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Water Status, Vegetative Growth and Yield Responses of *Vitis vinifera* L. *cvs.* Sauvignon blanc and Chenin blanc to Timing of Irrigation during Berry Ripening in the Coastal Region of South Africa

P.A. Myburgh

ARC Infruitec-Nietvoorbij*, Private Bag X5026, 7599 Stellenbosch, South Africa

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The effects of additional irrigation during berry ripening on water relations, growth and yield in Sauvignon blanc and Chenin blanc grapevines were investigated. In all treatments the grapevines were irrigated when berries reached pea size in December. One treatment received no further irrigation until after harvest. All of the remaining treatments received a second irrigation at véraison. Except for a single treatment, which was not irrigated during ripening, these treatments received a third irrigation at either 14, 21, 28 or 31 days after véraison. The six treatments were applied in a field trial carried out in the Stellenbosch district of the coastal winegrowing region of South Africa over consecutive seasons, between 1990 and 1993. Irrigation at pea size berries and at pea size berries plus véraison increased leaf water potential, but did not affect vegetative growth and yield in either cultivar. Relative to a single application at pea size berries, irrigation at pea size, at véraison and during ripening increased berry size in both cultivars, though not consistently, over the three seasons. However, this result must be viewed in terms of the fact that qualitative assessments of root development and distribution have revealed that effective soil preparation contributes to well-developed root systems. Results confirmed that these root systems could sustain vegetative growth and yield where a single irrigation was applied at pea size berries compared with additional irrigations applied at véraison and during ripening. Irrigation applied at, and after, véraison resulted in yield losses of both cultivars when rainfall favoured *Botrytis cinerea* infection.

Wine grapes in the Coastal Region of the Western Cape are either non-irrigated or irrigated at a low frequency, i.e. one to six irrigations per season, depending on water availability and climatic conditions. In contrast to this so-called "supplementary" irrigation, vineyards in the warmer Breede River and Little Karoo regions require more frequent, or "intensive", irrigation (Van Zyl & Fourie, 1988). Since rain occurs primarily during winter, high levels of soil water depletion during summer can cause water stress in non-irrigated grapevines. Minimum leaf water potentials (Ψ_l) of ca. -1.5 MPa measured in non-irrigated grapevines in the Coastal Region (Myburgh *et al.,* 1996; Conradie *et al*., 2002; Laker, 2004), are lower than -1.2 MPa, which is accepted as the onset of water stress that would be detrimental to grapevines (Williams *et al*., 1994). Similarly, low Ψ_l was also found in water-stressed Shiraz in Australia (Smart & Coombe, 1983), Sauvignon blanc in Israel (Naor *et al*., 1993), Concord in America (Naor & Wample, 1994), Chardonnay, Pinot Noir and Silvaner in Italy (Mattii *et al*., 1998) as well as Alphonse Lavallé in Venezuela (Araujo *et al*., 1998). It therefore seems that low Ψ_l occurs commonly in grapevines, irrespective of cultivar or locality.

Relative to non-irrigated vineyards, Chenin blanc grapevines in the Coastal Region show positive vegetative growth responses to irrigation only where the irrigation occurs after flowering, i.e. at fruit set (Van Zyl & Weber, 1977). More frequent irrigation applied from November until March did not increase vegetative growth of third-leaf grapevines compared with non-irrigated ones in the Coastal Region (Myburgh *et al*., 1996). The lack of response to irrigation in the second half of the season, particularly during berry ripening, is to be expected, since most of the vegetative growth generally occurs during the first part of the season, i.e. before December. Since work by Naor *et al*. (1993) has shown that different irrigation levels applied after véraison did not affect Sauvignon blanc shoot length, irrigation during ripening is unlikely to affect wine quality indirectly through increased canopy density.

Berry size, juice composition and colour are influenced by the water status of the grapevine, and also have determining effects on wine quality (Williams & Matthews, 1990). Smaller berries are produced by grapevines that experience water deficits compared with those produced by continually irrigated grapevines (Goodwin & Macrae, 1990; Williams & Matthews, 1990; Myburgh, 1996; Myburgh, 2003). According to Hardie & Considine (1976), Van Zyl (1984) and McCarthy (1997), the effects of water deficits on berry size development are greater when the deficit occurs early in the season compared with when the deficit occurs during ripening. In contrast, Van Zyl (1984) showed that water deficits during ripening reduced the berry size of Colombar. Irrigation generally increases yield in comparison

E-mail address: myburghp@arc.agric.za

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to grapevines under dry land conditions (Smart & Coombe, 1983). Where Chenin blanc grapevines in the Coastal Region were irrigated after flowering, at pea size berries and at véraison, yield increased compared with grapevines that received no irrigation (Van Zyl & Weber, 1977). A survey of 103 vineyards in the Upper Berg River Valley showed that grapevine yield does not increase linearly with an increase in the number of irrigations (Van Zyl & Van Huyssteen, 1983). The most pronounced contribution towards increased yield compared with dry land conditions occurred when vineyards received only one or two irrigations. Furthermore, it was shown that a single irrigation applied either at fruit set, or at véraison, increased yield, whereas a single irrigation at the end of cell division had no effect when compared with non-irrigated grapevines (Van Zyl & Van Huyssteen, 1983). Hence, yield increase appears to be a function of the number of irrigations, as well as the timing of the irrigations. If water is available for additional irrigation at stages other than those mentioned above, there is a degree of uncertainty about the optimum timing of these additional irrigations, particularly during berry ripening, with respect to grapevine response and wine quality.

