Published in Tree Physiology 26, 219 – 228 (2005)

Comparative water use by the riparian trees *Melaleuca argentea* (W.Fitzg.) and *Corymbia bella* (Hill and Johnson) in the wet/dry tropics of Northern Australia

O'Grady A.P.[1*] and Eamus D.[2], Cook PG[3], Lamontagne S[3].

[*]Corresponding author

1Co-operative Research Centre for Sustainable Production Forestry

Locked Bag 12

Hobart Tasmania 7000

Australia

tony.o'grady@ffp.csiro.au

[2]Institute for Water and Environmental Resource Management

University of Technology, Sydney

PO Box 123 Broadway

NSW 2007

Australia

[3]CSIRO Land and Water

Urrbrae SA 5064

Summary

We examined sources of water and daily and seasonal patterns of water use in two riparian zones throughout the wet-dry tropics of northern Australia: *Corymbia bella* is found along the top of levee banks and *Melaleuca argentea* is restricted to riversides. Patterns of tree water use (sap flow) and leaf water potential were examined at three locations along the Daly River in the Northern Territory of Australia during 2000 and 2001. Despite large seasonality in rainfall, pre-dawn leaf water potential was generally was higher than-0.5 MPa throughout the dry season in both species. Pre-dawn leaf water potential was, however, slightly lower at the end of the dry season than at the end of the wet season. Contrary to expectations, pre-dawn leaf water potential was lower in M. *argentea* trees along the river than in the *C. bella* trees along the levees. In contrast, mid-day leaf water potential was lower in the *C. bella* trees along the levee than the *M. argentea* trees along the river. Consequently, the difference between pre-dawn and mid-day leaf water potential was larger in *C. bella* trees than *M. argentea* trees. There were no seasonal differences in tree water use in either species, however daily water use was lower, for any given tree size, in *M. argentea* along the river than *C. bella* along the levees. There were good relationships between tree water use and tree diameter, but they were more variable in the *M. argentea* trees than the *C. bella* trees. Whole tree hydraulic conductance, estimated from the slope of the relationship between leaf water potential and sapflow, although considerably variable, was not significantly different between species, but was higher in the dry season than during the wet season. Xylem deuterium concentrations indicated that *M. argentea* trees along the riverbank were principally reliant on river water or shallow groundwater. In contrast *C. bella* trees along the levee were solely

reliant on soil water reserves. This study demonstrated strong gradients of tree water use within tropical riparian communities, this has implications for estimating riparian water use requirements and the management of groundwater water resources.

Introduction

Riparian vegetation is an integral component of riparian ecosystems and vital for maintaining a number of key environmental services. Vegetation along riverbanks protects water quality by filtering water moving across the soil as surface runoff as well as subsurface water to the river. Riparian vegetation helps to maintain stream water quality by regulating; stream temperature (through shading), turbidity (through erosion control and trapping debris) and maintaining bank stability (Askey-Dorin et al. 1999). Furthermore, riparian communities are an important source of in-stream and terrestrial habitat (Catteral 1993), act as corridors for the movement of fauna through the landscape and often have higher biodiversity than surrounding ecosystems. Despite this, water use requirements of riparian vegetation are poorly understood, and rarely if ever taken into account during environmental flow assessments (Murray et al. 2004).

A number of recent studies have examined patterns of water use in savanna trees of wet/dry savannas (O'Grady et al. 1999, Meinzer et al. 1999, Hutley et al. 2000, Eamus et al. 2000). In north Australian savannas, in contrast to temperate Australia, many evergreen tree species exhibit little or no seasonality in water use, despite a highly seasonal climate with respect to rainfall and vapour pressure deficits (O'Grady et al. 1999). Savanna eucalypts are able to maintain water use throughout the year by reducing leaf area in response to increasing vapour pressure deficits (O'Grady et al. 1999) and by exploiting a large volume of soil (Kelley 2002). Comparatively little is known about the patterns of water use in tropical riparian systems, especially throughout the prolonged dry season. An understanding of this is important as, throughout northern Australia, there is increasing pressure on natural resources, in particular surface water and groundwater, resulting from expansion of the horticultural, pastoral and tourism industries. Major landscape-scale changes are occurring to ecosystems within the region and there is an immediate requirement to gain a better understanding of the water regimes of tropical ecosystems so that water and landscape resource managers can manage existing water resources sustainably, thereby maintaining important environmental services and values.

The principle aim of this study was to examine spatial and temporal patterns of water use in two riparian species, *Melaleuca argentea* and *Corymbia bella*, along the Daly River in Northern Australia and to gain an understanding of the water use requirements of these two species. These two species were chosen because of their contrasting position in the landscape and their likely differences in access to groundwater. The Daly River and its surrounding catchment is relatively undisturbed providing a unique opportunity to study water use requirements of riparian vegetation before large-scale land use changes have impacted on the hydrological cycle. The principle questions addressed in this study were:

How does water use in *C. bella* and *M. argentea* vary with site and season?
What are the relationships between tree water use and tree size for the two species?
How does leaf water potential vary between the two species, as well as between site sites and seasons?
What is the relationship between tree water use and leaf water potential in these two species?
Are there differences in sources of water transpired by the two species?

Methods

Site Description

The Daly River is one of the Northern Territory's largest perennial rivers with a catchment area of approximately 52 577 km^2 (Fig. 1), and is a significant biological, cultural and economic resource. Climate within the Daly River region is dominated by a distinct monsoonal wet season occurring from October to April followed by a prolonged dry season with little or no rainfall. Annual rainfall varies spatially within the catchment but is, in general, lower than that recorded at Darwin and ranges between 1000 and 1300 mm within the catchment. Pan evaporation rates are high throughout the year, as are temperatures. Climatic variables for Katherine (the catchments' major centre) and Darwin are shown in Figure 2.

Catchment discharge is highly variable, reflecting the variable annual rainfall patterns within the region. Further, there is strong connectivity between surface and groundwaters. As a result, groundwater levels vary annually and are principally a function of the amount of rain falling in the preceding wet seasons (P. Jolly unpub. data). During the wet season, a large proportion of water entering the river is derived from rainfall and surface runoff dominates river flow. However, during the dry season, base flow within the river is dominated by groundwater discharge from underlying limestone aquifers (Faulkes 1998).

Riparian vegetation, along the Daly River, varies in width from a single line of trees to dense closed forests along the levee banks and contains many species typical of closed-monsoon forests (Faulkes, 1998). Riparian vegetation exhibits distinct zonation. Riverbanks are steep and rise in a series of terraces from the river. *Melaleuca argentea* and *Melaleuca leucadendra* (L.) L. trees occur on the lower river banks. Behind this strip of *Melaleuca* trees, closed-monsoon forest communities dominate river terraces. Open-forest communities occur along the levee banks (approximately 20 m above river base flow) and tend to be dominated by *Corymbia bella*. However, other species commonly found in savanna woodlands also occur. Faulkes (1998) mapped in detail the cross sectional vegetation profiles within all major rivers and tributaries in the Daly River catchment.

All plant water use and leaf water potential measurements (described below) were conducted at three sites along the Daly River: 1. Dorisvale crossing; 2. downstream from Oolloo crossing and 3. at the confluence of the Douglas and Daly Rivers (Fig 1). These sites were chosen principally as they could be accessed for most of the year, including the wet season when much of this remote river system is inaccessible.

