DOES SALT STRESS INCREASE WEEDS INVASIVENESS?

LO STRESS SALINO AUMENTA L'INVASIVITA' DELLE SPECIE INFESTANTI?

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Abstract
Weed management is critical in agricultural productions. However, the link between environmental changes, weeds growth and their invasiveness has been not sufficiently addressed. Weeds are known for their ability to survive and spread in unfavorable environments including soils affected by high salinity. Salinization of agricultural lands is increasing due to reduced rainfall and inadequate irrigation management. Therefore, if weeds are less affected by salinity than crops expanding salinization could increase weeds invasiveness, enhancing their competition vs. crops.
In this context, we started to elaborate a meta-analysis study based on original research papers in which we associated the relative tolerance of weeds and crops to salt stress and we highlighted possible implications for weed management. Our findings, at this stage, showed that weeds generally exhibit halophytic behavior when subjected to salt levels that are unacceptable for most agricultural crops. These results may anticipate increasing weeds invasiveness in future agricultural systems.

Key words: weeds, competition, salinity, plant growth, environmental changes.
Parole chiave: erbe infestanti, competizione, salinità, crescita della pianta, cambiamenti ambientali.

Introduction
Weeds are responsible for significant crop yield losses in agricultural productions (Oerke, 2006). High competition with crops occurs when the availability of a resource is not adequate (Patterson, 1995). Yield loss depends on the infesting weed species, their population density and duration of infestation, as well as the soil conditions including high salinity levels (Azmi et al., 2007).
The progressive salinization of cultivated lands is a major abiotic stress responsible for reduced crop production in many of the world's regions (Rengasamy, 2006). Plants may have different growth responses to salinity and therefore different tolerance levels (Munns and Tester, 2008).
With increasing soil salinization weed control methods could benefit of a better understanding of the physiological mechanisms associated to crops and weeds response to salinity (Radosevich et al., 2007; Gurevitch et al., 2009). The field composition of weed species is strongly influenced by environmental heterogeneity, which is related in part to crop type and management practices and in part to specific environmental conditions and availability of environmental resources (Patterson, 1995; Petit et al., 2011).
Soil salinity can influence the germination and growth of weed species (Chauhan and Johnson 2010). Based on these findings, we started to investigate the response of several weeds and associated affected crops to salinity. Our purpose is to develop a database that could provide a range of information aimed at better understanding future invasiveness of weeds with the increasing salinization of cultivated lands.

Materials and methods
A meta-analysis was started based on original research papers in which the tolerance of over 70 weed species to different levels of salinity was evaluated. For assessment of crop salinity tolerance, we referred to the Maas and Hoffman model (1977) and Tanji and Kielen (2002). We used tolerance threshold and percentage slope per increase of electric conductivity (EC) to make a linear regression of the dry weight reduction caused by increasing levels of salinity. The threshold (a) represents the level of salinity at which the dry weight does not decrease compared to unstressed conditions. After this point, each unit increase in electrical conductivity (ECe in dS/m) causes a dry weight reduction equal to slope (b) expressed in percent per dS/m. The equation below allowed us to estimate the dry weight reduction (DWr) at each electrical conductivity level.

$$DWr = 100 - b(ECe - a)$$

The same linear regression has been calculated for weeds, using the data found in the original research papers. Thus, we compared the linear regression of four major crops worldwide (corn, soybean, wheat and rice) and their most detrimental weeds (Zimdahl, 2004). In addition, we calculated and listed thresholds and slopes for the weeds discussed in these papers.

Results and discussion
The increasing salinity of the root zone strongly affects the dynamics of crop/weeds competitions (Patterson, 1995). Figure 1 shows the trend of the dry weight reduction in crops and their associated weeds exposed to increasing salinity. Among the crops under assessment, wheat has shown the highest salinity tolerance compared to its related weeds. On the other hand, corn, soybean (Essa, 2002) and rice (Aslam et al., 1993) resulted more sensitive than their most common weeds.

F. Ventura, G. Seddaiu, G. Cola (a cura di), Atti del XX Convegno AIAM e XLVI Convegno SIA.
Milano, 12-14 settembre 2017.
DOI 10.6092/unibo/amsacta/5692

