DEPARTMENT OF ENVIRONMENTAL STUDIES

(PUBLICATION)

2016

P. Sharmila, P. Kusuma Kumari, **Kavita Singh**, N. V. S. R. K. Prasad, and P. Pardha-Saradhi. Cadmium toxicity-induced proline accumulation is coupled to iron depletion. Protoplasma **(2016):** 1-8.[ISSN: 0033-183X (print version),ISSN: 1615-6102 (electronic version)]

Protoplasma (2017) 254:763–770
DOI 10.1007/s00709-016-0988-5

ORIGINAL ARTICLE

Cadmium toxicity-induced proline accumulation is coupled to iron depletion

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Received: 21 February 2016 / Accepted: 18 May 2016 / Published online: 16 June 2016

Abstract Investigations were conducted to elucidate the key factor behind Cd^{2+}-toxicity-induced proline accumulation in Indian mustard (*Brassica juncea*) by raising seedlings, independently in distilled water (DW) and mineral growth medium (MGM) in the presence of 0–500 μM $CdCl_2$. Invariably, Cd^{2+}-induced toxicity, measured in terms of growth, was significantly more prominent in seedlings raised in DW than those raised in MGM. Cd^{2+} brought about a significant reduction in growth and photosystem II activity with a concomitant increase in proline levels, in a concentration-dependent manner. Interestingly, the level of iron in shoots of seedlings decreased proportionately with increase in Cd^{2+} toxicity. Cd^{2+}-promoted proline accumulation was significantly higher in seedlings raised in DW than those raised in MGM. Depletion of essential cations (viz. Ca^{2+}, Mg^{2+}, K^+, and Fe^{2+}) from MGM one at a time revealed that depletion of Fe^{2+} leads to maximal proline accumulation under Cd^{2+} toxicity. Interestingly, proline level in seedlings raised under Cd^{2+} toxicity in DW supplemented with Fe^{2+} was similar to that recorded in seedlings raised in MGM. Our results convincingly demonstrated that Cd^{2+}-induced iron deficiency promotes proline accumulation.

Keywords Cadmium toxicity · Iron · Proline · Photosystem II · *Brassica juncea*

Handling Editor: Bhumi Nath Tripathi

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Introduction

Cadmium (Cd) is among the most hazardous environmental pollutants that are released into the environment through industries, automobiles, power stations, mining, and agriculture. Owing to its high toxicity, Cd^{2+} can be a potential threat to living systems as it interferes with various metabolic activities by influencing/inhibiting (i) micronutrient homeostasis, (ii) cellular redox reactions, (iii) activities of various enzymes, (iv) photosynthetic machinery, and (v) electron transport complexes (Alia and Pardha-Saradhi 1993; Atal et al. 1991; Chaffei et al. 2004; Clemens et al. 2002; Drazic et al. 2004; Jonak et al. 2004; Noriega et al. 2007; Sharmila and Pardha-Saradhi 2002). Cd^{2+}-induced suppression in role of various cellular components/complexes is often associated with accelerated generation of reactive oxygen species (ROS) (Han et al. 2008; Khan et al. 2015; Liu et al. 2007; Podazza et al. 2012; Rodriguez-Serrano et al. 2009; Sharmila and Pardha-Saradhi 2002; Wang et al. 2004) and/or disturbance in ratio of $NAD(P)^+$ to NAD(P)H (Alia and Pardha-Saradhi 1993).

Living systems evolved various strategies to combat the negative impact of various heavy metals including Cd^{2+}, on cellular metabolism. One of such strategies is the accumulation of a compatible solute, proline, which plays a vital role in (i) scavenging reactive oxygen species (Alia