Soil water availability

At each site, three replicate soil samples were collected using a hand augor at 0.1, 0.5 and 1 m depth. Samples were collected at the end of the dry season (September 2000) and at the end of the wet season (May 2001). Soil samples were stored in sealed containers and transported back the laboratory in insulated containers. Soil matric potential was measured using the filter paper technique (Greacen et al. 1989). Briefly, dried and weighed Whatman 42 filter papers were placed in between two more filter papers and sandwiched within the soil sample. The papers were allowed to equilibrate with the soil matric potential over a seven-day period in a constant temperature room (25 ˚C). Soil matric potential was then calculated as the relationship between the relative water content of the middle filter papers and matric potential for the filter paper, calculated as

$$\text{For } 0.278<RWC<0.453, \quad \Psi_s=-\exp(12.27-17.93\ RWC)$$

$$\text{For } 0.453<RWC<1.784). \quad \Psi_s=-\exp(5.55-3.11\ RWC)$$

Where Ψ_s (kPa) is soil matric potential and RWC (g/g) is the gravimetric water content of the filter paper.

Leaf water potential

Leaf water potential was measured on three leaves from each of four trees of the two species *C. bella and M. argentea*. Measurements of leaf water potential were conducted in July/August 2000 (Dry season), October 2000 (end of dry season) and in May 2001 (end of wet season) at all three sites. Leaves were harvested from trees for which tree water use was being concurrently estimated (see below). Measurements of leaf water potential were conducted pre-dawn and thereafter at approximately hourly intervals until early afternoon. Leaves were collected from the sunlit quarter of the trees and, once harvested, were placed immediately into sealed humid bags and stored in a dark insulated container until measurement (typically within 30 minutes).

Measurements were made using a Scholander type pressure bomb (Soil Moisture Corporation, USA).

Isotopic analysis

Deuterium concentrations were measured in xylem water and river water samples at Dorisvale and Oolloo in May 2000 and in September 2000. River water was sampled as groundwater is a major component of river base flow in the Daly River and the deuterium signatures of river water and groundwater in the Daly River are indistinguishable (Lamontagne et al. 2005). Water was collected from near the riverbank at a depth of approximately 0.5 m. Sampling was conducted to coincide with measurement of tree water use (see below).

Three twigs were collected from three trees of each species at each site for analysis of deuterium concentrations in xylem sap. Twigs were approximately 10-25 mm in diameter and were cut using pruning shears and immediately placed in glass McCartney bottles and covered with kerosene. Isotopic analysis was conducted by CSIRO Land and Water in Adelaide and is described in detail by Lamontagne *et al.* (2005).

Tree water use

Tree water use was examined in each of four *C. bella* and *M. argentea* trees at three sites along the Daly River (Fig. 1). Sampling was conducted during the dry season

(July/August 2000), at the end of the dry season (October 2000) and at the end of the wet season (May 2001). Tree water use was estimated using commercially available sapflow loggers (Greenspan Sapflow, Greenspan Technology Warwick QLD, Australia). A 1.8 second heat pulse was fired at 15-minute intervals over a five-day period in each tree at each site during each of the sampling periods. Heat pulse velocity was converted to sap velocity following Edwards and Warwick (1984) and Swanson and Whitfield (1981) corrections were applied to correct for the effects of wounding (wound diameter 3.1 mm). Sapwood area was determined by taking cores from each tree, and sapwood was distinguished from heartwood on the basis of a distinct colour change. These cores were used for determination of the volumetric wood and water contents of each sampled tree. Sap velocity was scaled to tree water use using the weighted averages technique (Hatton et al. 1990). For each tree, diameter at 1.3 m was recorded, bark thickness and depth of sapwood were also recorded.

Results

Soil water availability

Soil matric potential in the surface soils was highly variable. Despite this a number of trends were evident. Soil matric potential was low in the top meter of soil in both seasons. However, soil matric potential was, on average, higher at the end of the wet season than at the end of the dry season (-10.2 MPa, –26.2 MPa respectively). Matric potential increased towards zero with depth, and was lower in soils along the levee than soils along the river-banks. Average matric potential for soils along the levee in the wet and dry seasons were -15.1 MPa and -36.2 MPa respectively and for soils along the river –5.5 MPa and –16.2 MPa respectively. Soil matric potentials at each site are shown in table 1.

Leaf Water Potential

Patterns of pre-dawn and mid-day leaf water are shown in figure 3. Results of the analysis of variance for pre-dawn and mid-day leaf water potential are shown in Table 2. Pre-dawn leaf water potential was higher than -0.5 MPa in both species at all sites at all times with the exception of *M. argentea* trees Dorisvale site in July 2000. These trees had lower pre-dawn leaf water potential (-0.68 MPa) than *M. argentea* trees at either Oolloo or the Douglas/Daly confluence (-0.48 and -0.33 MPa respectively). Pre-dawn leaf water potential was slightly but significantly higher in *C. bella* (-0.29 MPa) along the levees, than for *M. argentea* trees along the river (-0.38 MPa, ANOVA $F=26.99, df, 1,18, p<0.01$). Furthermore, for *C. bella* trees, pre-dawn leaf water potential was lower at the end of the dry season (-0.35 MPa) than during the dry season (-0.24 MPa) or at the end of the wet season (-0.25 MPa). In contrast, *M. argentea* pre-dawn leaf water potential was lower during the dry season (-0.49 MPa) than at the end of the dry season (-0.32 MPa) or at the end of the wet season (-0.35 MPa).

Mid-day leaf water potential was significantly lower than pre-dawn leaf water potential (Fig 3). Generally mid-day leaf water potential was lower in *C. bella* (-1.7 MPa) trees along the levees than *M. argentea* (-1.4 MPa) streamside. The exceptions were *M. argentea* trees at Dorisvale during May 2001 (-1.7 MPa and –1.2 MPa for *M.*

argentea and *C. bella* respectively). For both species, mid-day leaf water potential was lower at the end of the dry season (October 2000, -1.8 MPa and –1.5 MPa for *C. bella* and *M. argentea* respectively) than at the end of the wet season (May 2001, -1.6 and –1.4 MPa *C. bella* and *M. argentea* respectively) or during the dry season (July 2000, -1.7 and –1.2 MPa, *C. bella* and *M. argentea* respectively). Consequently, the difference between pre-dawn and mid-day leaf water potential was larger in *C. bella* trees than *M. argentea* trees and was larger during the dry season than the wet season (Table 3).

Isotopic analysis

River water and xylem deuterium concentrations are shown in Table 4. Deuterium concentrations in the *M. argentea* trees were similar to the concentration of deuterium in river water at both sites and sampling times. However, deuterium concentrations of *M. argentea* trees and river water were more enriched than the xylem deuterium concentration of C. *bella* trees. Furthermore, at both sites deuterium concentrations in *C. bella* trees were more enriched by the end of the dry (September 2000) season compared to the end of the wet season (May 2000), however deuterium concentrations did not change seasonally in *M. argentea*.

Tree Water Use

Tree water use along the Daly River varied as a function of species, time of day and tree size. Tree water use in the *M. argentea* trees along the river was lower than tree water use for the *C. bella* trees along the levee (*ANCOVA F=9.08, df= 1,31, p<0.01*).

When normalised by sapwood area, water use was lower in *M. argentea* than *C. bella* trees. The exception to this was in August 2000 (2833, 2581 kg m^{-2} day^{-1} for *M. argentea* and *C. bella* respectively) at the Douglas Daly site and in May 2001 at the Oolloo site (4282, 3629 kg m-2 day-1 for *M. argentea* and *C. bella* respectively). Mean daily water use in *C. bella* was 4278 kg m^{-2} day^{-1} and 3244 kg m^{-2} day^{-1} for *M. argentea* (Table 5).

In both species, tree water use correlated with tree size. There were no significant differences in the relationship between DBH and tree water use between sites or seasons. However there was a trend for water use, at any given DBH, to be lower at the end of the wet season (May) than during the dry season (August –October). A power function was the best descriptor of the relationship between total daily tree water use and DBH (Fig 4). The relationship was more variable in *M. argentea* trees than *C. bella* trees. When normalised by sapwood area daily water use was 4662 kg m^{-2} day^{-1} in the dry season and 3511 kg m^{-2} day^{-1} at the end of the wet season for *C. bella* and 4190 kg m^{-2} day^{-1} in the dry season and 3130 kg m-2 day-1 at the end of the wet season for *M. argentea*. Examples of diurnal curves for the two species are shown in figure 5.