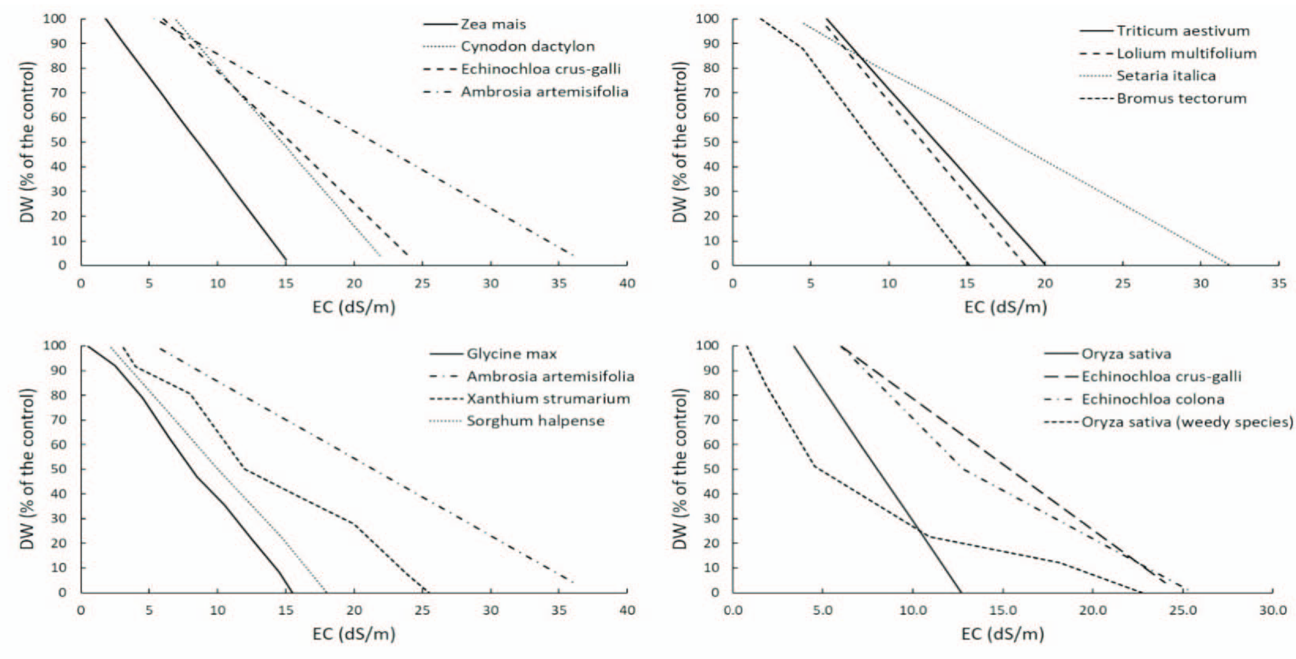

Figure 1. *Comparisons between linear regression of four of the most important crops worldwide with their most detrimental weeds.*
Figura 1. *Confronto tra le curve di regressione lineari di quattro tra le colture più rappresentative e le loro maggiori infestanti.*

An interesting aspect of this comparison is that weeds generally exhibit a lower slope than crops, i.e. smaller dry weight reduction at increasing salinity (dS/m) of the root zone after the specific tolerance threshold has been reached. This would indicate higher tolerance of weeds to salinity relative to crops. In addition to higher salt stress tolerance, weeds are characterized by remarkable adaptation to extreme environments. In water limited environments, various weeds are less sensitive to reduced soil water than crops with which they compete; this aspect, combined with more expanded root systems that weeds may have, may cause a rapid depletion of the water available for the crop (Patterson, 1995 and references cited therein). The combined drought and salinity tolerance of weeds may further amplify their competitiveness/invasiveness. Based on the Maas and Hoffman relationship (1977) we started to categorize most common weeds based on available literature data (Tab. 1). These data could be used as initial source to begin a systematic assessment of the relative and evolving tolerance of weeds respect to cultivated crops.

Table 1.: *Tolerance of some of the most critical weeds worldwide with their relative rating. Ratings (from sensitive to extremely tolerant) are defined following Tanji and Kielen (2002). Ratings have been calculated considering the relative threshold and slope at which the tolerance parameter showed a reduction of 50%.*
Tabella 1.: *Livello di tolleranza di alcune tra le più importanti infestanti. La classificazione delle infestanti (da sensibile a estremamente tollerante) è stata ricavata a partire dai limiti definiti n Tanji and Kielen (2002). I diversi livelli di tolleranza sono stati calcolati rispetto alle soglie e alle pendenze specifiche delle curve di ciascun livello, in cui il parametro considerato ha subito una riduzione del 50%.*

Common name	Botanical name	Tolerance based on	Threshold (EC_e in ds/m)	Slope (% per ds/m)	Rating*	References
Annual ragweed	Ambrosia artemisifolia	Shoot DW	6.55	1.38	ET	Eom*et al*., 2013
Cheatgrass	Bromus tectorum	Leaf DW	3.05	8.26	S	Kaylie *et al*.,2002
Lambsquarters	Chenopodium album	Germination	2.65	1.17	ET	Yao *et al*., 2010
Feathertop	Chloris virgata	Germination	4.55	4.40	T	Li *et al*., 2011
Field bindweed	Convolvulus arvensis	Germination	1.09	4.43	T	Tanveer*et al*., 2013
Bermuda grass	Cynodon dactylon	Shoot DW	6.90	6.40	MS	Tanji and Kielen 2002
Nutsedge	Cyperus spp.	Shoot Length	0.53	4.17	S	Hakim *et al*., 2011
Barnyard grass	Echinochloa crus-galli	Shoot DW	6.00	5.33	MT	Chauhan *et al*., 2017
Indian goosegrass	Eleusine indica	Germination	0.70	5.72	MS	Chauhan and Johnson, 2008
Catchweed	Galium aparine	Germination	2.80	11.96	S	Wang, H *et al*., 2016
Cogongrass	Imperata cylindrica	Shoot DW	1.00	2.91	ET	Hameed *et al*., 2009
Purselane	Portulaca oleracea	Shoot DW	1.42	4.41	T	Kafi and Rahimi, 2011
Foxtail millet	Setaria italica	Seedling DW	3.85	3.58	ET	Veeranagamallaiah*et al*., 2008
Johnson grass	Sorghum halepense	Total DW	2.09	6.24	MS	Sinha *et al*., 1986

* S= sensitive; MS= moderately sensitive; MT= moderately tolerant; T= tolerant; ET= extremely tolerant

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Conclusions

Salinized areas of the world are expanding rapidly for various reasons, including reduced rainfall, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. As salinity of impacted soils is strongly limiting the production of crops, especially in environment with limited resources, competition with other species becomes an increasingly critical issue.

At this stage of our analysis, we predict that a population of weeds, regardless its specific composition throughout the cultivation cycle, could be more tolerant to a wide range of salinity levels and become highly competitive to cultivated crops. This could anticipate increasing weed invasiveness and deleterious effects in resource limited environment. Currently, the implications of climate change scenarios on weed invasiveness and competition effects is largely overlooked. Future findings will allow us to better understand the complex range of interactions between crops and weeds, also with respect to environmental heterogeneity and evolving dynamics of cultivated area.

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