The aim of this study was to determine how the timing of an additional irrigation during ripening would affect water status, seasonal vegetative growth and yield of Sauvignon blanc and Chenin blanc grapevines.

MATERIALS AND METHODS

Experiment vineyards

The trial was carried out in a seven-year-old Sauvignon blanc/99Richter, and an adjacent nine-year-old Chenin blanc/99Richter vineyard, on the Nietvoorbij experiment farm in the Stellenbosch district. Based on heat summation over the growing period (September until March), this locality is a class III climatic region (Saayman, 1981 and references therein) at 33° 55' South latitude. The vineyards were both located on soil of the Glencoe form (Soil Classification Work Group, 1991). The soil profile was characterised by a 0.55-m deep, fine sandy loam upper layer and sandy clay loam subsoil. Signs of periodic wetness were apparent below 0.9-m depth. The soil was delve ploughed to 1.0 m before planting. Grapevines were planted at 3.0 m x 1.5 m, and trained onto a 1.5-m slanting trellis (Zeeman, 1981). Throughout the duration of the experiment, both vineyards were irrigated by 32 L/h micro-sprinklers installed at 1.5-m intervals along the row. At this flow rate and spacing, and since the micro-sprinklers wetted the total area, the irrigation application rate amounted to 7.1 mm/h.

Experiment layout

Six irrigation treatments were applied during the 1990/91, 1991/92 and 1992/93 seasons. In all six treatments the grapevines were irrigated when berries reached pea size in December. One treatment (I00) received no further irrigation until after harvest. All of the remaining treatments received a second irrigation at véraison. Except for a single treatment (II0), which was not irrigated during ripening, these treatments received a third irrigation either at 14 days (II14), 21 days (II21), 28 days (II28) or 31 days (II31) after véraison (Table 1). Grapevines of all treatments were irrigated once during the post-harvest period in March. Since the duration of the ripening period averaged 34 days, this meant that the third irrigation was applied at approximately 40%, 60%, 80% and 90% of ripening for II14, II21, II28 & II31, respectively. The last irrigation of the II31 treatment was normally applied three days before harvest. Treatments were replicated five times in a randomised block design. Each 126 m^2 experiment plot consisted of two rows of three experiment grapevines with two buffer grapevines at each end, and a buffer row on each side to limit overlapping treatment effects.

Each of the irrigations (pea size, véraison and post harvest) supplied approximately 95 mm of water. Consequently, the total amount of irrigation was 190 mm and 285 mm per season for the I00 and II0 treatments, respectively. In the case of the II14, II21, II28 and II31 treatments, mean evapotranspiration (ET) was estimated using a crop coefficient of 0.25 for low-frequency irrigation (Van Zyl & Fourie, 1988) and the long-term mean daily American Class-A pan evaporation for the Nietvoorbij experiment farm (Table 2). Irrigation amounts required to replenish soil water deficits were obtained by multiplying the mean daily ET by the number of days after véraison. Total irrigation for treatments II14 to II31 were, respectively, ca. 314 mm, 329 mm, 343 mm and 349 mm per season. Both cultivars received the same treatments.

TABLE 1

Irrigation treatments applied during 1990/91, 1991/92 and 1992/93 seasons to determine responses of Sauvignon blanc and Chenin blanc to irrigation during berry ripening at Nietvoorbij, Stellenbosch. ("X" indicates irrigation).

Treatment	Stage(s) at which irrigation was applied					
	Pea size berries	Véraison	Days after véraison			
			14	21	28	31
I00	X					
II0	X	X				
II14	X	X	X			
II21	X	X		X		
II28	X	X			X	
II31	X	X				X

TABLE 2

Mean January and February air temperature, relative humidity, wind run, American class-A pan evaporation and total rainfall measured over the duration of the field trial at Nietvoorbij, Stellenbosch in comparison to the 23 year long term mean (Anonymous, 1989).

