each of about 14 days from start of the flowering to harvest. Measurements were carried out on freshly cut, healthy and fully expanded (mature) leaves from each vines for each of the soil tillage and cluster thinning.

Yield and berry components

Harvest date was fixed on the basis of ripening dynamics of the berries related to sugar concentration (*g.l*$^{-1}$), titratable acidity (*g-tartaric acid.l*$^{-1}$) and pH (not shown). At harvest all clusters were sampled from each vine in early morning (08:00 to 10:00 AM) and transported to the laboratory. After that, classical measurements on berries and clusters were made. Clusters from different applications were weighed. Berries were sampled and total soluble solids (TSS) (*Brix*°), sugar concentration (*g.l*$^{-1}$), sugar content per berry (*mg.berry*$^{-1}$), titratable acidity (*g-tartaric acid.l*$^{-1}$), anthocyanin content (*mg.kg*$^{-1}$) and phenolic compound content (*mg.kg*$^{-1}$) in juice were analysed.

Yield (kg.vine^{-1})

At harvest all clusters from different applications for each vine were sampled in early morning (08:00 to 10:00 am) and then were weighed and calculated as kg.vine^{-1}.

Total soluble solids (Brix°)

Total soluble solids (TSS) were measured using an Abbé-type refractometer (Cemeroglu, 2007).

Sugar concentration in juice (g.l^{-1})

Sugar concentration in juice in response to Brix° was based on the scale conducted by Blouin and Guimberteau, (2000).

Quantity of sugars per berry (mg.berry^{-1})

Sugar content per berry was calculated with the formula below:

Sugars (*mg.berry*$^{-1}$) = (1x1.3^{-1})x[sugars (*g.l*$^{-1}$)]x(1x100^{-1})x[100 berries weight (*g*)] (Carbonneau and Bahar, 2009).

Titratable acidity (g-tartaric acid.l^{-1})

Titratable acidity (TA) in juice was measured by titration with NaOH 0.1N to the end point of pH 8.2 and results were expressed as a *g-tartaric acid.l*$^{-1}$ (Cemeroglu, 2007).

Anthocyanin content in juice (mg.kg^{-1})

Anthocyanins were analysed as reported by Cemeroglu (2007) with different pH method using a spectrophotometer. The absorbance of the grape juice samples was measured at 520 - 700 nm at two different pH level (1.5 - 4.0 pH). Anthocyanin concentration was calculated as mg.kg^{-1}.

Phenolic compound content in juice (mg.kg^{-1})

Total phenolic compound content was analysed according to Cemeroglu (2007) by using colorimetric method of Folin-Cioccalteu. The absorbance measurements were done at 720 nm and the total phenolic compound content was calculated as mg.kg^{-1}.

All data analyses were performed with SPSS (PASW® Statistics 18 for Windows) software. LSD tests was used to assess the significant differences of measured traits between groups at the P<0.01 level.

RESULTS AND DISCUSSION

To determine the effects of soil tillage and cluster thinning treatments on the vegetative growth, yield and quality components in variety, the phenologic stages were observed according to Lorenz et al. (1995).

Bud burst occurred at the same date on April 15th for each three applications (CVT, MIT, CST). Flowering in both minimized tillage (MIT) and conservative tillage (CST) occurred on June 2nd while in the conventional soil tillage (CVT) occurred on June 5th. According to Tesic et al. (2007) CST treatments' results in Chardonnay while there is a 4 day delay in veraison on the contrary in our study veraison were seen initially in CST on 1th of August and following MIT (August 3th) and CVT (August 5th) respectively. The harvest for all the treatments was done on September 15th (Figure 2).

$_{pd}$ decreased progressively in all treatments during the growing season (Figure 3a). From the flowering to the end of August, $_{pd}$ dropped from -0.3 to -0.56MPa depending on the treatments. But because of the extreme rainfall in July $_{pd}$ values increased for short period (from -0.5 to - 0.3MPa) (Figures 2 and 3). In conservative tillage-no cluster thinning (CST-NTH) interaction, $_{pd}$ was maintained low (higher stress compared to the other treatments) through the growing seasons. This could be due to a high yield and competitive natural grassing. With regard to $_{pd}$ there was not found any significant difference among the treatments and their interactions in the last measurements (at the end of August). Our results for this period are appropriate to Deloire et al. (2004) and Carbonneau et al. (1998) scales (it should be between -0.4< $_{pd}$>-0.6MPa). A very high stress (<-0.6MPa) was not determined in none of the applications.

