Can dendrometers be used to measure stem water potential?

Dendrometers are sensors to measure fluctuations in stem and fruit diameter (Figure 1). Diurnal fluctuations in stem diameter have been correlated with plant water use, soil moisture content, and irrigation practises.

It has been hypothesised that the diurnal shrinkage of a stem, the Maximum Daily Trunk Shrinkage (MDS), is directly correlated with stem water potential.

That is, as MDS increases stem water potential decreases (becomes more negative) in direct proportion. If this hypothesis is correct then stem dendrometers, such as the DRL26, can be used as a measure of stem water potential.

The aim of this application note is to show that dendrometers cannot reliably be used to measure stem water potential and the only instrument available to continuously monitor stem water potential is the PSY1 Stem Psychrometer.

Dendrometers offer useful data on short-term and long-term timescales. Over the long-term (months to years) dendrometers measure stem increment and is useful in assessing experimental treatments or irrigation efficiency over a growing season.

Over the short-term, that is day-to-day monitoring, dendrometers show the shrinkage and swelling of stems. During the day stems “shrink” as stomata open and the tree transpires. At night the stem “swells” due to cessation of transpiration and trunk refilling of moisture.

Figure 1. The DRL26 is an example stem dendrometer sensor. It can measure tree trunks with a stem diameter greater than 8cm. The DEX or LVDT dendrometers can measure smaller plant stems as well as fruits.

Figure 2 shows a data set from an *Acacia implexa* (Hickory Wattle) tree trunk over a five day period during a warm, dry week in summer, near Armidale, northern New South Wales. Maximum stem diameter occurred around 6am just after sunrise.

Minimum stem diameter occurred around 9pm, about an hour after sunset. The difference between maximum and minimum stem diameter is called Maximum Daily Trunk Shrinkage (MDS) and for this tree values ranged between 425µm and 766µm.

It has been hypothesised that MDS is inversely and linearly correlated with stem water potential.