Water use and leaf water potential

There were, in general, strong relationships between tree water use and leaf water potential in both species, and the slope of this relationship is used as an estimate of hydraulic conductance. However these relationships were highly variable between trees (R^2 varied between 0.58 and 0.96, Fig. 6). Tree water use, increased during the morning as leaf water potential decreased. There were no significant differences in hydraulic conductance between species. Hydraulic conductance was however, igher during the dry season in both species than during the wet season (*ANOVA* $F=4.53$, $df=1,29$, $p<0.05$). Mean ± standard deviation hydraulic conductance during the dry season was 0.07±0.04 and 0.07±0.04 kg s^{-1} m^{-2} MPa^{-1} for *C. bella* and *M. argentea* respectively and during the wet season hydraulic conductance was 0.04 ± 0.02, 0.04 ± 0.05 kg s^{-1} m^{-2} MPa^{-1} for *C. bella* and *M. argentea* respectively.

Discussion

Pre-dawn and midday leaf water potential

Pre-dawn leaf water potential was generally higher than -0.5 MPa year round, indicating that that neither of these riparian species trees developed significant water stress during the dry season, despite soil matric potential in the top metre (Table 1) being very low. Pre-dawn leaf water potential was slightly lower at the end of the dry season than at the end of the wet season. In contrast, pre-dawn leaf water potential of canopy species in open savanna forests near Darwin in northern Australia was considerably lower at the end of the dry season (Duff et al. 1997, O'Grady et al. 1999). Decreased pre-dawn leaf water potential in these species was associated with declines in maximum stomatal conductance, leaf scale transpiration rates (Myers et al. 1997) and lower canopy cover (Duff et al. 1997). Favourable water status in riparian tree species in this study, throughout the dry season, might result in higher productivity in these species and would explain the larger height and diameter of riparian trees compared to trees occurring in the surrounding savannas (pers. obs.).

Pre-dawn leaf water potential was lower in *M. argentea* trees growing along the river than in *C. bella* trees that occur high on the river terraces and levees. This result was contrary to expectations as *M. argentea* trees were directly accessing river water or groundwater (Table 4). Lower pre-dawn leaf water potentials in *M. argentea* may reflect the proportion of the total root system with access to groundwater or river water. Root systems of *M. argentea* are relatively shallow (pers obs.) and a large proportion of the root system may be in dry sandy soils with very low matric potentials (see Table 1), contributing to the lower 'average' leaf water potential observed in this study. Alternatively, *M. argentea* trees may experience significant waterlogging due to their position in the landscape. Connell (1998) demonstrated that water logged *Eucalyptus nitens* trees in Tasmania developed lower pre-dawn leaf water potentials than trees that were not waterlogged. Soil matric potential was highly variable along the riverbank, but was often saturating at depths lower than one metre (Table 1, Lamontagne et al. 2005), suggesting that these trees may experience waterlogging.

Tree Water Use and Hydraulic Conductance

Tree water use was lower in the *M. argentea* trees along the river than in the *C. bella* trees along the levee. Lower rates of water use in *M. argentea* trees may be related to microclimatic differences between the river channel itself and the levees. The Daly River is a broad deeply incised river system, temperatures and hence vapour pressure deficits within the river channel were generally lower than along the levee, although this was not measured. Lower rates of transpiration would be associated with reduced declines in midday leaf water potential. In the current study, the difference between pre-dawn and midday leaf water was less for *M. argentea* trees than for *C. bella* trees and as a result there was no differences in hydraulic conductivity between the two species.

Despite large seasonal variations in atmospheric vapour pressure deficit (Fig. 2) and soil water availability in shallow soils (Table 1) there was no reduction in water use during the dry season in either of these riparian species. Indeed, total daily water use was slightly, although not significantly, higher during the dry season and hydraulic conductance was significantly higher in the dry season.   O'Grady *et al.* (1999) and Eamus *et al.* (2000) found that there was no seasonality in water use for the dominant eucalypts in the savanna woodlands and open-forests of the northern Territory. They proposed that eucalypts in these savannas lower leaf area, in addition to reducing stomatal conductance (Myers et al. 1997) and predawn leaf water potential (Duff et al. 1997) to control water loss in response to increased atmospheric demand during the dry season.   In contrast to the eucalypt trees in the studies of O'Grady et al. (1999) and Eamus et al. (2000) pre-dawn leaf water potential did fall below 0.5 MPa. Slightly increased water use and higher hydraulic conductance by these riparian tree species during the dry season may reflect lower sensitivity to increased atmospheric demand due to higher water availability in these riparian environments.

Hydraulic conductance

The estimates of hydraulic conductance in this study were highly variable, suggesting that the method of estimating hydraulic conductance from the slope of the relationship between water use and leaf water potential measurements on large trees is problematic. Both individual tree water use, on a sapwood area basis and leaf water potential measurements were highly variable (Fig. 6). Meinzer et al. (2001) suggested that measuring the water potential of covered, non-transpiring leaves is preferable to measurements of uncovered transpiring leaf water potential, as this reflects xylem water potential which should be less variable. However, logistical constraints (canopy height and steep river banks) meant that this approach was impractical in this study. Despite this the hydraulic conductance of trees in this study were within the range of hydraulic conductance's measured in other tree species in the wet-dry tropics of Northern Australia (Prior 1997, Kelley 2002) using similar technique.

Sources of water

High year-round pre-dawn leaf water potential, despite marked seasonality in rainfall and evaporative demand, is indicative of access to reliable sources of water such as groundwater or stream water. Drake and Franks (2004) found that pre-dawn leaf water potential in five riparian tree species in Northern Queensland remained high throughout the year but noted that there was a significant drop at the end if the dry season in two species that did not have access to groundwater or stream water, as inferred by isotopic analysis of the different water sources. Horton et al. (2001) demonstrated that pre-dawn leaf water potential was positively correlated with depth to groundwater in riparian trees in Nevada and Cooper et al. (2003) demonstrated that *Populus* trees showed marked declines in pre-dawn leaf water potential in response to groundwater pumping.

For water sources along the Daly River, there was no isotopic discrimination between groundwater and river water (Lamontagne *et al.* 2005). Deuterium concentrations in xylem of *M. argentea* trees along the river were similar to the deuterium concentration in the river water (Table 4). Furthermore, soil matric potential in the top metre were generally lower than both pre-dawn and mid-day leaf water potential suggesting that these trees were solely reliant on river water or groundwater. Graham (2001) demonstrated that sapflow in roots of *M. argentea* trees in the Pilbara (NW Western Australia) with direct access to river water was higher than roots in dry river bank soils. She found that *M. argentea* trees were sourcing most of their water requirements directly from the river (Graham 2001).

Deuterium concentrations in xylem of *C. bella* trees were lower than that of riverwater or groundwater suggesting reliance on soil water reserves. Soil water potential in the top metre was generally lower than both pre-dawn and mid-day leaf water potential, suggesting that there was no available water at these depths. Soil matric potential in May was approximately –0.5 MPa at three meters at Dorisvale and Oolloo (data not shown), and Lamontagne *et al.* (2005) demonstrated that soil matric potential increased with depth and that deuterium became more enriched with depth. Xylem deuterium concentrations in *C. bella* were more enriched in September compared to May suggesting increased reliance on deeper soil water reserves during the dry season.

