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Full Length Research Paper

Yield and growth Reaction of cv. Merlot to early water stress

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Reproductive growth is less sensitive to water deficit than vegetative growth. For this purpose, the main aim of this study is to find out the effects of early water deficits on vegetative and generative development of Merlot/SO_4 grapevines. This research was carried out in ECOTRON System, Montpellier - SupAgro/INRA, 03°51'22'' E and 43°37'04'' N and 40 m altitude. The stressed period was started in the 17th E-L stage on the second week of May and stopped in 27th E-L stages on the second week of June. Four stress groups were established which were; well watered WS_0 as a control (4 L day^{-1}), second was WS_1 (3 L day^{-1}) third was WS_2 (2 L day^{-1}) and the fourth was WS_3 (1 L day^{-1}) respectively. A randomized complete block design was used and treatments were compared using LSD test to determine the significant differences. In water deficit treatments yellowing of the leaves and partial leaf fall at the shoot bases were observed at WS_2 and WS_3 plants. Final measurements of shoot lengths showed about 60 cm differences between control and stressed grapevines. Shoot elongation was suppressed linearly to increase water deficit. When the average cluster weights and yield per vine in the control were compared with WS_3 about 50% reduction was found. It can be stated that the most sensitive period was between 17th and 27th Eichhorn and Lorenz phenological stages which negatively affect the yield of Merlot cv.

Key words: Merlot, early water deficit, growth, cluster weight, shoot elongation.

INTRODUCTION

Grapevine growth and performance are mostly based on water as in other higher plants. Concerning climate changes have the potential to impact on viticulture irrigation is a powerful management tool for improving vine performance. The use of deficit irrigation strategies, implying that water is supplied at levels below full crop evapotranspiration throughout the growing season or in specific phenological stages, relies on observations in several crops subjected to moderate water deficits that yield is not significantly reduced and quality of production may even increase under such conditions (Chaves, 2010). Water use are changed by stage of grapevine development, thus grapevine annual water requirement is related with the growth stages. From bud break to flowering <5%, flowering to fruit set 15%, fruit set to veraison 60%, veraison to harvest 20%, and harvest to leaf fall 3 to 5% were respectively (Wample, 2002). However different results are reported by Chalmers (2009), grapevine water utilization ranges are listed as follows: budburst to flowering 9%, flowering to fruit set 6%, fruit set to veraison 35%, veraison to harvest 36% and harvest to leaf fall 14%.

It is known that grape sensitivity to water deficit depends on the timing of the application being particularly more sensitive during anthesis and just after anthesis (Hardie and Considine, 1976). Recent studies also show that different irrigation regimes to manipulate yield and quality in harvest are dependent on when the irrigation is applied in relation to the stage of berry growth (Chalmers, 2009). Generally, red grape varieties require less water than white varieties. Water stress resulting in excessive leaf loss (basal to upper) and bunch exposure increases the risk of sunburn which may reduce flavours and quality (Anonymous, 2010). Previous studies show the highly

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important role of the water status of the plant and the bunch microclimate in relation to the biochemistry of the berry from berry set onwards. Several researchers document water deficit effects on berry growth (Bahar et al., 2011a, b and c; Carbonneau, 1998; Carbonneau and Bahar, 2009; Ojeda et al., 2001 and 2002). It is reported that there are two types of berry responses to water deficit, an indirect and always positive effect on the concentration of phenolic compounds due to berry size reduction and a direct action on biosynthesis that can be positive or negative depending on type of phenolic compound, period of application, and severity of water deficit (Ojeda et al., 2002). However, Ojeda et al. (2001), reported that berry weight and diameter affected water deficits between anthesis and veraison. Also, McCarthy (1999) report that the water deficits inhibit berry growth in general. Water stress has a major influence on shoot growth, and in general, vegetative growth is more sensitive to water stress than is berry growth. Wang et al. (2003) report that the water stress can affect the rate of photosynthesis of plant, stomatal conductance, abscisic acid content and osmotic potential; it can also affect photoassimilate translocation. Severe water stress can actually inhibit the accumulation of sugar in grape berries. Carbonneau and Bahar (2009) report that the water limitation reduces infunction of its intensity: berry weight, berry sugar content, quantity of sugar per berry but this limitation is less important for Merlot cv.