Atmospheric parameter	Long term	Season		
	mean	1990/91	1991/92	1992/93
Maximum air temperature (°C)	27.7	27.2	27.7	27.9
Minimum air temperature (°C)	15.1	14.5	15.6	15.1
Mean air temperature (°C)	21.4	20.8	21.7	21.5
Maximum relative humidity (%)	90.0	92.7	92.6	88.9
Minimum relative humidity (%)	40.0	44.2	46.2	38.2
Daily wind run (km)	226	160	176	140
American class-A pan (mm/day)	8.3	7.7	7.9	7.2
Rainfall (mm)	42	14	48	51

Soil water

Soil water content was measured at 0.3-m depth intervals to a depth of 1.2 m using the neutron scattering technique. Access tubes for the neutron probe (HYDROPROBE 305DR, CPN, California) were installed in the vine row, 0.5 m from a grapevine. Since the total area was wetted, placement of access tubes with respect to the micro-sprinklers was not a consideration. Neutron counts were calibrated against gravimetric soil water contents (mass %) determined for each 0.30-m depth interval. On the assumption that no differences in soil water content were likely to develop before veraison, soil water content was only measured before and after the irrigations that were applied at véraison and during ripening. Soil water content was only measured in the Sauvignon blanc vineyard.

Soil bulk density for each 0.3-m depth interval was determined on undisturbed soil cores. The bulk density was used to convert soil water content (mass %) to depth of soil water (mm) per 0.3-m soil depth for the first two layers and 0.4 m for the third layer. The water contents (mm) of the three layers were summed to obtain total water content for the 1.0-m root depth. Mean daily ET during ripening was calculated by subtracting the soil water content measured before the next irrigation from the water content measured after the previous irrigation, and dividing the difference by the number of days between the irrigations. Soil water retention curves for the undisturbed cores were determined by means of the pressure chamber method (Klute, 1986). Total plant available water (PAW) was calculated as the difference in soil water content between -0.01 MPa and -1.5 MPa matric potential (Hillel, 1980).

Root distribution

Root distribution was determined in six plots in the Sauvignon blanc vineyard during August 1990 before the treatments were applied. The profile wall method of Böhm (1979) was used to qualify and quantify root distribution within the constraints imposed by this method. A trench, 1.5-m long and 1.0-m deep, was dug across the vine row between two experiment grapevines, with the trench sides 0.15 m from each vine. Exposed roots were mapped with the aid of a portable grid, divided into 0.25-m squares. Roots were classified into four classes, namely: fine (< 0.5 mm diameter), medium (0.5 mm to 2.0 mm diameter), coarse (2.0 mm to 5.0 mm diameter) and thick (> 5.0 mm diameter).

Leaf water potential

To quantify grapevine water status, leaf water potential (Ψ_l) was measured using the pressure chamber technique (Scholander *et al*., 1965). Because of the practical limitations involved in measuring Ψ_l in large numbers of grapevines during the relatively short pre-dawn period, and the possibility that gas-exchange measurements over the warmest part of the day may be affected by partial stomatal closure (Van Zyl, 1987) or by oscillatory transpiration (Rose & Rose, 1994), the measurement of Ψ_l was carried out at around 15:00. It has been shown that differences in grapevine water status, induced by different soil water depletion levels, remained relatively stable during the afternoon (Grimes & Williams, 1990; Araujo *et al*., 1998; Pire & Ojeda, 1998; Myburgh, 2003). Only one un-bagged, mature leaf, fully exposed to sunlight was assessed in each experiment plot. Measurements were performed weekly during ripening as well as on the day before the grapes were harvested. Leaf water potential was only determined in the Sauvignon blanc vineyard.

Berry size, yield and vegetative growth

Fresh berry mass changes in Sauvignon blanc were determined weekly during ripening. Berry mass and volume were determined in both cultivars on the day before harvest. Due to the limited number of experiment grapevines per plot, removing bunches at regular intervals to obtain more accurate berry samples would have caused a significant crop load reduction. Therefore, only 100 berries were sampled weekly per plot by picking five berries from each of twenty bunches. Berries were picked at different positions along the longitudinal bunch axis. Grapes were harvested in February at mean TSS to TTA ratios of approximately 2.5. Total grape mass per plot was measured and converted to yield (t/ha). During the 1992/93 season, grapes were severely infected by *Botrytis cinerea*. Infected bunches were weighed separately to calculate the percentage rot damage on a mass basis. Vegetative growth was quantified by measuring cane mass annually, during July.

Atmospheric conditions

Air temperature, relative humidity, daily wind run, American class-A pan evaporation and rainfall were measured at a weather station approximately 600 m from the experiment vineyards.

Statistical analysis

The data were subjected to an analysis of variance. Student's t least significant difference (LSD) values were calculated to facilitate comparison between treatment means. Means which differed at $p \leq 0.05$ were considered to be significantly different.

RESULTS AND DISCUSSION

Root distribution

A consequence of the deep soil preparation was that the root systems were well developed in terms of vertical and horizontal distribution, and also in terms of the numbers of fine roots (< 0.5 mm diameter) which constituted 87% of the total root number. Furthermore, root distribution was exceptionally homogeneous with 18%, 29%, 28% and 25% of the roots occurring in the respective 0.25-m increments to 1-m depth. These characteristics enabled the root systems to exploit the available soil volume almost to its full extent with regard to available water and nutrients (Smart & Coombe, 1983). A similarly uniform root distribution pattern was obtained where granitic clay loam soil in the Stellenbosch district was deep ploughed to 0.85 m. In contrast, shallow loosening to 0.45 m resulted in less than 20% of the roots penetrating deeper than 0.5 m (Van Zyl, 1988).

