Salt stress impacts the photosynthetic activity of *Amaranthus cruentus*: an *-omic* and physiological analysis

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1. INTRODUCTION

Soil salinity is a serious issue worldwide, especially in arid areas and irrigated fields. Major crops are usually unable to tolerate salt stress. In a context of growing food demand, it is urgent to find plants able to produce good yields on salt-contaminated soils.

Several **amaranths** (*Amaranthus* spp.) are C_4 plants cultivated for leaves or grain production, mainly in tropical regions and/or highlands. Both organs are highly nutritive. Moreover, their good tolerance to several biotic and abiotic stresses is recognized.

2. OBJECTIVES

- Comparing the **salt tolerance** of grain and leaf *A. cruentus* cultivars.
- Using **-omic data**, **gas exchange** and **fluorimetry** to understand underlying molecular mechanisms of tolerance.

3. MATERIALS & METHODS

- **Four cultivars** of *A. cruentus* (2 'grain' + 2 'leaf').
- Salt stress : **75 mM NaCl** in Hoagland solution, in greenhouses.
- **Growth** & **yield** monitoring.
- **Gas exchange**, **proteomics**.

4.1. RESULTS – Photosynthetic activity

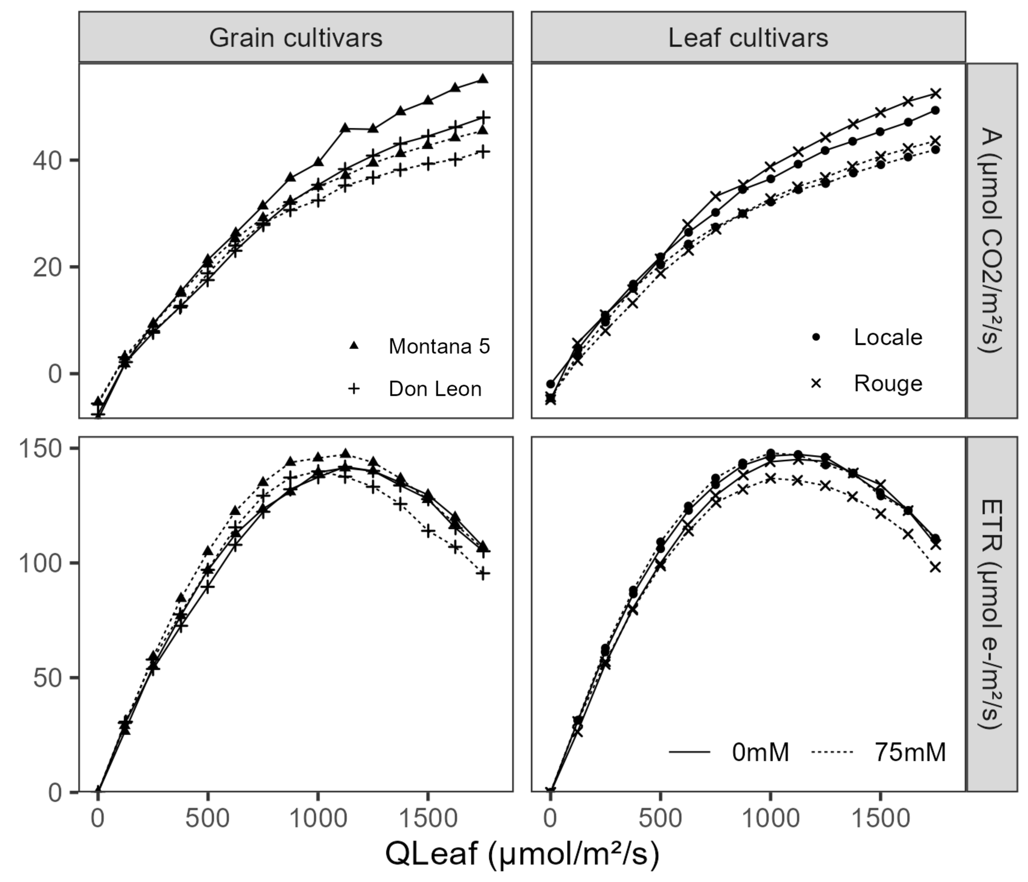

Figure 1. Photosynthesis-irradiance curves after 38 days of growth, 21 days after stress (75 mM NaCl) application. QLeaf: light intensity; A: net assimilation of CO_2; ETR: electron transport rate.

