Response of *Vitis vinifera* L. cv. Barlinka/Ramsey to Soil Water Depletion Levels with Particular Reference to Trunk Growth Parameters

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***Vitis vinifera* L. cv Barlinka/Ramsey was irrigated with micro sprinklers at 10%, 40% and 60% depletion of plant available water (PAW) in a field trial on a sandy soil in the Hex River Valley. A fourth treatment was trickle-irrigated at 40% PAW depletion. Irrigations were scheduled with tensiometers. A system which measures trunk diameter was used for automatic trickle irrigation of a fifth treatment. Measuring trunk growth continuously using linear variable differential transformers revealed no increase in diameter between budbreak and bloom. From bloom until veraison trunk diameter increased, whereafter it decreased slightly. Average seasonal trunk diameter increases were 0,8 mm, 1,2 mm and 2,1 mm, for the 60%, 40% and 10% PAW depletion levels, respectively. When well supplied with water, diurnal trunk contraction ranged between 0 mm and 0,01 mm per day. As water stress increased, trunk contraction increased curvilinearly to a maximum value of *ca* 0,1 mm per day. The most acceptable combination of growth, yield, berry size and eating quality was obtained by irrigation using micro sprinklers at 40% PAW depletion. Irrigation at 10% as well as 60% PAW depletion reduced berry taste and colour significantly. Root studies by means of the profile wall method showed that irrigation at 10% PAW depletion limited fine root development in comparison to 40% PAW depletion. Trickle irrigation stimulated development of fine roots within 500 mm of the grapevine as opposed to micro sprinklers. Trickle irrigation at 40% PAW depletion tended to increase water stress in comparison to micro sprinklers. This tended to improve grape quality, but reduced production and berry size. Although automatic irrigation held no significant advantages regarding yield and quality in comparison to manual scheduling with the aid of tensiometers, it did simplify irrigation management.**

Irrigation plays a vital role in ensuring the production of quality table grapes. However, water resources in the viticultural regions of South Africa are limited. Furthermore, increasing cost of irrigation water contributes to already high production inputs. These constraints force producers to schedule irrigation of vineyards more accurately. Water consumption of grapevines is generally calculated using reference evapotranspiration and appropriate crop coefficients (Van Zyl & Weber, 1981; Fourie, 1989; Myburgh, 1992). Monitoring soil water content by means of tensiometry, or the neutron scattering technique , is generally used as an aid in irrigation scheduling (Van Zyl, 1985). Plant parameters such as leaf water potential, stomatal resistance and leaf temperature are also used as irrigation scheduling aids (Van Zyl, 1987; Grimes & Williams, 1990). According to Smart & Coombe (1983) measuring grapevine trunk diameter offers promise as an irrigation guide, but the method requires further evaluation. Since the grapevine itself is surely the best indicator of its water needs, measuring plant parameters can be regarded as the most suitable aid for irrigation scheduling. Furthermore, this approach could be more practical and reliable in trickle-irrigated vineyards where partial and uneven soil wetting complicates monitoring soil water depletion.

If grapevine water status could be monitored continuously, it would enable complete automatic operation of irrigation systems. On normal sunshine days transpiration can exceed water uptake by roots, causing internal water deficits. This will decrease cell turgor and cause shrinkage. Depletion of soil water will increase the water deficit during the day and consequently diurnal shrinkage will increase. Turgor is usually regained at night when both absorption of water and transpiration are low, but absorption is somewhat greater of the two (Kozlowski, 1972). Shrinkage and growth rate values which correspond with the onset of plant water stress are regarded as threshold values and can be used to trigger automatic irrigation. In this regard, a promising system which monitors diurnal shrinkage and growth of plant organs has been developed (Huguet, 1985). Threshold values of shrinkage and growth for automatic irrigation purposes have been tested on apples (Huguet & Orlando, 1987; Vaysse, Soing & Mandrin, 1989), citrus and kiwi fruit (Huguet & Orlando, 1987). However, as for any manual irrigation scheduling system, automatic systems should be able to ensure optimum growth and maximum yield while maintaining optimum quality. To enable this, available plant water content, growth, yield and quality must be related to the plant parameters used in a specific automatic irrigation system.

The aims of this study were (i) to characterise diurnal and seasonal grapevine trunk growth and to evaluate its use as a practical and reliable indicator of plant water status as affected by soil water content, (ii) to relate general grapevine response to soil water depletion to determine threshold values that would ensure optimum yield and grape quality and (iii) to investigate the feasibility of automatic trickle irrigation, as opposed to trickle irrigation scheduled manually with tensiometers.

MATERIALS AND METHODS

Experimental vineyard: Fourteen year old *Vitis vinifera* L. cv. Barlinka, grafted onto Ramsey, was used

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in a field experiment over three seasons (1992/93 - 1994/95) in the Hex River Valley. The soil, containing more than 95% sand, was of the Fernwood form (Soil Classification Work Group, 1991). Vines were planted 1,5 m x 3,0 m and trained onto a 1,5 m slanting trellis (Zeeman, 1981). Three treatments (M1, M2, & M3) were irrigated using micro sprinklers (32 l h^{-1}) at 60%, 40% and 10% plant available water (PAW) depletion levels. A fourth treatment (T1) was trickle-irrigated at 40% plant available water depletion. Ticklers (2 l h^{-1}) were spaced 600 mm in the vine row. During the first season a fifth treatment (T2) was irrigated using ticklers at 40% PAW depletion. Soil water depletion level of this treatment was increased to 80% during December 1992 to determine the course of trunk contraction under relatively dry soil conditions. Using threshold values that correspond to 40% soil water depletion, irrigation of T2 was scheduled by means of an automatic system (Pepista, Copa Informatique) during the 1993/94 and 1994/95 seasons. Each treatment was replicated four times in a randomised block design. Experimental plots comprised a row of ten experimental vines with a buffer vine at each end and a buffer row on each side. Each experimental plot covered 162 m^2.