Conclusions

There was very little seasonality in tree water use in the two tree species studied along the Daly River in the Northern Territory. This was the result of higher hydraulic conductance in the dry season and a larger leaf water potential gradient between the soil and the atmosphere during the dry season. Pre-dawn leaf water potential remained high throughout the year, despite a prolonged dry season and very low soil matric potentials in the top metre, suggesting that both species along the Daly River had adequate access to deep soil water, groundwater or stream water. Pre-dawn leaf water potential and tree water use in *M. argentea* trees was lower than pre-dawn leaf water potential and water use by *C. bella* trees, despite their position in the landscape, suggesting that there were strong gradients in water use within the riparian zone.

References

*Find appropriate journal abbreviation

Askey-Dorin, M., N. Pettit, L. Robins and McDonald. 1999. The role of vegetation in riparian management. In Riparian Land Management Technical Guidelines, Volume 1. Principles of sound management. Eds. S. Lovett and P. Price. LWRRDC Canberra, pp 97-120.

Catteral, C.P. 1993. The importance of riparian zones to terrestrial wildlife. In: Ecology and Management of riparian zones. Eds. S.E. Bunn, B.J. Pusey and P. Price. LWRRDC *Occasional Paper* 05/93, Canberra pp 41-52.
Chen et al. 2002

Connell D. 1998. The comparative effects of water logging on the plantation eucalypts *E. globulus*, *E. nitens* and *E. regnans.* Honours Thesis, University of Tasmania pp120.

*Doley, D. 1967. Water relations of *Eucalyptus marginata* SM. under natural conditions. British Ecological Society 55: 597-614.

Duff, G.A., B.A. Myers, R.J. Williams, D. Eamus, A.P. O'Grady, and I.R. Fordyce. 1997. Seasonal patterns in soil moisture, vapour pressure deficit, tree canopy cover and pre-dawn water potential in a northern Australian savanna. Aust. J. Bot. 45: 211-224.

*Edwards, W.R.N. and N.W.N. Warwick. 1984. Transpiration from a kiwifruit vine as estimated by the heat pulse technique and the Penman-Monteith equation. NZ. J. Agric. Res. 27: 537-543.

Eamus, D., A.P. O'Grady and L.B Hutley. 2000. Dry season conditions determine wet season water use in the wet dry tropical savannas of northern Australia. Tree Physiol. 20: 1219-1226.

Faulkes J.J. 1998. Daly River Catchment: I. An assessment of the physical and ecological condition of the Daly River and its major tributaries. Northern Territory Department of Lands Planning and Environment. Technical Report TR99/10.

Graham, J. 2001. The root hydraulic architecture of *Melaleuca argentea*. Honours thesis, Department of Botany, University of Western Australia. Pp 80

Greacen, E.L., G.R. Walker and P.G. Cook. 1989. Procedure for filter paper method of measuring soilwater suction. CSIRO Division of Soils. Divisional Report No. 108.

Hatton, T.J., E.A. Catchpole and R.A. Vertessy. 1990. Integration of sapflow velocity to estimate plant water use. Tree Physiol. 6: 201-209.

Hutley L.B., A.P. O'Grady and D. Eamus. 2000. Daily and seasonal patterns of evapotranspiration from eucalypt open forest savanna of tropical northern Australia. Funct. Ecol. 14: 183-194.

Kelley, G.K. 2002. Tree water use and soil water dynamics in savanna of Northern Australia. PHD Northern Territory University, Darwin. pp203.

Lamontagne, S., P.G. Cook, A.P. O’Grady and D. Eamus 2005. Determination of groundwater use in a tropical savanna riparian zone (Daly River, Australia). J. Hydrol. (in press).

Li, Y., M. Fuchs, S. Cohen, Y. Cohen, and R. Wallach. 2002. Water uptake profile response of corn to soil moisture depletion. Plant Cell Environ. 25: 491-500.

*Meinzer, F.C., M.J. Clearwater and G. Goldstein 2001. Water transport in trees: current perspectives, new insights and some controversies. Environmental and Experimental Botany. 45: 239-262.

Mensforth, L.J., P.J. Thorburn, S.D. Tyerman and G.R. Walker. 1994. Sources of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater. Oecologia 100: 21-28.

Myers, B.A., G.A. Duff, D. Eamus, I.R. Fordyce, A.P. O’Grady and R.J. Williams. 1997. Seasonal variation in water relations of trees of differing phenology in a wet-dry tropical savanna near Darwin, Northern Australia. Aust. J. Bot. 45: 225-240.

O’Grady, A.P., D. Eamus and L.B. Hutley. 1999. Transpiration increases in the dry season: patterns of tree water use in the eucalypt open forests of Northern Australia. Tree Physiol. 19: 591-597.

O’Grady, A.P., X. Chen, D. Eamus and L.B. Hutley. 2000. Composition, leaf area index and standing biomass of Eucalypt open forests near Darwin in the Northern Territory, Australia. Aust. J. Bot. 48: 629-638.

Prior, L.D. 1997. Ecological physiology of *Eucalyptus tetrodonta* F. Muell and *Terminalia ferdinandiana* Excell saplings in the Northern Territory. PHD Thesis Northern Territory University, Darwin pp144.

Swanson, R.H. and D.W.A. Whitfield. 1981. A numerical analysis of heat pulse velocity theory and practice. J. Exp. Bot. 32: 221-239.

Table 1. Mean (± SE) soil matric potential, at three sites along the Daly River at the end of the dry season and at the end of the wet season.

Date	Site	Depth (m)	Levee (MPa)	River (MPa)
September 00	Dorisvale	0.1	-41.6±1.6	-89.2±7.6
		0.5	-10.4±4.5	-7.4±6.3
		1.0	-3.3±2.6	-1.2±1.2
	Oolloo	0.1	-125.7±43.9	0.0±0.0
		0.5	-24.8±9.2	0.0±0.0
		1.0	-4.0±2.4	-0.6±0.6
	Douglas/Daly	0.1	-48.8±1.6	-42.2±0.0
		0.5	-39.8±4.6	-2.5±0.3
		1.0	-27.6±13.6	-3.3±0.6
May 01	Dorisvale	0.1	-55.2±21.5	-1.0±0.75
		0.5	-3.3±2.4	-5.5±2.7
		1.0	-0.5±0.4	-0.4±1.8
	Oolloo	0.1	-65.9±5.4	-19.8±0.0
		0.5	-10.4±2.8	-8.5±0.0
		1.0	-4.3±1.2	-1.2±0.5
	Douglas/Daly	0.1	-16.7±8.0	-1.9±0.9
		0.5	-9.5±3.1	-2.3±1.0
		1.0	-6.4±1.1	-6.9±5.1

Table 2. Statistical model and ANOVA results for pre-dawn and mid-day leaf water potential at sites along the Daly River.

Factor	df	ψ_{pd}	Ψ_{md}
Date	2	2.41***	8.01***
Site	2	4.54***	2.13
Species	1	26.99***	51.80***
Date:Site	4	7.12***	1.74
Date:Species	2	6.38***	2.71
Site:Species	2	1.72**	25.68***
Date:Site:Species	4	1.06	6.41***
Tree	18	1.99**	1.24
Residual	129		

*** $p<0.01$

** $P<0.05$

Table 3. Difference between pre-dawn and mid-day leaf water potential (mean ± s.e.) for *C. bella* and *M. argentea* trees at three sites along the Daly River (DD= Douglas Daly, DV=Dorisvale crossing, Oolloo= Oolloo crossing)

Date	Site	*C. bella* (MPa)	*M. argentea* (MPa)
Aug-00	DD	-1.45±0.25	-0.72±0.30
	DV	-1.51±0.07	-0.71±0.09
	Olloo	-1.25±0.15	-0.67±0.05
Oct-00	DD	-1.37±0.07	-0.66±0.19
	DV	-1.42±0.04	-1.54±0.07
	Olloo	-1.47±0.12	-1.09±0.06
May-01	DD	-1.21±0.23	-0.63±0.21
	DV	-1.00±0.07	-1.27±0.17
	Olloo	-0.95±0.25	-0.36±0.18

Table 4. Deuterium concentration (‰) in *M argentea*, *C. bella* and the Daly River at Oolloo and Dorisvale in May 2000 and September 2000. Data represent the mean ± SD of three samples unless otherwise noted.