In Merlot cv. water deficits from the onset of ripening until maturity are researched. Water deficit reduce berry weight and increase the concentration of anthocyanins in all four seasons (2004, 2005, 2007, and 2008), and increase the concentration of tannins three of four seasons. These results demonstrate that management of vine water deficit during ripening is a much more effective tool to increase anthocyanins than tannins in Merlot grapes (Buchetti et al., 2011). In a different study, six years old plants of the cv. Merlot, grafted on SO_4 rootstock, grown in a gravelly loam of the Friuli plane (North-Eastern Italy). Two different levels of water supply (Control and stress, 80 and 20% of available water, respectively) are established from veraison to harvest. In conclusion, water stress confirm the known effect in decreasing polyphenolic compounds in grapes (Peterlunger et al., 2002). In another study, green berries appear very sensitive to water stress which often brings about yield reduction. Furthermore, xylem water backflow from the cluster into the shoots has been ascertained in the presence of water stress (Poni, 2000). Bahar et al. (2011a) report that the drought symptoms for extreme water stress in Merlot cv. vines is observed 6 days after the stress started (in the 211^{th} calendar day).

Vandeleur et al. (2009) describe the term isohydric, physiological and anatomical characteristics of water transport across roots of grapevine differing in response to water stress. Chaves et al. (2010) describe that the case of isohydric type of response by controlling stomatal aperture via feed-forward mechanisms buffers plant water potential. Also, they report that the Merlot cv. is anisohydric as a function of the response of the water potential to water deficit. Mild water deficits also exert direct and/or indirect effects on berry development and composition. Many researches on water deficit in grapevine were done before. These water deficits were typically examined from veraison to maturity. For this purpose, the main aim of this research was to find out effects of early water deficits on vegetative and generative development of grapevine.

MATERIALS AND METHODS

Plant material and cultivation

This research was carried out in ECOTRON System, Montpellier - SupAgro/INRA in 2008 vegetation period. Experiment was established in Longitude 03°51'22'' E Latitude 43°37'04'' N altitude 40 m.Uniform plant material was seven years old Merlot/SO_4. Potted grapevines were grown under vineyard conditions, and had a volume of 70 L for individual vine. The growing medium was a mixture of perlite and coarse sand. Before starting the experiment pots were isolated with black plastic from rainfall.

Experimental design

A randomized complete block design was used with 3 replications and each parcel had 2 grapevines and 4 water stress levels [WS_0 (no water deficit) WS_1 (mild to moderate water deficit), WS_2 (moderate to severe water deficit), WS_3 (severe to high water deficit)]. In the trial, totally 24 grapevines were used. At the beginning of the trial, the minimum rule was used for limiting clusters to equal number (~ 28).

Irrigation treatments

The stressed period was started in the 17^{th} Eichhorn and Lorenz stage on the second week of May and stopped in the 27^{th} Eichhorn and Lorenz stage on the second week of June (Eichhorn and Lorenz, 1977). Four stress groups were set up according to Carbonneau (1998); the first one was well watered WS_0 as a control (4 L day^{-1}), second was WS_1 (3 L day^{-1}), third was WS_2 (2 L day^{-1}) and fourth group was WS_3 (1 L day^{-1}) respectively. Drip fert-irrigation was applied four times in a day at 11:00, 16:00, 23:00 and 04:00. 160 days after bud burst all groups were well irrigated (6L day -1) till the harvest

Plant water status (-MPa)

Predawn Leaf Water Potential (Ψ_{pd}) was measured at 03:A.M, at three days intervals by Scholander Pressure Chamber (Scholander et al., 1965). Pre-dawn measurements are preferred as the plant water is believed to be in equilibrium with the soil water (Taylor, 2010).