Soil water depletion and evapotranspiration

Plant available water was 128 mm for the 1-m root depth. Since atmospheric conditions did not differ significantly between seasons (Table 2), and rainfall was generally less than 5 mm/day (data not shown), soil water depletion patterns were comparable for the three seasons. However, rainfall in excess of 30 mm which occurred just before harvest increased the soil water content of all treatments (Fig. 2). Where the last irrigation was applied at pea size berries (I00), soil water content showed a slow decrease, which indicated that ET of these Sauvignon blanc gapevines was extremely low (*i.e.* < 0.7 mm/day) during the ripening period. This was comparable with the mean ET of non-irrigated Sauvignon blanc vineyards of 0.75 mm/day in February on deep

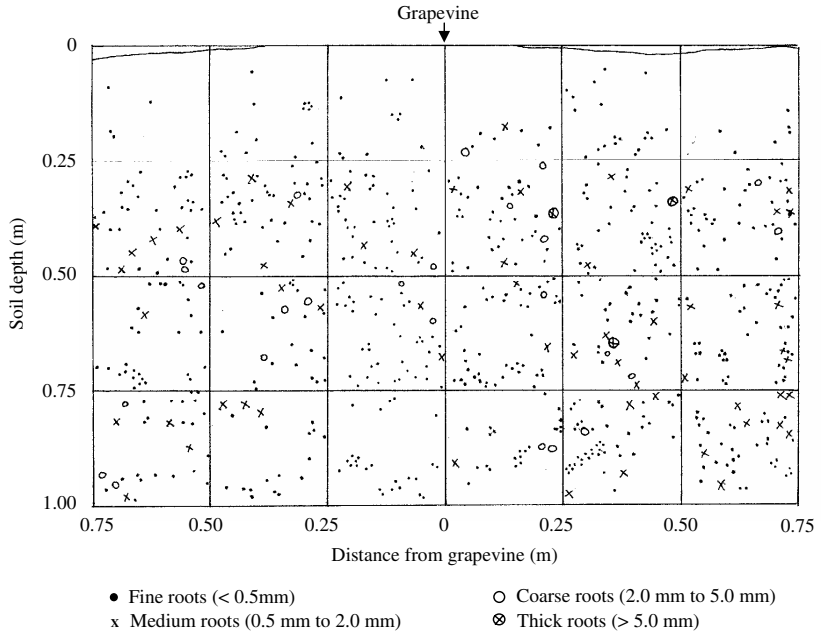

FIGURE 1

Example of Sauvignon blanc/99R root distribution plotted during August 1990 to illustrate the homogenous root distribution and the large number of fine roots in relation to thicker ones.

red soils, where PAW was 144 mm/m (Laker, 2004). Where PAW was only 103 mm/m, and shoot growth less vigorous, ET was 0.56 mm/day. Since the soil surface layer was dry, which greatly reduced evaporation losses, ET was primarily a function of transpiration (Myburgh, 1998). Furthermore, the low ET agreed with the 2.5 liters transpiration per grapevine per day (equivalent to 0.6 mm/day) estimated from sap flow measurements in non-irrigated Pinot noir grapevines (Myburgh, 1998). This result suggested that, although ca. 90% of the available soil water in the root zone of the I00 treatment was depleted before harvest, transpiration was not seriously reduced. The deep, well-developed root system probably enabled adequate water uptake to sustain transpiration. It was shown that transpiration rates of non-irrigated Pinot noir grapevines increased when root depth increased from 0.4 m to 1.2 m (Myburgh *et al*., 1996).

Where the last irrigation was applied at véraison (II0), the mean ET was approximately 2.6 mm/day during the ripening period. At this ET rate, approximately 80% of the available water was depleted before harvest. The difference in ET between the I00 and II0 treatments was attributed to increased evaporation losses from the soil surface of the II0 treatment after the second irrigation was applied at véraison. High rates of evapotranspiration from non-irrigated grapevines following rainfall in early summer was also attributed to increased evaporation from the soil surface relative to that in seasons when less rainfall occurred (Van Zyl & Weber, 1981). An additional irrigation during the middle stages of ripening increased the mean ET to 4.3 mm/day, which was in line with the value of 4.0 mm/day reported for Pinot noir grapevines that were irrigated frequently during January and February in the Stellenbosch district (Myburgh *et al*., 1996).

