MICROMORPHOMETRIC CHANGES IN TRUNK DIAMETER IN RELATION TO MILD WATER STRESS IN FIELD GROWN VINES

MICROVARIATIONS DE DIAMÈTRE DU TRONC EN RELATION AVEC DE FAIBLES DÉFICITS HYDRIQUES DE VIGNES EN PLEIN CHAMP

C. VAN LEEUWEN[1,2]*, O. LERICH[1], R. RENARD[3], O. TREGOAT[1] and P.-L. ALLA[1]

[1]ENITA de Bordeaux, 1 cours du Général de Gaulle, 33175 Gradignan cedex (France)
[2]Faculté d'Œnologie, Université Victor Ségalen Bordeaux 2, 351 cours de la Libération, 33405 Talence cedex (France)
[3]ITV Midi-Pyrenées, Domaine de Mons, 32 Caussens (France)

Summary : Continuous measurement of micro variations in the diameter of woody organs provides an early detection of mild water deficits in field grown vines. Trunk diameter variations gives more reliable data than cane diameter variations. Water deficit induces trunk shrinkage and increases the Daily Contraction Amplitude / Potential Evapo Transpiration ratio (DCA / PET). This does not occur on irrigated control vines. Moreover, micromorphometry appears to be an accurate technique for detecting short-term water deficits, because the measurements are continuous. Major constraints in the use of micromorphometry on field grown vines include the positioning of sensor needles on the trunk and the need to maintain fragile equipment permanently in the vineyard. Additionally, this method does not quantify water deficits.

Résumé : Il a été montré qu'un déficit hydrique modéré de la vigne constitue un facteur important de réduction de la vigueur et de la production et d'augmentation du potentiel œnologique de la récolte. Parmi les techniques permettant d'évaluer l'état hydrique de la vigne en plein champ, la mesure du potentiel hydrique foliaire de base est couramment employée. Celle-ci présente néanmoins l'inconvénient de ne pas pouvoir révéler de faibles déficits hydriques. Nous avons montré, dans ce travail, que la mesure en continu de micro variations de diamètre d'organes ligneux de la vigne permet de détecter des déficits hydriques, éventuellement de courte durée, plus tôt que par la mesure des potentiels foliaires de base. La micromorphométrie appliquée sur le tronc des ceps a donné les résultats les plus cohérents; les courbes de réponse obtenues sur le long bois laissé à la taille sont plus difficilement interprétables. Un déficit hydrique, même faible, provoque une diminution du diamètre du tronc. Cette diminution est annulée par l'arrivée de précipitations ou par le déclenchement d'une irrigation. Parallèlement, le déficit hydrique provoque une augmentation du rapport Amplitude de Contraction Diurne / Evapo Transpiration Potentielle (ACD / ETP). La technique présente cependant un certain nombre d'inconvénients. Elle nécessite l'installation d'un équipement lourd et fragile pendant une longue période dans le vignoble. Le nombre de ceps équipés par parcelle est limité par le coût des capteurs, ce qui rend l'extrapolation des résultats à l'ensemble de la parcelle délicate si le sol et la profondeur d'enracinement sont hétérogènes. Le positionnement des aiguilles des capteurs sur le tronc est délicat et le contact de l'aiguille avec un morceau de tissu mort (nécrose ou écorce) ou un bouchon de colle affecte la qualité de la courbe de réponse. Enfin, si la micromorphométrie est une méthode très sensible, elle ne permet pas une quantification du déficit hydrique, contrairement à la méthode des potentiels foliaires de base.

Key words: vine, water supply, micromorphometry, trunk diameter, pre-dawn leaf water potential.

Mots clés : vigne, irrigation, micromorphométrie, diamètre du tronc, potentiel hydrique foliaire

INTRODUCTION

Vine development depends to a great extent on its water supply. Mild water deficits before veraison is an important factor in yield (HARDIE and CONSIDINE 1976; MATTHEWS and ANDERSON 1989) and berry composition (BOURZEIX *et al.* 1977; DUTEAU *et al.* 1981; VAN ZYL 1984a; MATTHEWS and ANDERSON 1988; VAN LEEUWEN et SEGUIN 1994). The assessment of vine responses to mild water stress requires sensitive indicators of vine water status.

