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Responses of plant water use to a severe summer drought for two subtropical tree species in the central southern China

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ABSTRACT

Study region: Western suburb of Changsha, Hunan Province, the central southern China.
Study focus: Plant transpiration plays a significant role in the terrestrial water cycle and is closely associated with ecosystem primary production. Summer drought in the study area poses a stress on plant water use and associated carbon assimilation in growing season. In this study, water use response of two evergreen tree species to variation in environmental conditions was examined during a severe summer drought.
New hydrological insights: The results show that a decrease in water use during the drought for both two species is closely associated with an increase in vapor pressure deficit and a decrease in stem water potential. The two species appear to be anisohydric, but to a different degree in response to the drought. The hydrodynamic water potential gradient ($\Delta\psi$) maintains relatively constant with an average value of 0.59 MPa for *C. camphora*, and 1.59 MPa for *O. fragrans*. *O. fragrans* is less sensitive to drought than *C. camphora*, while *C. camphora* shows an effective survival mechanism via leaf shedding and dieback of shoots.

1. Introduction

Forests store 45% of terrestrial carbon and sequester a large amount of carbon annually (Bonan, 2008). Droughts, especially longer droughts and heat waves, impact tree mortality, reduce global net primary production (Zhao and Running, 2010), and may even cause ecosystem restructuring (McDowell et al., 2008). For example, wide spread forest mortality in tropical forests during droughts has been reported leading to a change from a net carbon sink into a large carbon source (Lewis, 2006; Phillips et al., 2009).

Climate change is likely to see an increase in frequency and severity of extreme droughts, high temperature and heat waves (Saxe et al., 2001; Sterl et al., 2008; Allen et al., 2010; Dai, 2012). Droughts, which are often accompanied with high temperature, have important consequences on tree growth and survival. Tree mortality occurs frequently in arid and semi-arid regions during droughts (McDowell et al., 2008). Recent studies suggest that drought impacts also occur in tropical, subtropical and temperate regions (Kocher et al., 2009; Allen et al., 2010; McDowell et al., 2011).

Several mechanisms have been proposed in the literature regarding how trees respond to droughts. Among them, hydraulic failure and carbon starvation are two widely accepted mechanisms (McDowell et al., 2008; Anderegg and Callaway,

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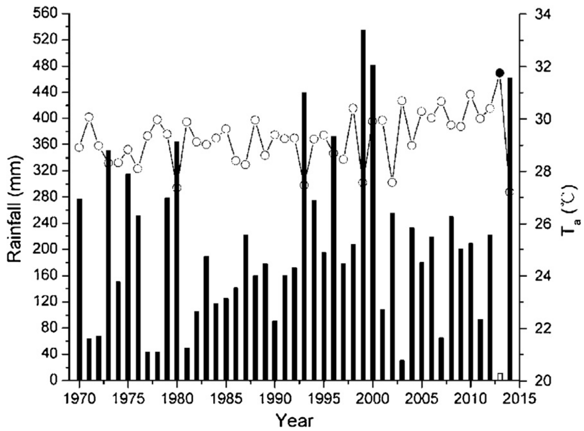

Fig. 1. Rainfall (black bars) and average temperature (T_a, circles) during the selected period corresponding to the 2013 midsummer drought (1th July to 18th August) from 1970 to 2014. The 2013 data are highlighted with the white bar and black dot.

2012; Hartmann et al., 2013). Under drought stress, trees of different functional types have different mechanisms to find a balance between maintaining photosynthesis and reducing transpiration to avoid xylem embolisms. McDowell et al. (2008) demonstrate that different mechanisms can lead to contrasting mortality during a severe multiple-year drought, which may further result in changes in tree species composition.

Droughts, especially those in summer growing season, often occur in the central southern China. Previous studies on forest trees in this area were focused on photosynthesis (Tian et al., 2004; Zhang et al., 2014), variation of vegetation index (Jiang et al., 2011; Guo et al., 2015). However, no studies have examined plant water use in response to drought stress in this subtropical environment. With this knowledge gap, we investigate whole tree water use and short-term regulation mechanisms for two common tree species (*Cinnamomum camphora and Osmanthus fragrans*) in Hunan Province, the central southern China.

This study aims at understanding the response of tree water use to droughts in the subtropical monsoon area in the central southern China. The primary objectives are (1) to examine the response of tree water use to variations of vapor pressure deficit (*VPD*) and root-zone water potential in a summer drought, and (2) to investigate water use strategies and drought response mechanisms of the selected tree species. The study is based on field measurements performed during a severe summer drought in 2013. The result will improve our understanding of the drought tolerance and short-term strategies in coping with droughts for the studied tree species.

2. The study site and measurements

2.1. The study site

The study site is located in the western suburb of Changsha in the central southern China (28°09′46″N, 112°53′20″E, 70 m above sea level). It is characterized with a humid subtropical monsoon climate, with a mean annual precipitation of 1360 mm and mean annual temperature of 17.2 °C. Resulting from different air mass influences in the summer monsoon season, precipitation distributes unevenly between months, often leading to high temperature and low precipitation in midsummer.

The field experiments were conducted from April to October of 2013. A severe drought with frequent high temperatures occurred from 1th July to 18th August, 2013 in the study area. It had the lowest midsummer precipitation and highest air temperature in the recent four decades (Fig. 1). The 2013 midsummer high temperature and drought have been most severe since 1951 (Luo and Li, 2014). This drought provided a good climatic setting to perform the experiments for this study.

Two subtropical evergreen species (*O. fragrans* and *C. camphora*) were selected for this study. The two species are common native species widely distributed to the south of Yangtze River in China. Physiological characteristics of sample trees are listed in Table 1. The *O. fragrans* sample trees are part of a 1500 m^2 plantation established on previous cropland in 2003, and the *C. camphora* trees grow in a natural grove on a nearby hill.

2.2. Measurement of sap flow

Eight sets of heat-pulse sap flow sensors (SFM1, ICT International Pty Ltd., Australia) were used to monitor sap flow of all four sample trees. For each tree, the south and north sides of the trunk were respectively installed with three 35-mm probes (two temperature measurement probes installed at 5 mm above and below the heat probe) at a height of 1.3 m above ground. Two temperature measurement points in each of the two probes were posited in sapwood to capture the sap flux.