Site	Date	*M. argentea* (‰)	*C. bella* (‰)	Daly River (‰)
Dorisvale	May 2000	-55.9±3.8	-100.1±4.2	-52.5±0.2 (2)
	Sept. 2000	-56.4±2.6	-85.3±5.0	-45.4
Oolloo	May 2000	-45.2±1.4	-70.0±8.6	-46.4±2.6 (6)
	Sept. 2000	-45.6±2.4	-63.3±6.6	-44.2±0.8 (5)

Table 5. Seasonal water use (kg day^{-1} m^{-2}) normalised by sapwood area for *Corymbia bella* and *Melaleuca argentea* trees along the Daly River. Data represent the mean ± s.e.

Season	Site	*C. bella*	*M. argentea*
Aug-00	DD	2581.2±503.2	2833.5±1576.9
	DV	5280.0±1548.9	5065.2±1088.2
	Oolloo	5177.2±1425.9	2776.8±565.8
Oct-00	DD	2864.0±1211.7	1526.2±937.8
	DV	6116.7±642.0	4763.9±1603.8
	Oolloo	5481.9±1873.6	4944.9±3308.3
May-01	DD	4123.0±1567.2	1819.3±565.1
	DV	2935.1±610.4	2242.1±933.5
	Oolloo	3628.8±590.9	4282.1±1513.8

Figure 1. Location of the Daly River in Northern Australia including sites where tree water use, soil and leaf water potentials were measured.

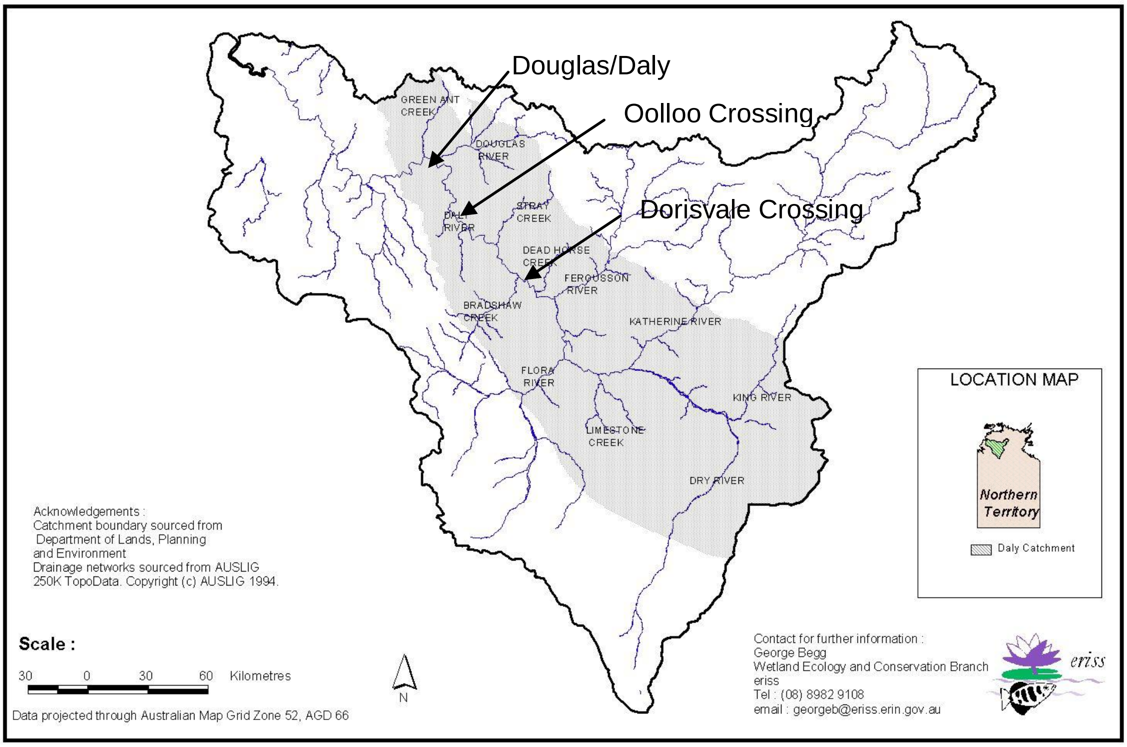
Figure 2. Patterns of rainfall, pan evaporation and maximum and minimum temperatures for Katherine (within the Daly River catchment) and Darwin in the Northern Territory Australia.

Figure 3. Pre-dawn (right) and midday (left) leaf water potential for July/August 2000 (top), October 2000 (middle) and May 2001 (bottom) at three sites along the Daly River. Filled bars represent the mean ± s.e. for *C. bella* and open bars represent the mean ± s.e. for *M. argentea*. DD= Douglas/Daly, DV=Dorisvale and Ol= Oolloo.

Figure 4. Relationship between DBH and water use for *C. bella* (top) and *M. argentea* (bottom) trees along the Daly River. Data was pooled for sites and each point is the mean daily water use of each tree.

Figure 5. Diurnal patterns of water use in *Corymbia bella* (closed symbols) and *Melaleuca argentea* (open symbols) trees at Douglas/Daly (top), Dorisvale (middle) and Oolloo on the Daly River in northern Australia during the late dry (left) and wet season (right). Data are presented as mean ± s.e hourly fluxes

Figure 6. Relationship between flow and leaf water potential in *C. bella* (closed symbols) and *M. argentea* (open symbols) trees along the Daly River in the Northern Territory. Dry season (October 2000) hydraulic conductance (right) and wet season (May 2001) hydraulic conductance (left).

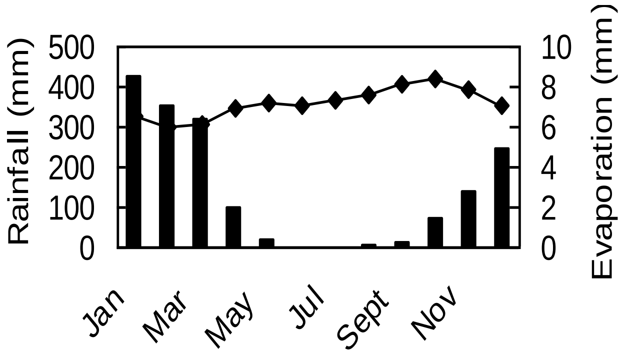


Acknowledgements :
Catchment boundary sourced from
Department of Lands, Planning
and Environment
Drainage networks sourced from AUSLIG
250K TopoData. Copyright (c) AUSLIG 1994.