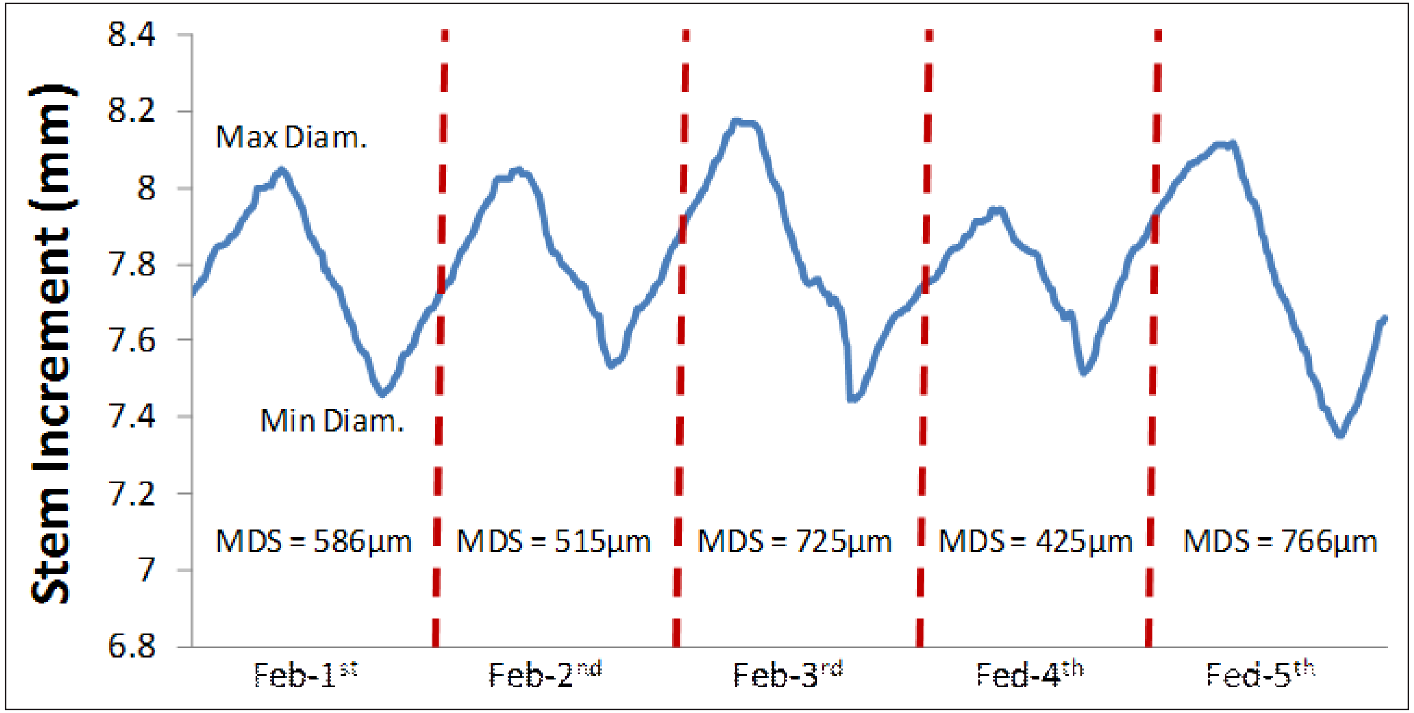

Figure 2. A five-day data set demonstrating how to calculate Maximum Daily Trunk Shrinkage (MDS). Daily stem minimum stem diameter is subtracted from daily maximum stem diameter to find MDS. Data is from an *Acacia implexa* (Hickory Wattle) tree growing near Armidale, northern New South Wales, during a warm, dry week of summer. Data courtesy of Michael Forster.

Water potential is a measure of the absolute water status of the plant and, by inference, is a direct measure of plant health. Traditionally, plant water potential has been measured on leaves.
Pre-dawn leaf water potential is the most accurate measure of plant water status as the plant has reached equilibrium with the soil environment. Researchers also measure leaf water potential throughout the day and have a particular interest in midday leaf water potential.

However, leaf water potential can fluctuate widely throughout the day depending on stomatal behaviour and prevailing weather conditions (for example, a cloud momentarily covering the sun can cause stomata to close rapidly and in turn this can affect leaf water potential).

Additionally, leaf water potential is a destructive measurement. Typically it is measured with a Scholander pressure chamber (Figure 3) minutes after the leaf has been excised from the plant. Although care is usually taken this method still leads to unavoidable error.

Figure 3. A plant water status console, also known as a Scholander pressure chamber or Scholander pressure bomb, has traditionally been used to measure leaf water potential.

Stem water potential is a much more stable measurement and tends to vary according to overall plant water status rather than minute by minute changes in weather and stomata condition behaviour. Therefore, a sensor which can measure stem water potential has been sort and the dendrometer, through the measurement of MDS, has been promoted as a good candidate.

Figure 4 shows the relationship between MDS and midday stem water potential in olive trees (*Olea europaea*), lemon trees (*Citrus limon*), mandarin (*Citrus clementina* Hort. ex Tanaka x *Citrus reticulata* Blanco), and grapevine (*Vitis vinifera*). For all species the relationship between MDS and stem water potential is curvilinear. As hypothesised, as stem water potential decreases (becomes more negative) MDS increases however for all species a threshold is reached where MDS decreases as stem water potential continues to decrease (becomes more negative). Figure 4 clearly demonstrates that MDS cannot be used as a measure of stem water potential.

For example, a MDS value of 0.4mm for the olive tree can equate to a stem water potential of approximately -0.8MPa or approximately -3.0MPa. Consequently recording a MDS of 0.4mm can mean either a plant is well hydrated or a plant is suffering severe moisture stress. Without knowing more information on the plant environment and the plant itself a meaningful interpretation of the MDS value cannot be made. Therefore, MDS cannot equivocally be used as a measure of stem water potential.

