Cane Water Content and Yield Responses of *Vitis vinifera* L. cv. Sultanina to Overhead Irrigation During the Dormant Period

P.A. Myburgh* and L.D. van der Walt

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

Submitted for publication: September 2003

Accepted for publication: April 2005

Key words: Cane, dormant, irrigation, overhead, Sultanina, yield

The possibility to increase grapevine cane water content during the dormant period by applying overhead irrigation, and thereby increasing yield, was investigated in a semi-arid summer rainfall climate. A field trial was carried out with Sultanina grapevines in the Lower Orange River region over two seasons. During the 2000/2001 season control grapevines (T1) that received no overhead irrigation in winter were compared to ones receiving overhead irrigation applied over a ca. 30-day period, starting either in July (T2), mid-July (T3), August (T4) or mid-August (T5). Overhead irrigation was applied as ten-minute pulses on the hour from 10:00 until 16:00. Due to the lack of winter rainfall, all treatments received normal, under-vine irrigation in winter to avoid severe water deficits. All treatments, except T2, were repeated during the 2001/2002 season. Two additional treatments which received no irrigation during winter were included during the second season. Of these two, T6 received overhead irrigation in August, whereas T7 received no overhead irrigation. Compared to the T1 control, overhead irrigation applied during August 2000 (T4) not only increased cane water content measured before bud break, i.e. early September, but also increased yield. The other overhead irrigation treatments did not affect cane water content or yield. During the second season overhead irrigation started in mid-July (T3) or in the beginning of August (T4) induced higher yields compared to grapevines that received overhead irrigation in the period before bud break (T5). Where available soil water depletion of 90% occurred, overhead irrigation (T6) seemed to negate the adverse effects of dry soil on yield. In contrast, cane water content and yield were considerably lower where neither normal nor overhead irrigation was applied (T7), compared to T3 and T4. These results confirmed that overhead irrigation can increase cane water content and yield, and that soil water deficits during the dormant period should be avoided. Overhead irrigation and/or water deficits during winter did not affect cane mass, as measured at the end of the following growing season.

Seasonal yield variation of Sultanina grapevines is a common phenomenon in the semi-arid Lower Orange River region of South Africa (Smit, 1970; Myburgh, 2003a), and also in regions such as the Murray Valley of Australia (May & Antcliff, 1963). Since most grapevines are grown under Mediterranean conditions (dry summers/wet winters), knowledge on the effects of water deficits during winter, or dormant period, in summer rainfall regions (wet summers/dry winters) is limited. Efforts to study water deficits during the post-harvest period in a field trial at Robertson under winter rainfall conditions failed due to untimely rain (Van Zyl, 1984). Field observations in the Lower Orange River region showed that too dry conditions during dormancy can be detrimental to growth at the beginning of the season (Goosen, 1956). The opposite was found in California, where bud break in Perlette grapevines occurred earlier, when irrigation was cut-off early in the post-harvest period (15 September) compared to the normal, later cut off date on 1 December (Williams *et al.*, 1991). However, the earlier irrigation cut-off had no effect on the number of active buds at the end of the bud break period. On the other hand, over-irrigation of Sultanina during the post-harvest period, in combination with high temperatures at that stage, can induce excessive vegetative growth (Goosen, 1956). Although this could limit reserve accumulation and induce stunted spring growth, reduced irrigation during the post-harvest period had no significant effect on cane starch content of Sultanina at pruning, irrespective of the occurrence of vigorous shoot growth after the grapes had been removed (Myburgh, 2003b).

Evaporative cooling during the post-harvest period is used to achieve earlier and more uniform bud break in many warm grape-growing areas, where chilling is minimal or non-existent (Williams *et al.*, 1994 and references therein). Some table grape growers in the warmer, western part of the Lower Orange River region use evaporative cooling to induce dormancy. This is obtained by applying overhead irrigation in the post-harvest period during four to five relatively cool days, i.e. when the weather forecast predicts maximum temperatures lower than 16°C (J.J. Burnett, personal communication). When the temperature reaches 10°C on these days, overhead irrigation is switched on and applied for five minutes at 20-minute intervals until sunset. By following this approach, maximum temperature can be reduced by ca. 4°C. For early cultivars, evaporative cooling would usually start mid-May and for late cultivars early in July.