There was not found any significant difference among the treatments and their interactions in the last measurements of $_{md}$ (at the end of August). In all the

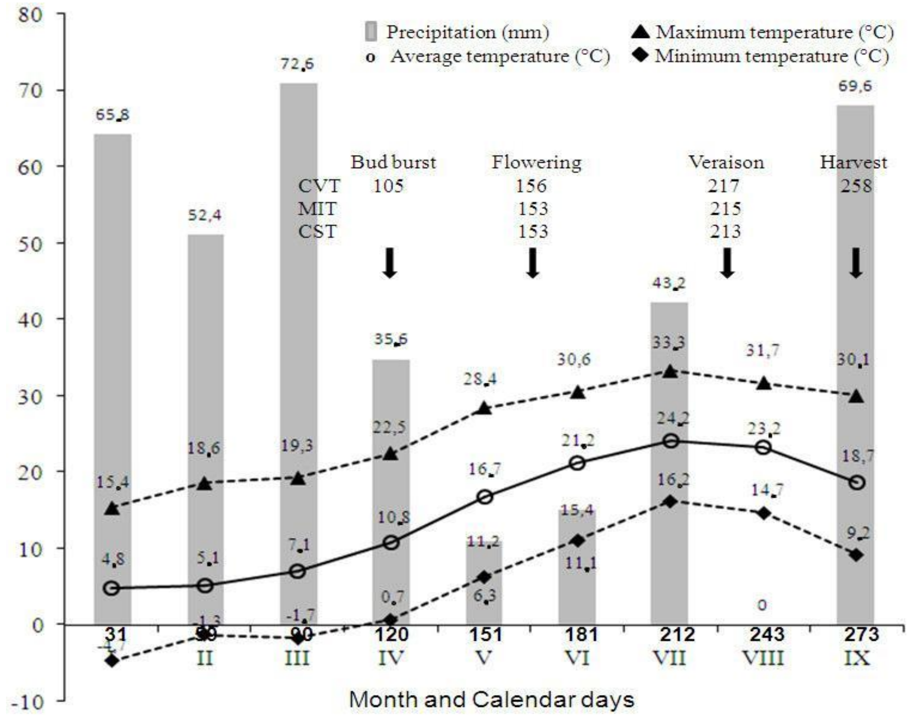

Figure 2. Phenologic stages (from April 15th to harvest time), temperatures (°C) and precipitations (mm) in 2009 vegetation period. (CVT: Conventional Tillage, MIT: Minimized Tillage, CST: Conservative Tillage)

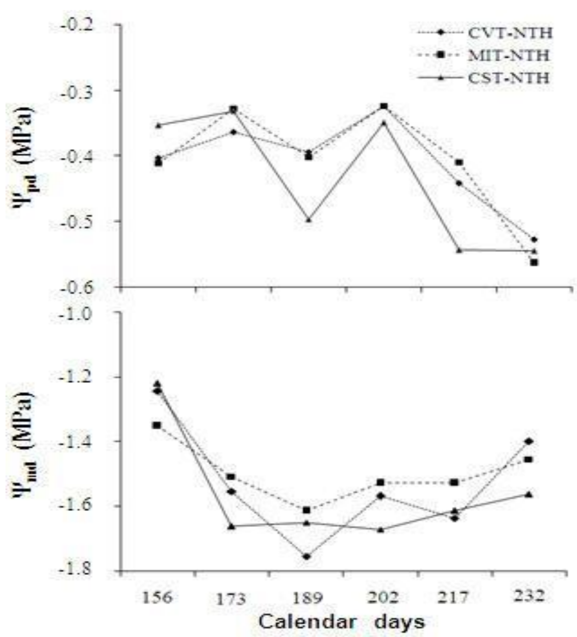

Figure 3a. $_{pd}$ and $_{md}$ values depending on treatments in 2009 vegetation period. (CVT-NTH: Conventional Tillage-No Cluster Thinning, CVT-CTH: Conventional Tillage-50% Cluster Thinning, MIT-NTH: Minimized Tillage- No Cluster Thinning, MIT- CTH: Minimized Tillage-50% Cluster Thinning, CST-NTH: Conservative Tillage-No Cluster Thinning, CST-CTH: Conservative Tillage-50% Cluster Thinning).