Soil water: Soil water matrix potential was measured twice a week using mercury manometer tensiometers at 300 mm, 600 mm and 900 mm depths. Tensiometers were placed on the vine row 500 mm from an experimental grapevine. To convert matrix potential to soil water content and irrigation requirements, bulk density and a soil water retention curve were determined under field conditions. A drainage curve was obtained by monitoring soil water content and matrix potential after saturation. Field capacity was estimated at the point where drainage rate decreased sharply.

Trunk parameters: Trunk circumference was measured manually 300 mm above ground level on all experimental plots at pruning in 1992 before treatments were applied and again at pruning in 1995. The difference between 1992 and 1995 was used to calculate average annual trunk diameter increase. Variations in trunk diameters were measured with linear variable differential transformers (Schurmberger). Measurements were made hourly on single vines on two replications of M1, M2, M3 and T2. Grapevines with comparable trunk diameters were used and all diameters were measured in an east-west direction. Measurements commenced prior to budbreak in August and were terminated after harvest in March during the 1992/93, 1993/94 and 1994/95 seasons.

Plant water: To quantify plant water status, leaf water potential was measured once a month just before irrigations using the pressure chamber technique (Scholander *et al.*, 1965). An unbagged, mature leaf, fully exposed to sunlight, was used on each experimental plot. Considering that grapevine leaf water potential differences were largest during the time maximum stress around 14:00 to 15:00 (Van Zyl, 1987) measurements were made at 15:00. All measurements commenced at budbreak in September and were terminated after harvest in March.

Root distribution: Roots were plotted using the profile wall method of Böhm (1979). To save labour and time, root distribution was only determined where the most roots were expected. A 1,5 m long and 1,0 m deep trench was dug across the vine row between two experimental vines, with the sides 150 mm from each vine. After the roots were exposed, a 250 mm x 250 mm portable grid system, 1,0 m high and 1,5 m wide, was placed against the profile wall for mapping of the roots. Roots were classified into three classes, namely fine (<2 mm diameter), medium (2-10 mm diameter) and thick (>10 mm diameter). Roots were plotted on all replications of M1, M2, M3, T1 and T2 during July 1995.

Yield and grape composition: Production was quantified by measuring total yield at harvest. Vegetative growth was quantified by measuring pruning mass annually during August. Total soluble solids (TSS) and total titratable acidity (TTA) were determined on juice samples from all replications of each treatment using standard Nietvoorbij methods. Berry mass and volume were determined on samples consisting of 100 berries per experimental plot. After packing grapes according to export standards, two 5 kg cartons were sampled from each experimental plot and stored for four weeks at 4°C followed by 1 week at 10°C. Grape quality was organoleptically judged by a tasting panel consisting of at least 19 members. A four point score card system was used to evaluate grape taste, colour, firmness as well as skin taste.

Statistical analyses: Grape quality scores were transformed to parametric data. STATGRAPHICS was used for statistical analysis and curve fitting.

RESULTS AND DISCUSSION

Soil water: From the drainage curve, field capacity was estimated as 7,5% gravimetric soil water content at *ca* 16 hours after saturation (Fig. 1). At the same time, this corresponded to a soil water matrix potential of -2,8 kPa, which was relatively high compared to -10 kPa generally accepted for sandy soils. The higher matrix potential at field capacity probably resulted from the high coarse sand fraction (23,6%) in this specific soil. Similar results were obtained for a sandy soil near Lutzville (Unpublished data). An exponential equation fitted the soil water retention curve best and was used to convert tensiometer data to soil water content (Fig. 2). Readily PAW, i.e. between field capacity (-2,8 kPa) and -100 kPa, amounted to *ca* 70 mm for the 800 mm kPa depth where most of the roots occurred. The soil water retention curve revealed that at a soil matrix potential of -20 kPa most of the PAW was depleted. This indicated that plant water stress could be expected at relatively high soil water matrix potentials.

