

## Effect of water stress on potassium distribution in young seedlings of maritime pine (*Pinus pinaster* Ait.)

A. Nguyen<sup>1</sup> and A. Lamant<sup>2</sup>

<sup>1</sup> INRA, Laboratoire d'Amélioration des Arbres Forestiers, Pierrotot, 33610 Cestas, and

<sup>2</sup> Laboratoire de Biologie et Physiologie Végétales, (CNRS UA568), Université de Bordeaux I, av. des Facultés, 33405 Talence, France

### Introduction

One possible adaptational response of plants with respect to drought is osmotic adjustment (Kramer, 1980). At low water potential, the maintenance of turgor is needed to sustain cell enlargement. Two cellular processes may be involved in turgor maintenance: variation in cell wall elasticity and/or accumulation of intracellular solutes. Actually, without any information on the volumetric modules of elasticity, most authors ascribe the maintenance of turgor to an increase of intracellular solutes. The cation potassium, which is the major osmotic component in plant cells, is often thought to be a possible osmoregulator (Wyn Jones and Gorham, 1983).

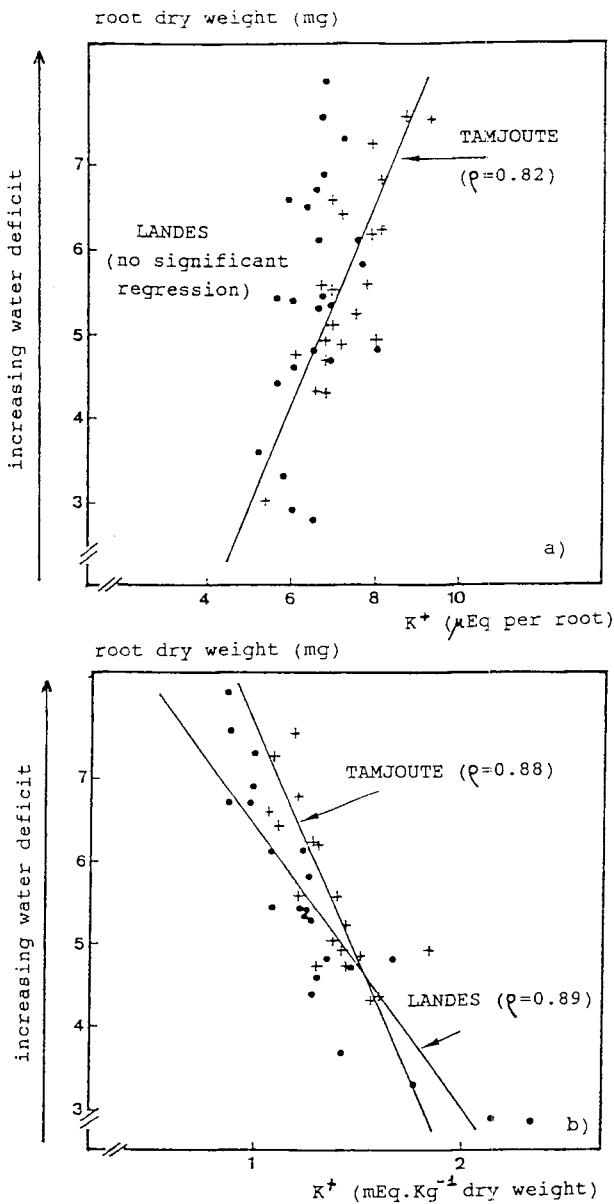
In this paper, two populations of maritime pine (*Pinus pinaster* Ait.), a drought-sensitive one ('Landes' from France) and a better adapted one ('Tanjoute' from Morocco) were compared for potassium content and migration to the aerial parts. In a previous study (Nguyen and Lamant, 1989), a more intense osmoregulation was found in root apices of young seed-

lings of the Tanjoute population compared to seedlings of the Landes population.

### Materials and Methods

Seedlings were grown on an aerated nutrient solution (Seillac, 1960). The intensity of light was 30 W·m<sup>-2</sup>, with a 14 h photoperiod, a relative humidity of 45/70% day/night and a temperature of 24/22°C. Water deficit was applied only to roots by a step-wise addition of PEG (polyethylene glycol) to the solution (-0.1 MPa/12 h or 24 h). The different final degrees of water stress were: -0.03 (nutrient solution without PEG); -0.2, -0.5 and -0.8 MPa. K<sup>+</sup> contents were determined by emission spectrophotometry.

Measurements of K<sup>+</sup> transport from roots to shoots were performed according to the method detailed by Jeschke and Jambor (1981). A set of 20–25 plants, previously water-stressed as described above were placed in labeled (<sup>86</sup>Rb<sup>+</sup>) PEG solutions ( $S_0 = 400 \mu\text{Ci} \text{ }^{86}\text{Rb}^+ \cdot \text{mM}^{-1}$  K<sup>+</sup>). Experiments were run at 23–25°C in the dark so that the fluxes were not disturbed by stomatal regulation. Samples of 2–4 plants were regularly harvested at intervals from  $t = 0$  to  $t = 30$  h and 2 replicates of the experiment were performed. Tracer contents in the aerial parts were converted into meq of K<sup>+</sup> and expressed on a root fresh weight basis in order to limit the effect



**Fig. 1.** Relations between root dry weight (mg) and a)  $K^+$  content ( $\mu\text{Eq per root}$ ) and b)  $K^+$  concentration ( $\text{meq} \cdot \text{kg}^{-1}$  dry weight). Each point represents one root. Provenances: Landes (●); Tamjoute (+).

of variation in the absorptive surface. Roots accumulated labeled  $K^+$  and, after 5–6 h, the absorbed  $K^+$  shoot contents showed a linear

variation as a function of time, the slope being the expression of the migration to the aerial parts.

