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Potential of Photosynthetic Characteristics in Polymorphic Leaves of *Populus euphratica* Olivier

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Abstract: A distinct leaf shape polymorphism occurs within single plants of *Populus euphratica* Olivier. Gas exchange was investigated in broad-ovate (BOL) and lanceolate (LL) leaves, located respectively in the upper crown and lower crown of mature *P. euphratica* growing in its native habitat. This study was designed to clarify the differences of photosynthetic characteristics in wet conditions between those of BOL and LL. BOL showed high Pn_{max}; LL showed low light compensation. Results show that, during wet periods, BOL performs very high photosynthesis production with much water loss. LL has a low photosynthetic rate, but LL can perform effective photosynthesis production in a dark condition.

Keywords: Photosynthetic characteristic, Polymorphism, *Populus euphratica* Olivier

1. Introduction

Being sessile and long-lived, perennial plants might experience widely various environmental changes during their lives. Riparian forests in oases are unstable water resource environments. Oases can reduce negative effects of environmental conditions on plants through evaporative cooling: the so-called oasis effect (Oke, 1987). However, such water-resource-based oasis ecosystems are unreliable because of anthropogenic effects and environmental impact. Riparian forests in oases will experience radical changes in conditions: from wet to hyper-arid. Therefore, specific strategies are necessary to maintain high levels of growth and carbon gain. *Populus euphratica* Olivier is the most common species in oases (Wickens, 1998), distributed from Morocco in the west to the Ordos Plateau in the east (Kurschner, 2004). Mature *P. euphratica* have broad-ovate leaves (BOL) at the upper crown, and lower in crown with sprout of lanceolate leaves (LL) (**Fig. 1**). Juveniles have only the LL type.

In a preceding study, the photosynthesis of BOL and LL with a crown on mature *P. euphratica* was measured in the actual state (Wang *et al*., 1997; Zhang *et al*., 2003). For average daily photosynthetic characteristics, the water use efficiency (WUE) of BOL was higher than that of LL as a result of the higher transpiration rate (*E*) of LL (Wang *et al*., 1997). Regarding the net photosynthetic rate (*Pn*) of BOL, severe photosynthetic depression was observed at midday. In contrast, no midday depression was observed in LL (Zhang *et al*., 2003). Those results, especially that for midday, indicates the photosynthesis characteristic of a water stress condition.

The objective of this study is to clarify the differences of photosynthetic characteristics in wet conditions between the BOL and LL in a crown on mature *P. euphratica* by measuring photosynthesis under conditions that let a branch absorb water.

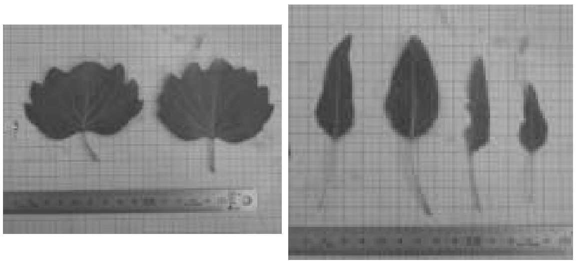

Fig. 1. Morphology of broad-ovate leaves (left, BOL) and lanceolate leaves (right, LL) of *Populus euphratica*.

2. Materials and Methods

This study was conducted in a natural *P. euphratica* forest established along the Heihe River in the Ejina Oasis, Inner Mongolia, China (41˚57'–59'N, 101˚04'–10'E) (**Fig. 2**). This region is in a hyper-arid climatic zone. It has low precipitation and humidity, and wide temperature variation: annual precipitation is 34 mm; relative humidity ranges from 15 to 53%; maximum and minimum air temperatures were 40 ˚C and -26 ˚C, respectively, in 2004. Therefore, Ejina Oasis ecosystems rely heavily on water resources

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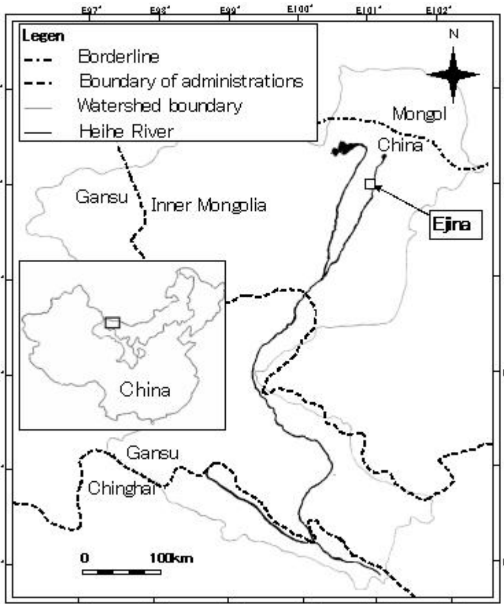

Fig. 2. Study area.

supplied by the Heihe River.