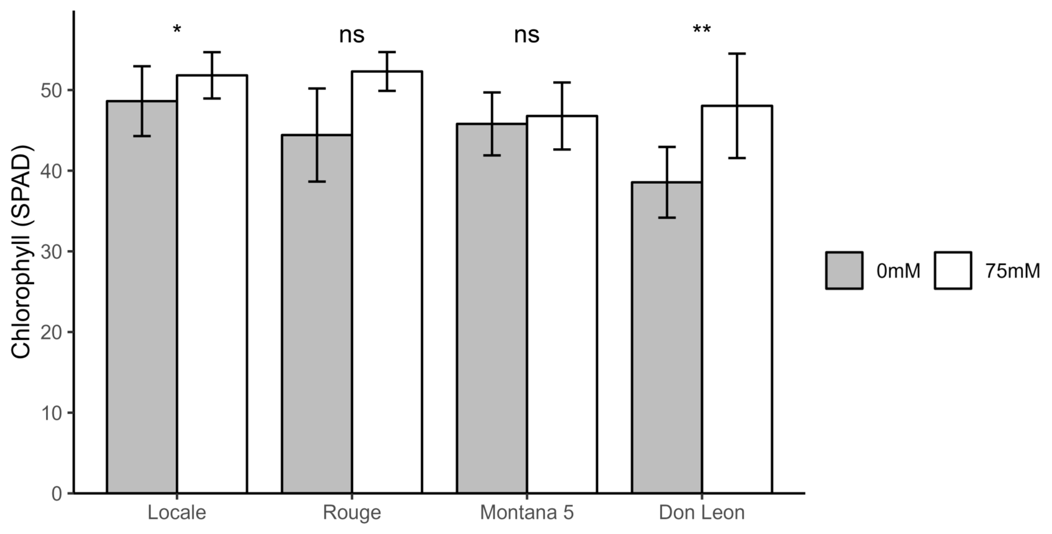

Figure 2. Chlorophyll content (SPAD units) of leaves of four cultivars of *A. cruentus* exposed to 75 mM NaCl.

- The light reactions of photosynthesis were less affected by salinity than dark reaction, as shown by the constant ETR among cultivars and salt treatments, except in Rouge (fig. 1). Net carbon assimilation rate was decreased by salt stress in both grain and leaf cultivars (fig. 1).
- Chlorophyll content of leaves increased slightly in response to stress ($p < 0.001$), especially in Locale and Don Leon cultivars (fig. 2).