Irrigation: The long-term average daily American Class-A

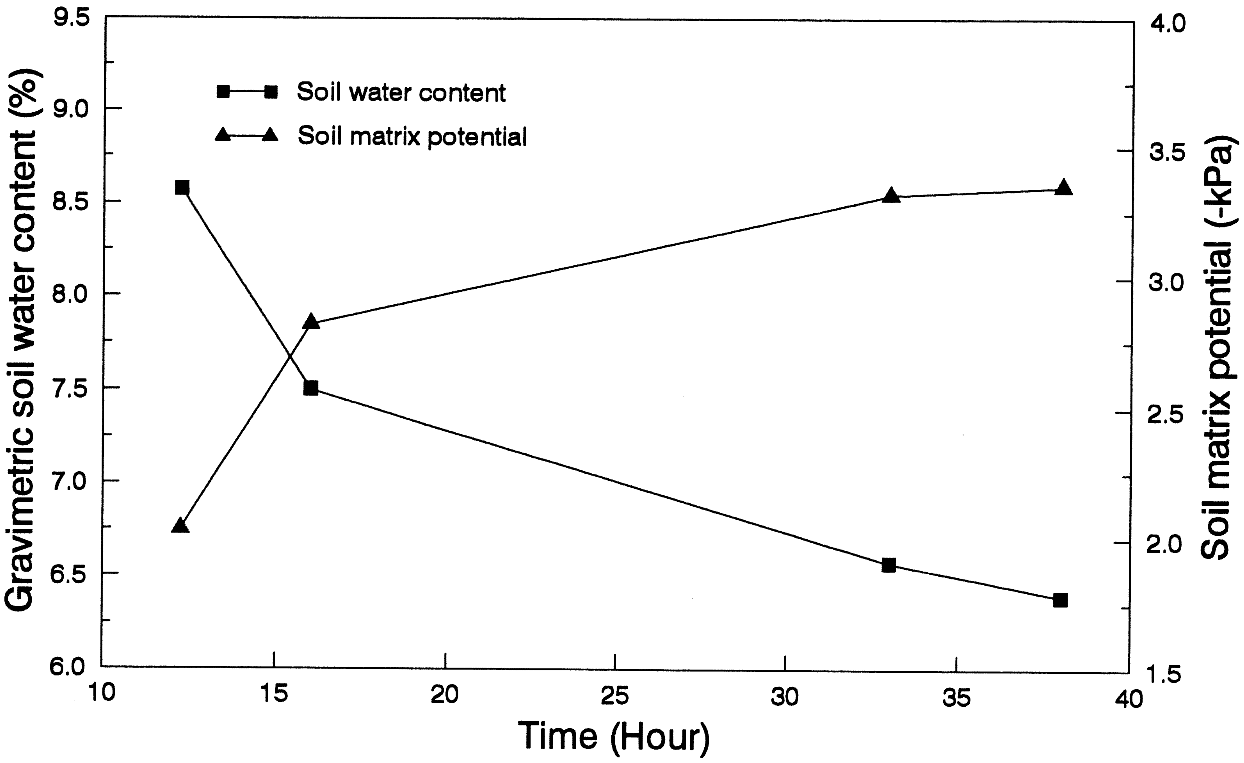

FIGURE 1

Drainage curve of a sandy soil in the Hex River Valley as determined after saturation by monitoring soil water content and matrix potential at 600 mm soil depth.

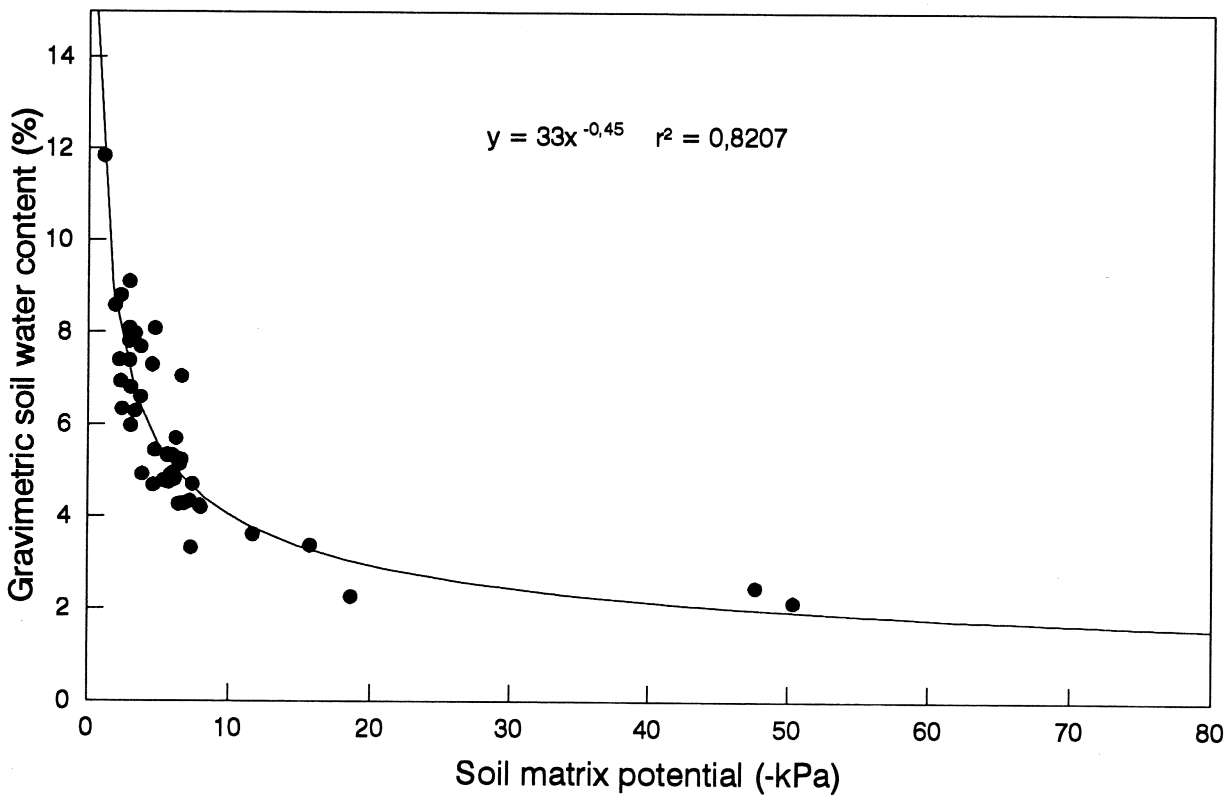

FIGURE 2

Soil water retention curve at 600 mm depth as established under field conditions on a sandy soil in the Hex River Valley.

TABLE 1
Long term average daily American Class-A pan evaporation (ET_P) for the Hex River Valley and average number of irrigations applied to maintain the desired soil water depletion levels during the growing season of Barlinka grapevines.

Month	ET_P (mm d^{-1})	Number of irrigations per month			
		10% depletion	40% depletion		60% depletion
			Micro sprinkler	Trickle	
September	5,1	0	0	0	0
October	7,1	5	1	4	1
November	8,8	8	3	5	2
December	10,0	8	3	6	2
January	10,3	8	3	6	1
February	9,2	7	3	5	1
March	7,0	5	2	4	1
April	4,7	5	2	4	0

pan evaporation values measured at the Hex River Experimental Station are presented in Table 1. The irrigation intervals needed to obtain the desired soil water depletion levels under the given climatic and soil conditions are also presented in Table 1. Considering an 80% irrigation system efficiency, 12 mm, 32 mm and 66 mm water were applied per irrigation for the 10%, 40% and 60% soil water depletion treatments respectively. The number of irrigations required to maintain the desired soil depletion levels are presented in Table 1. Average total irrigation applied over the growing season (September to April) amounted to approximately 541 mm. This was close to the 500 mm consumption for bearing grapevines in the coastal region of the Western Cape reported by Van Zyl & Van Huyssteen (1984).

