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Original Article

Measurement of stem water potential as a sensitive indicator of water stress in neck orange (*Citrus reticulata* Blanco)

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Abstract

Measurements of stem water potential, leaf water potential and stomatal conductance were simultaneously done in 3-year old trees of neck orange. The trees were subjected to 3 levels of watering: 1) daily watering (control), 2) 4-day interval watering and 3) 8-day interval watering. It was found that stem water potential was more sensitive to soil moisture than leaf water potential. This led to high correlation between soil moisture and stem water potential ($r^2 = 0.80$), but the correlation between soil moisture and leaf water potential was low ($r^2 = 0.66$). Likewise, stomatal conductance was highly correlated with stem water potential ($r^2 = 0.74$). The correlation was higher than that of stomatal conductance with leaf water potential ($r^2 = 0.62$). Therefore, stem water potential appears to be a sensitive indicator to assess water stress in neck orange.

Keywords: leaf water potential, soil moisture, stomatal conductance, water stress

1. Introduction

Neck orange (*Citrus reticulata* Blanco) is a localized citrus in Songkhla province, southern Thailand, and it is now gaining increased recognition because of its unique fruit shape and flavor. However, water stress causes a limitation in commercial production. This is due to the impact of climatic change. Sdoodee and Kaewkong (2006) reported that leaf water potential and stomatal conductance of neck orange leaves decrease during the progress of water stress. Therefore, water status is an important factor to determine the progress of water stress in neck orange. Recently, it has been reported that stem water potential is a more sensitive indicator of plant water status comparing with leaf water potential. (Naor, 1998; Naor, 2004; Chone *et al.*, 2001). Begg and Turner (1970) suggested that stem water potential is measured on a non-transpiring leaf. Daily stem water potential is the result of whole plant transpiration, and soil and root /soil hydraulic conductivity. Stem water potential indicates the capacity of plant to conduct water from soil to atmosphere, whereas daily leaf water potential measured on a single leaf reflects a combination of many factors: vapour pressure deficit (VPD), leaf intercepted radiation, internal plant hydraulic conductivity and stomatal regulation. For this reason, stem water potential has been successfully applied as a water stress indicator on many fruit trees: apple (Naor *et al.*, 1995; 1997), nectarine (Naor *et al.*, 2001), peach (Granier and Berger, 1985), pear (Ramos *et al.*, 1994; Naor *et al.*, 2000), prune (McCutchan and Shackel, 1992; Lampinene *et al.*, 1995; Shackel *et al.*, 2000), plum (Naor, 2004) and litchi (Stern *et al.*, 1998)

The objectives of the present study were to determine stem water potential of neck orange trees under various soil moisture conditions and establish the relations between stem and leaf water potential, stomatal conductance and soil moisture. Then, the sensitivity of stem water potential in response to water stress was assessed.

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2. Materials and Methods

The experimental site was located at Songkhla Province, southern Thailand (6° 17' N, 100° 7' E); and the study was conducted in March, which corresponds to the dry-period in summer. Twelve 3-year-old trees (average plant height = 1.62±0.25 m) of neck orange on rootstock (neck orange) were used. Each tree was grown in a container (0.4 m^3) containing mixed media of sand, compost and soil (1: 1: 1 by volume). The experiment was arranged in a completely randomized design with 3 treatments: 1) control or daily watering 2) 4-day interval watering and 3) 8-day interval watering. Four replicates (one tree per replicate) were used in each treatment. The amount of water applied to each tree at each time of rewatering was around field capacity of soil moisture.

2.1 Soil moisture measurement

During the experimental period, soil moisture was continuously monitored at 4-day intervals in the evening (6.00 pm) or before rewatering in each treatment. Theta probes (Delta- T Devices, Burwell, UK) were used for the measurement of soil moisture at a 20 cm depth in each treatment.

2.2 Leaf and stem water potential measurement

Midday leaf water potential was measured from leaves on the outer part of the canopy. A pressure chamber (PMS, USA) was used for the measurement, whereas midday stem water potential was measured from leaves in the inner part of the canopy; while still attached, they were enclosed in plastic bags covered with aluminum foil and equilibrium was reached within 90 minutes. Then, the sampled leaves were detached for the measurement with the pressure chamber. Both midday leaf and stem water potential were measured in 3 replicates on each tree, and they were done at 4-day intervals during the experimental period.

2.3 Stomatal conductance measurement

Simultaneously measurements of leaf water potential, stem water potential and stomatal conductance were preformed on midday at 4-day interval during the experimental period. Young fully expanding leaves from the outer part of canopy were used for the measurement of stomatal conductance using AP4 porometer (Delta-T Devices, UK), and measurements were made in 3 replicates on each tree.