Grapevine water status

Results for the 1992/93 season showed that leaf water potential in Sauvignon blanc grapevines subjected to the driest soil conditions (I00) tended to decrease during the ripening period as the soil water content decreased (Fig. 3). During this particular season, Ψ_l in these grapevines was well below -1.2 MPa, which is regarded as the upper threshold for water stress (Williams *et al*., 1994). The low Ψ_l was in agreement with values reported for water stressed grapevines (Smart & Coombe, 1983; Naor *et al*., 1993; Myburgh *et al*., 1996; Mattii *et al*., 1998; Conradie *et al*., 2002; Laker, 2004). Stomatal closure was observed when Ψ_l in grapevines reached approximately -1.6 MPa (Van Zyl, 1987). This indicated that a reduction in transpiration was unlikely to have restricted ET of the I00 grapevines appreciably during the ripening period, as discussed above. However, cool weather conditions and rainfall, which occurred prior to harvest during the 1992/93 season, did increase Ψ_l in these grapevines. For the major part of the ripening period Ψ_l values in Sauvignon blanc grapevines irrigated at véraison (II0) were comparable with those that were only irrigated at pea size (Fig. 3). In fact, the difference between these two treatments did not exceed 0.1 MPa. At the end of ripening, the equally low soil water contents of the I00 and II0 treatments resulted in comparable Ψ_l values.

Leaf water potential was ca. 0.3 MPa to 0.4 MPa higher when a third irrigation was applied during the later stages of ripening compared to Ψ_l in grapevines of the I00 and II0 treatments (Fig. 3). These results corresponded to the differences between irrigated and non-irrigated grapevines reported by Smart & Coombe (1983). During the 1992/93 season, Ψ_l in grapevines of the II21 treatment were comparable to the I00 and II0 treatments on the day before the third irrigation was applied (data not shown). However, on the day following the irrigation, Ψ_l in the II21 grapevines did not respond to the higher soil water content. Similarly, it was found that Ψ_l in Colombar grapevines which had been subjected to water deficits did not increase immediately after irrigation to the same level as in non-stressed grapevines

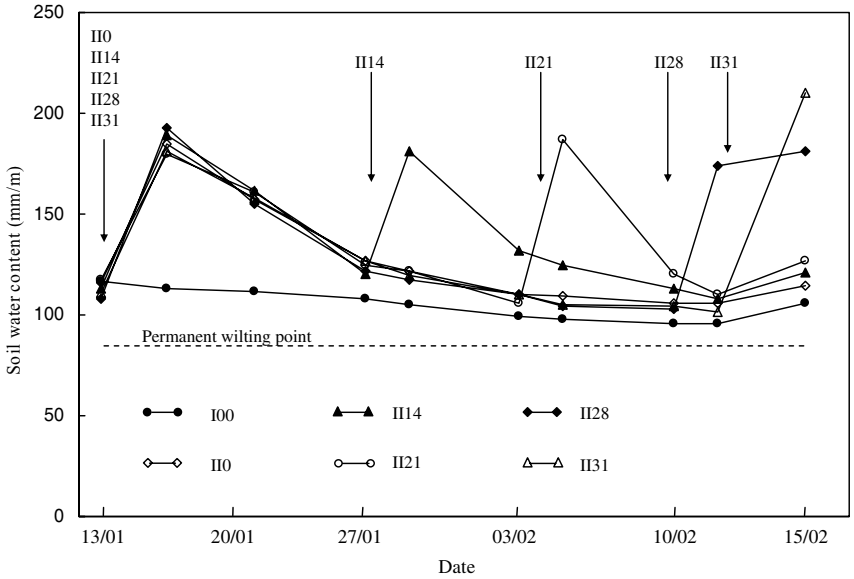

FIGURE 2

Variation in soil water content during ripening as measured during the 1992/93 season in an irrigation trial near Stellenbosch. Arrows indicate when various treatments were irrigated (refer to Table 1 for explanation of treatments).

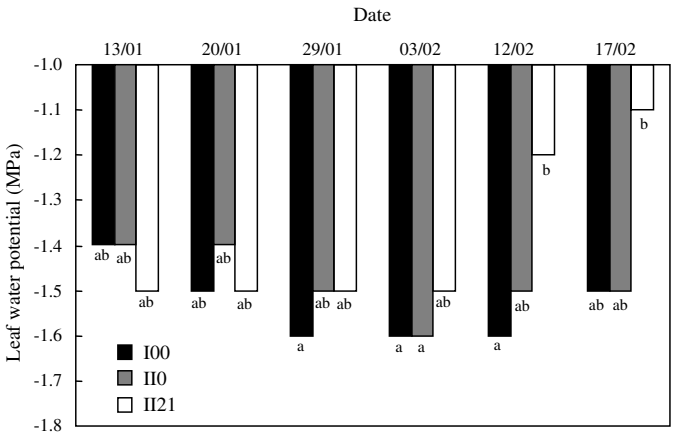

FIGURE 3

Variation in leaf water potential during ripening in Sauvignon blanc grapevines as measured during the 1992/93 season. Bars designated by the same letter do not differ significantly (refer to Table 1 for explanation of treatments).