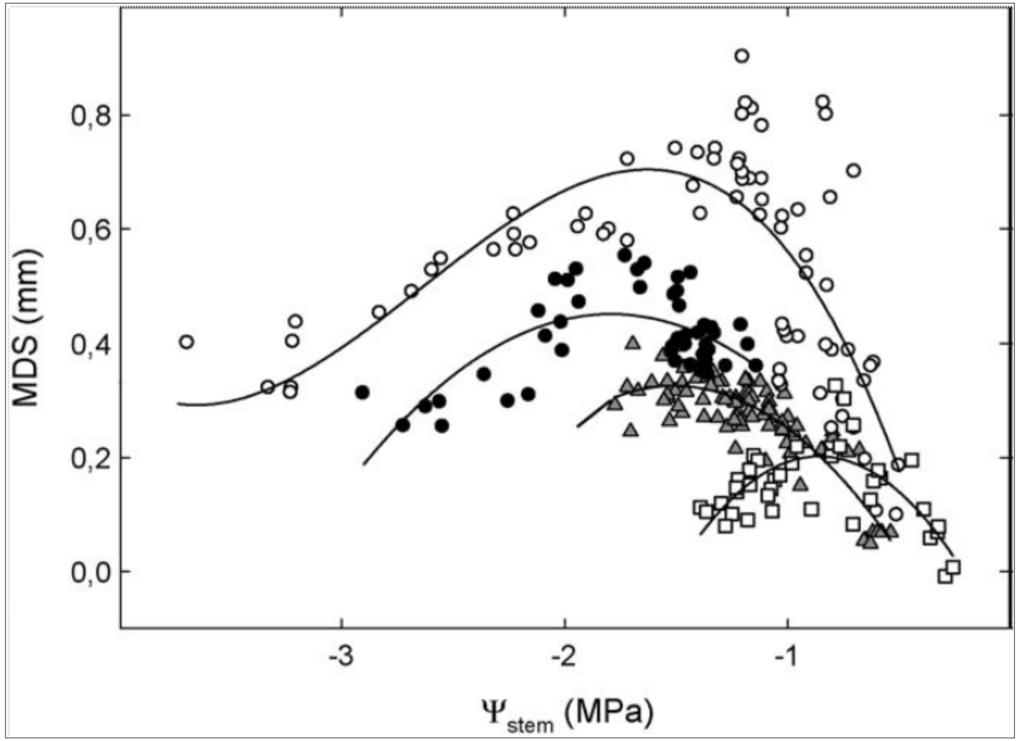

Figure 4. The relationship between MDS and stem water potential (ψ_{stem}) in four species. Open circles: olive tree; closed circles: lemon tree; closed triangles: mandarin; and open squares: grapevine. Figure has been reprinted with permission from Arturo Torrecillas Melendreras, originally published in Ortunõ et al. (2010). The curvilinear relationship between MDS and stem water potential means dendrometers cannot be used to measure stem water potential.

The PSY1 Stem Psychrometer is an instrument specifically designed to continuously measure stem water potential. The PSY1 is a non-destructive technique and is installed directly onto the plant stem (Figure 5). Measurements can be made at least every 10 minutes and, depending on the species, it can be left installed on the stem for up to months at a time. For example,

Figure 5. The PSY1 Stem Psychrometer and the sensor installed on a tree stem.

Figure 6 shows a 17 day dataset from an *Acacia melanoxylon* (Blackwood) tree growing in a glasshouse. Figure 7 shows a 45 day dataset from a coffee plant growing in Costa Rica. As these example datasets demonstrate, the PSY1 Stem Psychrometer is the only instrument which can continuously measure stem water potential.

