Effects of elevated CO2 levels on root morphological traits and Cd uptakes of two Lolium species under Cd stress*

Yan JIA1,2,3, Shi-rong TANG†1,2, Xue-hai JU1,2, Li-na SHU1,2,3, Shu-xing TU3, Ren-wei FENG1,2, Lorenzino GIUSTI4

(1Centre for Research in Ecotoxicology and Environmental Remediation, Agro-environmental Protection Institute, Ministry of Agriculture, Tianjin 300191, China)
(2Open Key Laboratory of Agro-environment and Food Safety of Ministry of Agriculture, Tianjin 300191, China)
(3College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China)
(4Faculty of Health and Life Sciences, University of the West of England, Coldharbour Lane, Bristol BS16 1QY, UK)

†E-mail: tangshir@hotmail.com

Received May 17, 2010; Revision accepted Nov. 15, 2010; Crosschecked Mar. 2, 2011

Abstract: This study was conducted to investigate the combined effects of elevated CO2 levels and cadmium (Cd) on the root morphological traits and Cd accumulation in Lolium multiflorum Lam. and Lolium perenne L. exposed to two CO2 levels (360 and 1000 μl/L) and three Cd levels (0, 4, and 16 mg/L) under hydroponic conditions. The results show that elevated levels of CO2 increased shoot biomass more, compared to root biomass, but decreased Cd concentrations in all plant tissues. Cd exposure caused toxicity to both Lolium species, as shown by the restrictions of the root morphological parameters including root length, surface area, volume, and tip numbers. These parameters were significantly higher under elevated levels of CO2 than under ambient CO2, especially for the number of fine roots. The increases in magnitudes of those parameters triggered by elevated levels of CO2 under Cd stress were more than those under non-Cd stress, suggesting an ameliorated Cd stress under elevated levels of CO2. The total Cd uptake per pot, calculated on the basis of biomass, was significantly greater under elevated levels of CO2 than under ambient CO2. Ameliorated Cd toxicity, decreased Cd concentration, and altered root morphological traits in both Lolium species under elevated levels of CO2 may have implications in food safety and phytoremediation.

Key words: Elevated CO2 levels, Lolium multiflorum Lam., Lolium perenne L., Root morphology, Cd uptake, Cd stress


1 Introduction

The world’s industrialization has given rise to increases in the atmospheric carbon dioxide (CO2) concentrations (from 280 to 380 μl/L) (IPCC, 2007) and environmental pollution. Elevated levels of CO2 and increased heavy metal concentrations in the agriculural environment potentially affect both plant growth and development, and pose possible hazards to human health through food chain. Consequently, the impacts of elevated levels of CO2 and metal contamination on plants are receiving more attentions (Tang, 2006). It is now known that under non-contaminated conditions, elevated levels of CO2 increase photosynthesis, leading to the increased photosynthetic product allocation to roots. This resulted in more highly branched roots and an increase in the capacity of the root system to exploit soil volume through alteration of root morphological traits (Rogers et al., 1992; Wechsung et al., 1999; Prior
The changes in root morphology are often associated with a variation in nutrient uptake (Jia and Gray, 2007; Jin et al., 2009; Jin and Evans, 2010), though considerable variation between species and systems exists (Bowes, 1993; Kimball et al., 2002; Franzaring et al., 2008). Previous studies have shown the effect of elevated levels of CO2 on plant uptakes of essential micronutrients, such as Cu, Fe, Mn, and Zn (Jia et al., 2007; Yang et al., 2002). Studies have shown the effect of elevated levels of CO2 and metal stress and alteration of root distribution patterns remains poorly understood.

As model plants, Lolium multiflorum and Lolium perenne species have been frequently studied because of their abilities to survive in metal-contaminated soil and to accumulate metals (Marseille et al., 2000; Kiss et al., 2002; Palazzo et al., 2003; Arienzo et al., 2004; Caggiano et al., 2005; Guo and Wang, 2009). They contain extensive root systems with high biomass, have high adaptability and low-cost management, and possess the ability to accumulate Cd (Sabreen and Sugiyama, 2008). Understanding the combined effects of elevated levels of CO2 and metal contamination on their biomass productions, root morphological traits, and metal accumulations will improve both our knowledge of food safety and their survival abilities in metal contaminated environments. It also allows an interspecies comparison of the behaviors of L. multiflorum vs. L. perenne in metal contaminated environments under elevated levels of CO2. Elevated levels of CO2 improve photosynthesis of C3 plants, reduce stomatal resistance, and as a result, increase water-use efficiency, while aiding in the decrease of photorespiration and oxidative stress (Urban, 2003; Kirschbaum, 2004; Rogers et al., 2004). Researches have shown that elevated levels of CO2 increase the ability of plants to combat abiotic stress, such as O3, drought, and salt (Sgherri et al., 1998; Donnelly et al., 2001; Oksanen et al., 2001; Geissler et al., 2009). We hypothesize that better growth and physiological responses to elevated levels of CO2 will help plants combat the stress induced by Cd. The objective of this study was to investigate effects of elevated levels of CO2 on plant growth, root development, and Cd uptake of L. multiflorum and L. perenne under Cd stress, and implications for food safety and phytoremediation efficiency.

2 Materials and methods

2.1 Plant materials and growth

Seeds of L. perenne L. and L. multiflorum Lam. (obtained from the Institute of Plant Protection, Chinese Academy of Agricultural Sciences, China)