Among the various techniques used to assess water supply in the vines, measurement of pre-dawn leaf water potential (ψdawn, SCHOLANDER *et al.* 1965) is a useful tool for identifying water deficit (SMART 1974; VAN ZYL 1987; VAN LEEUWEN 1991). While this method offers the advantage of quantifying water defi-

*For correspondence: k-van-leeuwen@enitab.fr

J. Int. Sci. Vigne Vin, 2000, **34**, n°2, 41-47

cit, it has a number of disadvantages. It has been shown that when soil humidity is heterogeneous (which is often the case for vineyard soils), pre-dawn leaf water potential (ψdawn) underestimates plant water stress (AMEGLIO et ARCHER 1996). ψdawn indicates overnight vine water status recovery. High ψdawn does not necessarily mean that no water stress occurred during the day. Moreover, ψdawn measurements are generally carried out only on a weekly basis, which is inappropriate for measuring short-term water deficits. Finally, the implementation of ψdawn is constraining, since measurements must be taken before sunrise. Due to these drawbacks, other vine water status indicators should be investigated.

Diurnal cycles of variations in water content have been identified in various plant tissues (HUGUET 1985). Throughout the day, plants mobilize part of their water reserves to compensate for evaporative demand, which is often greater than their root absorption, even in the case of unlimited soil water supply. This produces a temporary, reversible reduction in the diameter of plant organs. As water reserves are replenished during the night, the diameter of these organs follows a sigmoid curve. Over a 24-hour time span, under conditions of unrestricted water supply, the diameter of these organs is slightly greater than the initial one, therefore resulting in net growth. In the case of water deficit, two phenomena are to be noted: a) the Daily Contraction Amplitude (DCA) may increase, and b) water reserves are not totally replenished during the night, resulting in shrinkage in overall diameter of the organ. A method for scheduling irrigation in peach orchards has been developed on the basis of microvariations in the diameter of the trunk, as evidenced by DCA and changes in overall diameter (HUGUET *et al.* 1992).

Although research on micromorphometry has been carried out on various species (HUGUET 1985; KATERJI *et al.* 1990; LI *et al.* 1989b), few papers have discussed micromorphometry in relation to water deficits in vines. GREENSPAN *et al.* (1996) studied grape water budget by measuring micro variations in berry diameter. MYBURGH (1996) related diurnal trunk contraction and seasonal trunk growth to soil water depletion in irrigated vines (*Vitis vinifera* L. cv. Barlinka). In this paper, an assessment is made on the possibility to use continuous measurement of micro variations in the diameter of vine organs as a means of detecting mild water deficits on field grown vines. Results are compared to ψdawn values obtained on the same vines.

MATERIALS AND METHODS

I - PLOTS

This study has been carried out from 1997 to 1999 in Saint-Emilion (Bordeaux, France) on 8 *Vitis vinifera* cv. Merlot vines, grafted on 3309C rootstocks and planted in 1961 in a gravelly soil with a very low water holding capacity. A very compact layer at 110 cm of depth limits Root development. The vines are part of a plot planted at 6,000 vines per hectare. Vines are Guyot trained, with one spur and one cane. Two watering patterns were compared: one involving a plot receiving only natural rainfall (Non Irrigated: 'NI') and the other involving a plot irrigated three times per week, with 15 liter of water per vine at each irrigation, starting at the beginning of the measuring period (Irrigated 'I').