4.2. RESULTS – -omic insight into the effect of salt stress on amaranth photosynthesis

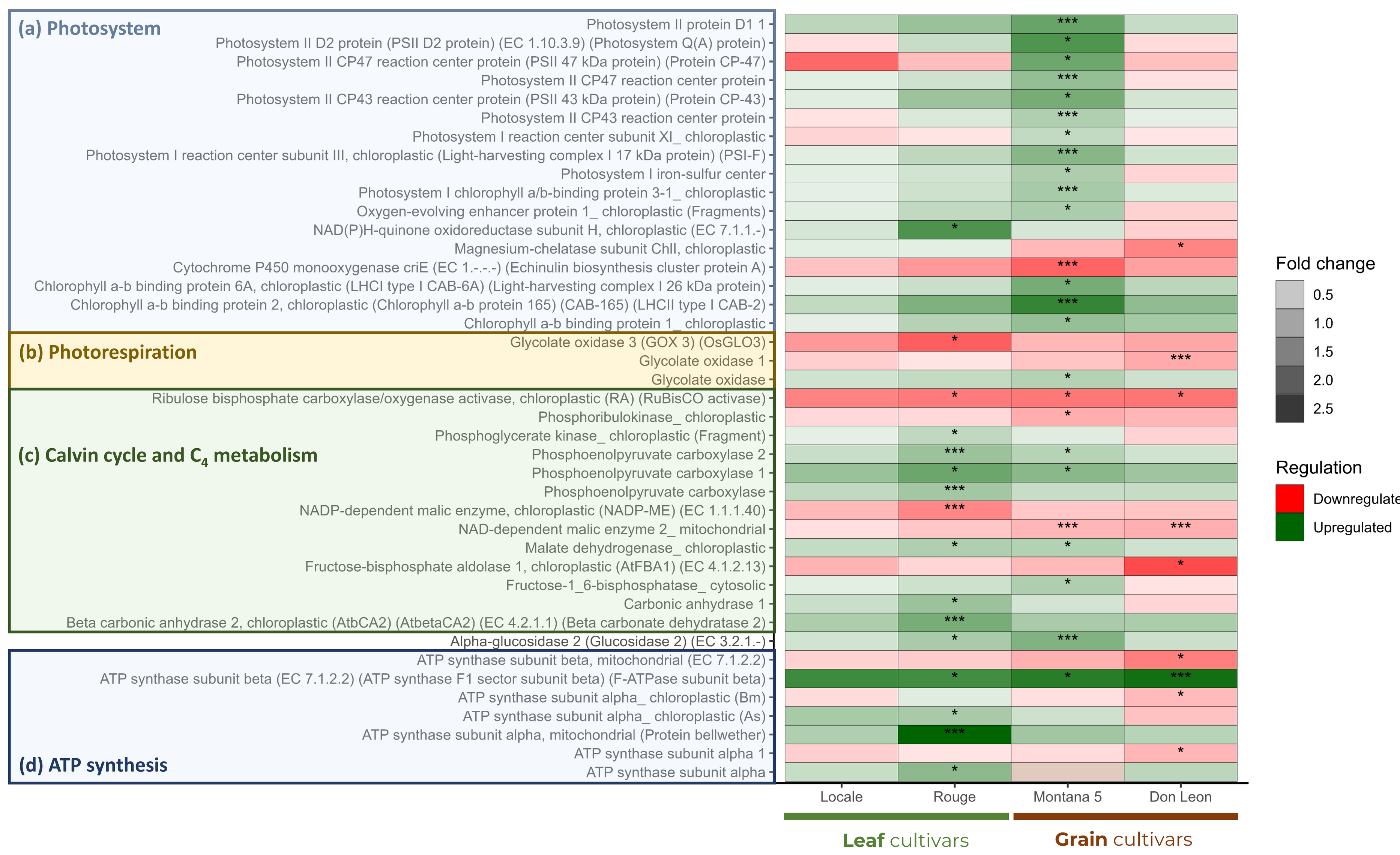

Figure 3. Proteomic analysis on leaves of four cultivars of *A. cruentus* exposed to 75 mM NaCl: significantly down- or upregulated proteins related to photosynthetic activity. Proteins are grouped into proteins involved in (a) photosystems, (b) photorespiration, (c) Calvin cycle and C_4 metabolism and (d) ATP synthesis.