## Results

### *Variation in K<sup>+</sup> content with applied water deficits*

Potassium concentrations varied significantly only in roots: expressed on a tissue water content basis, an increase of +30 mm (-0.5 MPa treatment) was observed for both populations; expressed on a dry matter basis, potassium contents decreased with the water deficit treatments. These responses are the result of 3 simultaneous variations: accumulation of dry matter in roots with water stress (Nguyen and Lamant, 1989), water loss and variation in the K<sup>+</sup> content. Fig. 1a and b (inspired by the work of Hajji (1979)) were

used to evaluate the differentiated K<sup>+</sup> response of the two populations of pine; they illustrate the relations between the dry weight of a sample and its K<sup>+</sup> content. An accumulation of K<sup>+</sup> was found in roots of the Moroccan seedlings, while the contents were maintained for the French plants.

### *Potassium migration to the aerial parts*

Under well-watered conditions (-0.03 MPa treatment), K<sup>+</sup> migration to the aerial parts was two times higher for the Landes population. (Fig. 2). However, the translocation decreased with water stress, while it was maintained for the Tamjoute population.

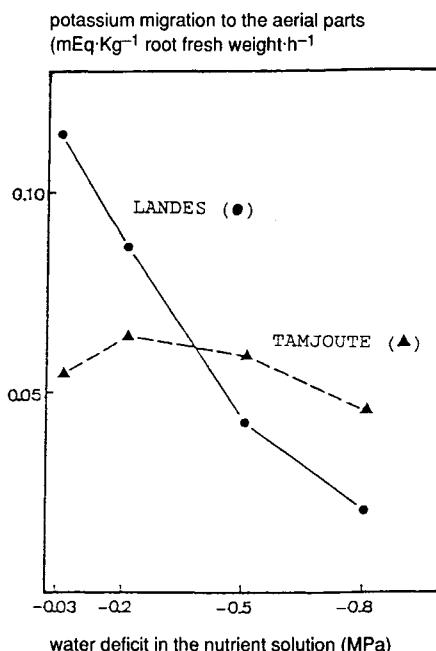
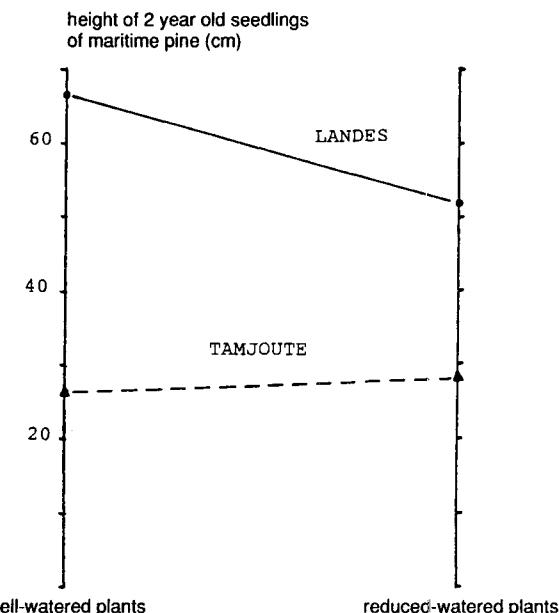


Fig. 2. Variation in the potassium migration to the aerial parts of seedlings subjected to a range of osmotically imposed water deficits. Provenances: Landes (●); Tamjoute (▲).



**Fig. 3.** Height values of 2 yr old seedlings from the two provenances (Landes and Tamjoute) subjected to well-watered or reduced-watered conditions in a greenhouse (from Sarrauste, 1982).

### Discussion and Conclusion

The examination of variations in the K<sup>+</sup> content under water stress showed that the potassium amount per root remained constant for French seedlings, while it increased for Moroccan seedlings, and the evolution of dry matter was similar for both populations. A slightly lower water loss was found for the Tamjoute population (Nguyen and Lamant, 1989): this would mean that the increase of +30 mM was only the result of root tissue dehydration in French seedlings, while the same increase in Moroccan seedlings integrated a part of the K<sup>+</sup> supply resulting in better tissue water status.

According to this analysis, the active contribution of K is underlined. With the hypothesis that the cation is homogeneously distributed in the plant cell, an

increase of +30 mM means that the variation of osmotic potential due to K<sup>+</sup> is only of about -0.07 MPa. However, the intracellular distribution of potassium has to be considered: other experiments (Nguyen, 1986) showed that the osmotic contribution of K<sup>+</sup> seemed to be quite significant in the cytoplasmic compartment.

It is interesting to note that the variation in potassium translocation closely parallels the height growth performances of 2 yr old seedlings subjected to different watering conditions (Fig. 3). The question is raised as to the contribution of a reduced supply of potassium to the lower growth under water stress. Pitman and Cram (1977) found that the rate of K<sup>+</sup> export from the root to the shoot in barley seedlings was proportional to the relative growth rate.

The control of K<sup>+</sup> export to the aerial parts could be localized at 2 boundaries in the root: 1) the ion secretion mechanism into xylem vessels and 2) the net K<sup>+</sup> uptake from the substrate at the plasmalemma of cortical and endodermal cells. The K<sup>+</sup> accumulation with water stress found in Moroccan seedling roots and some preliminary studies tend to favor the second possibility.

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