Trunk parameters: Linear variable differential transformers (LVDT'S) produced measurements of changes in grapevine trunk diameter with an accuracy of 0,01 mm (Huguet, 1985). Trunks typically contracted during normal sunshine days as transpiration exceeded the water uptake through the root system (Fig. 3). Low transpiration rates during early morning and late afternoon might have been the reason why shrinkage did not correspond with stomatal opening generally occurring from sunrise to sunset. During the night trunks expanded to their original diameters as the daily water deficit was replenished. However, from bloom to veraison trunk diameter expansion generally exceeded the contraction that occurred during the preceding day and this resulted in nett growth (Fig. 3). Reduced cell turgor during the day probably resulted in slower growth rates compared to higher turgidity during the night (Kozlowski, 1972). Growth was defined as the difference in midnight trunk diameter on two consecutive days (Huguet, 1985). On rainy days, grapevine trunks did not shrink during the day (Fig. 4). This suggested that water uptake was more or less equal to transpiration losses and that some increase in turgidity prevented shrinkage during the rest of the day. Consequently, only sunshine days should be considered for determination of grapevine trunk growth parameters to be used as indicators of plant water stress. From budbreak to flowering no nett trunk growth was observed and from veraison to harvest trunk diameters tended to decrease slightly (Fig. 5). Van Zyl (1984a) also measured a decrease in grapevine trunk diameter during ripening. Average total seasonal trunk diameter increase measured with LVDT'S on individual vines of the micro sprinkler irrigated treatments was 0,8 mm, 1,2 mm and 2,1 mm, respectively, for the 60%, 40% and 10% soil water depletion levels. Average annual diameter growth, calculated from trunk circumference measurements, tended to decrease with increasing soil water depletion level (Table 2). These values were of the same magnitude as the trunk diameter increases recorded with LVDT'S on individual grapevines. This confirmed that trunk growth measured with LVDT'S was a function of available soil water and as such could be used as an indicator of grapevine water stress.

Average leaf water potential of the micro sprinkler-irrigated grapevines measured from bloom to veraison was -1200 kPa, -1030 kPa and -930 kPa respectively, for the 60%, 40% and 10% soil water depletion levels. This indicated

TABLE 2

Average annual trunk diameter increase of Barlinka between 1992/93 and 1994/95 seasons as measured manually in an irrigation trial in the Hex River Valley.

Treatment No.	Irrigation system	Available soil water depletion (%)	Diameter increase (mm year^{-1})
M1	Micro sprinklers	60	1,0
M2	Micro sprinklers	40	1,7
M3	Micro sprinklers	10	2,2
T1	Tricklers	40	1,7
T2*	Tricklers	40	1,8
D-value ($p \leq 0,05$)			1,2

* Irrigations scheduled using tensiometers during first season (1992/93) and an automatic system during 1993/94 and 1994/95 seasons.

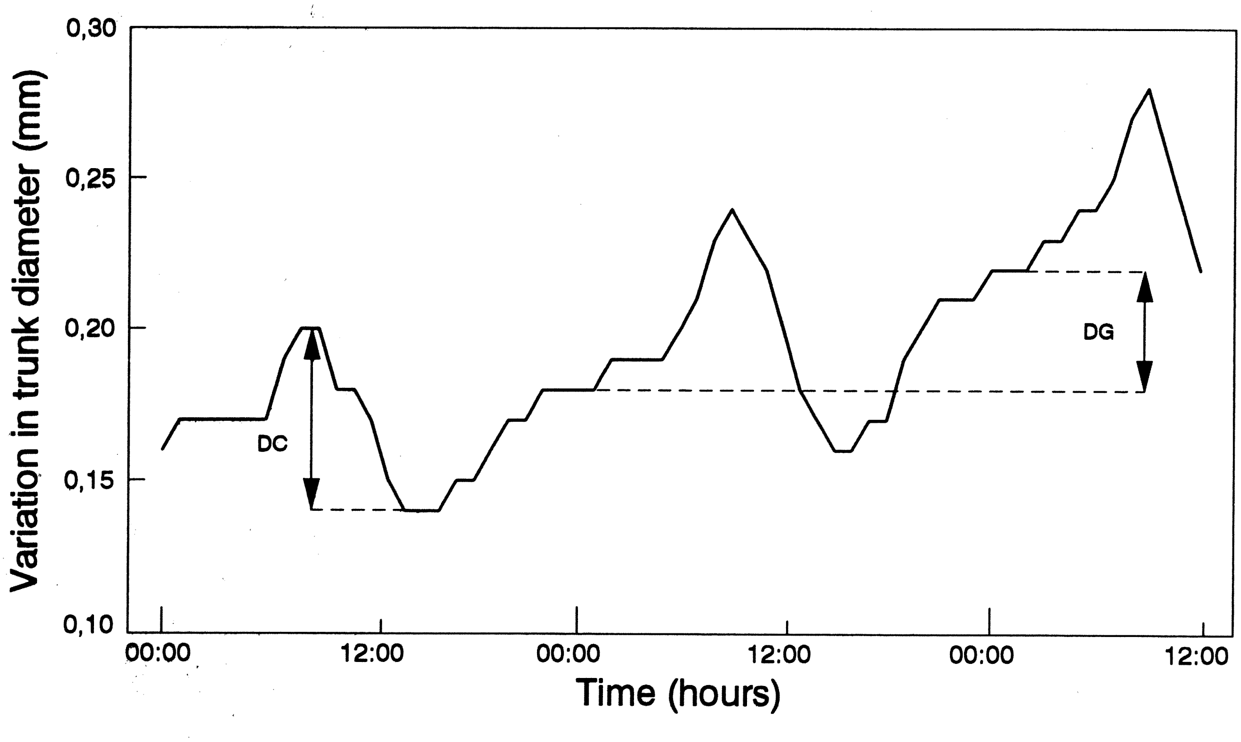

FIGURE 3

An example of diurnal variation in trunk diameter of Barlinka/Ramsey measured during two normal sunshine days in December 1993 (DC = diurnal contraction and DG = diurnal growth).

