Remodeling of carbon and nitrogen metabolites in durum wheat: a simple response to complex stimuli

Giovanna Marta Fusco, Emilia Dell'Aversana, Pasqualina Woodrow, Loredana F. Ciarmiello, Petronia Carillo

Department of Environmental, Biological and Pharmaceutical Sciences and Technologies,
University of Campania "Luigi Vanvitelli", Via Vivaldi 43, 81100 Caserta, Italy;

INTRODUCTION

Plant stress studies dealing with a single stress approach have been useful for dissecting stress perception of defined stimuli and related gene expression and metabolic changes. However, in real-world scenarios plants are simultaneously exposed to a plethora of stresses counteracted by tailored responses completely different from the responses to individual stresses. Durum wheat seedlings were used as experimental model to investigate the plant response to salinity (100 mM NaCl) and low/high light (350/900 µmol m^{-2} s^{-1}), focusing on the physiological and metabolic changes potentially involved in osmotic adjustment and antioxidant defense. Previous studies showed that N- containing metabolites proline and glycine betaine (GB) are of pivotal importance in durum wheat plants under salinity because they are used as compatible solutes and antioxidants [1]. In glycophytes, they are accumulated at lower concentrations than in halophytes but, being partitioned exclusively to the cytoplasm (<10% of the volume of the cell), they determine significant osmotic pressure and balance the vacuolar osmotic potential [2, 3]. Proline is rapidly synthetized, particularly in senescing leaf tissues at high N nutrition, and broken down upon relief of stress to provide energy, C and N to recover and repair stress induced damages. While GB accumulates during prolonged stress, preferentially in younger leaves and roots, independently of N, but it cannot be metabolized, even if efficiently transported to other tissues [2]. Notwithstanding the important role of these compatible compounds, proline decreases, and GB is not accumulated under high light and salinity [4, 5]. How do plants face salinity under high light?

METHODS

Durum wheat seedlings (*Triticum durum* Desf. cv Ofanto) were grown in hydroponics according to [4]. On day six of hydroponic culture 10mM nitrate was added and starting from day 10 of culture, the hydroponic medium was supplemented with 50 mM NaCl, increased to 100 mM NaCl on the day 11. Data presented in the results were determined in shoot tissues harvested at the end of the experiment (20 d of culture). The analyses were performed as described in Woodrow et al. [5].

RESULTS

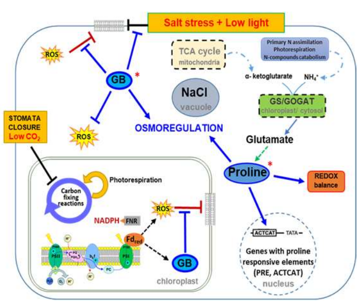

Figure 1 - In durum wheat plants under salt stress + low light, the salt dependent stomata closure decreases the CO_2 exchange and the enzymatic CO_2-fixation activity, determining over-excitation of the photosynthetic apparatus and production of ROS. Hence, GB synthesis is induced in chloroplasts to protect photosynthetic apparatus. GB, together with proline, contribute to scavenge ROS, osmoregulate the cytosolic compartments, stabilize membranes, buffer redox potential and induce salt responsive genes [5, 6].

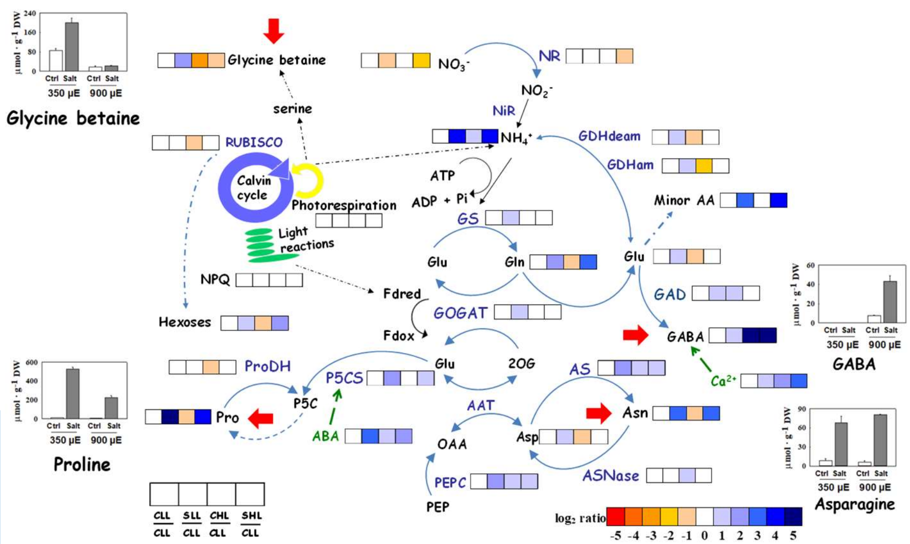

Figure 2 - Heat map analysis summarizing the response of enzymes and metabolites involved in nitrogen and carbon metabolism to salt stress (100 mM NaCl) and low (LL)/high (HL) light. Results were calculated as logarithm base 2 of LL control values (CLL), LL salt stressed values (SLL), HL control values (CHL) and HL salt stressed (SHL)/ CLL and were visualized using a false color scale, with blue indicating an increase and red a decrease of values relative to those in controls. No differences were visualized by white squares [5].

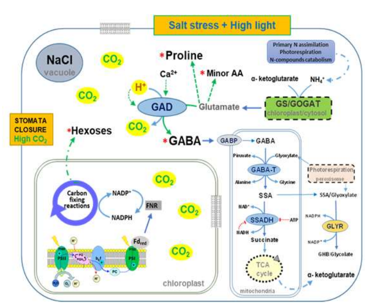

Figure 3 – Under salt stress + high light the synthesis of GABA from glutamate catalyzed by glutamate decarboxylase (GAD) may contribute to dissipate the excess of energy and release CO_2, allow the Calvin cycle to function, lower the pressure on photosynthetic electron chain and decrease ROS and photodamage. Moreover, GABA shunt supplies NADH and/or succinate to the mitochondrial electron-transport chain under conditions in which respiration and TCA cycle are impaired and ROS increased [7].

CONCLUSIONS

The complex interplay seen in durum wheat plants under salinity at low light is simplified under simultaneous salinity and high light. GB and antioxidants did not play a main role [5, 6]. The fine tuning of few specific primary metabolites reshapes metabolism and defense processes. GABA and asparagine may act as temporary N storage to decrease the excess of NH_4^+ accumulated under stress. GABA proton consuming synthesis buffers cytosolic acidosis (pH-stat). Moreover, GABA, as zwitterion, can function as osmolyte without toxic effects, and is able to exert a scavenging activity exceeding those of proline and GB [7].

References

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email: petronia.carillo@unicampania.it