Shoot lengths (cm) and elongation ratios (%)

They were measured in three days intervals. Measurements were started on the 22^{nd} of May and finished on the 18^{th} of June. These data were used for determination of the shoot elongation rates

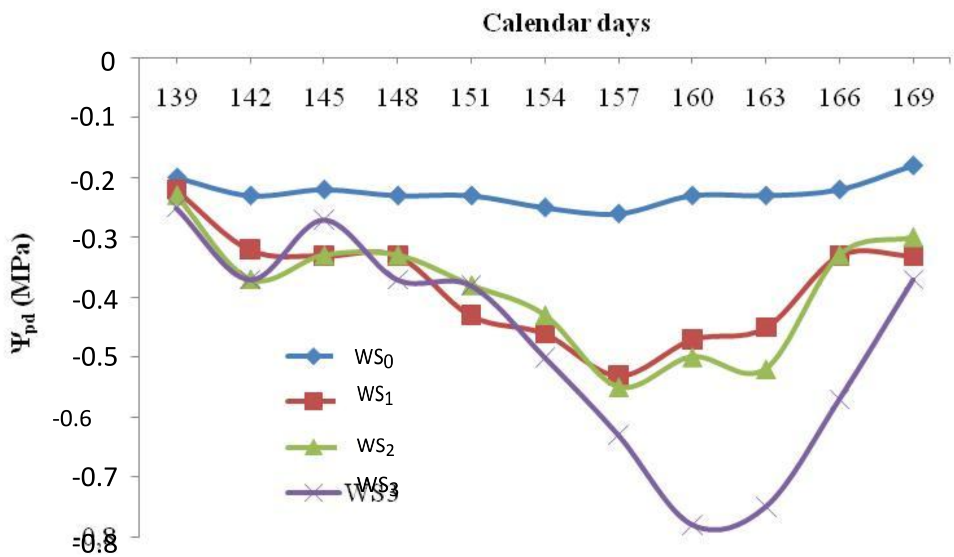


Figure 1. Water stress changings in early growing period in 2008. Each point is the mean of 3 replications; vertical bars represent the standard deviation (SD).

(cm/3 days). In 11th of September all clusters were harvested, then average cluster weights (g) and yield per grapevine (kg/vine) were determined.

Statistical analysis

Analysis of variance was performed using the MSTAT statisticsprogram. Differences between means of treatments were compared using LSD test for significant differences at the $P < 0.01$ level.

RESULTS AND DISCUSSION

It was obtained in the first measurement (from bud burst to the 139th day) in plant leaf water potential that all stress groups had almost the same values and these were approximately -0.2 MPa. The differences between control vines and the others along with the development were striking. The highest stress level (Ψ_{pd}) was found in WS_3 (-0.78 MPa), the lowest stress level was in control. 160 days after bud burst regular irrigation was applied, 6 L day^{-1} of water was given to grapevines, the Ψ_{pd} values of the vines started to increase suddenly. However on the 169th day, the stress group vines Ψ_{pd} values did not reached the values of the control vines (Figure 1). The stress levels between -0.4 to -0.6 MPa; berry set till veraison; from mid to high level; can decrease or stop the vegetative growth, causes irregular leaf surface area, blocks berry growth and cuts off tannins biosynthesis which are all undesirable conditions (Bahar et al., 2011b). Our findings were in this direction. In water deficit treatments, yellowing of the leaves and partial leaf fall at the shoot bases were observed at WS_2 and WS_3 plants. Ojeda et al. (2001) showed that subjected to early water deficit in Syrah, 30% of water treatment between anthesis and veraison corroborated our results. Matthews et al. (1987) results support our findings which are studied in Cabernet Franc berries, subjected to water stress before veraison and normally reirrigated, recover growth 10 days before the control berries, at the moment of water supply, water deficits causing no differences in bloom, veraison and harvest. In the first measurements of shoot length, vines were showing the same growth. Then after the fourth measurement (151 days after bud burst) there was about10cm’s difference between the stress groups compared to the control. In the final measurement of shoot lengths there was approximately 60 cm's difference determined between control group and the others. This result was important to indicate that the early water deficits had an inhibitive effect on vegetative growth (Figure 2). Most studies on grapevine irrigation demonstrate that water deficits affect vegetative growth to a greater degree than they affect reproductive growth. A reduction in shoot growth is one of the first visible symptoms of vine water stress. Potted vine studies indicate that root growth is less sensitive to water deficits than is shoot growth (Williams, 2000; Keller, 2004). The results show that the lowest shoot elongation ratios were in WS3. Water deficit and shoot elongation ratios have inverse relationship and because of this increase of water deficit the shoot elongation ratio decreases (Figure 3). In parallel to our observations, Williams (2000) and Keller (2004) report that water influences the rate of shoot growth (vigor) and thus canopy microclimate. Moderate water decrease deficits the rate of shoot elongation, along with internode length and radial expansion. It is often stated that reproductive growth (and thus yield) is less sensitive to water deficit than is vegetative growth