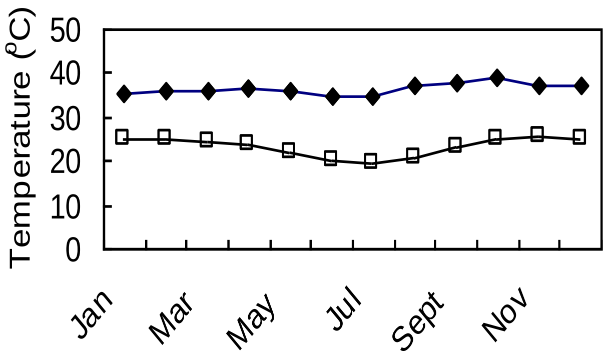
Data projected through Australian Map Grid Zone 52, AGD 66

Contact for further information :
George Begg
Wetland Ecology and Conservation Branch
eriss
Tel : (08) 8982 9108
email : georgeb@eriss.erin.gov.au

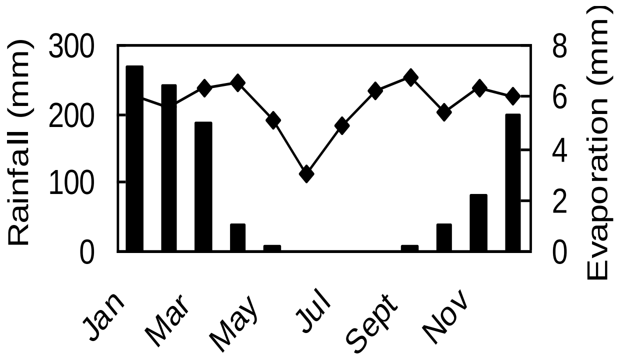
Darwin



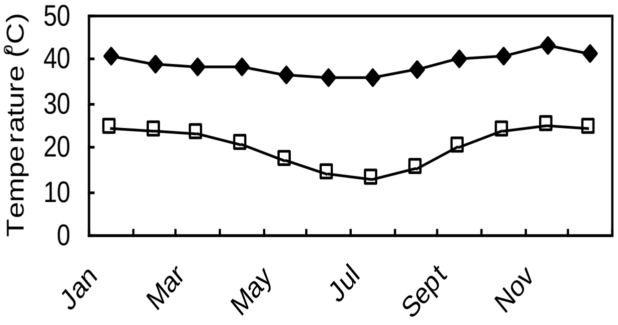
Darwin

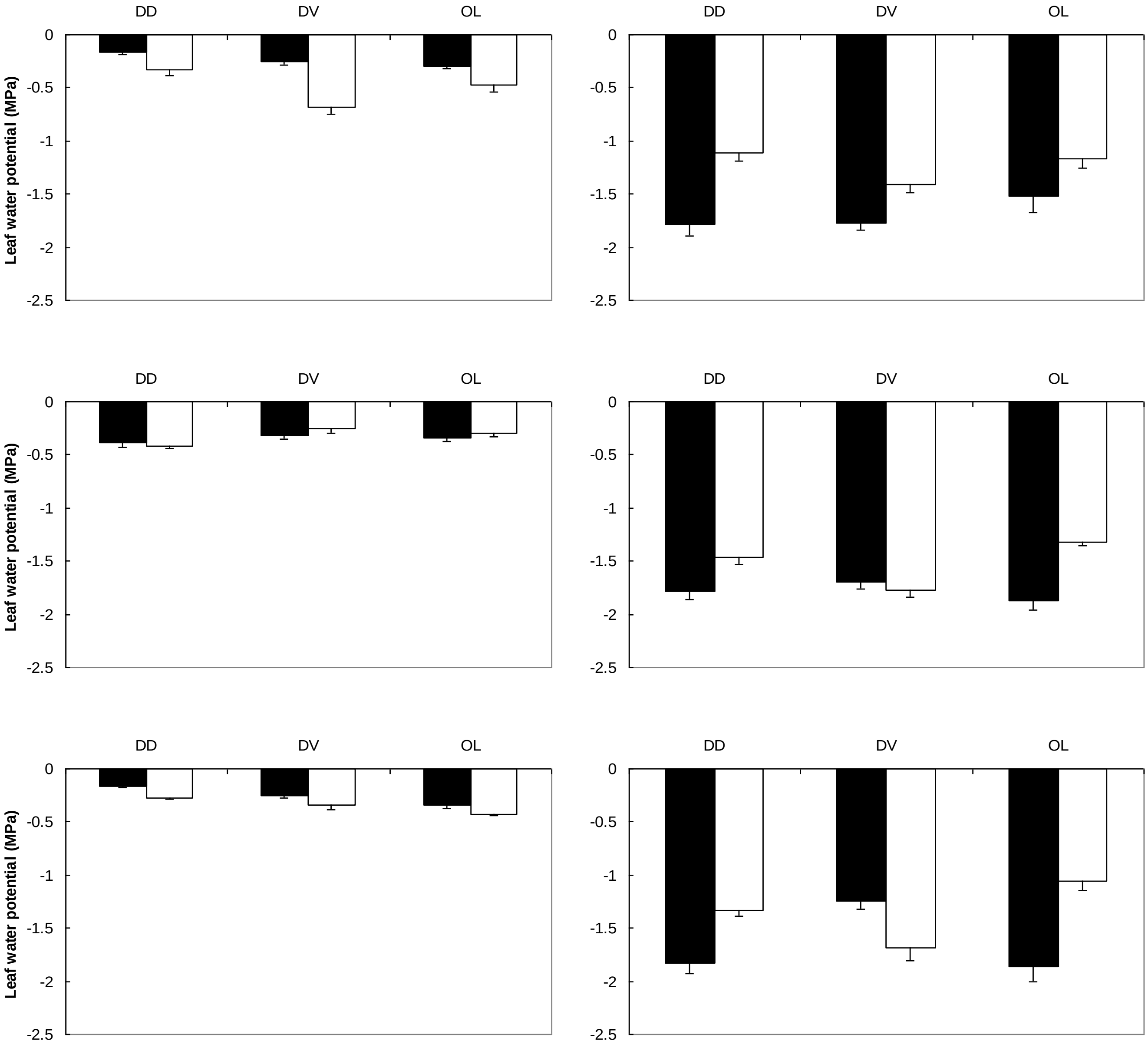


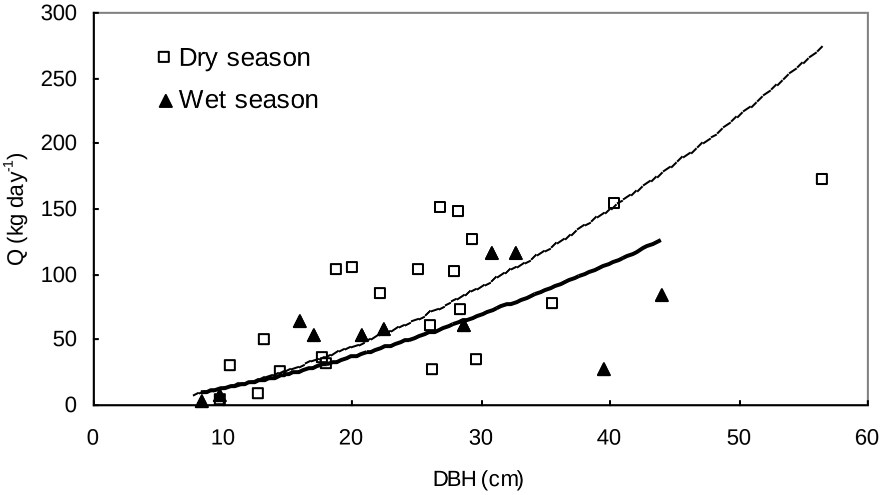
Katherine

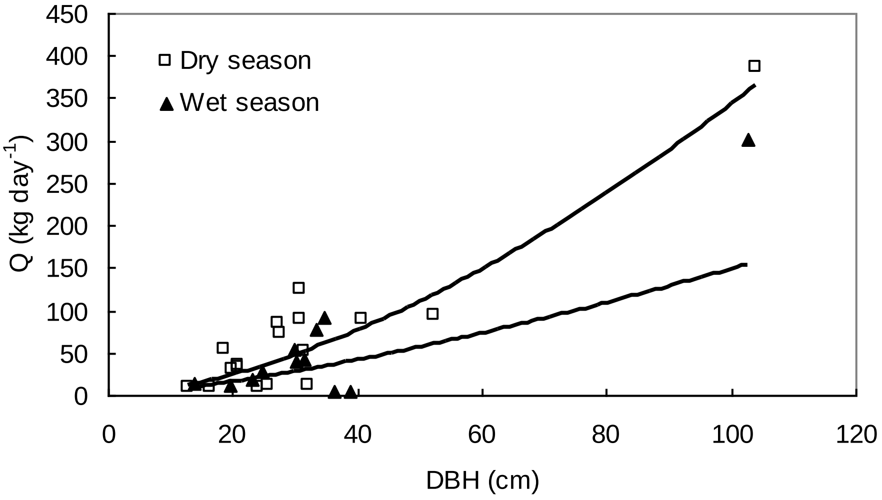


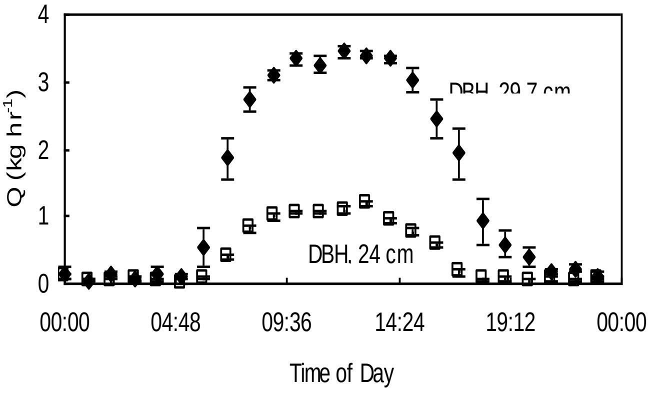
Katherine

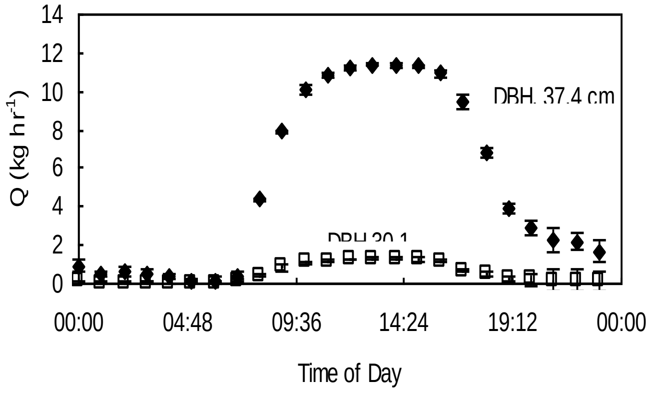


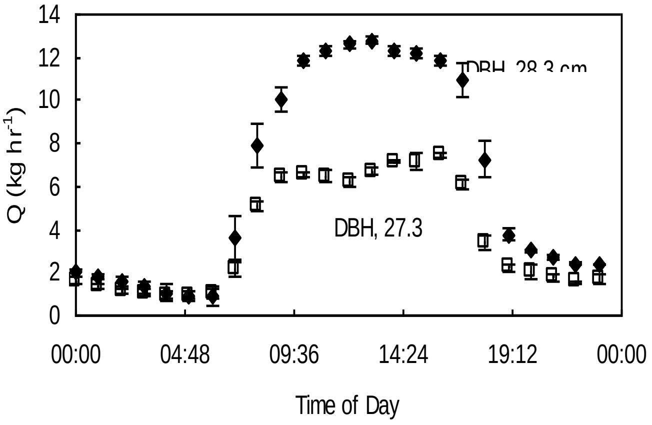

DD
DV
OL
Leaf water potential (MPa)
0
-0.5
-1
-1.5
-2
-2.5
DD
DV
OL
0
-0.5
-1
-1.5
-2
-2.5
DD
DV
OL
Leaf water potential (MPa)