treatments from bunch closure till the end of August high or very high stress levels (-1.4 > $_{md}$>-1.6MPa or $_{md}$<-1.6MPa) were determined. Our results were described in accordance with the scale of Deloire et al. (2004) and Carbonneau et al. (1998) and the values of Smith and Prichard (2002) . Mid-day leaf water potential ($_{md}$) decreased from -1.2 to -1.6MPa, from the flowering to bunch closure, in a short time and approximately the same values were obtained after bunch closure to the end of August, varied to the treatments (Figure 3). The extreme rainfall in July did not affect $_{md}$ values as so much as $_{pd}$ (Figures 2 and 3b). In conservative tillage-no cluster thinning (CST-NTH) and conservative tillage-cluster thinning (CST- CTH) interactions, $_{md}$ was maintained low (high and very high stress levels) from the bunch closure till the end of August in compared to the other treatments. This can be due to a daily high temperature and competitive natural grassing.

There were significant differences (P<0.01) in yield among cluster thinning treatments. Yield was lower about 30 - 35% in all cluster thinning treatments because of the 50% cluster thinning. In similar studies, 30 - 35% reduction of yield was indicated (Keller et al., 2005; Kennedy et al., 2009; Palliotti and Cartechini, 2000). However among the soil tillage treatments there are not statistically significant differences (Table 2). Monteiro and Lopes (2007) stated that, CST application did not cause a significant difference in yield in grape. A decrease in yield

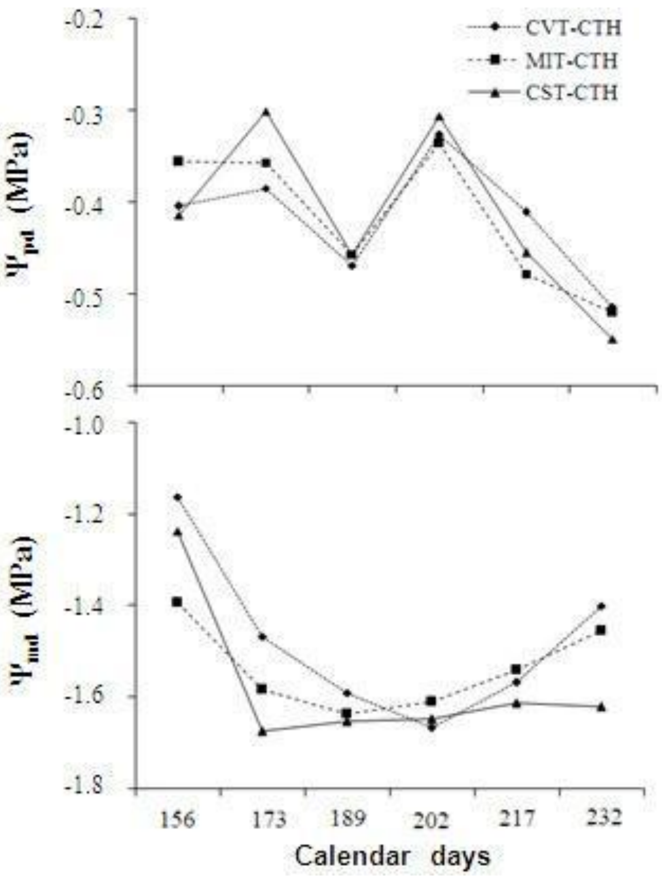

Figure 3b. *pd* and *md* values in phenological stages in 2009 vegetation period. (CVT-NTH: Conventional Tillage-No Cluster Thinning, CVT-CTH: Conventional Tillage-50% Cluster Thinning, MIT-NTH: Minimized Tillage- No Cluster Thinning, MIT-CTH: Minimized Tillage-50% Cluster Thinning, CST-NTH: Conservative Tillage-No Cluster Thinning, CST-CTH: Conservative Tillage-50% Cluster Thinning)

was determined as a result of CST treatment as it is mentioned in some of the previous studies (Tesic et al., 2007; Wheeler et al., 2005).

According to Murisier (1996) and Wolpert et al. (1983) decreasing yield was an effective method of increasing sugar content. All treatments produced juice with acceptable total soluble solids (TSS). There were not significant differences in final TSS concentration (Figure 4). Differences between interactions with the highest (CST-CTH = 21.52Brix°) and the lowest (CVT-CTH = 20.92Brix°) sugar concentrations were 0.6Brix°. In previous studies, similar to our results, it was determined that cluster thinning treatments (Gao and Cahoon, 1998; Palliotti and Cartechini, 2000) and CST applications (Tesic et al., 2007; Wheeler et al., 2005) have increasing effect on TSS. In result of cluster thinning, because of increase in leaf surface area/yield ratio, a rise in TSS was determined.

