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# Drought resistance of two Douglas fir species (*Pseudotsuga menziesii* (Mirb.) Franco and *Pseudotsuga macrocarpa* (Torr.) Mayr.): relative importance of water use efficiency and root growth potential

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## Introduction

In order to optimize the choice of species for reforestation in regions subjected to summer water shortage, it is important to determine which physiological components may be involved in their drought adaptation. Therefore, we have carried out this study aimed at comparing the ecophysiological behavior of 2 Douglas fir species: *Pseudotsuga menziesii* (Mirb.), originating from a relatively wet coastal zone (Ashford, WA, U.S.A., 300 m elevation) and *Pseudotsuga macrocarpa* (Torr.) Mayr., growing under drier conditions (CA, U.S.A., 1315 m elevation).

## Materials and Methods

Carbon dioxide assimilation rate *(A)*, stomatal conductance $(g_s)$ and transpiration rate *(E)* were measured on 2 yr old seedlings: 1) during a soil water depletion cycle (the water status of the plants was determined by predawn water potential measurements), while the leaf-to-air water vapor pressure difference $(\Delta W)$ was maintained at 4.6 Pa·KPa$^{-1}$, and 2) in response to increasing $\Delta W$ in well-watered plants. The measurements were performed with an assimilation chamber in which air temperature, ambient $CO_2$ concentration, photosynthetic photon flux density and water vapor pressure were controlled. Analyzing the data trough *A* *vs* Intracellular $CO_2$ molar fraction $(C_i)$ graphs, we could determine stomatal and mesophyll components of changes in *A* (Prioul *et al.*, 1984; Jones, 1985). The gas exchange response to $\Delta W$ was also examined with respect to the optimization theory of Cowan and Farquhar (1977).

In a second experiment (Grieu and Aussenac, 1988), non-destructive measurements of the number of growing roots and root elongation were made on 3 mo old seedlings of the 2 species grown in root boxes.

## Results

Data of Fig. 1a show that the peak rates of *A* were higher in *P. menziesii* than in *P. macrocarpa*. After an initial increase, mesophyll photosynthesis remained unchanged over a wide predawn water potential range in both species, while $g_s$

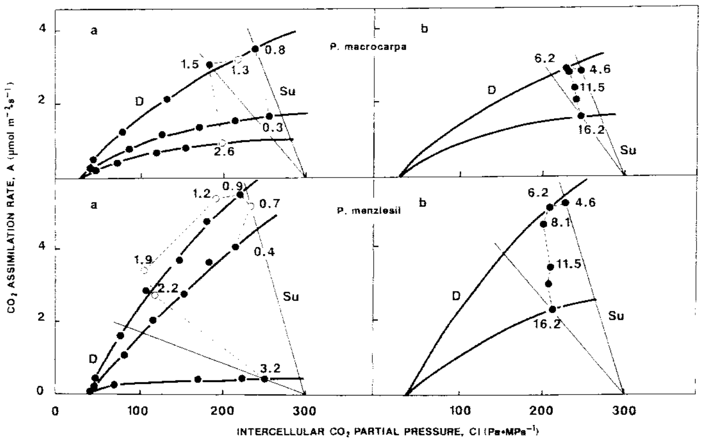

**Fig. 1.** Rate of $CO_2$ assimilation *(A)* against intercellular $CO_2$ molar fraction *($C_i$)*. **a.** At different leaf predawn water potential levels reported on the figure (absolute values in MPa) at a $\Delta W$ = 4.6 Pa·KPa$^{-1}$. **b.** At different $\Delta W$ levels reported on the figure (Pa·KPa$^{-1}$) in well-watered plants. *D:* photosynthetic demand functions for $CO_2$, *Su:* $CO_2$ supply functions at ambient $CO_2$ molar fraction $C_a$ = 300 Pa·MPa$^{-1}$. *D* has been established either experimentally by varying $C_a$ or extrapolated ($\Delta W$ responses) from experimental data not reported here. For a given species and experiment, only the 2 extreme *Su* have been reported. In both experiments, the points obtained at $C_a$ = 300 Pa·MPa$^{-1}$ have been joined (dashed line). (Adapted from Grieu *et al.*, 1988.)