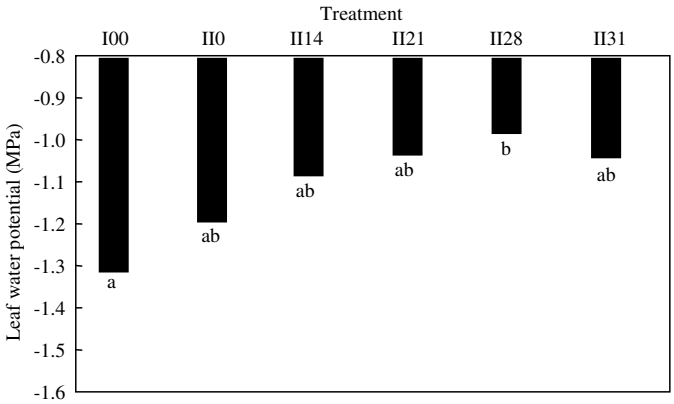

FIGURE 4

Effect of irrigation during ripening on leaf water potential in Sauvignon blanc grapevines prior to harvest. Bars designated by the same letter do not differ significantly (refer to Table 1 for explanation of treatments).

(Van Zyl, 1984). In fact, Ψ_l only increased to the same level as in non-stressed grapevines after a second irrigation was applied 10 days later. Low, or even decreasing, Ψ_l, despite high soil water contents after irrigation, has also been observed in Sultanina (Araujo *et al*., 1995). Since no abnormalities in atmospheric conditions that could have caused this unexpected lag in Ψ_l response were recorded on that particular day (data not shown), these results suggest that some physiological parameter which limits water uptake had not been able to adjust to the wetter soil conditions on the day following the irrigation. Mean grapevine water stress on the day before harvest, as measured over the three seasons, decreased with an increase in the period between véraison and the irrigation applied during ripening (Fig. 4). On average, Ψ_l in grapevines in the driest treatment was ca. -1.3 MPa, which was not far below the -1.2 MPa threshold value. In contrast to the driest treatment, higher Ψ_l in grapevines that were irrigated during the later stages of ripening indicated that they experienced no detrimental water stress when the grapes were harvested.

Vegetative growth

In general, growth vigour of both cultivars was moderate to low. No corrective canopy management practices were therefore necessary. Mean cane masses were ca. 2.7 t/ha and 2.5 t/ha, for Sauvignon blanc and Chenin blanc, respectively (Table 3). These masses were considerably lower than the 4 t/ha reported for irrigated Colombar on a horizontal trellis in the Breede River Valley by Van Zyl (1984) and the 5.8 t/ha observed by Myburgh (1996), where Barlinka grapevines on a horizontal trellis were irrigated at 10% available water depletion. In the latter case, vigorous growth caused inferior colouring of the red grapes compared with those where irrigation at 40% available water depletion produced a cane mass of 4.1 t/ha. Mean cane masses of Sauvignon blanc and

TABLE 3

Effect of irrigation during berry ripening on cane mass at pruning of cvs. Sauvignon blanc and Chenin blanc measured over three seasons at Nietvoorbij, Stellenbosch.

Treatment number[1]	Cane mass (t/ha)							
	Sauvignon blanc				Chenin blanc			
	1990/91	1991/92	1992/93	Mean	1990/91	1991/92	1992/93	Mean
I00	2.4a[2]	2.6a	2.7a	2.6a	1.8a	2.2a	2.4a	2.2a
II0	2.3a	2.4a	3.0a	2.6a	2.0a	2.2a	2.7a	2.3a
II14	2.5a	3.3a	2.7a	2.8a	2.0a	2.6a	2.9a	2.5a
II21	2.3a	2.9a	2.9a	2.7a	2.4a	2.8a	3.1a	2.8a
II28	2.4a	3.1a	3.0a	2.8a	2.2a	2.9a	2.7a	2.6a
II31	2.3a	2.8a	2.6a	2.6a	2.1a	2.4a	2.6a	2.4a

[1] Refer to Table 1 for explanation of treatments.
[2] Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

Chenin blanc were more comparable to the 3.1 t/ha that was obtained when Barlinka grapevines were irrigated at 60% available water depletion. Irrigation applied at, and after, véraison did not affect cane mass in the two cultivars relative to the single irrigation applied at pea size (Table 3). The lack of vegetative growth response to additional irrigation during ripening was to be expected since irrigation treatments were applied after the vegetative growth phase that normally ends around mid-December. Van Zyl & Van Huyssteen (1983) reported that irrigation applied at pea size or véraison did not increase cane mass of Chenin blanc in the Coastal Region compared with non-irrigated grapevines. Vegetative growth of Sauvignon blanc also did not respond to different irrigation levels during ripening (Naor *et al*., 1993).