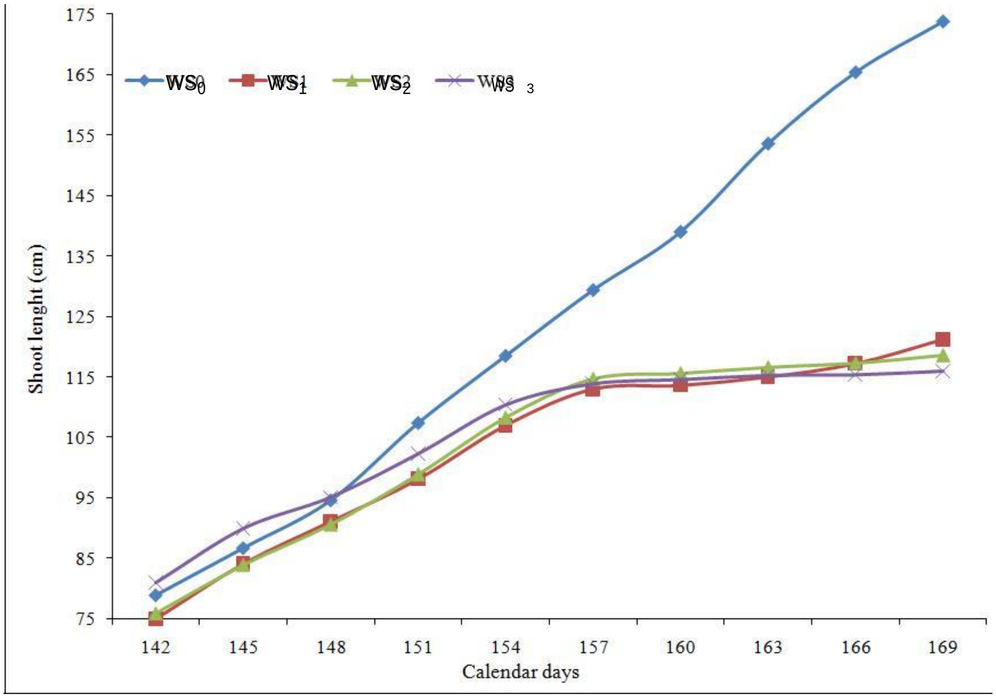


Figure 2. Shoot length (cm). Each point is the mean of 10 measurements; vertical bars represent the standard deviation (SD).