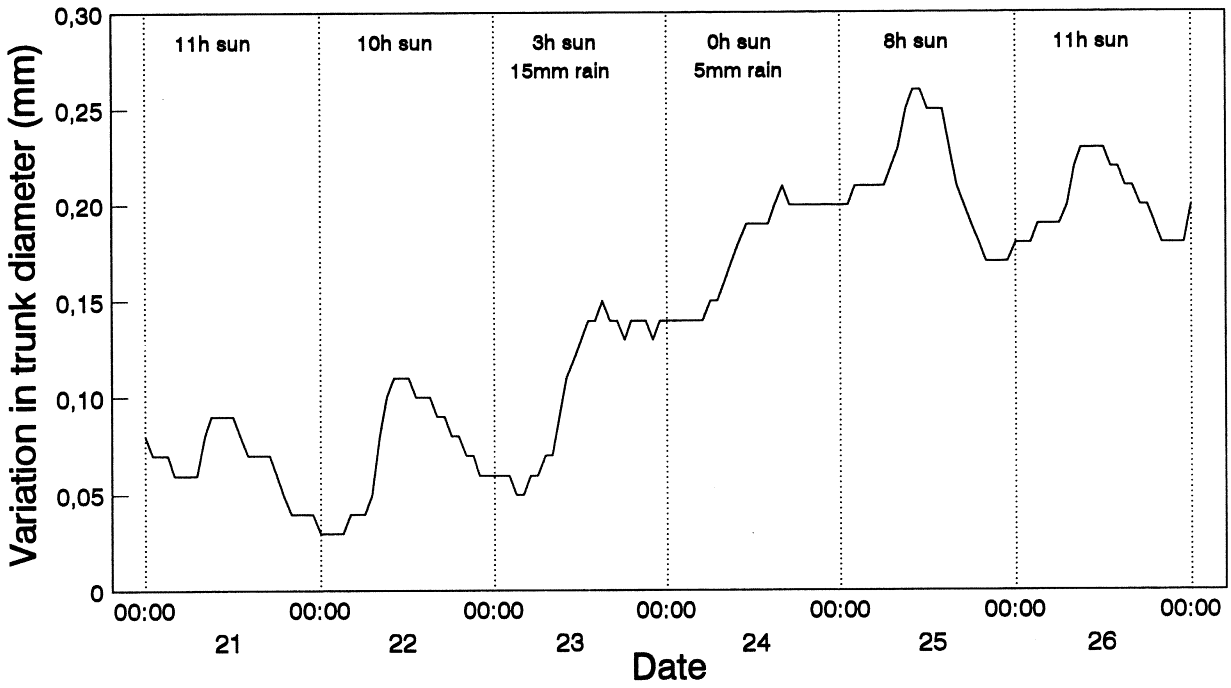

FIGURE 4

Effect of rain and overcast conditions on variations in trunk diameter of Barlinka/Ramsey measured from 21 until 26 October 1992.

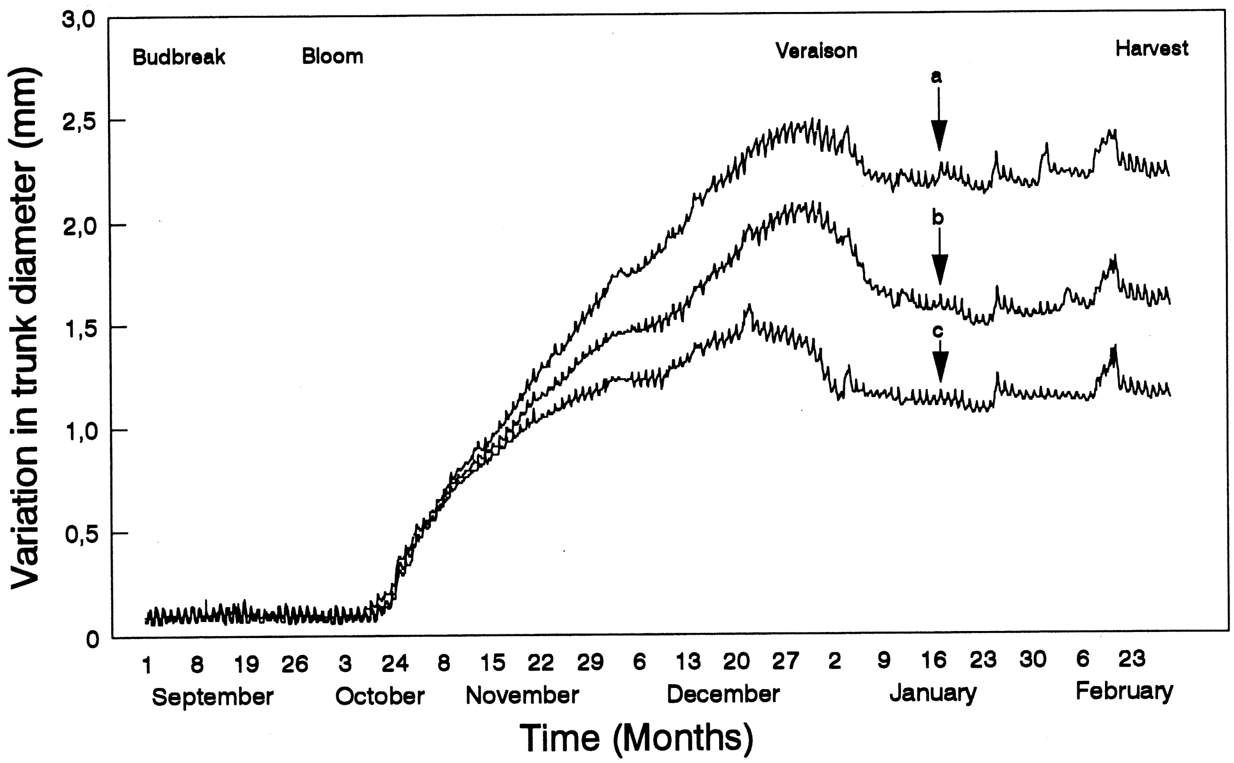

FIGURE 5

Effect of soil water depletion on seasonal variation in trunk diameter of micro sprinkler-irrigated Barlinka/Ramsey as measured during the 1993/94 season in the Hex River Valley (a = 10%, b = 40% and c = 60% depletion of available soil water).