Yield

Berries of grapevines irrigated only at pea size (I00), as well as those that received a second irrigation at véraison (II0), showed some mass increase during the initial stages of ripening (Fig. 5). In the final stage, berry mass remained fairly constant. Compared with the I00 and II0 treatments, a third irrigation applied during the ripening period only tended to increase the rate of berry mass development. During the first two seasons the irrigation treatments did not affect final berry mass and volume of Sauvignon blanc (Tables 4 & 5). However, during the 1992/93 season berry mass and volume in grapevines that were irrigated at pea size and véraison (II0) were higher than from those grapevines that received a single irrigation at pea size (I00). During that particular season (1992/93) berry mass was also higher when a third irrigation was applied 28 days after véraison. Colombar berries reacted in a similar way to different irrigation levels during ripening (Van Zyl, 1984). This showed that although irrigation applied at, or after, véraison can result in larger berries, the effect of the irrigation may not be consistent over seasons. Similar to Sauvignon blanc, the different irrigation treatments did not affect berry mass of Chenin blanc during the first two seasons (Table 4). During the 1992/93 season, irrigation applied 14 days, 21 days and 28 days after véraison, respectively, increased berry mass and volume compared with the I00 treatment. Mean berry density, i.e. berry mass divided by its volume, in both cultivars, was 1.08 g/cm^3 for the three seasons. The irrigation treatments did not affect berry density of the two cultivars during any season (data not shown).

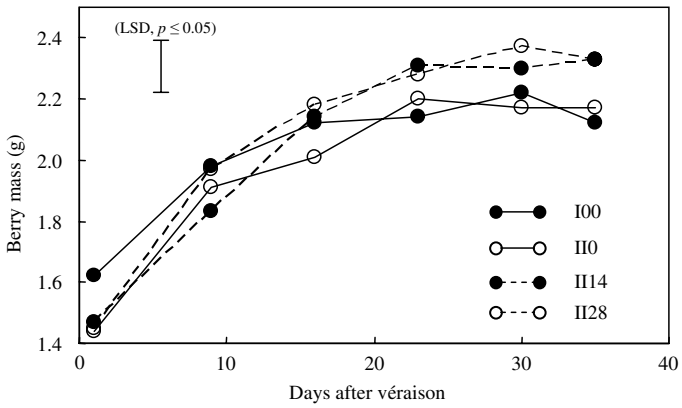

FIGURE 5

Effect of irrigation during ripening on berry mass development of Sauvignon blanc during the 1992/93 season (refer to Table 1 for explanation of treatments).

Yields of Sauvignon blanc or Chenin blanc were not affected by the irrigation treatments during the three seasons (Table 6). Although severe water stress during ripening can reduce grape yield (Hardie & Considine, 1976), the single irrigation at pea size was adequate to prevent yield reduction compared with irrigations applied at, and after, véraison. This suggested that the well-developed root systems enabled sufficient water to be absorbed to support full yield potential under the specific conditions. However, the mean yield to cane mass ratio was 3.9 for Sauvignon blanc and 6.9 for Chenin blanc, respectively. This suggests that, irrespective of the amount of irrigation water applied, the vegetative growth of Chenin blanc grapevines, which was comparable to that of Sauvignon blanc, could sustain a substantially greater crop load. The irrigation treatments did not affect the yield to cane mass ratios of the two cultivars during any of the seasons (data not shown).

Except for the II28 treatment, irrigation applied at, and after, véraison increased the incidence of *B. cinerea* in Sauvignon blanc grapes during the 1992/93 season (Table 7). Up to ca. 20% more crop damage occurred compared with the treatment that was only irrigated at pea size. Irrigation applied 21 days after véraison substantially increased crop damage to Chenin blanc compared with

TABLE 4

Effect of irrigation during berry ripening on berry mass of cvs. Sauvignon blanc and Chenin blanc measured over three seasons at Nietvoorbij, Stellenbosch.

Treatment number[1]	Berry mass (g)							
	Sauvignon blanc				Chenin blanc			
	1990/91	1991/92	1992/93	Mean	1990/91	1991/92	1992/93	Mean
I00	2.01a[2]	1.98a	2.07b	2.02b	1.77a	1.70a	1.85b	1.77b
II0	2.02a	2.11a	2.32a	2.15a	1.96a	1.81a	2.04ab	1.94ab
II14	2.14a	2.15a	2.12ab	2.14ab	2.05a	1.90a	2.20a	2.05a
II21	2.05a	2.03a	2.19ab	2.09ab	2.05a	1.80a	2.13a	2.00a
II28	2.07a	2.19a	2.27a	2.18a	1.93a	1.93a	2.17a	2.01a
II31	1.96a	2.03a	2.16ab	2.05ab	1.83a	1.78a	2.02ab	1.88ab

[1] Refer to Table 1 for explanation of treatments.
[2] Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

TABLE 5

Effect of irrigation during berry ripening on berry volume of cvs. Sauvignon blanc and Chenin blanc measured over three seasons at Nietvoorbij, Stellenbosch.