**Corresponding author: E-mail address: myburghp@arc.agric.za*

Acknowledgements: Technical assistance of the Soil Science staff at ARC Infruitec-Nietvoorbij and C. Jackson of the SADOR farm.

After initiation of floral primordia in early summer, differentiation into bunches can either occur at the end of the growing season, in winter or in spring (Pratt, 1971 and references therein). According to Buttrose (1974), final differentiation of individual floral organs into bunches takes place shortly before and after bud break. It was shown that low relative humidity of the atmosphere, in combination with extremely low soil water content, during the dormant period (July to August) in the Lower Orange River region can induce poor bunch differentiation (Myburgh, 2003b). As a result, smaller bunches contribute to lower grapevine yields. There are also indications that dry atmospheric and soil conditions after pruning in July can cause bunch abortion in the dormant buds, thereby reducing grapevine fertility (Myburgh, 2003b). These adverse conditions also seem to delay bud break and induce stunted spring growth. Grapevines on sandy soils away from the river (Myburgh, 2003b), as well as those on fertile, alluvial soils (Myburgh, 2003c), are susceptible to the negative effects of severe soil water deficits and low ambient humidity during the dormant period. At this stage there is no clear physiological explanation for the low fertility and poor bunch differentiation under such conditions, except for possible bud desiccation or insufficient hormone production in roots and/or solute translocation from roots via canes to buds. Earlier results indicated that cane water content can be related to soil water content (Myburgh, 2003b). Hence, the effect of extremely dry soil conditions on cane or bud water status could contribute to low grapevine fertility and poor yield. Other external factors, such as climate and location, were also found to affect grapevine cane water content (Misik & Szívós, 1998).

The aim of this study was to determine if grapevine yield could be improved if cane water content was increased by overhead irrigation applied during the dormant period.

MATERIALS AND METHODS

Experiment vineyard

The field trial was carried out during the 2000/2001 and 2001/2002 seasons in a 16-year-old, own-rooted Sultanina (Clone 14/2) vineyard on the SADOR farm of the South African Dried Fruit Co-operative near Upington. This locality is a region V (Winkler, 1962) at 28° 27' South latitude with a mean annual precipitation of 120 mm. The soil, which belongs to the Plooysburg form (Soil Classification Work Group, 1991), consisted of 600 mm to 900 mm deep red sand on undulating, nodular, cemented limestone [Aridisol, (Soil Survey Staff, 1975)]. Before planting, the soil was ripped to a depth of 800 mm. Grapevines were planted 3.0 m x 2.0 m, trained onto a gable trellis (Zeeman, 1981) and pruned to six canes, allowing 12 to 18 nodes per cane. No canopy management was performed during summer, which is the norm for dried grape vineyards in this particular region.

Normal, under-vine irrigation was applied by means of 32 L/h micro-sprinklers. During the first season the vineyard was irrigated according to the standard schedule of the SADOR farm. However, during the 2001/2002 season, irrigations were applied according to soil water matric potential (Ψ_m) levels. The latter was measured once a week as well as before and after irrigations on two replications of each treatment using tensiometers installed in the vine row at 300 mm and 600 mm depths ca. 500 mm from a grapevine. During the post-harvest period irrigation was applied when mean Ψ_m at 300 mm and 600 mm depths reached –0.05 MPa and from bud break (early to mid-September) until harvest (end January), when mean Ψ_m reached –0.03 MPa (Fig. 1). To determine if the overhead irrigation had any effect on the water content of surface soil layers, Ψ_m was also measured at 150 mm depth in one replication of the T1, T3, T4 and T5 treatments.

