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Classification and salt tolerance analysis of barley varieties

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ABSTRACT

Six varieties of barley (*Hordeum vulgare*), five of which were provided by ICARDA, were tested in a green house experiment for their salt tolerance. Afterwards the ICARDA variety Melusine, selected from this experiment for its combination of high yield and salt tolerance, was compared in a lysimeter experiment with the variety ISABON3, a very salt tolerant land race originally from Afghanistan.

The variety ISABON3 showed a larger grain and straw yield under non-saline and saline conditions. The higher salt tolerance expressed itself during the growth period in:

- a higher stomatal conductance during the irrigation interval;
- a higher maximum osmotic potential;
- a more vigorous growth, less affected by salinity;
- no salinity effect on plant height and number of productive stems;
- less salinity effect on water use efficiency.

The less tolerant variety Melusine showed a better grain quality, expressed by its protein content that even slightly increased at increasing salinity against a decrease of the protein content of ISABON3.

The varietal salt tolerance clearly affects the water use efficiency and the salt tolerance classification.

1. Introduction

Barley (*Hordeum vulgare*) is an important crop used as feed for animals, malt, and human food. Its importance derives from the ability to grow and produce in marginal environments, which are often characterized by drought, low temperature and salinity (Van Oosterom et al., 1993; Baum et al., 2004; Maas and Hoffman, 1997). The barley breeding research has been trusted by world mandate to ICARDA.

Considerable progress was made during the last 20 years in identifying barley varieties tolerant to drought and the characteristics associated with drought tolerance (Acevedo

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and Ceccarelli, 1989; Ceccarelli and Grando, 1996; Grando et al., 2001). The characteristics consistently associated with higher grain yield under drought are growth habit, early growth vigor, earliness, plant height under drought, long penducle and short grain filling duration (Ceccarelli et al., 2004). Three traits related to survival under severe drought are stomatal conductance (Sinclair, 2000), osmotic adjustment (Serraj and Sinclair, 2002) and desiccation tolerance (Ramanjulu and Bartels, 2002).

In all salt tolerance classifications barley, cotton and sugar beet are listed at the top of the annual crops (Maas and Hoffman, 1997; Ayers and Westcot, 1985; Francois and Maas, 1994; Maas and Grattan, 1999). These classifications, however, are only based on observations of one or two varieties (Sharma and Goyal, 2003). The varietal salt tolerance of barley is a largely unexploited subject. The only paper on this subject, to our knowledge, was published in 1953 by Ayers, concerning germination and emergence. The recent study of Jaradat et al. (2005) cannot be considered as a veritable comparison of barley varieties since it only compares seven subpopulations of the same land race.

The delay in the analysis of varietal salt tolerance holds true for almost all crops (Sharma and Goyal, 2003). A lack of clarity exists in literature about the concept of varietal salt tolerance. According to Maas and Grattan (1999) it is not always clear if the varietal differences reflect differences in salt tolerance or differences in adaptation to the particular climatic or nutritional conditions under which the crops were tested.

This study regards the varietal salt tolerance of barley and is a follow-up of previous studies on chickpea, faba bean and durum wheat (Katerji et al., 2001; Katerji et al., 2005a,b). The study consists of two parts:

- A greenhouse experiment for the salt tolerance classifications of six barley varieties, five of which were selected by ICARDA for their drought tolerance or high productivity. The varieties are classified according to the relationship between irrigation water salinity and grain yield.
- A lysimeter experiment with two varieties: a variety of ICARDA (variety Melusine), selected from the greenhouse experiment as highly productive and salt tolerant, and the variety ISABON3. The latter is a land race, originally from Afghanistan and identified as particularly salt tolerant during a field study in Iran (Grando, personal communication). The experiment aims at comparing the salt tolerance of both varieties and to identify a number of physiological and agronomic parameters associated with salt tolerance of barley.

For salt tolerance analysis of cereals in general and barley in particular a large number of parameters are used such as germination percentage (Jaradat et al., 2005), rates of Na and Cl accumulation in leaves (Munns et al., 1995), ion concentration in root cells (Flowers and Hajibagheri, 2001), osmotic potential (Morgan, 1983), leaf water potential (Katerji et al., 1992), midday stomatal conductance and differential canopy temperature (Katerji et al., 1992; Isla et al., 1998), carbon isotope discrimination (Isla et al., 1998), relationship between grain yield and soil salinity (Maas and Grattan, 1999) and water use efficiency (Katerji et al., 2003).

The parameters used for the salt tolerance analysis of barley in this study include short-term observations (pre-dawn leaf water potential, stomatal conductance), middle-term observation (osmotic adjustment, development of phenological stages, growth) and long-term observations (yield, evapotranspiration, water use efficiency). By choosing these parameters it is possible to analyse the salinity effect on plant growth during the whole growth period (Munns, 2002) and to give practical indications for saline water use.

2. Experimental procedure

2.1. *Greenhouse experiment*

2.1.1. *Set-up*

The set-up consisted of 72 pots made from sections of 0.4 m diameter polyvinyl chloride pipe cut into 0.6 m sections and sealed at the bottom with a 0.2 mm mesh and filled with 5 cm coarse gravel on the bottom and then 50 cm of the same clay as used in the lysimeter experiment.

Three water qualities were used for irrigation: fresh water as a control with an EC of 0.9 dS/m and two saline waters with an EC of 5 and 10 dS/m, obtained by adding equivalent amounts of NaCl and $CaCl_2$ to fresh water. Water was applied with a leaching fraction of 0.25 when the moisture content decreased to 70% of the available water in the root zone and drainage water was collected.

2.1.2. *Crops*

Table 1 presents the name and characteristics of the six varieties. Five varieties were selected by ICARDA in the barley selection program for their high productivity and drought tolerance. The basic philosophy of this program was discussed in a recent paper by Ceccarelli et al. (2004). As the program does not include salt tolerance, no data are available about this aspect of the varieties. The variety California Mariout is an ancient American variety resistant to diseases, drought and salinity.

The barley varieties were sown on 23 November 2002 at a rate of 40 seeds per tube. Fresh water was used for seed emergence. Three weeks after sowing, when the seedlings were well developed, the plants were thinned out to 30. Immediately after thinning fertilising was done, using KH_2PO_4 at a rate corresponding with 150 kg P_2O_5/ha and 100 kg K/ha, and NH_4NO_3 at a rate of 120 kg N/ha.

After complete maturity, the plants of each tube were harvested, divided in straw and grain and dried for 18 h at 70 °C.

The experiment comprised six barley varieties and three water qualities in four replications.

2.2. *Lysimeter experiment*

2.2.1. *Set-up*

The set-up consisted of 30 lysimeters of reinforced fibre glass with a diameter of 1.20 m and a depth of 1.20 m. A layer of coarse sand and gravel, 0.10 m thick, was overlain by a repacked soil profile of 1 m. At the bottom of the lysimeter, a pipe serving as a drainage outlet connected the lysimeter to a