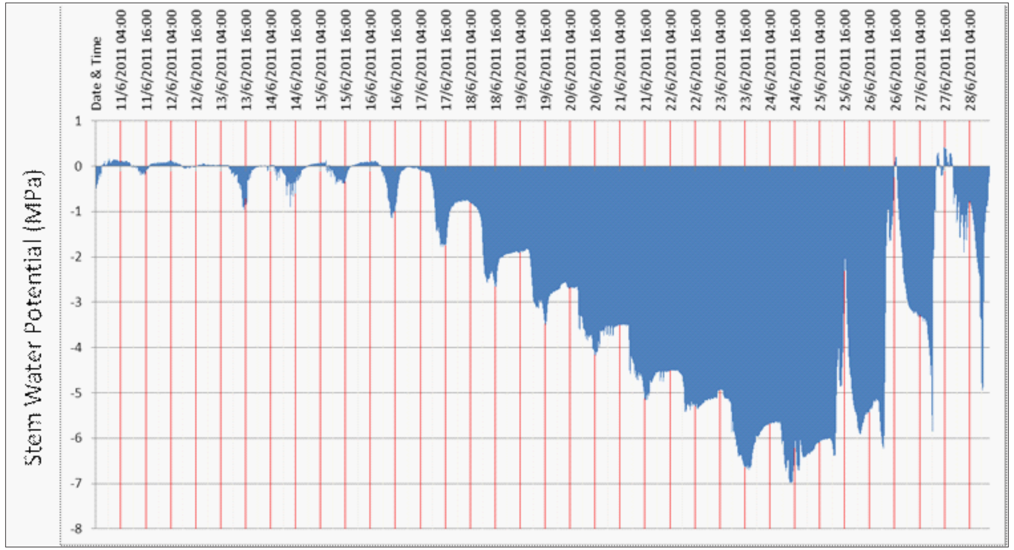

Figure 6. A 17 day stem water potential dataset collected from a PSY1 Stem Psychrometer. Data collected on *Acacia melanoxylon* tree growing in a glasshouse, Armidale, New South Wales. Stem water potential became more negative due to withholding of watering from the pot. Data courtesy of Jaime Barrera.

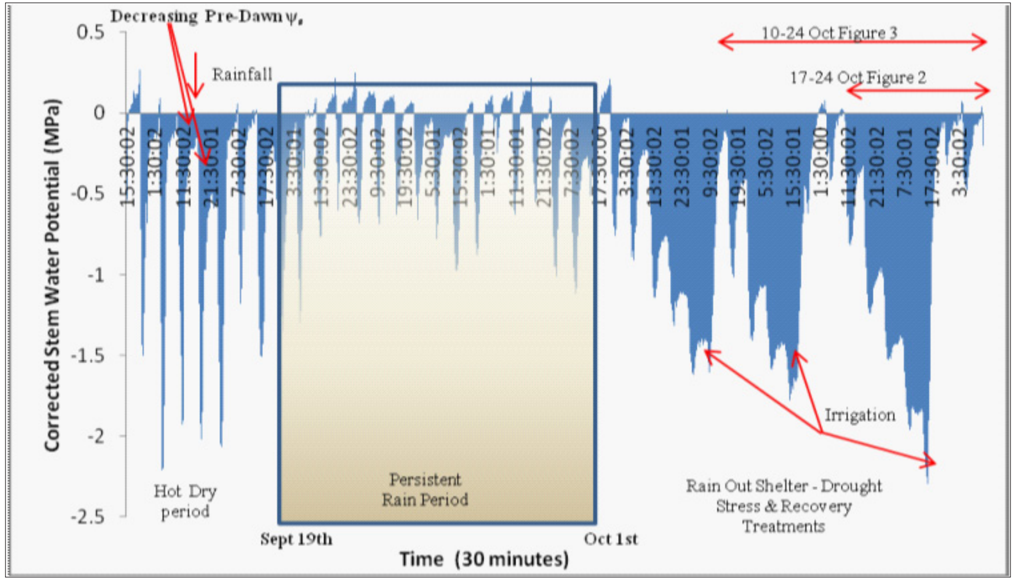

Figure 7. A 45 day stem water potential dataset collected from a PSY1 Stem Psychrometer. Data collected on coffee (*Coffea arabica*) tree growing in a field in Costa Rica. Data courtesy of Alec Downey and Alvaro Arias.

References

Ortunõ M.F., W. Conejero, F. Moreno et al. 2010. Could trunk diameter sensors be used in woody crops for irrigation scheduling? A review of current knowledge and future perspectives. Agricultural Water Management **97**: 1-11.

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