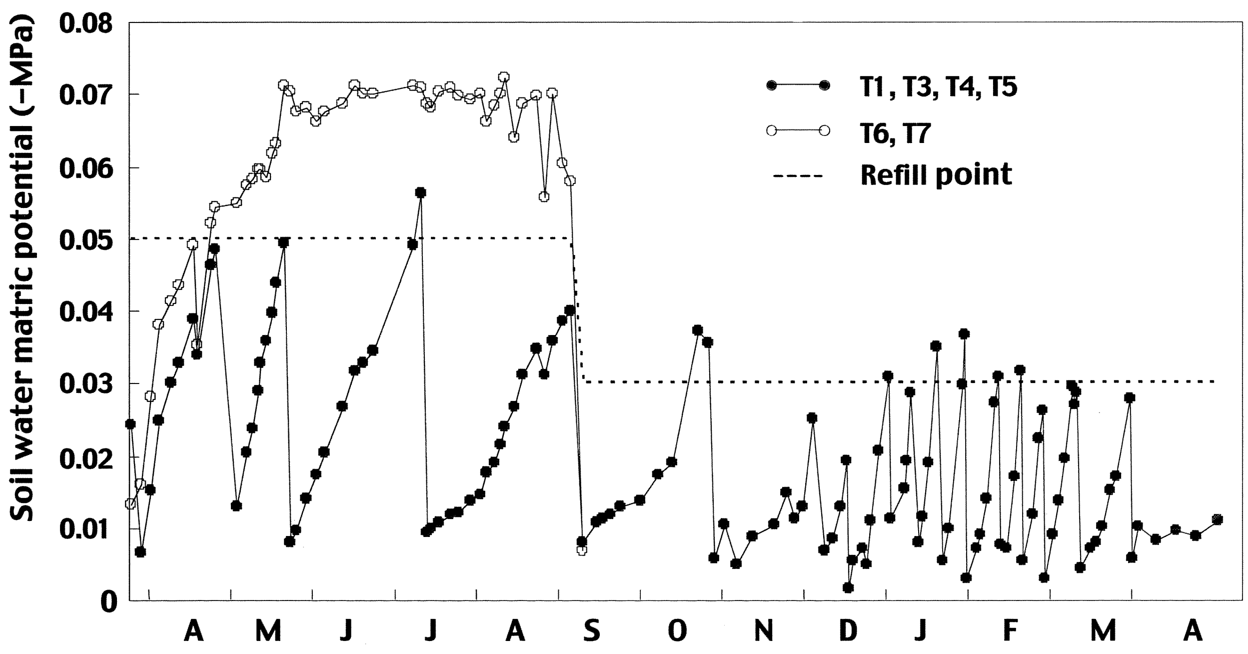

FIGURE 1
Soil matric potential measured in a field trial, where effects of overhead irrigation and soil water deficits on Sultanina yield were determined during the 2001/2002 season near Upington. (Refer to Table 1 for explanation of treatments.)

Experiment layout

During the 2000/2001 season, a control and four overhead irrigation treatments, where pulses were applied for ca. 30-day periods to wet the canes at various times during the winter months, were imposed (Table 1). To assess the effects of soil water deficits during the dormant period in the 2001/2002 season, T2 was omitted and two additional treatments added (Table 1). Treatments were replicated four times in a randomised block design. Each 1260 m^2 plot contained six experiment vines with twelve buffer vines at each end and three buffer rows on each side. Overhead irrigation was applied by means of 32 L/h fine spray micro-sprinklers installed on riser tubes 700 mm above the centre of each experiment grapevine of the overhead irrigation treatments. A steel wire was installed 600 mm above the central cordon wire to support the riser tubes. Overhead irrigation was applied in ten-minute pulses on the hour from 10:00 until 16:00. Due to logistical problems overhead irrigation was not applied on weekends. A total of ca. 120 mm of water was applied via overhead irrigation during each 30-day period.

Plant parameters

Vegetative growth was quantified by measuring cane mass at pruning (July). Grapes were harvested at a total soluble solids content of ca. 22°B. Yield was obtained by measuring total grape mass per plot at harvest. Since no bunch thinning was done, grapevine fertility was quantified at harvest by determining the number of bunches per grapevine for each treatment. Cane water content was determined in the second week of September, before bud break. Cane samples were obtained by cutting ca. 50 mm cane lengths with a bud in its centre. The total sample per plot consisted of cane lengths from upper, middle and lower canes collected from three grapevines, respectively. Samples were weighed to obtain fresh mass, which amounted to ca. 120 g. Dry mass was obtained by drying samples at 60°C in an oven until a constant mass was attained. Water content of the fresh cane samples was calculated as the percentage water loss using the following equation:

$$\%water = (fresh\ mass - dry\ mass) / fresh\ mass \times 100 \qquad (Eq. 1)$$

Statistical analysis

The data were subjected to an analysis of variance using the SAS statistical program (SAS Institute Inc., 1999). Student's t least significant difference (LSD) was calculated to facilitate comparison between treatment means. Means which differed at $p \leq 0.10$ were considered to be significantly different.