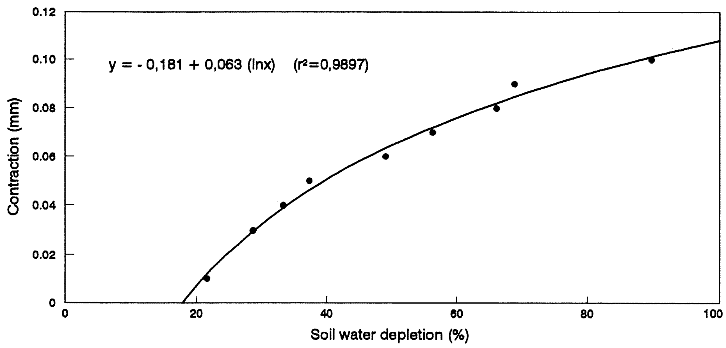

FIGURE 6

The relationship between daily trunk contraction of micro sprinkler-irrigated grapevines on normal sunshine days and depletion of available soil water.

that plant water stress increased as the available soil water decreased. Diurnal trunk diameter contraction could also be related to available soil water content (Fig. 6). Only data from the driest treatment (M1) were used to determine the relationship between diurnal growth parameters and soil water depletion.

After irrigations, diurnal contraction increased from day to day as the available soil water decreased. Under minimum plant water stress conditions, trunk contraction was in the order of 0 mm to 0,01 mm per day. Maximum plant water stress, under the given experimental conditions, resulted in diurnal contraction of up to 0,10 mm per day. However, the increase in contraction with the decrease in available soil water was curvilinear, which suggested that there were probably increasing anatomical limitations to trunk contraction as the soil dried out.

Root distribution: Average soil bulk density was 1 490 kg m^{-3}. Mechanical restriction to root development and distribution was therefore not expected (Van Huyssteen, 1988). Allowing only 10% depletion of PAW between micro sprinkler irrigations (M3) tended to reduce the number of fine roots (Table 3). It is not clear if the high soil water availability reduced the need for fine root development, or if poor aeration restricted root development. Where 60% PAW was depleted (M1), root numbers tended to be less compared to 40% depletion. Maintaining a balance between limited vegetative growth and root development might have caused this tendency towards lower root numbers. In a study using micro sprinkler-irrigated Colombar/99R, 50% depletion of PAW had the highest total root number in comparison to 10% depletion (Van Zyl, 1988). This indicated that high soil water availability could reduce the need for extensive fine root development. On the contrary, limited root development may prevent adequate water uptake during heat waves whereupon berry damage may occur. Medium and coarse root development and distribution showed no significant differences between treatments. In comparison to micro sprinklers, trickle irrigation tended to promote development of fine roots (i.e. <2 mm diameter) close to the vine row (Fig. 7). A similar tendency was reported by Van Zyl (1988) for Colombar/99 R. This was probably the result of increased rooting density to improve water uptake from the limited wetted soil volume under the tricklers. Increased soil water extraction on the vine row required higher irrigation frequencies to maintain 40% soil water depletion by means of tricklers compared to micro sprinklers (Table 1).

Vegetative growth and yield: Late afternoon leaf water potential (LWP) showed that plant water stress over the growing season increased with an increase in the level of soil water depletion (Fig. 8). Although mostly insignificant, vegetative growth decreased correspondingly (Table 4). Irrigation by means of micro sprinklers at 10% depletion of PAW (M3), resulted in vigorous growth which had to be controlled frequently by topping shoots that exceeded the capacity of the trellising system. In the case of 60% depletion of PAW (M1), poor shoot growth exposed bunches to direct sunlight. Visual observation confirmed that sunburn had occurred on berries on the shoulders of bunches. At 40% depletion of PAW (M2), neither sunburn nor too vigorous growth occurred, therefore suggesting balanced vegetative growth. Compared to 10% depletion of PAW (M3), yield decreased significantly during 1993/94 and 1994/95 seasons at the 60% PAW depletion level (M1) (Table 3). However, the decrease in yield from 10% to 40% depletion of PAW was not significant. Considering the foregoing factors a more acceptable balance between yield and vegetative growth of micro sprinkler-irrigated grapevines was obtained at 40% depletion of PAW compared to M1 and M3.

Although irrigated at 40% depletion of PAW, trickle irrigation scheduled with tensiometers (T1) resulted in consistently higher water stress compared to micro sprinklers (M2) (Fig. 8). This suggested that tensiometers did not portray representative soil water depletion in the unevenly wetted root zone. Intensified water depletion in densely rooted soil near the vine could have restricted the rate of water uptake. In heavier textured soils, with wider wetting and root distribution patterns, this might not be the case. However, on this sandy soil consistently higher water stress tended to reduce vegetative growth as well as yield of trickle-irrigated grapevines (Table 4).

Grape composition and berry quality: During the first two seasons (1992/93 & 1993/94) 40% soil water depletion tended to favour accumulation of total soluble solids in grapes of micro sprinkler-irrigated vines (Table 5). However, due to seasonal effects in the Hex River Valley during 1994/95, ripening of Barlinka was generally delayed. During this season, the micro sprinkler treatment that was subjected to the most water stress (M1) tended to accumulate soluble solids more readily compared to the wetter treatments (M2 & M3). Total titratable acidity for micro sprinkler irrigation decreased significantly at 60% depletion of PAW (M1) compared to M3. These results showed that irrigation treatments affected TTA more than TSS. Similar results were obtained for field-grown Colombar grapes over a period of six years (Van Zyl, 1984b). Depletion to 40% and 60% of PAW generally tended to enhance ripening and

TABLE 3

Root development of Barlinka/Ramsey on a sandy soil as affected by available soil water depletion and irrigation system. (Roots were plotted to 1,0 m depth and to 0,75 m on either side of the vine row).