II - MEASURING DEVICE

Micro-variations in organ diameter were measured continuously by a PEPISTA micromophometer (Agro Ressources, 84800 l'Isle-sur-Sorgue, France), which consists of 8 induction sensors (resolution 1/100th mm) and 8 INVAR alloy sensor holders, which are only very slightly affected by heat expansion, and a data logger. Measurements were taken at one-hour intervals. Data represented in figures indicate diameter variations (* 0,01 mm) rather than absolute cane or trunk diameters. The data was downloaded weekly to a laptop computer and processed using TAMARIS software, either by plotting response curves directly, or by transferring the data to a spreadsheet (EXCEL). Major discontinuities in the curves, caused by accidental disturbances (wind, agricultural equipment, spraying), were eliminated from the curves. The system was powered by a 12V battery, installed under the row of vines, next to the data logger. Vine water status was determined several times during the season by measuring pre-dawn leaf water potential (ψ dawn) on the same vines, using a pressure chamber (SCHOLANDER *et al.* 1965). Two measurements were taken in 1997, four in 1998 and six in 1999, each value plotted in the graphs representing the average of eight replicates.

III - POSSIBLE DRAWBACKS

The induction sensor needle is used as a measuring device. First, the bark of the organ (cane or trunk) is carefully removed. Then the induction sensor needle is fitted to the organ. Silicone glue is used to hold the needle in place. Proper positioning of the sensor needle is essential to obtain a reliable growth curve. The following artifacts can easily occur and thus may interfere the results.

During a sunny day, the maximum diameter of the organ is detected in the morning, about two hours after sunrise. The minimum diameter is reached in the late afternoon, when plant water loss by transpiration is the greatest. In a few cases, pattern occurs with a swelling in the afternoon and a shrinkage during the night. This can be explained by thermal dilatation (figure 1) and happens when the needle is in contact with dead tissue (a piece of bark or necrosis).

Another drawback is a flat response curve, showing little or no ACD. This usually indicates a buffer effect of the silicone glue. The glue should be positioned around the tip of the needle, and not between the tip of the needle and the organ.

RESULTS AND DISCUSSION

I - CHOICE OF THE ORGAN

In 1997 measurements were taken on trunks and one year old wood (canes) to assess which organ would best reveal vine water deficits. Two vines were subjected to the watering pattern 'I' (irrigated) and two other vines were left 'NI' (non irrigated). Two sensors were installed on each vine, one on the trunk and one on the cane. Measurements started on 6 July, after a rainy period (143 mm of rain from 1st June to 4 July). Soil humidity was close to field water capacity on 6 July, as calculated by the seasonal water budget model (LEBON 1995, data not shown). No significant rainfall occurred during the measurement period.

The curves obtained using the one-year-old wood did not result in any coherent interpretation. DCA was small on both irrigated and non irrigated vines, most days under 0.05 mm. Cane diameter showed an overall increase in 'NI' and an overall shrinkage in 'I' from 10 July to 30 July, which was opposite to the expected response.

However, the sensors placed on the vine trunks produced similar curves for both vines that were subjected to the same watering pattern (data not shown). DCA was high, though not different between 'N' and 'NI' (most days between 0.05 and 0.1 mm). On 'NI', the overall trunk diameter decreased throughout the measurement period, reflecting drying soil conditions. On 'I', the trunk diameter shrinkage stopped after the irrigation started on 18 July (figure 2). Pre-dawn leaf water potential was similar for 'I' and 'NI' on 22 July (-0.08 MPa). On 31 July, ψdawn was -0.08 MPa on 'I' and -0.16 MPa on 'NI'. Despite the fact that only two ψdawn measurements were taken in 1997, the overall trunk diameter growth seemed to indicate differences between 'I' and 'NI' earlier than did ψdawn. These preliminary results indicated that trunk diameter variations could be considered as an indicator of vine water status, whereas cane diameter cannot.

II - MICRO VARIATIONS IN TRUNK DIAMETER ON IRRIGATED AND NON-IRRIGATED VINES IN 1998

In 1998, sensors were positioned on the trunk of 4 vines in the 'I' plot and 4 in the 'NI' plot. One of the sensors in each series of 4 did not operate properly, giving DCA readings that were either abnormally low ('I' vine) or excessively high ('NI' vine). The curves from the mean of the remaining three sensors under each watering pattern are shown (figure 3). May and June 1998 were dry (58 mm in two months). 32 mm rain fell on the 1st of July, just before the measurement period. During the measurement period (2 July to 5 August), significant rainfall occurred on two days: 13 July and 21 July. In the 'NI' plot, a slight water deficit was observed on 12 July (decrease in trunk diameter). Rain that fell on 13 July (8 mm) regenerated trunk growth on 14 July. A more significant water deficit became apparent starting on 18 July, followed by a clear decrease in trunk diameter. Growth resumed on 22 July, after rainfall on 21 July (16 mm). The decrease in trunk diameter during those same periods in vines subjected to the 'I' regime was very slight, or even nonexistent.