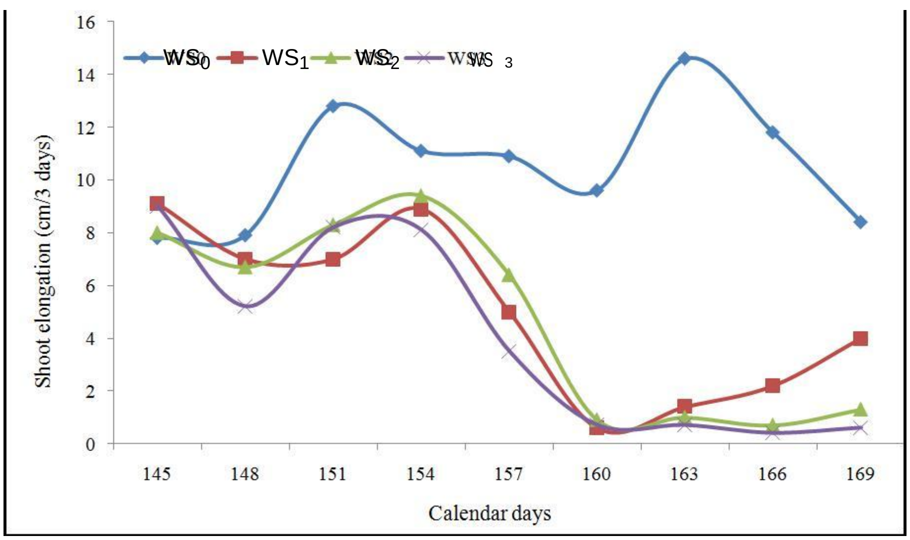
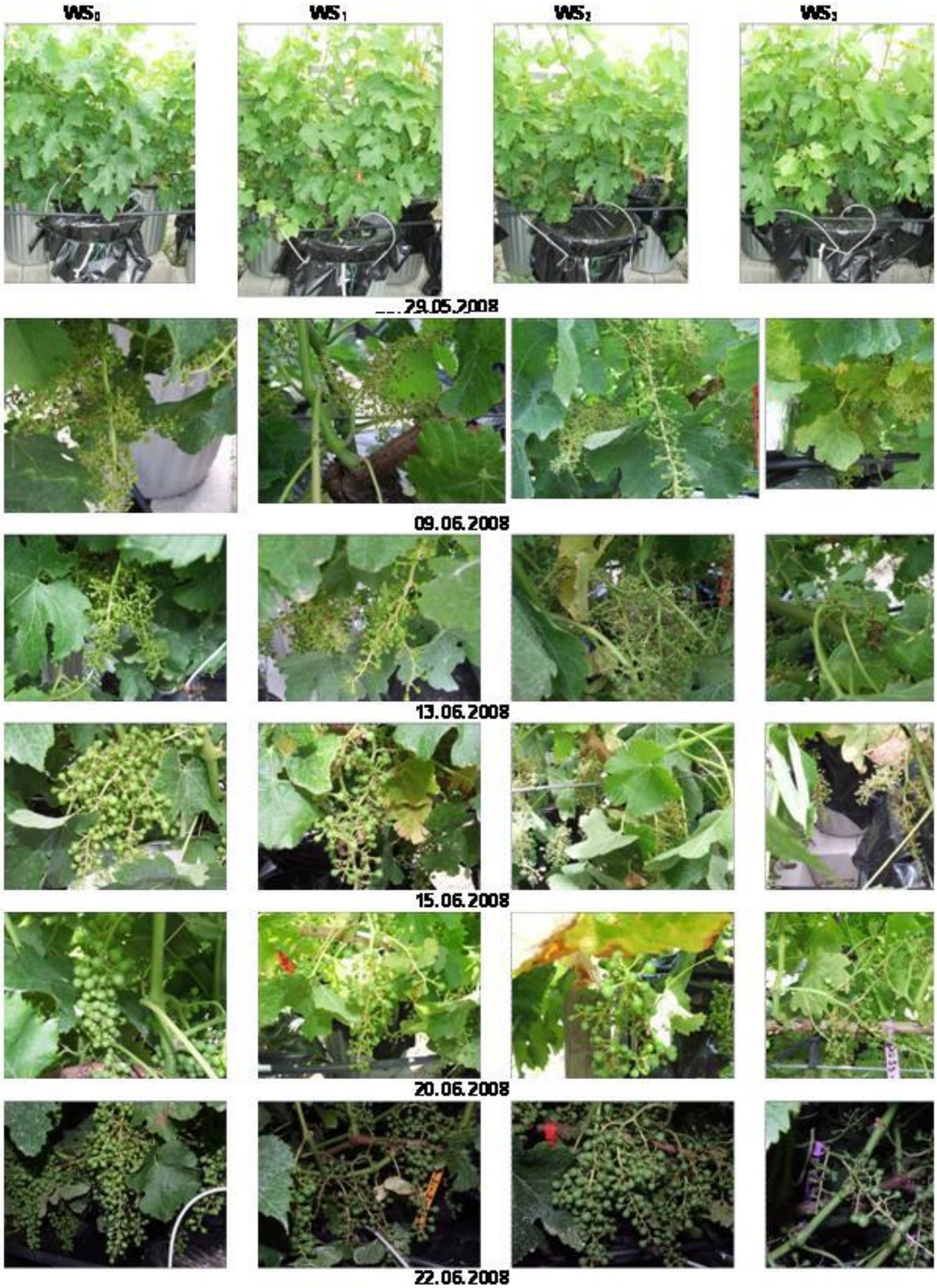


Figure 3. Shoot elongation ratios (cm/3 days). Each point is the mean of 10 measurements; vertical bars represent the standard deviation (SD).