In result of cluster thinning, because of rise in leaf surface area/yield ratio, an increase in sugar concentration ($g.l^{-1}$) was obtained. At harvest, all treatments produced juice with acceptable sugar concen-tration ($g.l^{-1}$) (>202.9 $g.l^{-1}$). But no significant differences in final sugar concentration ($g.l^{-1}$) were found (Figure 4). The highest value was determined from CST-CTH (209.10 $g.l^{-1}$) while the lowest sugar concentrations were obtained from CVT-CTH (202.90 $g.l^{-1}$). Monteiro and Lopes (2007) findings on sugar concentration of CST applications were similar to our results.

Quantity of sugar per berry was calculated according to both sugar concentration and 100 berry weight with the formula.

As it is seen in the equilibrium the berry weight and sugar concentrations are the main determinants in quantity of sugar per berry. By determining the real quantity of sugar per berry the dilution effect on concentration is being eliminated. Thus, it is provided the possibility of determining real sugar loading of berry and harvesting on the right time. Although the concentration in the juice is low the quantity of sugar per berry can be higher because of the berry weight difference. Such example is clearly seen in CVT-NTH (205.70 $g.l^{-1}$, 234.58 $mg.berry^{-1}$) and CVT-CTH (202.90 $g.l^{-1}$,236.78 $mg.berry^{-1}$) treatments.

Titratable acidity and pH (not shown) are of great importance for grape juice and wine stability, and both parameters are commonly used as indicators of quality. At the time of harvest, titratable acidity levels were very similar for all the treatments. In CST-CTH (8.76 $g.l^{-1}$) titratable acidity was the highest while in CVT-CTH (8.52 $g.l^{-1}$) was the lowest (Figure 5). Although according to Penter et al. (2008) cluster thinning effect in titratable acidity did not show any difference, as for Morris et al. (1987); Palliotti and Cartechini (2000); Kennedy et al. (2009) the cluster thinning decreased the titratable acidity. With respect to Tesic et al. (2007) and our results, CST increased titratable acidity with the contrast of Lopes et al. (2008); Wheeler et al. (2005); Mattii et al. (2005).

Since the anthocyanins are synthesized in the skin, larger berry weight in a lower skin- to-flesh ratio and thus, anthocyanins are diluted. The non significant differences in anthocyanin concentrations in the juice were found at the time of harvest. In recent years it was determined that CST treatments increased anthocyanin content as the same as our results (Wheeler et al., 2005; Palma et al., 2007; Lopes et al., 2008). As it is the same as our results Kennedy et al. (2009) indicated that cluster thinning treatments in different periods did not have any statistical effect in anthocyanin content. The highest and lowest anthocyanin contents were determined in CVT-CTH treatments (520.63 $mg.kg^{-1}$) and in MIT-CTH (374.61 $mg.kg^{-1}$) respectively (Figure 6).

Generally the phenolic compounds of plants are changed depending on variety and climate conditions in maturation period. Many changes in phenolic contents of berry were determined by the physical and chemical properties of soil and viticultural practices (Prior et al., 1998; Arozarena et al., 2002; Ojeda et al., 2002; Ozden and Vardin, 2009).

Table 2. The effects of different soil tillages and cluster thinning treatments on yield in *cv.* Cabernet-Sauvignon (*Vitis vinifera* L.)

Soil tillage	Cluster thinning		Main effect of soil tillage
	NTH	**CTH**	
CVT	3.5	2.3	2.9
MIT	3.4	2.2	2.8
CST	3.4	2.2	2.8
Main effect of cluster thinning	3.4 ***a***	2.2 ***b***	2.8

(CVT: Conventional tillage, MIT: Minimized tillage, CST: Conservative tillage).* Main effect of cluster thinning $LSD_{P<0.01}$: 0.985.

