

Woody Species Variations in Biomass Allocation, Photosynthetic WUE and Carbon Isotope Composition under Natural Drought Condition in Mongolia

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ABSTRACT

Water is one of the most limiting environmental factors for successful rehabilitation in Mongolia. In this study, variations in biomass allocation, water use efficiency (WUE) and carbon isotope composition of five woody species (*Caragana arborescens* Lam., *Hippophae rhamnoides* L., *Larix sibirica* Ledeb., *Pinus sylvestris* L. and *Ulmus pumila* L.) seedlings were investigated in an open field nursery. There are diverse responses of species under drought conditions. Hardwood species, *U. pumila*, showed the lowest photosynthetic WUE and carbon isotope composition among five species but demonstrated superior morphological response in terms of root weight ratio (0.49 ± 0.02) and root biomass allocation compared to other species ($p < 0.01$). Conifer species, *L. sibirica* and *P. sylvestris*, showed higher photosynthetic WUE (4.52 and $3.59 \mu\text{mol CO}_2/\text{mmol H}_2\text{O}$ in July and 7.66 and $6.86 \mu\text{mol CO}_2/\text{mmol H}_2\text{O}$ in August, respectively) than other species with lower transpiration rate relative to photosynthesis ($p < 0.05$). However, shrub species, *H. rhamnoides*, exhibited higher carbon isotope composition ($-26.5 \pm 0.3 \delta^{13}\text{C}$) and demonstrated high potential competitiveness than tree species under drought condition ($p < 0.001$). It is concluded in this study that all the studied species showed diverse responses under drought condition owing to their specific morphological, physiological and genetic characteristics. Although the results of ranking species were different when measuring various parameters, WUE which was measured by photosynthetic parameters may not be a representative of the overall WUE. Also, carbon isotope composition has several conceptual and logistic advantages to monitor plants' drought tolerance. In line with this, *H. rhamnoides* and *L. sibirica* are the most recommended species for rehabilitating arid areas in Mongolia.

Key words: *Caragana arborescens*, carbon isotope discrimination, drought tolerance, field nursery, *Hippophae rhamnoides*, *Larix sibirica*, photosynthesis, *Pinus sylvestris*, root weight ratio, *Ulmus pumila*, water deficit

INTRODUCTION

Mongolia is one of the biggest land-locked nations in Asia experiencing serious drought and desertification (Tsogtbaatar 2007). More than 40% of the territory is composed of deserted areas, and over 90% of the territory is referred to as arid, semi-arid, moderately arid and moisture deficient regions (Sarantuya 1999). It is mainly caused by low annual precipitation lower than 400 mm yr^{-1} as well as forest degradation and exploitation (Park et al. 2009; Tsogtbaatar 2004). During the last decade, Mongolia has lost approximately 4 M ha of forests, averaging to 40,000 ha annually. Between the year 1990 and 2000, the rate of deforestation increased to 60,000 ha yr^{-1} . As a result of this ongoing loss and degradation, 5.3 M ha of forests are fragmented and degraded (World Bank 2002).

A tree replanting program has been conducted by the Mongolian Government for 30 years but the area successfully replanted represents only 5% of the total forest lost, mostly due to low survival rates of the seedlings (Mühlenberg et al. 2006). At present, 150,000 ha of forest need to be rehabilitated but only 5,000 ha are being planted annually (UNEP 2001). Rehabilitation activities encounter numerous

challenges which includes soil moisture deficit as one of the most limiting environmental factors for tree survival and growth in Mongolia. Thus, selection of drought tolerant trees may represent the best option to promote seedling survival and growth rate in large-scale rehabilitation of Mongolia (Ykhanbai 2010).

Several studies have been conducted to compare species and population variations under drought condition using several methods and techniques (Correia et al. 2008; Cregg 1994; Patterson et al. 1997; Poorter and Markesteijn 2008). As a result of water limitation, plant responses are complex involving stress avoidance and adaptive changes (Chaves et al. 2002; Chen et al. 2007), and have developed a wide diversity of drought tolerance mechanisms from both morphological and physiological aspects (Blum 1997; Meier and Leuschner 2008). The change in root to shoot dry mass ratio has been considered as one of the mechanisms involved in the adaptation of plants to drought stress (Turner 1997).

Water use efficiency (WUE) is an important indicator

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