(Keller, 2004). Early water deficits (WS1, WS2 and WS3) affected vegetative growth of grapevines. The results are seen in Figure 4, clearly.

These results correlate with Chaves et al. (2010). They suggest that the changes take place very early during berry development such as at the green berry stage, and may have a profound effect on the final berry maturity.

McCarthy (2002), state that the water deficit is applied during the post-set period of berry development to reduce vegetative growth (Alexander, 1965) and, as necessary, berry size of red-winegrape varieties. Also, McCarhty (1997) signify that the berry weight at harvest is reduced by water stress (Hardie and Considine, 1976) impose immediately after flowering but is insensitive to water



WS_0
WS_1
WS_2
WS_3
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09.06.2008
13.06.2008
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22.06.2008

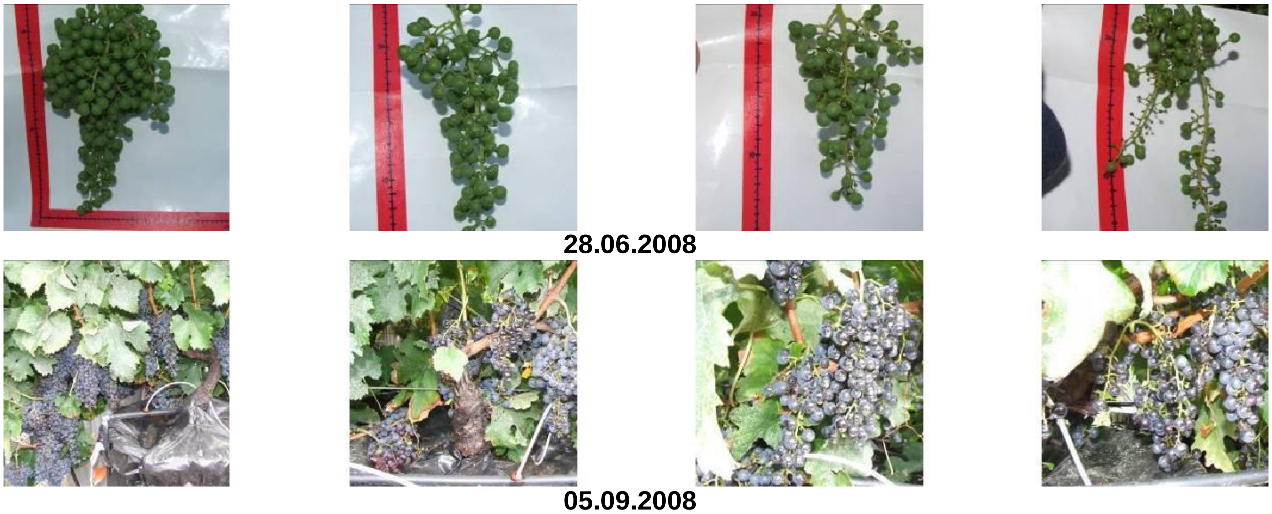

Figure 4. Water stress effects on reproductive and vegetative growth in Merlot.

Table 1. Average cluster weight according to water stress treatment (g).

WS_0	WS_1	WS_2	WS_3
106.397^{a}	90.277^{b}	64.480^{c}	50.253^{c}

P < 0.01: 16.059.

Table 2. Yield per grapevine (kg/vine) (11.09.2008).

WS_0	WS_1	WS_2	WS_3
2.983^{a}	2.557^{ab}	1.793^{ab}	1.423^{c}

P < 0.01: 0.858.

stress applied prior to harvest. Bahar et al. (2011a) determine that the severe and sudden stress in grapevines strongly affect berry size. These results were s upported our results (Figure 4).If the stress occurs to bloom time, the more susceptible the inflorescences become. Even moderate water stress during the bloom-berry set period can lead to poor fruit set and abortion of entire clusters. Therefore, water stress should be avoided before fruit set (Keller, 2004). Similar results were found in this study (Figure 5). When the severe water deficit (WS3) compared to control (WS0) about 20% reduction was found. Early water stress applied vines were harvested in 11th of September (244 days after bud burst). Among the applications average cluster weight differences were statistically important according to P < 0.01. Control grapevines (106.397 g) was the group which had the highest average cluster weight. As for WS_1 group the average cluster weight was in the secondgroup of importance and its average cluster weight was 90.277 g. WS_2 (64.480 g) group and WS_3 (50.253 g) group were in the same group of importance P < 0.01. In Merlot cv. average cluster weight is 250 g and is described as medium cluster sized (Celik, 2006). However in our study the clusters were smallerBecause of the water stress (Table 1).