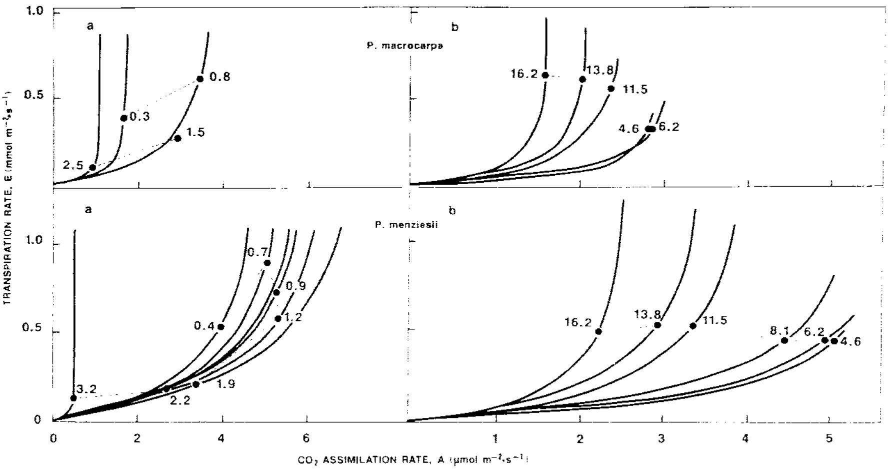

**Fig. 2.** Transpiration functions *E*(*A*) **a.** At different leaf predawn water potential levels and $\Delta W$ = 4.6 Pa·MPa$^{-1}$. **b.** At different $\Delta W$ (Pa·KPa$^{-1}$) levels in well-watered plants. The different water potential and $\Delta W$ values are directly reported in the figure. For a given water potential or $\Delta W$, *E*(*A*) is the function that would be obtained if only stomatal conductance were changed. The slope of *E*(*A*) at the actual experimental point is equal to the marginal unit water cost of $CO_2$ assimilation ($\partial E/\partial A$). Optimal stomatal functioning would imply $\partial E/\partial A$ to be constant with $\Delta W$. (Adapted from Grieu *et al.*, 1988.)

was reduced. At higher soil drought, a dramatic decline of mesophyll photosynthesis was noted starting from −1.5 MPa in *P. macrocarpa* and −1.9 MPa in *P. menziesii.*

In both species, stomatal conductance and especially mesophyll photosynthesis were dramatically decreased, as $\Delta W$ was increased (Fig. 1b).

*P. macrocarpa* had the highest and the most unstable – and thus non-optimal – values of $\partial E/\partial A$ in response to increasing $\Delta W$ (Fig. 2a). *P. macrocarpa* also had the highest $\partial E/\partial A$ at high water potential (Fig. 2b).

Growth of the pre-existent roots was more important in *P. macrocarpa* than in *P. menziesii* and growth of the new roots was similar in both species (Fig. 3). Furthermore, *P. macrocarpa* explored the deep soil layers more quickly tha *P. menziesii* (Fig. 4.).

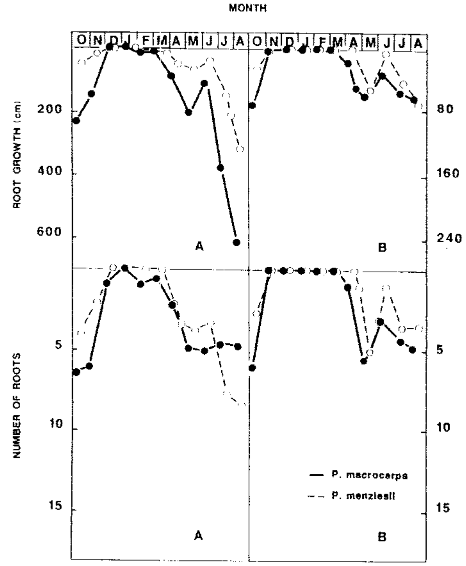

**Fig. 3.** Monthly time-course of number of growing roots and of root elongation in the 2 species studied. **A.** Existing roots. **B.** New roots. (Adapted from Grieu and Aussenac, 1988.)

## Conclusions

Unexpectedly, in the present comparative study the results show that the drought-resistant *P. macrocarpa* had the lowest gas exchange rates and exhibited the least conservative water economy.

The high drought adaptation of *P. macrocarpa* seems to be due mainly to

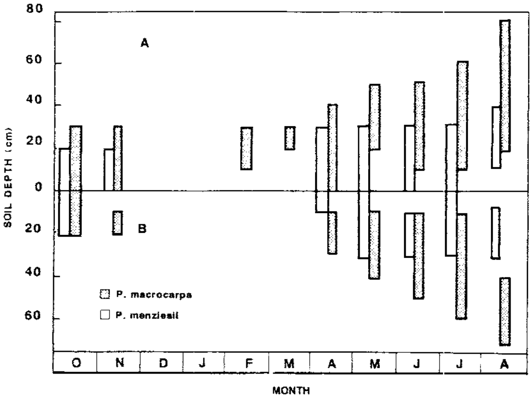

**Fig. 4.** Soil depth at which monthly root growth of the 2 species studied was observed. **A.** Growth of the pre-existing roots. **B.** Growth of the new roots. (Adapted from Grieu and Aussenac, 1988.)

efficient root growth and soil exploration abilities, whereas, surprisingly, no adaptation features seem to have developed at the leaf level.

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