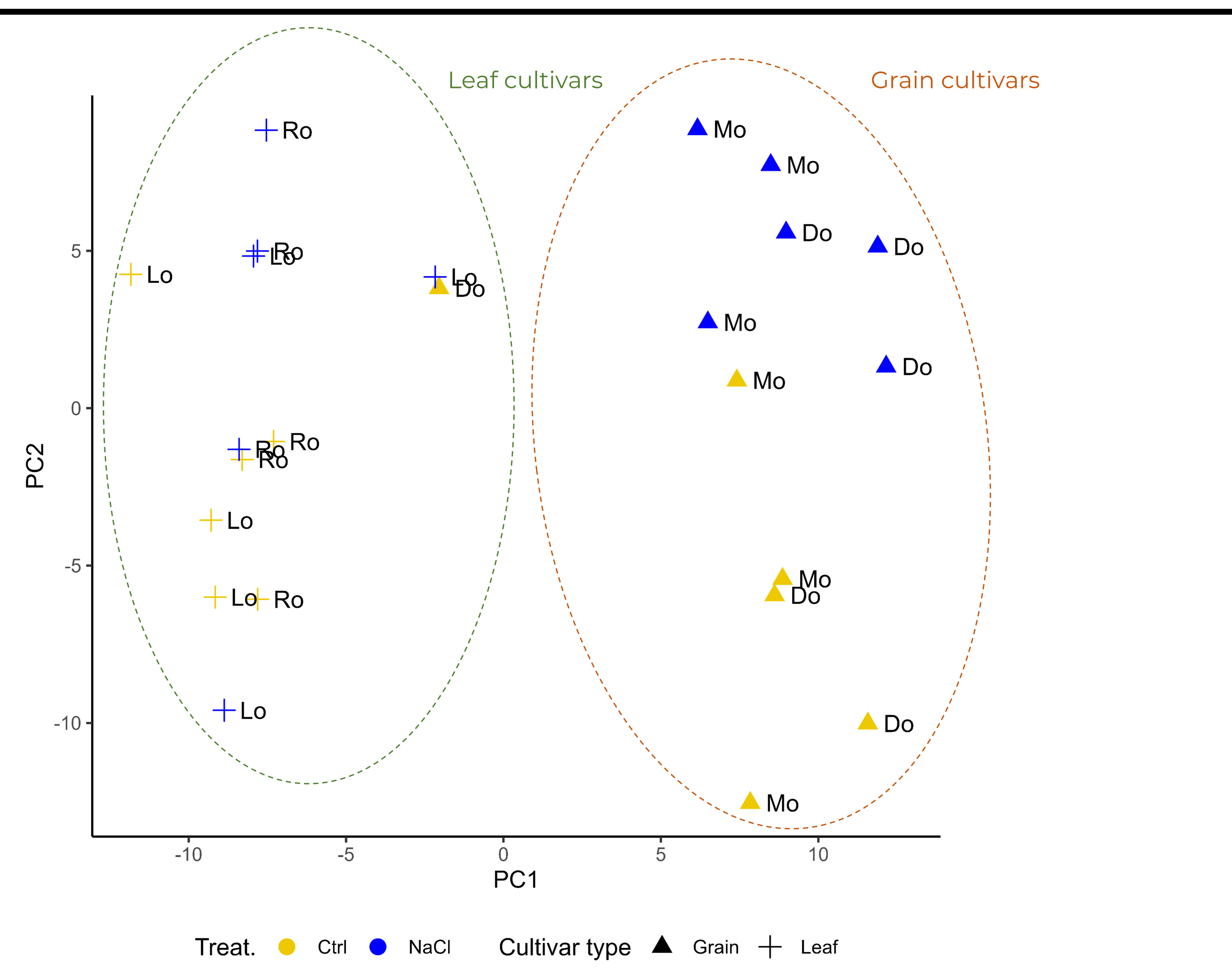

Figure 4. Principal component analysis of proteomic data on leaves of four cultivars of *A. cruentus* exposed to 75 mM NaCl. Cultivars : Lo = Locale, Ro = Rouge, Mo = Montana 5, Do = Don Leon.

- Most of the proteins involved in photosystems significantly regulated by salt stress were upregulated in Montana 5 cultivar only (fig. 3). Regarding proteins involved in Calvin cycle, most of them were strongly upregulated in Rouge cultivar, and some of them slightly in Montana 5. Malic enzymes, however, were downregulated in Rouge, Montana 5 and Don Leon. Carbonic anhydrase and PEPC (involved in C_4 metabolism) and several ATP synthase subunits were upregulated by salt in Rouge. No protein involved in photosynthesis was significantly regulated by salt stress in Locale, and few in Don Leon.
- Principal component analysis of proteomic data separated cultivar type (leaf and grain) on axis 1, wheras salt treatments were separated by axis 2 (fig. 4).

5. CONCLUSIONS

- Photosynthetic activity of *A. cruentus* was regulated by salt stress at the protein level, but with significant variability among the four cultivars with contrasted salt tolerance. Most of the variation was observed in Montana 5 (salt-sensitive grain cultivar), and, to a lesser extent, in Rouge (salt-tolerant leaf cultivar). No protein involved in photosynthetic activity was regulated in Locale, despite the fact that this cultivar is the most sensitive to salt. These results suggest that this cultivar is not able to implement molecular mechanisms in response to salt stress, explaining its sensitivity. However, the opposite was observed in Montana 5, suggesting other metabolic pathways affected by salt in this genotype.
- Light response curves were only slightly affected by salt, and more on dark- than on light- reactions.
- Proteomics, along with other –omic approaches and physiological analysis, is a powerful method to analyse in depth the effects of an abiotic stress on a specific metabolic pathway.