3. Results and Discussion

3.1 Changes of soil moisture

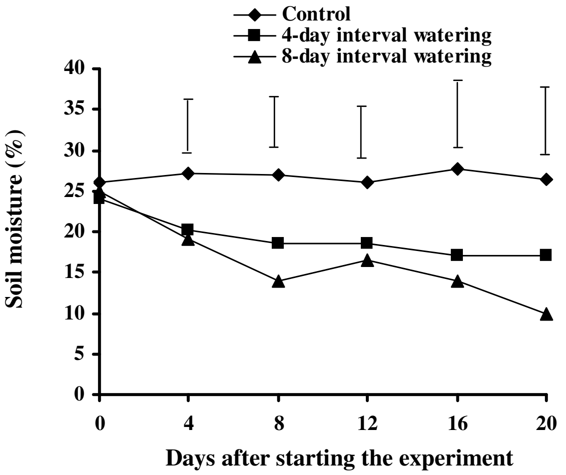

Figure 1. Changes of soil moisture measured in the evening on day 0, 4, 8, 12, 16 and 20 after starting the experiment. (Bars indicate $LSD_{.05}$)

It was prominent that soil moisture in the treatment of 8-day interval watering markedly decreased and dropped to 10% at the end of experimental period, whereas the decrease of soil moisture in the 4-day interval watering was moderate. In the control, the soil moisture remained around 27% (Figure 1). Therefore, soil moisture in the treatment of 8-day and 4-day watering was significantly lower than that of the control.

3.2 Leaf and stem water potential

The effect of different soil moistures among the treatments led to a significant difference of leaf and stem potential among the treatments (Figure 2). Leaf water potential of the trees subjected to 8-day interval watering decreased sharply on day 4 after starting the treatment. Then, it decreased to -2.7 MPa, followed by the leaf water potential in the treatment of 4-day interval watering (-2.3 MPa). The leaf water potential in the control remained around -1.7 MPa. Comparing with the stem water potential measurement, it was remarkable that leaf water potential was lower than stem water potential in all treatments.

During the progress of water stress, midday leaf water potential at the end of experimental period ranged from -1.7 MPa (control) to -2.7 MPa (8-day interval watering) (Figure 2). Midday stem water potential varied from -1.3 MPa (control) to-2.6 MPa (8-day interval watering). This indicated that stem water potential exhibited larger amplitude compared with leaf water potential. Chone *et al.* (2001) also found similar result in grapevine. Therefore, stem water potential is a sensitive indicator to discriminate moderate and severe water stress.

3.3 Stomatal conductance

After starting the treatments, stomatal conductance in the treatment of 8-day and 4-day watering was significantly lower than that of the control along the experimental period

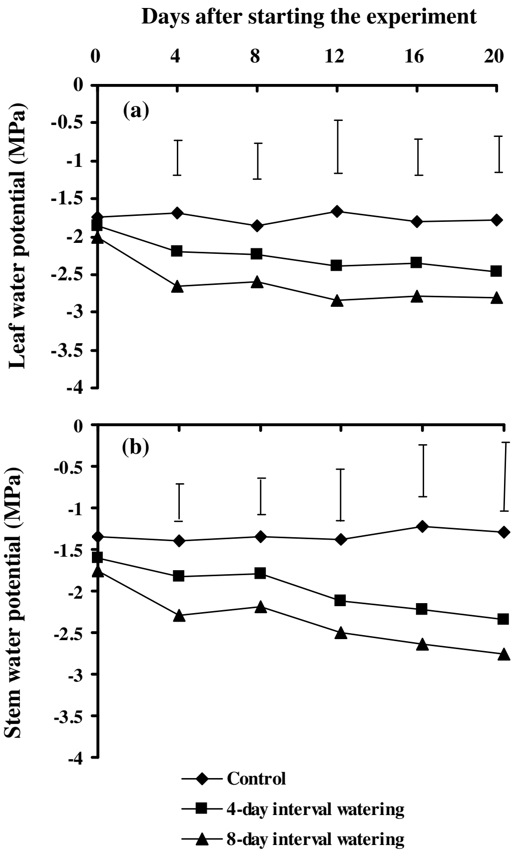

Figure 2. Changes of midday leaf water potential (a) and stem water potential (b) in the 3 treatments of watering during the experimental period.(Bars indicate $LSD_{.05}$)