If the stress occurs to bloom time, the more susceptible the inflorescences become. Even moderate water stress during the bloom-berry set period can lead to poor fruit set and abortion of entire clusters. Therefore, water stress should be avoided before fruit set (Keller, 2004). Similar results were found in this study. There were significant differences in yield per grapevine (kg/vine) because of the water stress levels (Table 2) (P < 0.01 level). When yields were compared depending on water stress levels, the highest yield in WS_0 grapevines were 2.983 kg/vine. WS_1 (2.557 kg/vine) and WS_2 (1.793 kg/vine) grapevines were in same group statistically. As the lowest yield per grapevine was found in WS_3 group (1.423 kg/vine). Shellie (2010) researched the effect of vine water deficit on berry tissue components and berry weight uniformity at maturity. Field-grown grapevines cv. Merlot are differentially irrigated over six consecutive years to maintain a high or low level of vine water stress from fruit set until harvest. Vine water deficit is associated with up to a 27% increase in the proportion of seed to total berry fresh weight regardless of berry size. Berry weight within each irrigation regime is distributed normally and water deficit does not affect berry weight uniformity at maturity.

In this study, the yield decreased because of poor berry set (Figure 5) reliance on water stress. Berry growth is reduced either by moderate and severe water stress, improving the skin to flesh ratio (Sivilotti et al., 2002). According to Bahar et al. (2011a) the extreme water stress has a negative effect on the berry quality during

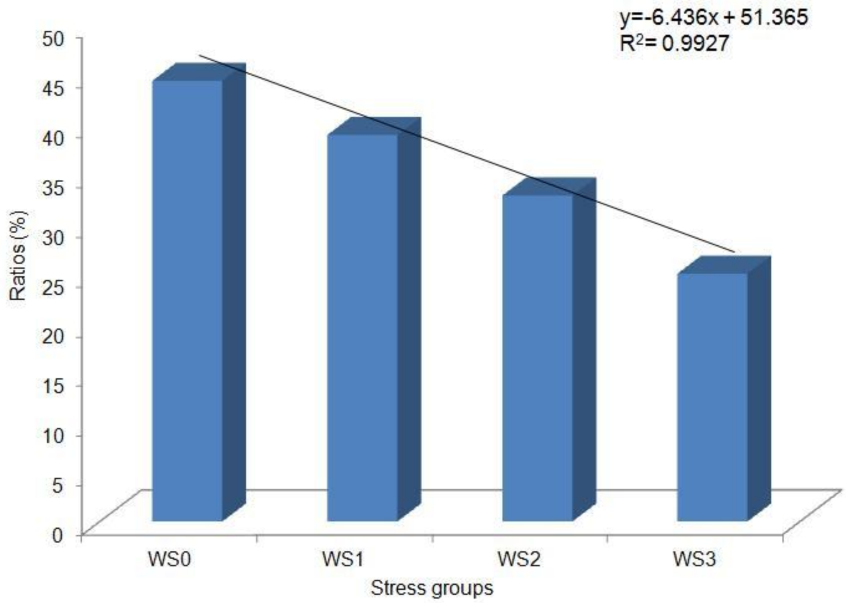

Figure 5. Berry set ratios of Merlot cv.

the lag phase (pre-veraison). The size of stressed berries are smaller than well irrigated berries. 100 berry weights and berry volumes are decreased 21% in Merlot cv (Bahar et al., 2011a). Similar to their findings in this study, yield decreased approximately 50% because of the water stress applied between the beginning of flowering and berry set.

Conclusion

Our results indicate that, under conditions of this experiment, between 17th and 27th phenological stages, which is the subject in this study, shoot growth rate and shoot elongation rate were negatively affected by water deficit, thereby average cluster weight and yield per grapevine decreased and responses varied with different water stress levels. Additionally, it can be stated that the most sensitive period was between 17th and 27th Eichhorn and Lorenz phenological stages which negatively affect berry set therefore yield of vine.

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