0
-0.5
-1
-1.5
-2
-2.5
DD
DV
OL
0
-0.5
-1
-1.5
-2
-2.5
DD
DV
OL
Leaf water potential (MPa)
0
-0.5
-1
-1.5
-2
-2.5
DD
DV
OL
0
-0.5
-1
-1.5
-2
-2.5

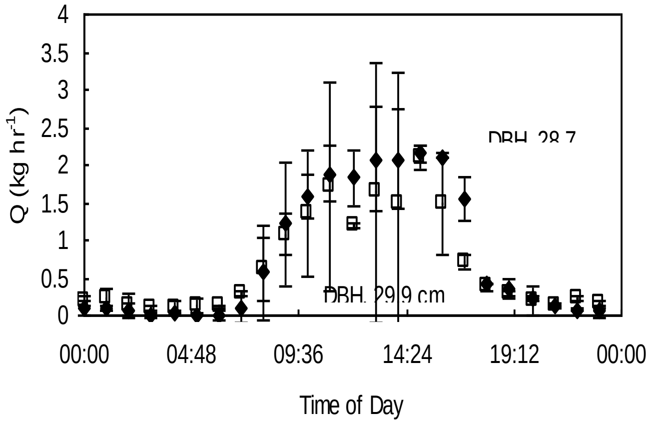

Dry season
Wet season
Q (kg day^{-1})
300
250
200
150
100
50
0
0
10
20
30
40
50
60
DBH (cm)

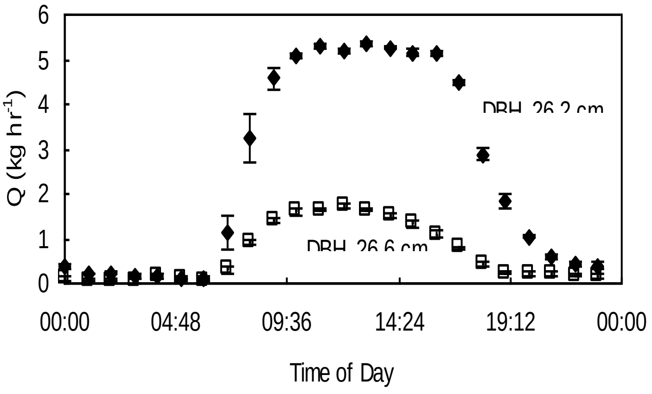

Dry season
Wet season
Q (kg day^{-1})
450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
DBH (cm)

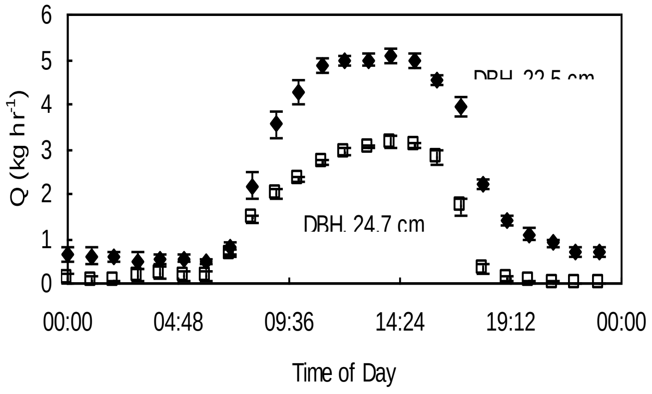

Q (kg hr^{-1})
4
3
2
1
0
DBH, 29.7 cm
DBH, 24 cm
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

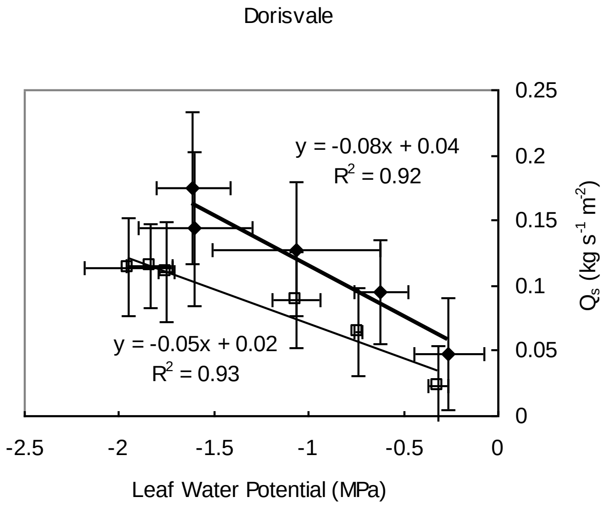

Q (kg hr^{-1})
14
12
10
8
6
4
2
0
DBH, 37.4 cm
DBH 30.1
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