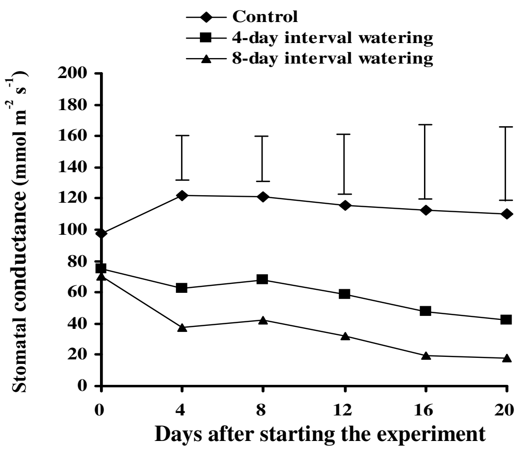

Figure 3. Changes of stomatal conductance in the 3 treatments of watering during the experimental period. (Bars indicate $LSD_{.05}$)

(Figure 3). At the end of the experimental period, the minimum stomatal conductance (18 m mol m^{-2} s^{-1}) was found in the treatment of 8-day interval watering, followed by that of 4-day interval watering (50 m mol m^{-2} s^{-1}) and the control (around 110 m mol m^{-2} s^{-1}), respectively.

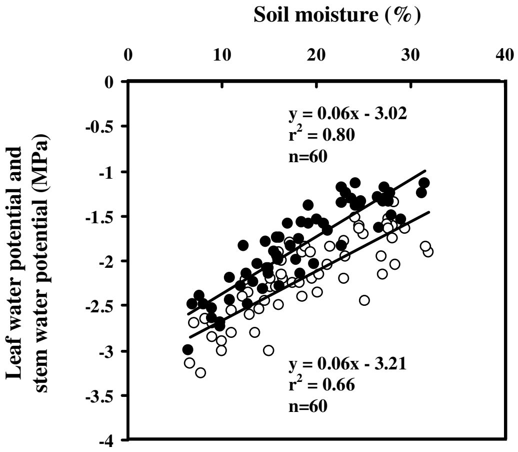

Figure 4. Relationships between soil moisture, stem water potential (●) and leaf water potential (O).

3.4 Relationships between soil moisture and leaf and stem water potential

Leaf water potential and stem water potential decreased with decreasing soil moisture (Figure 4). It was noticeable that stem water potential exhibited a highly significant relationship with soil moisture. The correlation between stem water potential and soil moisture (r^2 = 0.80) was higher than that of leaf water potential and soil moisture (r^2 = 0.66).

The higher correlation of soil moisture with stem water potential than that with leaf water potential could be explained using a water transport model (Tardieu and Davies, 1993). Decreasing soil moisture leading to a decrease of root water potential increases the intensity of the root signal which decreases stomatal conductance and, therefore, transpiration rate. This response is expected to be correlated with stem water potential. However, leaf water potential may be affected by any perturbation of the boundary conditions (VPD and wind speed) (Naor, 1998).

3.5 Relationships between stomatal conductance and leaf and stem water potential.

Figure 5 shows that stomatal conductance decreased with decreasing of leaf and stem water potential. Stem water potential exhibited high correlation with stomatal conductance (r^2 = 0.74), while the correlation between leaf water potential and stomatal conductance was low (r^2 = 0.62).

The correlation of stomatal conductance with stem water potential was better than with leaf water potential. This evidence might be explained by soil-plant-atmosphere continuum, because perturbations in boundary conditions occur mainly in the atmosphere (light intensity, wind speed and VPD). These perturbations occurs closer to the leaf than to the stem (Naor, 1998). Therefore, this causes a major weakening effect on the correlation of stomatal conductance with leaf water potential.

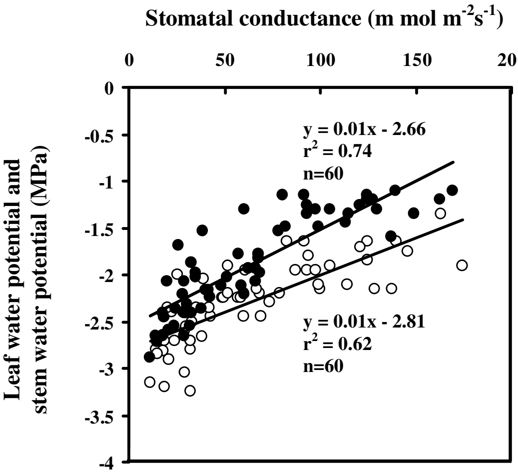

Figure 5. Relationships between stomatal conductance, stem water potential (●) and leaf water potential (O).

4. Conclusions

Measurement of stem water potential, leaf water potential, stomatal conductance and soil moisture in neck orange under 3 levels of watering showed that stem water potential was more sensitive to changes of soil moisture than was leaf water potential. The correlation of soil moisture with stem water potential ($r^2 = 0.80$) was higher than that with leaf water potential ($r^2 = 0.66$). Likewise, the correlation of stomatal conductance with stem water potential ($r^2 = 0.79$) was higher than that with leaf water potential ($r^2 = 0.62$). It is suggested that stem water potential is a sensitive indicator or for the assessment of water stress in neck orange.

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