RESULTS AND DISCUSSION

During the 2000/2001 season minimum relative humidity of the atmosphere (RH_n) was generally lower from July until September, compared to the long-term means (Table 2). In August RH_n was 5.9% lower than the long-term mean. Cane water content (Table 3) was slightly higher than the ca. 45% reported for Riesling and Zenit in the dormant period (Misik & Szívós, 1998) and ca. 43% found for Sultanina prior to bud break (Myburgh, 2003b). Overhead irrigation applied during August 2000 (T4) increased cane water content prior to bud break compared to the T1 control (Table 3). Canes of treatments T2 and T3 probably dried out in the lapse of time between overhead irrigations and bud break. Overhead irrigation from mid-August until the second week in September (T5) was probably applied too late to have any effect on cane water content compared to T1 grapevines. Yields were relatively low (Table 3), compared to yields obtained with Sultanina Clone H4 under similar conditions (Myburgh, 2003a). This was probably due to poor performance of the clone (14/2) used in this study (J.J. Kotze, C.J. Smit; personal communications). Overhead irrigation applied in August 2000 increased yield of T4 grapevines

TABLE 1

Treatments applied during two seasons to determine the effect of overhead irrigation during the dormant period on Sultanina yield.

Season	Treatment number	Irrigation in winter	Overhead irrigation
2000/2001	T1	Yes	None
	T2	Yes	July
	T3	Yes	Mid-July until mid-August
	T4	Yes	August
	T5	Yes	Mid-August until mid-September
2001/2002	T1	Yes	None
	T3	Yes	Mid-July until mid-August
	T4	Yes	August
	T5	Yes	Mid-August until mid-September
	T6	None	August
	T7	None	None

TABLE 2

Maximum (RH_x), minimum (RH_n) and mean daily relative humidity of the atmosphere measured at Upington (Data obtained from ARC Institute for Soil Climate and Water, Pretoria).

Month	Relative humidity (%)								
	Long-term mean			2000/2001			2001/2002		
	RH_x	RH_n	*Mean*	RH_x	RH_n	*Mean*	RH_x	RH_n	*Mean*
June	86.6	28.9	*57.8*	93.0	29.9	*61.5*	84.6	23.7	*54.2*
July	82.6	26.7	*54.7*	88.9	25.0	*57.0*	79.2	25.7	*52.5*
August	79.2	25.7	*52.5*	81.3	19.8	*50.6*	75.1	20.1	*47.6*
September	75.9	24.7	*50.3*	81.6	22.8	*52.2*	74.5	17.0	*45.8*

TABLE 3

The effect of overhead irrigation during the dormant period on cane water content, yield, fertility, bunch size and cane mass of Sultanina on sandy soil in the Lower Orange River region during the 2000/2001 season.

Treatment number(1)	Cane water content (%)	Yield (t/ha)	Bunches per grapevine	Bunch mass (g)	Cane mass (t/ha)
T1	54.5b(2)	13.7bc	33ab	244a	2.0a
T2	55.4ab	15.4abc	36ab	259a	2.0a
T3	56.1ab	16.3ab	38ab	266a	1.8a
T4	57.7a	19.1a	42a	276a	2.0a
T5	55.5ab	12.2c	29b	248a	1.8a

(1) Refer to Table 1 for explanation of treatments.

(2) Values followed by the same letter within a column do not differ significantly ($p \leq 0.10$).

compared to the control and T5 grapevines (Table 3). Compared to the latter treatment, T4 grapevines produced more bunches per grapevine. At this stage there is no acceptable physiological explanation for the higher fertility induced by T4, except for the possibility that more of the floral primordia, which were initiated in spring (Pratt, 1971; Buttrose, 1974), eventually differentiated into bunches during winter compared to T5. Similar positive effects of higher cane water content on yield were reported for Sultanina in the Lower Orange River region (Myburgh, 2003b). Although not quantified, the possibility of evaporative cooling by overhead irrigation, and its contribution to increased grapevine fertility should not be ruled out. At the end of the 2000/2001 growing season, overhead irrigation had no effect on cane mass compared to T1 grapevines (Table 3).