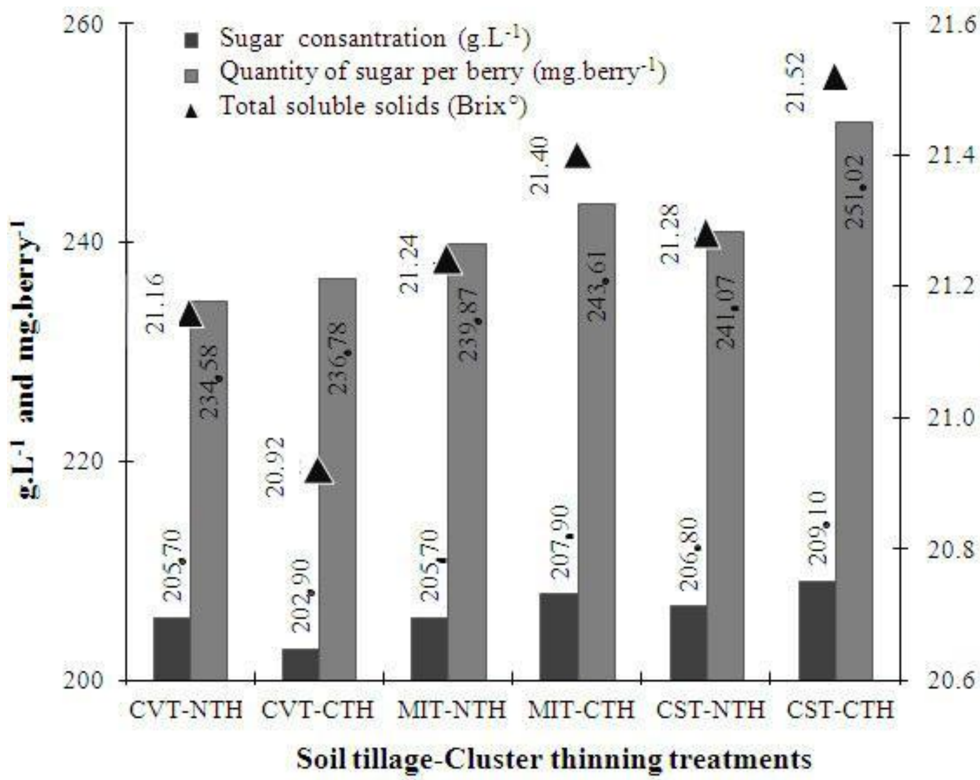

Figure 4. Sugar concentration in juice, quantity of sugar per berry and total soluble solids (CVT-NTH: Conventional Tillage-No Cluster Thinning, CVT-CTH: Conventional Tillage-50% Cluster Thinning, MIT-NTH: Minimized Tillage- No Cluster Thinning, MIT-CTH: Minimized Tillage-50% Cluster Thinning, CST-NTH: Conservative Tillage-No Cluster Thinning, CST-CTH: Conservative Tillage-50% Cluster Thinning)

The phenolic compounds were increased by CST according to previous studies as the same as in our study (Monteiro and Lopes, 2007; Palma et al., 2007; Lopes et al., 2008). Penter et al. (2008) indicated that the cluster thinning has no effect on phenolic content in cv. Cabernet-Sauvignon (*Vitis vinifera* L.) while according to Palliotti and Cartechini (2000) there is an increasing effect. The lowest values were obtained from CVT-NTH (361.93 mg.kg^{-1}) treatment. While in both conservative soil tillage [CST -NTH (488.36 mg.kg^{-1}) and CST-CTH (467.79 mg.kg^{-1})] applications values were higher (Figure 6).

The present study shows the importance of different soil tillage and cluster thinning. The obtained results show that different soil tillage and cluster thinning treatments are effective on the $_{leaf}$, yield and berry composition. For the grape yield and its quality during the vegetation period the most appropriate $_{pd}$ was obtained as indicated in literature. $_{pd}$ changed gradually from flowering (<-0.3 MPa) to maturity (>-0.6 MPa). Due to the extreme rainfall during the critic period $_{pd}$ did not exceed -0.6 MPa. Daily temperature which reached over