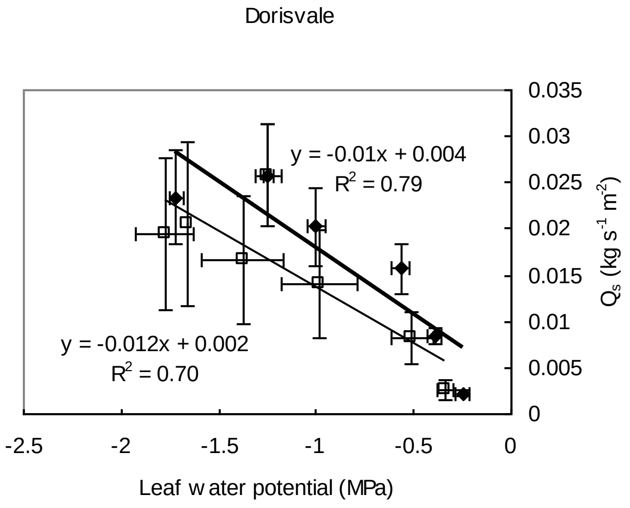

Q (kg hr^{-1})
14
12
10
8
6
4
2
0
DBH, 28.3 cm
DBH, 27.3
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

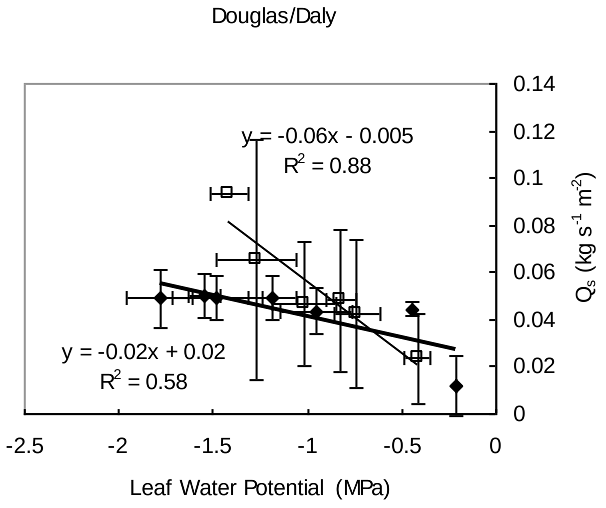

Q (kg hr^{-1})
4
3.5
3
2.5
2
1.5
1
0.5
0
DBH, 28.7
DBH, 29.9 cm
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

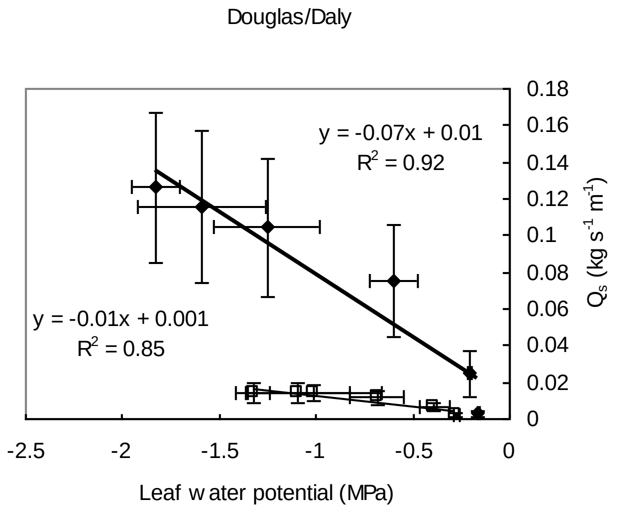

Q (kg hr^{-1})
6
5
4
3
2
1
0
DBH, 26.2 cm
DBH, 26.6 cm
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

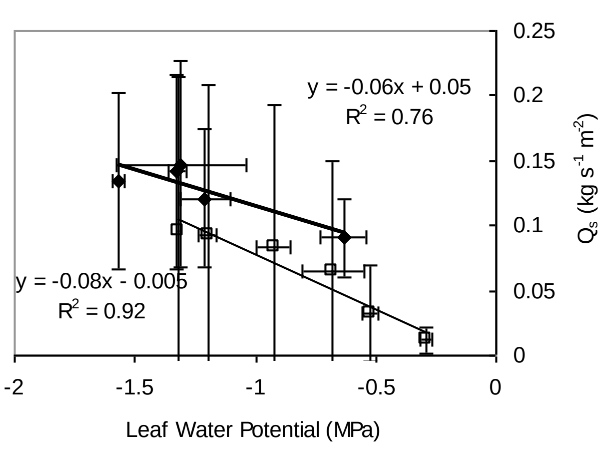

Q (kg hr^{-1})
6
5
4
3
2
1
0
DBH, 22.5 cm
DBH, 24.7 cm
00:00
04:48
09:36
14:24
19:12
00:00
Time of Day

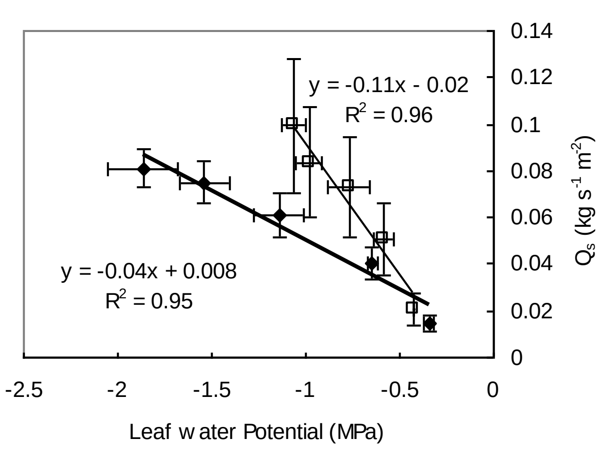

Dorisvale
y = -0.08x + 0.04
R2 = 0.92
y = -0.05x + 0.02
R2 = 0.93
0.25
0.2
0.15
0.1
0.05
0
-2.5
-2
-1.5
-1
-0.5
0
Leaf Water Potential (MPa)
Qs (kg s-1 m-2)


Dorisvale
y = -0.01x + 0.004
R2 = 0.79
y = -0.012x + 0.002
R2 = 0.70
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-2.5
-2
-1.5
-1
-0.5
0
Leaf water potential (MPa)
Qs (kg s-1 m-2)


Douglas/Daly
y = -0.06x - 0.005
R2 = 0.88
y = -0.02x + 0.02
R2 = 0.58
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-2.5
-2
-1.5
-1
-0.5
0
Leaf Water Potential (MPa)
Qs (kg s-1 m-2)


Douglas/Daly
y = -0.07x + 0.01
R2 = 0.92
y = -0.01x + 0.001
R2 = 0.85
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-2.5
-2
-1.5
-1
-0.5
0
Leaf water potential (MPa)
Qs (kg s-1 m-1)


Oolloo Crossing
y = -0.06x + 0.05
R2 = 0.76
y = -0.08x - 0.005
R2 = 0.92
0.25
0.2
0.15
0.1
0.05
0
-2
-1.5
-1
-0.5
0
Leaf Water Potential (MPa)
Qs (kg s-1 m-2)


Oolloo crossing
y = -0.11x - 0.02
R2 = 0.96
y = -0.04x + 0.008
R2 = 0.95
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-2.5
-2
-1.5
-1
-0.5
0
Leaf water Potential (MPa)
Qs (kg s-1 m-2)