These short-term water deficits were not shown by pre-dawn leaf water potentials. ψdawn measurements are constraining and cannot be carried out on a daily basis. Later in the season, when water deficit is more severe on 'NI', significant differences appear in ψdawn between 'I' and 'NI' (26 July and 5 August). At that stage, the DCA of 'NI' increased dramatically, which is a second type of micromorphometric response of plant organs to water stress (HUGUET 1985). There is no clear explanation why, during this period, no decrease in trunk diameter happened on 'NI'.

III - MICRO VARIATIONS IN TRUNK DIAMETER ON NON-IRRIGATED VINES IN 1999

1) Growth curve

In 1999, micro variations in trunk diameter were measured only on non-irrigated vines, from 7 June through 31 July (figure 4). Rainfall from the first of May to 7 June was 124 mm and soil humidity was close to field capacity at the beginning of the measurement period, as calculated by the seasonal water budget model (LEBON 1995, data not shown). Trunk diameter increased during June and July, but the process was interrupted by three main shrinking events, on 22 June, 10 July and 24 July, probably induced by water deficits. Each time, rainfall quickly relieved the water deficit, and growth resumed. The greatest water stress seemed to have occurred up from 24 July, when shrinkage started 5 days before the occurrence of significant rainfall.

Each trunk shrinking event corresponded to a low point on the soil water depletion curve (figure 5, according to LEBON 1995 modified). It is worth noting that the second and third trunk shrinking happened at a greater level of soil water depletion (around -100 mm) than the first (-50 mm). This might indicate vine adaptation to water deficits.

A diminution of pre-dawn leaf water potential was noticed only at 27 July (figure 4), more than one month after the first water deficit signal was registered by micromorphometry.

2) Daily Contraction Amplitude (DCA)

MYBURGH (1996) has shown that DCA depends on both soil and weather conditions. DCA is notably lower on rainy and overcast days, when Potential Evapo Transpiration (PET) is low. In order to relate DCA to soil water conditions, we eliminated the influence of the weather by dividing DCA by PET. In our 1999 experiment, each shrinking event fits with an increase of the DCA / PET ratio (figure6). This is consistent with HUGUET (1985), who has shown that water deficit in peach trees induces an amplification of DCA, as well as a global decrease in trunk diameter.

CONCLUSION

Micro-variations in trunk diameter can provide an early signal of mild water deficit in field grown vines. Vine water deficit induces a trunk diameter shrinkage as well as an increase of the DCA / PET ratio. A micromorphometry signal for vine water deficit is detected before a drop in pre-dawn leaf water potential. Moreover, as the measurements are continuously recorded, short periods of water deficit may easily be detected. Yet, micromorphometry cannot replace measurement of pre-dawn leaf water potential in any situation. Micromorphometry requires permanent fragile equipment in the vineyard. The installation of the sensors on the trunk is a delicate operation which has its drawbacks caused by the presence of dead tissue (bark, necrosis) or a glue buffer. Due to the high cost of the sensors, few vines per plot can be monitored, and vine-to-vine variations caused by heterogeneous root depth or soil cannot be ruled out. Moreover, if micromorphometry is useful for detecting mild water deficits early in the season, the intensity of the stress cannot be quantified.

More research is needed to assess how vine transpiration, photosynthesis rate and shoot elongation are affected during micromorphometric variations in trunk diameter. If transpiration is reduced, this would evidence that the micromorphometric response correspond to true water stress. These measurements might also indicate which process of photosynthesis or shoot elongation is more affected by short term and mild water stress.