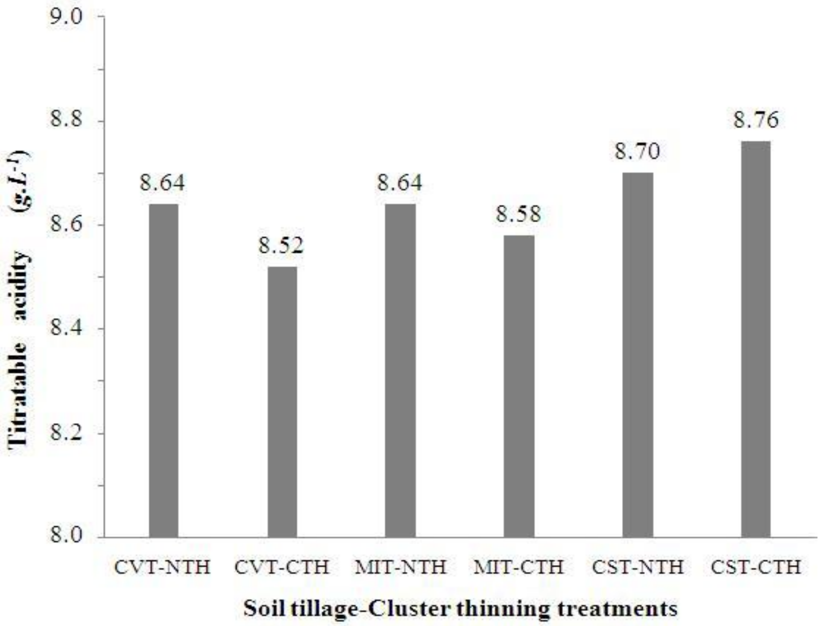

Figure 5. Titratable acidity (CVT-NTH: Conventional Tillage-No Cluster Thinning, CVT-CTH: Conventional Tillage-50% Cluster Thinning, MIT-NTH: Minimized Tillage- No Cluster Thinning, MIT-CTH: Minimized Tillage-50% Cluster Thinning, CST-NTH: Conservative Tillage-No Cluster Thinning, CST-CTH: Conservative Tillage-50% Cluster Thinning).

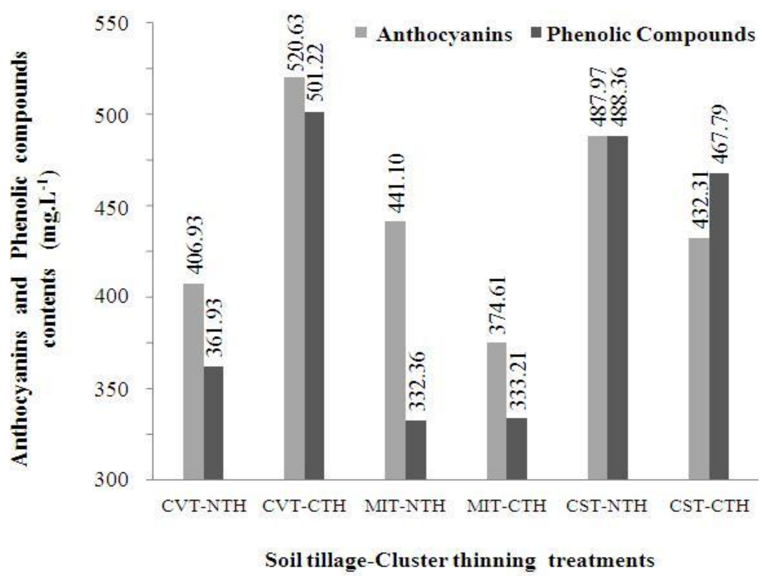

Figure 6. Anthocyanins and total phenolic contents at harvest. (CVT-NTH: Conventional Tillage-No Cluster Thinning, CVT-CTH: Conventional Tillage-50% Cluster Thinning, MIT-NTH: Minimized Tillage- No Cluster Thinning, MIT-CTH: Minimized Tillage-50% Cluster Thinning, CST-NTH: Conservative Tillage-No Cluster Thinning, CST-CTH: Conservative Tillage-50% Cluster Thin ing).

30°C $_{md}$ varied between -1.4< $_{md}$>- 1.7MPa. Therefore the stress was high in mid-day. The differences of soil tillage treatments affected $_{leaf}$ more than 50% cluster thinning treatments in veraison.

The conservative tillage treatment (CST) presented high total soluble solids (TSS), sugar concentration in juice (g.l^{-1}), quantity of sugar per berry (mg.berry^{-1}), titratable acidity (g-tartaric acid.l^{-1}), anthocyanin content (mg.kg^{-1}) and phenolic compounds content (mg.kg^{-1}) values when compared to conventional tillage treatment (CVT). As a result of 50% cluster thinning treatment (CTH), about 30 - 35% decrease in yield occurred. Also an increase was determined in all criterias except titratable acidity (g-tartaric acid.l^{-1}). In comparison conservative tillage (CST) 50% cluster thinning (CTH) treatment to conventional tillage (CVT) -No cluster thinning (NTH) treatment an increase was seen in all criterias (without considering yield.vine^{-1}).

The conclusion is that there was an increase in positive aspect in berry quality criterias with the conservative soil tillage and 50% cluster thinning treatments in grape *cv.* Cabernet-Sauvignon. However grape compositions can show differences according to soil, climate conditions and viticultural practices.

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