Treatment number[1]	Berry volume (cm^3)							
	Sauvignon blanc				Chenin blanc			
	1990/91	1991/92	1992/93	Mean	1990/91	1991/92	1992/93	Mean
I00	1.88a[2]	1.85a	1.93b	1.88b	1.57b	1.63a	1.75b	1.65b
II0	1.87a	1.95a	2.18a	2.00ab	1.80ab	1.67a	1.90ab	1.79ab
II14	1.98a	2.01a	1.96ab	1.89ab	1.86a	1.80a	2.05a	1.90a
II21	1.92a	1.88a	2.03ab	1.94ab	1.86a	1.72a	2.00a	1.86ab
II28	1.95a	2.03a	2.12ab	2.04a	1.81ab	1.82a	2.04a	1.89ab
II31	1.86a	1.89a	2.01ab	1.92b	1.69ab	1.66a	1.87ab	1.74a

[1] Refer to Table 1 for explanation of treatments.
[2] Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

TABLE 6

Effect of irrigation during berry ripening on yield of cvs. Sauvignon blanc and Chenin blanc measured over three seasons at Nietvoorbij, Stellenbosch.

Treatment number[1]	Yield (t/ha)							
	Sauvignon blanc				Chenin blanc			
	1990/91	1991/92	1992/93	Mean	1990/91	1991/92	1992/93	Mean
I00	8.2a[2]	9.1a	13.6a	10.3a	15.8a	16.9a	14.0a	15.6a
II0	8.9a	9.3a	12.0a	10.1a	15.3a	18.0a	13.8a	15.7a
II14	8.9a	8.9a	13.8a	10.5a	14.0a	20.9a	16.4a	17.1a
II21	8.9a	9.1a	14.0a	10.7a	19.8a	22.4a	16.7a	19.6a
II28	9.3a	9.3a	14.4a	11.0a	18.0a	20.4a	16.4a	18.3a
II31	8.9a	9.6a	13.6a	10.7a	17.1a	19.3a	14.0a	16.2a

[1] Refer to Table 1 for explanation of treatments.
[2] Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

the I00 treatment. Incidence of bunch rot was also reduced when Chenin blanc grapevines were not irrigated from véraison until harvest, in comparison to irrigation at 100% of evaporation (Sawyer, 1978). Similar results were reported for Colombar (Van Zyl, 1984). Since mean relative humidity during the 1992/93 season was low in comparison to that during the other seasons (Table 2), high atmospheric vapour content could not have triggered the notably higher incidence of *B. cinerea* observed during that season. Similarly, the problem could not have been exacerbated by higher canopy densities since vegetative growth was comparable in all seasons, and additional irrigation during ripening did not increase cane mass in comparison to the I00 treatment (Table 3). When the water flow into grapevine berries increases substantially relative to the outflow, the susceptibility of the berries to cracking increases (Lang and Thorpe, 1988). Cool weather during ripening in the 1992/93 season may have reduced transpiration

TABLE 7

Effect of irrigation during berry ripening on incidence of Botrytis cinerea in grapes of cvs. Sauvignon blanc and Chenin blanc as measured during the 1992/93 season at Nietvoorbij, Stellenbosch.

Treatment number[1]	*Botrytis cinerea* damage (%)	
	Sauvignon blanc	Chenin blanc
I00	7.6b	6.6c
II0	22.8a	13.0bc
II14	21.5a	22.2bc
II21	23.7a	28.2a
II28	16.6ab	21.9ab
II31	27.6a	15.1abc

(1) Refer to Table 1 for explanation of treatments.
(2) Values designated by the same letter within each column do not differ significantly ($p \leq 0.05$).

(water outflow), whereas wetting of the berries by rain could have increased osmotic uptake (water inflow). Higher soil water availability probably contributed to an increased water inflow which, in turn, increased the possibility of berry crack where grapevines received additional irrigation during ripening. Although berry crack was not quantified, the foregoing suggested that irrigation during ripening indirectly increased primary disease infection by increasing berry crack.

CONCLUSIONS

Since vegetative growth and yield of Sauvignon blanc and Chenin blanc grapevines that were irrigated only once when berries reached pea size were not inferior, compared with those that received additional irrigation, the well-developed root systems were clearly able to supply adequate water and nutrients from pea size up to harvest. Results also indicated that the grapes could ripen without delay, although Ψ_l in grapevines was as low as -1.6 MPa. However, on soils with low PAW due to sandy texture or limited root depth, berry ripening might be delayed. This emphasises the importance of efficient soil preparation where irrigation water is limited. Where smaller root systems are induced by limited soil wetting, as in the case of drip irrigation, more frequent irrigation may be required to sustain vegetative growth and yield. Irrigation during ripening of wine grapes under such conditions, particularly in the warm inland regions of South Africa, needs to be investigated by further research.

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