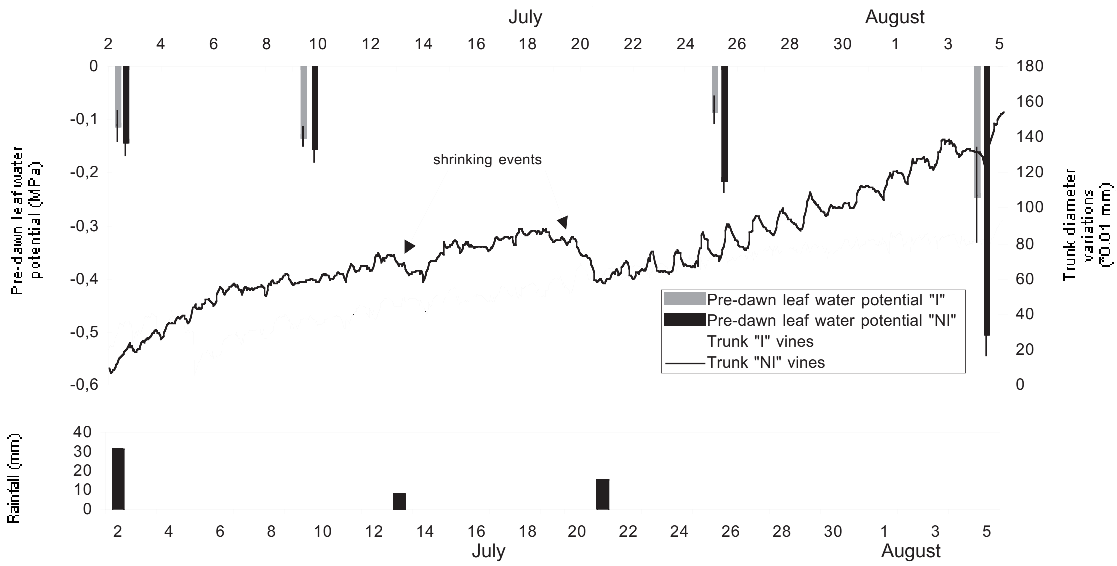

Fig. 3 - Variations in trunk diameter on irrigated and non irrigated vines in 1998.
Trunk diameter variations are means of data collected on three vines. Leaf water potential values are means of eight replicates; error bars indicate SE.

Fig. 3 - Variations du diamètre du tronc, mesurées sur des ceps irrigués et des ceps non irrigués, en 1998.
Les courbes représentent les valeurs moyennes obtenues sur trois ceps. Les valeurs de potentiel foliaire de base sont les moyennes de huit répétitions ; l'écart type figure sur les histogrammes.

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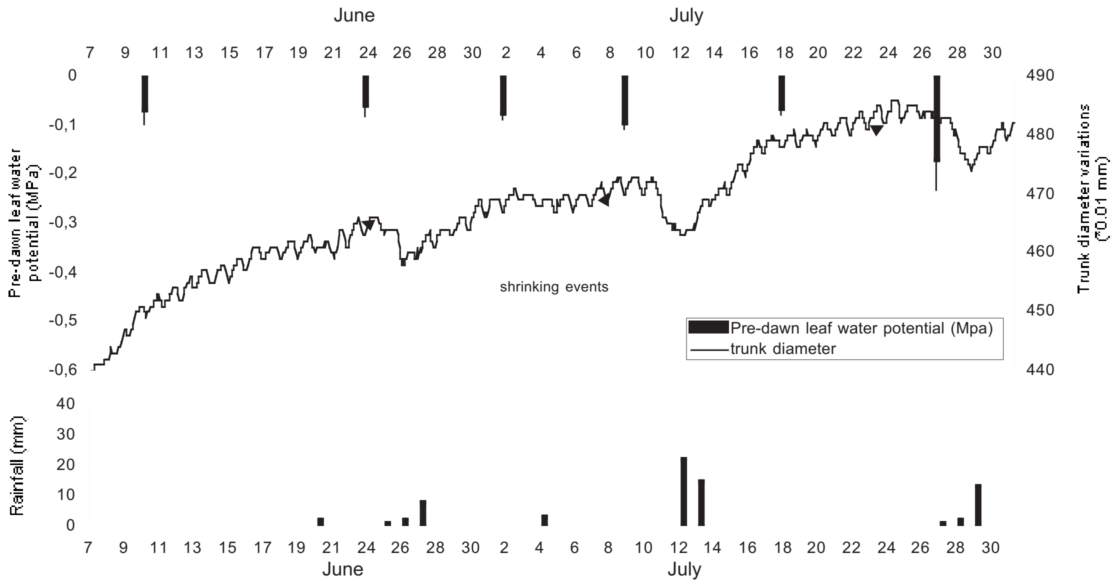