Treatment No.	Available soil water depletion (%)	Number of roots per 1,5 m² exposed profile wall		
		Fine (< 2 mm ø)	Medium (2-10 mm ø)	Thick (> 10 mm ø)
M1	60	353	69	11
M2	40	404	144	28
M3	10	220	105	24
T1	40	563	94	11
T2*	40	432	111	11
D-value (p≤ 0,05)		313	NS	NS

* Irrigations scheduled using tensiometers during first season (1992/93) and an automatic system during 1993/94 and 1994/95 seasons.

NS = Not significant.

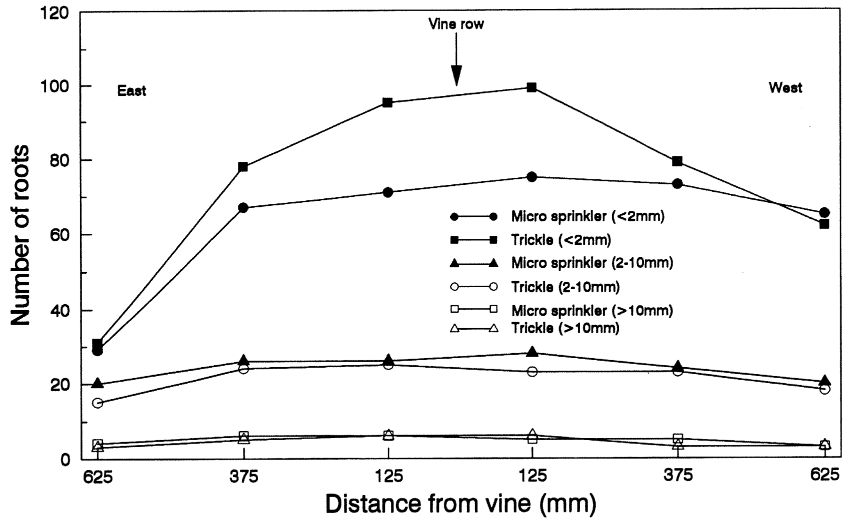

FIGURE 7

Root development and distribution of Barlinka/Ramsey across the vine row as affected by irrigation system. Irrigations were applied at 40% depletion of soil water. Number of roots implies the total over 800 mm rooting depth (<2 mm Ø = fine, 2-10 mm Ø = medium and > 10 mm Ø = thick).

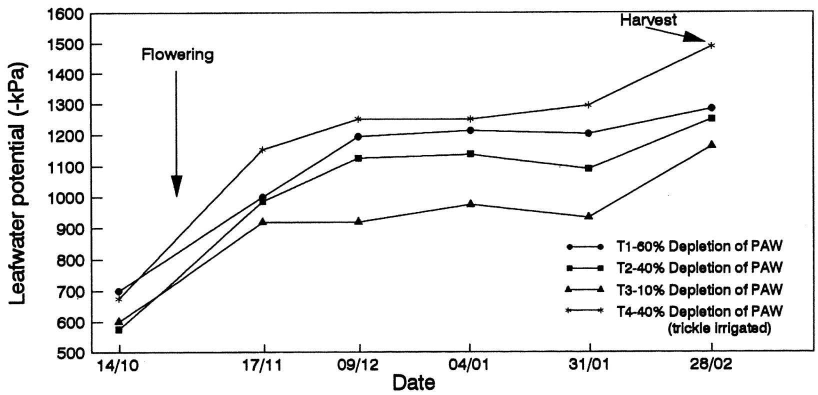

FIGURE 8

Seasonal variation in average late afternoon leaf water potential of Barlinka/Ramsey as measured during the 1993/94 season in the Hex River Valley (PAW = plant available water).

TABLE 4
Average yield and pruning mass of Barlinka as measured over three seasons in an irrigation trial in the Hex River Valley.

Treatment No.	Available soil water depletion (%)	Yield (kg vine^{-1})			Pruning mass (kg vine^{-1})		
		1992/93	1993/94	1994/95	1992/93	1993/94	1994/95
M1	60	4,35	5,09	6,12	1,50	1,19	1,55
M2	40	6,27	7,16	7,03	1,88	1,73	1,95
M3	10	6,34	9,16	10,98	2,43	2,08	3,28
T1	40	5,26	4,72	5,58	1,13	0,78	1,14
T2*	40	6,25	6,20	5,81	1,38	1,03	1,50
D-value ($p \leq 0,05$)		NS	2,88	4,16	0,50	1,00	0,95

* Irrigations scheduled using tensiometers during first season (1992/93) and an automatic system during 1993/94 and 1994/95 seasons.

NS = Not significant.

resulted in more favourable TSS:TTA ratios.

Similar to yield, berry mass increased significantly at 10% depletion of PAW (M3) compared to M1 (Table 6). However, there was no significant increases in berry mass when grapes were irrigated at 40% depletion of PAW (M2). Although lighter than M3, berries of M2 weighed more than 4,76 g which is the UNIFRUCO recommended minimum for export (Anon, 1994). During 1992/93 and 1993/94 berry mass of M1 was below this export standard. Berry volume responded similarly to berry mass (data not shown). Except during the 1994/95 season, when more water stress enhanced ripening, irrigation at 40% depletion of PAW tended to favour grape taste and colour compared to 10% and 60% depletion (M1 & M3) (Table 6). Under the 1994/95 conditions both 40% and 60% depletion of PAW significantly improved grape taste and colour. Skin taste and berry firmness showed no significant difference between treatments during any of the three seasons (data not shown). Considering all aspects regarding growth, yield and grape quality, micro sprinkler irrigation at 40% depletion of PAW (M2) held an advantage over micro sprinkler irrigation at 10% and 60% depletion (M1 & M3).