In Ejina Oasis, *P. euphratica* grows in a patchy forest stand with diverse structure (Monda *et al*., 2008). Three trees of *P. euphratica* were selected, which were 4.0 ± 0.3 m height, 3.1 ± 0.4 cm DBH on average and free of disease and pest damage. Furthermore, BOL appeared in the upper part of crown, and LL appeared in the lower part of crown. The vertical distance of BOL and LL was about 2 m.

To obtain a leaf sample that is not in a water stress condition, 2–3 year branches were taken at 8:00; the base of branch was cut off in the water immediately after sampling. The *Pn* and *E* of upper fully extended leaves were measured using a portable photosynthesis system (Li-6400; Li-Cor Inc., Lincoln, NE, USA) during June 3–4 in 2005. The CO_2 concentration and vapor pressure deficit (VPD) in the cuvette were held respectively to 360 ppm and less than 1.5 kPa during measurements. Then WUE was calculated from the P_n/E ratio. To construct light–photosynthesis curves, *Pn* values at different levels of photosynthetic photon flux (PPFD) were measured repeatedly for 3–4 sets of BOL and LL. The *Pn* was stabilized at an irradiance of 1300 μmol m^{-2} s^{-1}; then gas exchange was measured at 11 stepwise irradiance intervals to zero. To obtain the maximal net photosynthetic rate (Pn_{max}) and light compensation, we calculated gas exchange characteristics (Kaleida Graph Version 4.0; Synergy Software Technologies Inc.)

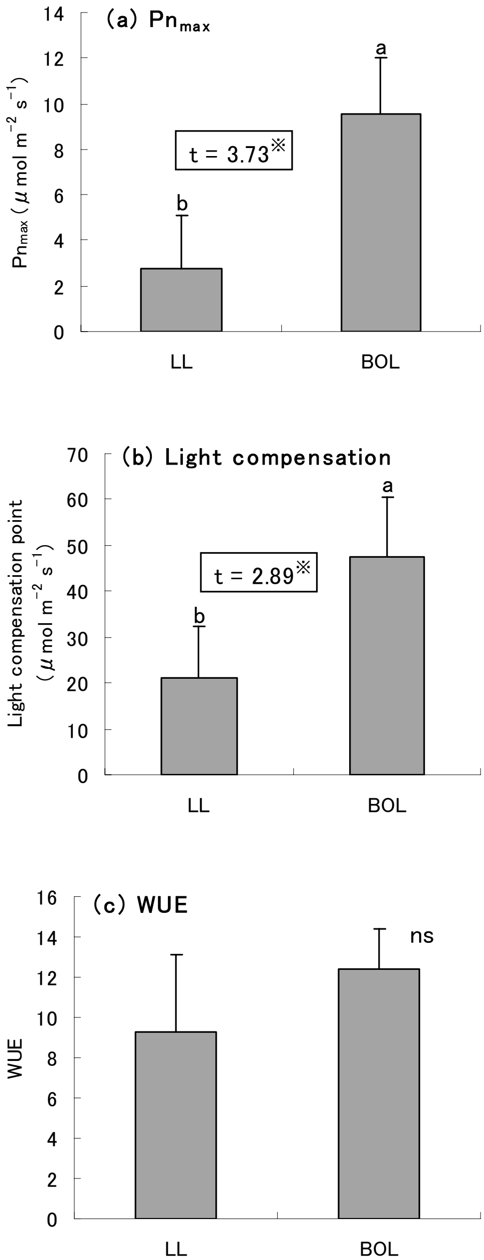

Fig. 3. Photosynthetic characteristics of BOL and LL at different locations in the crown (a) Maximal net photosynthetic rate (Pn_{max}), (b) Light compensation, (c) water use efficiency (WUE) in *P. euphratica*. Vertical bars represent SD (*n* = 4–5). Different letters denote significant difference using Student's *t*-test. (※ p<0.05, ns = not significant)

by non-rectangular hyperbola equation (Johnson and Thornley, 1984) using the observed photosynthesis –PPFD relation.

Differences in photosynthesis characteristics between BOL and LL were analyzed using Student's *t*-test.

3. Results

The Pn_{max} of BOL was significantly higher than LL (t (5) =3.73, p<0.05) (**Fig. 3a**). The light compensation of LL was significantly lower than BOL (t (5) =2.89, p<0.05) (**Fig. 3b**). Those of BOL and LL showed no significant differences in WUE (**Fig. 3c**).

