Effect of Saline Conditions on Germination of Herbicide-Resistant and Sensitive *Echinochloa crus-galli* Populations Collected in Italian Rice Fields

Francesco Vidotto, Francesca Serra, Silvia Fogliatto, Aldo Ferrero
Dip. di Scienze Agrarie, Forestali e Alimentari, Univ. Torino, IT, francesco.vidotto@unito.it

Introduction

Salinity represents one of the major limitations for yield and quality of crops (Maggio et al., 2011). According to the estimates of the United Nations Food and Agriculture Organization, about 20% of irrigated land is affected by the increase of salinity levels (Rozema and Flowers, 2008). This phenomenon is accentuated by the competition for fresh water for agricultural and civil uses, and it is reported to be associated to climate change, population growth (Maggio et al., 2011), socio-economic development and water contamination (Balia and Viezzoli, 2015). In Europe 26 countries, Spain, Portugal, Italy, Greece (Ghiglieri et al., 2012) and France (Fabre et al., 2005) are interested by cases of salinization (Maggio et al., 2011). In Italy, saltwater intrusion phenomena are found in some areas including the Po Plain and the Oristano Province, both interested by rice cultivation.
The process of salinization in combination with the presence of highly problematic weeds can potentially represent an additional threat to rice crop yield in the future. Among the main rice weed species, the control of *Echinochloa crus-galli*, in particular, has become problematic as a consequence of the selection of populations resistant to different herbicides (Panozzo et al., 2013).At present, the effects of salinity on herbicide-resistant weed populations have not been investigated and the response to salinity increase in terms of competition-related behavior is not known.
A study was carried out with the aim to evaluate the effect of salinity on germination behavior of *E. crus-galli* populations resistant and sensitive to ALS-inhibitor herbicides.

Methods

Plant material. Seeds of six *E. crus-galli* populations collected in Italian rice fields, three resistant and three sensitive to ALS-inhibitor herbicides, were used during the trials.
Effect of water salinity on germination. In order to evaluate the effect of water salinity on the germination, for each tested population, 20 seeds were placed in Petri dishes lined with one filter paper imbibed with 5 ml of deionized water or saline solution. Nine different salt (as NaCl) concentrations, ranging from 0 mM to 400 mM, were applied. These concentrations were chosen based on previous studies and on water salinity levels found in some European rice cultivation areas.
Petri dishes were incubated in a growing chamber at the constant temperature of 25 °C. Seed germination was recorded every day for 15 days. At the end of the incubation period, root and shoot length were measured on a sample of 10 seedlings for each Petri dish.
Statistical analyses. Seed germination data were fitted to a binomial log-logistic regression model. Shoot and root length data were fitted to a linear regression model. In both cases, salt concentration was set as the independent variable. The effective concentration (EC_{50}), which is the salt concentration required to reduce by 50% seed germination and root and shoot length, was calculated starting from the regressions.

Results

The results showed that seed germination and early growth of seedling of the tested *E. crus-galli* populations were, in general, affected by salinity. Variability between resistant and sensitive populations was found in terms of germination capacity (GC), time required for the first germination and length of roots and shoots under saline conditions. However, this variability must be attributed not only to salt stress but also to the variability observable among the tested populations; this is evidenced by the presence of significant differences also within the resistant and the sensitive populations.

In general, sensitive populations were characterized by a germination capacity higher than the resistant ones. Averaging among sensitive populations, GC remained higher than 80% up to a salt concentration of 250 mM; at 300 mM, 350 mM and 400 mM the recorded GC was 69%, 33% and 13%, respectively.
Averaging among resistant populations, GC was higher than 60% up to a salinity concentration of 250 mM, while at 300 mM, 350 mM and 400 mM GC dropped to 51%, 38% and 14%, respectively.
The NaCl concentration required to reduce by 50% the GC (EC_{50}) averaged 336 mM in the case of sensitive populations and 344 mM in the case of the resistant ones.
Increase of salinity resulted also in a delay of germination. In this case, at high salt concentrations the resistant populations showed a more rapid germination than the sensitive, even though the difference was not significant. On average, the time required for the first germination ranged from 2 days in the control to 9.5 days at 400 mM and from 2.33 to 6.5 days in the case of sensitive and resistant populations, respectively.
Root and shoot length decreased with the increase of salt concentration. Root length ranged from 10.30 cm in the control to 0.39 cm at 400 mM for the sensitive populations and from 9.47 cm to 0.22 cm for the resistant ones. The salt concentration required to reduce by 50% root length was 159.76 mM and 162.60 mM for sensitive and resistant populations, respectively.
Shoot length ranged from 6.62 cm in the control to 0.32 cm at 400 mM in the sensitive populations and from 5.59 to 0.33 cm in the resistant ones. The saline concentration required to reduce by 50% shoot length averaged 216.10 mM and to 246.10 mM in susceptible and resistant populations, respectively.

Conclusions
Salinity affected germination and first seedling growth in several *E. crus-galli* populations. The results showed that there is no clear evidence that populations resistant to ALS-inhibitor herbicides respond differently to salinity compared to sensitive. In general, shoot growth was less affected by salinity than the root growth. This may lead to changes in competition behavior exhibited by this species under saline conditions. The results obtained represent useful information for future *E. crus-galli* management, provided the potential increase of rice areas affected by water salinity in Europe.

References
Balia R. and Viezzoli A. 2015. Integrated interpretation of IP and TEM data for salinity monitoring of aquifers and soil in the coastal area of Muravera (Sardinia, Italy). Bollettino di Geofisica Teorica ed Applicata, 56: 31- 42.

Fabre D. et al. 2005. Characterizing stress effects on rice grain development and filling using grain weight and size distribution. Field Crop Res., 92:11-16.

Ghiglieri G. et al. 2012. Analysis of salinization processes in the coastal carbonate aquifer of Porto Torres (NW Sardinia, Italy). J. Hydrol., 432–433: 43–51.

Maggio A. et al. 2011. Saline agriculture in Mediterranean environments. Italian J. Agron., 6:e7: 36-43.

Panozzo S. et al. 2013. Target-site resistance to ALS inhibitors in the polyploid species Echinochloa crus-galli. Pestic. Biochem. Phys., 105: 93–101.

Rozema J. and Flowers T., 2008. Crops for a Salinized World. Science, 322: 1478-1480.