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Research article

Combined effect of Cr-toxicity and temperature rise on physiological and biochemical responses of *Atriplex halimus* L.

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ABSTRACT

An experiment was conducted to evaluate the combined effect of temperature (26 and 30 °C) and Cr toxicity (0, 100 and 1000 μM Cr) on growth, photosynthesis, water content, Cr and nutrients uptake and translocation. The role of antioxidative enzyme towards stresses tolerance was also investigated. Results showed that the maximum relative growth rate and leaf area per plant of *Atriplex halimus* L. were recorded at 100 μM Cr and 26 °C. However, presence of Cr reduced net photosynthetic and stomatal conductance rates. Overall, temperature rise enhanced the toxic effect of Cr by reducing growth and photosynthesis and inducing antioxidant enzymes activities. Furthermore, temperature rise increased nutrient uptake, as well as nutrient translocation to aboveground tissues; while it diminished Cr translocation. Finally, roots were the main sink for Cr accumulation in *A. halimus*. At 1000 μM Cr, root Cr concentrations reached 7.2 and 9.1 mg g^{-1} at 26 and 30 °C, respectively; while shoot Cr concentrations were 0.45 and 0.44 mg g^{-1} (26 and 30 °C, respectively). The high Cr-accumulation in roots suggests that *A. halimus* presents a great potential for phytoremediation, especially phytostabilisation of Cr contaminated soils.

1. Introduction

Due to anthropogenic activities heavy metal pollution has become a serious environmental and human health problem in the world (Cho et al., 2003; Liphadzi and Kirkham, 2005; Martínez-Fernández et al., 2011). Among metals, chromium (Cr) is the seventh most abundant element on earth (Shanker et al., 2005; Ahmad et al., 2013). Cr is not an essential element for plants (Ahmad et al., 2013), and its toxicity is highly dependent on its oxidation state. In fact, in nature, Cr can be found under two stable forms: hexavalent Cr(VI) and trivalent Cr(III). The hexavalent is highly toxic and mobile whereas trivalent is less toxic (Ahmad et al., 2013; Shanker et al., 2005). Cr(VI) has been reported to decreased plant growth (Amna et al., 2015; Redondo-Gómez et al., 2011), inhibited the net photosynthesis by disturbing plant water balance, stomatal conductance, CO_2 assimilation and reducing chlorophyll biosynthesis (Redondo-Gómez et al., 2011; Rodriguez et al., 2012). Cr (VI) toxicity is also related to its capacity to generate reactive oxygen species (ROS), which are very harmful for cells, since they can damage DNA, proteins and lipids (Halliwell, 2006; Mittler et al., 2004).

Temperature is one of the most important environmental factors controlling plants growth and productivity (Xu et al., 2016). The responses of plant to temperature variations have become a major concern nowadays (Gunderson et al., 2000); according to the Intergovernmental Panel on Climate Change temperature will be increased between 1.8 and 4.0 °C by the year 2100 (IPCC, 2014). Temperature affects transpiration, growth and metabolism of plants and therefore both uptake and elimination of pollutants (Yu et al., 2005). Consequently, it is important to understand the interaction between temperature variation and metal uptake and accumulation. Understanding the effect of temperature on metal accumulation could be also useful when planning phytoremediation indifferent bioclimatic zones (Brunham and Bendell, 2011).

Abbreviations: A_N, net photosynthetic rate; APX, ascorbate peroxidase; CAT, catalase; C_i, intercellular CO_2 concentration; GPx, guaiacol peroxidase; g_s, stomatal conductance; iWUE, intrinsic water use efficiency; LMA, leaf dry mass per unit leaf area; LWC, leaf water content; ROS, reactive oxygen species; RGR, relative growth rate; SOD, superoxide dismutase; SWC, stem water content; TF, translocation factor

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