4. Discussion

Results show a difference in the potential of photosynthetic characteristics between BOL and LL. Our result suggests that, in the wet condition, BOL can achieve higher Pn_{max} than LL (Fig. 3a). No significant difference was found between WUE of BOL and LL (Fig. 3c). Therefore, the achievement of high Pn_{max} of BOL is accompanied by the loss of much water.

In the water stress condition, no significant difference was found for average daily *Pn* between BOL and LL (Wang *et al*., 1997) by stomatal closure in midday (Zhang *et al*., 2003). As with other *Populus* species composing riparian forests (Rood *et al*., 2000, 2003; Horton *et al*., 2001), *P. euphratica* adapts itself to changing severe drought conditions through the sacrifice of branches of the upper part of the crown through dieback (Hukin *et al*., 2005; Monda *et al*., 2008). To depress evaporation loss during severe water shortage periods, the dieback phenomenon is observed among desiccation-avoidant trees (Sperry and Pockman, 1993; Horton *et al*., 2001; Rood *et al*., 2000, 2003; Cooper *et al*., 2003).

Therefore, mature *P. euphratica* adapt to environmental changes: during the wet condition, BOL performs very high photosynthesis production with much water loss; during periods of dry conditions, BOL adapts to the available water resources by controlling the loss of the water through stomatal control and crown dieback.

Another interesting point revealed by our study was that light compensation of LL was significantly lower than that of BOL (Fig. 3b), suggesting a shade-leaf type which fitted shaded conditions. Consequently, LL has a low photosynthetic rate, but LL can perform effective photosynthesis production in dark conditions. This photosynthetic characteristic will be advantageous for leaves of the lower part of crown, which easily receives self-cover shade and cover shade from other individuals. All development stages in *P. euphratica* have LL in all or part of the crown. Additional studies are necessary to clarify LL traits for adaptation to dry conditions.

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References

Cooper D.J., D'Amico D.R., Scott M.L. (2003): Physiological and morphological response patterns of *Populus deltoides* to alluvial groundwater pumping. *Environmental Management,* **31**(2):215-226.

Horton J.L., Kolb T.E., Hart S.C. (2001): Physiological response to groundwater depth varies among species and with river flow regulation. *Ecological Applications,* **11**(4):1046-1059.

Hukin D., Cochard H., Dreyer E., Thiec D.L., Boget-Triboulot M.B. (2005): Cavitation vulnerability in roots and shoots: does *Populus euphratica* Oliv., a poplar from arid areas of Central Asia, differ from other poplar species?. *Journal of Experimental Botany,* **56**(418):2003-2010.S

Johnson I., Thornley J. (1984): A model of instantaneous and daily canopy photosynthesis. *Journal of Theoretical Biology*, **107**:531-545.

Kurschner H. (2004): Phytosociological studies in the Alashan Gobi – A contribution to the flora and vegetation of Inner Mongolia (NW China). *Phytocoenologia,* **34** (2):169-224.

Monda Y., Miki N., Yoshikawa K. (2008): Stand structure and forest in the lower reaches of the Heihe River, NW China. *Landscape and Ecological Engineering*, **4**:115-124.

Oke T.R. (1987): Boundary Layer Climates, second ed. Routledge, New York.

Rood S.B., Patino S., Coombs K., Tyree M.T. (2000): Branch sacrifice: cavitation-associated drought adaptation of riparian

cottonwoods. *Trees - Structure and Function*, **14**(5):248-257.
Rood S., Braatne J., Hughes F. (2003): Ecophysiology of riparian cottonwoods: stream flow dependency, water relations and restoration. *Tree Physiology,* **23**:1113-1124.
Sperry J.S., Pockman W.T. (1993) Limitation of transpiration by hydraulic conductance and xylem cavitation in *Betula occidentalis*. *Plant Cell and Environment,* **16**(3):279-287.
Wang H., Yang S., Zhang C. (1997): The photosynthetic characteristics of differently shaped leaves in *Populus euphratica* Olivier. *Photosynthetica*, **34**(4):545-553.
Wickens G.E. (1998): *Ecophysiology of economic plants in arid and semi-arid lands*. Springer, Berlin.
Zhang L., Guo J., Li W., Zhang F., He W., Feng J., Bi Y. (2003): Diurnal changes in photosynthetic characteristics of two differently shaped leaves in the desert plant *Populus euphratica*. *Israel Journal of Plant Sciences*, **51**:251-259.