Although a substantial amount of water was applied to the overhead irrigation treatments compared to the ca. 1 mm/day required by vineyards under the specific conditions (Myburgh, 2003a), it had no effect on soil water content at 150 mm depth (data not shown). Visual observation revealed that most of the fine sprays reaching the soil surface evaporated between irrigation pulses. During the 2001/2002 season maximum as well as minimum humidity of the atmosphere was lower from June until September compared to the long-term means (Table 2). The tendency toward lower cane water content (Table 4) compared to the first season could have been the result of lower mean RH. During the second season overhead irrigation applied from mid-July until mid-August (T3) only increased cane water content compared to grapevines that received no irrigation (T7). However, higher yields were obtained with overhead irrigation applied from mid-July until August (T3 & T4) compared to T5 and T7. As in the first season, overhead irrigation applied before bud break had no effect on yield compared to the control. In both seasons highest yields were obtained by overhead irrigation that was applied later in winter compared to the stage(s) at which evaporative cooling is applied in commercial vineyards. This suggests that the higher yields could not have been primarily induced by evaporative cooling.

TABLE 4

The effect of overhead irrigation during the dormant period on cane water content, yield, fertility, bunch size and cane mass of Sultanina on sandy soil in the Lower Orange River region during the 2001/2002 season.

Treatment number[1]	Cane water content (%)	Yield (t/ha)	Bunches per grapevine	Bunch mass (g)	Cane mass (t/ha)
T1	50.8ab[2]	12.6ab	28ab	281ab	1.0a
T3	53.1a	18.4a	40a	279ab	1.2a
T4	52.5ab	18.9a	37a	305a	1.0a
T5	51.6ab	9.8b	30ab	202bc	0.7a
T6	52.1ab	14.4ab	33a	251ab	1.0a
T7	50.1b	7.6b	18b	147c	0.8a

(1) Refer to Table 1 for explanation of treatments.

(2) Values followed by the same letter within a column do not differ significantly ($p \leq 0.10$).

Where normal, under-vine irrigations were not applied in winter (T6 & T7), the minimum soil water matric potential amounted to approximately -0.07 MPa (Fig. 1). Similar potentials, which correspond to ca. 90% depletion of plant available water (Myburgh, 2003a), were attained where grapevines in the Lower Orange River region were not irrigated during winter (Myburgh, 2003b). Yield of grapevines that were subjected to dry soil conditions throughout winter, but received overhead irrigation during August (T6), were comparable to that of T1 grapevines (Table 4). This result suggests that overhead irrigation could negate the effects of dry soil conditions. However, where grapevines were subjected to soil water deficits, and received no overhead irrigation throughout winter (T7), yield was substantially lower compared to those that received overhead irrigation from mid-July until August (T3 & T4). Lower fertility and smaller bunches contributed to the lower yield of grapevines that received no irrigation during winter (Table 4). This indicated that the dry soil conditions and low cane water content not only induced abortion of bunches in the dormant buds, but also limited development of floral primordia into bunches during winter (Pratt, 1971; Buttrose, 1974). Furthermore, visual observation revealed that T7 grapevines showed typical delayed bud break symptoms, i.e. uneven bud break, white canes and stunted shoot growth in spring. The contribution of dry soil conditions and low cane water content to delayed bud break, as well as the negative effects thereof on yield, confirms the findings of Myburgh (2003b, 2003c). It also supports the recommendation that 80% depletion of plant available soil water, or more, should be avoided during the dormant period in this particular region. As in the 2000/2001 season, overhead irrigation had no effect on cane mass compared to T1 grapevines (Table 4). This indicated that shading of buds during the previous growing season (May & Antcliff, 1963; Buttrose, 1970) could not have reduced bud fertility in the case of the lower yielding treatments. According to Smit (1970), sunshine intensity and duration do not limit grapevine fertility in the Lower Orange River region. Since cane mass responds readily to irrigation (Williams *et al.*, 1994), and in particular that of Sultanina in the Lower Orange River region (Myburgh, 2003a), less irrigation in 2001/2002 probably contributed to the lower cane mass compared to the first season.