Compared to micro sprinklers (M2), trickle irrigation (T1) had no effect on accumulation of soluble solids, but significantly reduced TTA (Table 5). This resulted significantly more favourable TSS:TAA ratios compared to irrigation using micro sprinklers at 40% depletion of PAW (M2). Trickle irrigation enhanced ripening to such an extent that harvest was generally a week earlier compared to micro sprinklers. Although water stress induced by trickle irrigation tended to reduce berry mass, grape taste and colour were improved in comparison to micro sprinkler irrigation (M2).

Automatic *vs* tensiometric scheduling: Using a threshold value of 0,04 mm trunk contraction, which corresponded to 40% depletion of PAW, automatic trickle irrigation (T2) tended to increase grapevine growth and yield in comparison to scheduling with tensiometers (T1). There is no doubt that the automatic system simplified irrigation control. A further advantage was that irrigations were generally applied during late afternoon or early evening. Although not quantified in this study, this feature will limit evaporation losses from the soil surface and thus increase irrigation efficiency. LVDT sensors were simple to install and needed no maintenance over the three year period. This feature would be an advantage if the system is used by producers. System operation was disrupted by power failure on a number of occasions. Furthermore, the system was presumably damaged by lightning during March 1994 and could only be repaired by the manufacturers. These problems can be overcome with backup power packs and lightning protection. A major disadvantage was that the system could not determine the actual irrigation water quantities required when trunk contraction exceeded the threshold value. Actual soil water content at which threshold values are exceeded will have te be determined to calculate the amount of irrigation water required. In its current form the system is not suitable for automatic irrigation on a full farm scale. Appropriate software must be developed to link a LVDT recording system to the more extensive irrigation valve control systems currently in use on South African table grape farms.

TABLE 5
Average total soluble solids (TSS), total titratable acidity (TTA) and pH of Barlinka as measured over three seasons in an irrigation trial in the Hex River Valley.

Treatment No.	Available soil water depletion (%)	TSS (°B)			
		1992/93	1993/94	1994/95	Mean
M1	60	15,7	16,2	17,0	16,3
M2	40	16,1	17,2	16,2	16,5
M3	10	15,5	17,0	16,0	16,2
T1	40	16,2	17,4	17,4	17,0
T2*	40	16,4	17,2	16,9	16,8
D-value ($p \leq 0{,}05$)		NS	NS	NS	

Treatment No.	Available soil water depletion (%)	TTA ($g\ L^{-1}$)			
		1992/93	1993/94	1994/95	Mean
M1	60	6,9	3,5	4,1	4,8
M2	40	7,2	4,1	4,4	5,2
M3	10	7,8	4,7	5,1	5,9
T1	40	4,7	2,7	3,8	3,7
T2*	40	5,0	2,4	4,0	3,8
D-value ($p \leq 0{,}05$)		0,8	1,2	0,5	

Treatment No.	Available soil water depletion (%)	TSS:TTA			
		1992/93	1993/94	1994/95	Mean
M1	60	2,2	4,6	4,1	3,6
M2	40	2,2	4,2	3,7	3,4
M3	10	2,1	3,6	3,1	2,9
T1	40	3,4	6,4	4,6	4,8
T2*	40	3,3	7,2	4,2	4,9
D-value ($p \leq 0{,}05$)		0,5	2,0	0,7	

* Irrigations scheduled using tensiometers during first season (1992/93) and an automatic system during 1993/94 and 1994/95 seasons.

NS = Not significant.

TABLE 6
Average berry mass, taste and colour of Barlinka as measured over three seasons in an irrigation trial in the Hex River Valley.

Treatment No.	Available soil water depletion (%)	Berry mass (g)			
		1992/93	1993/94	1994/95	Mean
M1	60	4,70	4,63	5,31	4,88
M2	40	6,18	5,84	6,21	6,08
M3	10	6,30	6,16	6,89	6,45
T1	40	5,16	4,55	5,50	5,07
T2*	40	5,13	4,96	5,15	5,08
D-value (p≤ 0,05)		0,93	1,35	0,92	

Treatment No.	Available soil water depletion (%)	Taste			
		1992/93	1993/94	1994/95	Mean
M1	60	3,73	3,83	5,71	4,42
M2	40	5,37	5,46	5,34	5,39
M3	10	4,21	4,80	3,44	4,15
T1	40	6,09	5,48	5,71	5,76
T2*	40	5,60	5,43	4,80	5,28
D-value (p≤ 0,05)		1,43	1,63	1,26	

Treatment No.	Available soil water depletion (%)	Colour			
		1992/93	1993/94	1994/95	Mean
M1	60	1,74	2,43	6,79	3,65
M2	40	5,43	5,50	5,27	5,40
M3	10	2,53	3,49	2,68	2,90
T1	40	8,14	7,33	5,69	7,05
T2*	40	7,44	6,26	4,57	6,09
D-value (p≤ 0,05)		2,12	4,17	2,59	

* Irrigations scheduled using tensiometers during first season (1992/93) and an automatic system during 1993/94 and 1994/95 seasons.

CONCLUSIONS

The relationship between trunk growth and available soil water confirmed that diurnal trunk growth can be monitored to assess grapevine water status. Soil water characteristics of the sandy soil used in this study, which readily allowed the development of water stress in the grapevines, can be considered as ideal for studying soil-plant-water relations. Using micro sprinkler irrigation the most acceptable combination of growth, yield, berry size and eating quality was obtained when irrigation was applied at 40% depletion of PAW. It is significant that both under- and over-irrigation had a negative effect on eating quality of micro sprinkler-irrigated grapes. However, the ideal irrigation approach should be to combine the increased yield and berry size of a wetter soil regime with the improved grape quality of drier soil conditions. This could probably be achieved by irrigation at 10% PAW depletion up to some stage from after which it is increased to 40% or more. Further research is necessary to investigate the practical implementation of such an irrigation approach. Linear variable differential transformers presented a reliable method for the continuous monitoring of grapevine trunk growth. Results confirmed that automatic irrigation based on trunk diameter growth can be used to simplify irrigation system control. Using such an automatic system on a farm scale would need the development of appropriate software to link trunk monitoring to extensive irrigation valve control systems.

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