Fig. 4 - Variations in trunk diameter of a non irrigated vine in 1999.
Leaf water potential values are means of eight replicates; error bars indicate SE.

Fig. 4 - Evolution du diamètre du tronc d'un cep non irrigué en 1999.
Les valeurs de potentiel foliaire de base sont les moyennes de huit répétitions ; l'écart type figure sur les histogrammes.

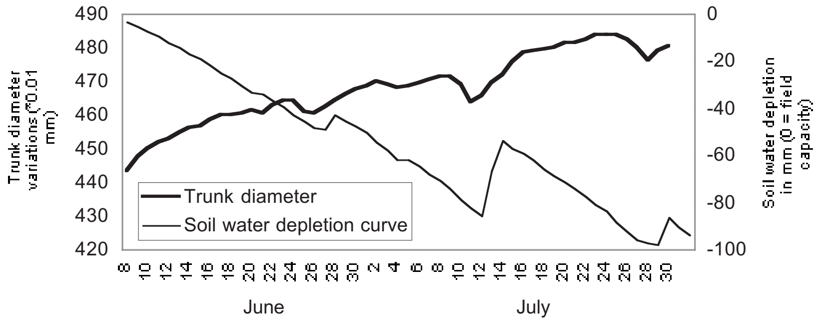

Fig. 5 - Overall trunk growth curve of a non irrigated vine in 1999 (DCA not shown), compared to the soil water depletion curve.

Fig. 5 - Croissance radiale du tronc d'un cep non irrigué en 1999 (l'Amplitude de Contraction Diurne n'est pas montrée), en comparaison avec le bilan hydrique théorique.

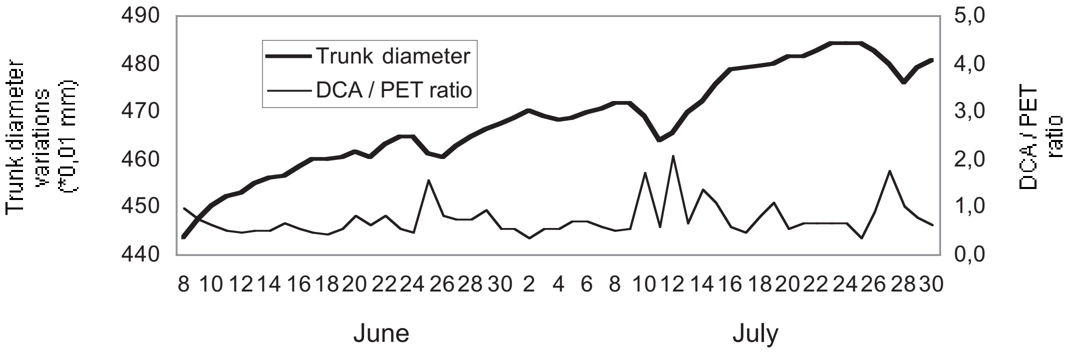

Fig. 6 - Overall trunk growth curve of a non irrigated vine in 1999 (DCA not shown), compared to the Daily Contraction Amplitude / Potential Evapo Transpiration ratio.

Fig. 6 - Croissance radiale du tronc d'un cep non irrigué en 1999 (l'Amplitude de Contraction Diurne n'est pas montrée), en comparaison avec le rapport Amplitude de Contraction Diurne / Evapo Transpiration Potentiel.

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Reçu le 22 février 2000
accepté pour publication le 29 juin 2000