CONCLUSIONS

Higher cane water content and grapevine yield were obtained by means of overhead irrigation pulses applied during late winter (mid-July to August), whereas overhead irrigation applied in the period immediately before bud break had no effect. This indicated that some of the seasonal yield variation in summer rainfall regions might be related to cane water content during the dry winters. Negative effects of low cane water content were increased by soil water deficits. These results confirmed previous findings that soil water deficits in excess of 80% plant available water depletion during the dormant period should be avoided in the Lower Orange River region. Possible physiological mechanisms causing the higher yields, obtained by means of overhead irrigation, need to be addressed by further research. Since overhead irrigation pulses did not increase soil water content of the surface soil layer, this would not contribute to over-irrigation during winter. If the capital investment of an additional irrigation system can be justified, overhead irrigation during the dormant period might serve as a means to increase, or at least produce more constant, grapevine yields in semi-arid summer rainfall regions.

LITERATURE CITED

Buttrose, M.S., 1970. Fruitfulness in grape-vines: The response of different cultivars to light, temperature and daylength. Vitis 9, 121-125.

Buttrose, M.S., 1974. Climatic factors and fruitfulness in grapevines. Hort. Abstracts 44, 319-326.

Goosen, R.J., 1956. Irrigation of Sultanas along the Lower Orange River. Farming in S. Afr. 32, 45-48.

May, P. & Antcliff, A.J., 1963. The effect of shading on fruitfulness and yield in the Sultana. J. Hort. Sci. 38, 85-94.

Misik, S. & Szívós, E., 1998. Changes of water state in vine canes during growing and dormant seasons. In: Rühl, E.H. & Schmid, J. (eds). Proc. 1st ISHS Workshop on Water Relations of Grapevines. May 1998, Stuttgart, Germany. Acta Hort. 493, 69-82.

Myburgh, P.A., 2003a. Responses of *Vitis vinifera* L. cv. Sultanina to level of soil water depletion under semi-arid conditions. S. Afr. J. Enol. Vitic. 25, 16-24.

Myburgh, P.A., 2003b. Responses of *Vitis vinifera* L. cv. Sultanina to water deficits during various pre- and post-harvest phases under semi-arid conditions. S. Afr. J. Enol. Vitic. 24, 25-33.

Myburgh, P.A., 2003c. Possible flood irrigation technologies to reduce water use of Sultanina grapevines in a hot, arid climate. S. Afr. J. Plant Soil 20, 1-8.

Pratt, C., 1971. Reproductive anatomy in cultivated grapes – A review. Am. J. Enol. Vitic. 22, 92-109.

SAS Institute Inc., 1999. SAS/STAT User's Guide, Version 8, Vol. 2. SAS Institute Inc., Cary, North Carolina.

Smit, C.J., 1970. Flower differentiation of Sultana vines. Dried Fruit, December 1970, 6-12.

Soil Classification Work Group, 1991. Soil classification – A taxonomic system for South Africa. Memoirs on natural resources of South Africa No. 15. Dept. Agric. Developm., Pretoria.

Soil Survey Staff, 1975. Soil taxonomy – a basic system of soil classification for making and interpreting soil surveys. U.S. Dept. Agric., Handbook No. 436. U.S. Govt. Printing Office, Washington.

Van Zyl, J.L., 1984. Response of Colombar grapevines to irrigation as regards quality aspects and growth. S. Afr. J. Enol. Vitic. 5, 19-28.

Williams, L.E., Neja, R.A., Meyer, J.L., Yates, L.A. & Walker, E.L., 1991. Postharvest irrigation influences bud break of 'Perlette' grapevines. HortScience 26, 1081.

Williams, L.E., Dokoozlian, N.K. & Wample, R., 1994. Grape. In: Schaffer, B. & Anderson, P.C. (eds). Handbook of environmental physiology of fruit crops, Vol. I, Temperate crops. CRC Press, Boca Raton. pp. 85-133.

Winkler, A.J., 1962. General viticulture, University of California Press, Los Angeles.

Zeeman, A.S., 1981. Oplei. In: Burger, J.D. & Deist, J. (eds). Wingerdbou in Suid-Afrika. Nietvoorbij, Stellenbosch, South Africa. pp. 185-201.