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Biotransfer of Cd along a soil-plant- mealybug-ladybird food chain: A comparison with host plants

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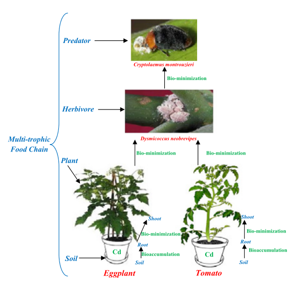
HIGHLIGHTS

- This study explains the transfer of Cd through a food chain consisting of plants (eggplant and tomato), pink hibiscus mealybug (*Dysmicoccus neobrevipes)* and its predator (*Cryptolaemus montrouzieri).*
- The Cd transfer was effectively reduced in shoot-mealybug – ladybird food chain.
- The Cd body burdens in *C. montrouzieri* adults were lower than mealybugs showing a considerable bio-minimization of Cd.
- The percentage of Cd body burden lost in pupal exuviae decreased with increase in body burden of adults.
- Tomato plants were more tolerant to the Cd amendments when compared to eggplants.

GRAPHICAL ABSTRACT



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ABSTRACT

Agro-ecosystem contamination by the heavy metals present in different agricultural products is a serious challenge faced by the living organisms. This study explains the cadmium (Cd) transfer from soils contaminated with different cadmium concentrations through a plant (eggplant and tomato) - mealybug (*Dysmicoccus neobrevipes)* - predator (*Cryptolaemus-montrouzieri)* food chain. The soils were amended with Cd at the rates of 0, 12.5, 25 and 50 mg/kg (w/w). Our findings showed that considerably higher Cd transfer through tomato plant. Cadmium was biomagnified during soil-root transfer while bio-minimization of Cd was observed for shoot-mealybug – ladybird transfer. Our results further showed sequestration of Cd during the metamorphosis of ladybird beetle whilst transfer of Cd through soil-plant-mealybug-ladybird multi-trophic food chain increased in a dose dependent manner. Our results

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emphasize the need of further studies to elaborate possible mechanisms of Cd bio-minimization by plants, mealybugs and ladybirds observed during this study.

1. Introduction

The increased frequency of activities like metalliferous mining, smelting, injudicious use of agricultural materials (fertilizer, sewage water) and atmospheric transfer of compounds released from these sources has resulted in contamination of ecosystem by heavy metals (Ashraf et al., 2015; Anjum et al., 2016a). Heavy metals have a strong affinity with organic matter which allows them to accumulate in soils whilst prolonged exposure of these metals may demolish growth and reproductive abilities of different living organisms (Santorufo et al., 2012), may cause changes in community structure (Butler and Trumble, 2008), and often results in oxidative damage (Anjum et al., 2016b).Cadmium (Cd), a non-essential element, which is highly toxic, even at low concentrations, and can cause mutations in living organisms (Baghban et al., 2014). Plants normally absorb Cd from soil and accumulate them in their different parts in various concentrations (Wang et al., 2006). The Cd accumulated in plant tissues is later transferred through food chain to organisms at higher trophic level (Nadal et al., 2004). Therefore a clear knowledge about the transfer of Cd from soil to higher trophic levels of food chain is required to know its effects on ecosystem (Green and Walmsley, 2013).

A clear understanding of the effects of increased Cd concentration on general processes of ecosystem requires information both on the effects of Cd on general processes of communities and effects on the particular species (Gorur, 2006). Host plant-herbivore insects-predatory insects relationships can be considered as a model system to examine the effects of Cd on different trophic levels of ecosystem (Green et al., 2003; Dar et al., 2015). Plants can be seen as a route for the transfer of Cd from soil to herbivorous insects. The trophic positing of herbivorous insects in Cd contaminated ecosystems is also linked to their accumulation as well as transfer to higher trophic levels (Devkota and Schmidt, 2000). Predatory insects are known to play important role in agro-ecosystems by contributing to pest control (Winder et al., 1999). Different fitness parameters of predatory arthropods are adversely affected by feeding on preys which have Cd accumulation from contaminated plants (Dar et al., 2015). Thus Cd contamination can suppress the beneficial role of predatory arthropods in agro-ecosystem by secondary poisoning in higher trophic levels of food webs (Green et al., 2010).

Plant species vary in their capacity for Cd uptake, transport and accumulation (Gharaibeh et al., 2016). The efficiency of different plants to absorb Cd is generally evaluated by soil to plant transfer factor (Cui et al., 2004). It has also been reported that transfer factor can vary with plant species (Mustin et al., 2003). Some plants can take up and accumulate higher metal concentrations known as hyper-accumulators while some cannot accumulate higher concentrations of metals to their tissues (Song et al., 2004). In addition Cd accumulation in plants differs greatly not only among plant species but among organs of the same plant (Oliver et al., 1995). The variations in the ability of a host plant to accumulate Cd can also influence Cd transfer from plants to herbivorous insects (Maryanski et al., 2002; Gorur, 2006), however, no study is available on the Cd transfer and accumulation in pink hibiscus mealybug (*Dysmicoccus neobrevipes)*, which is a serious pest of different crops (Ben-Dov, 1994). *Cryptolaemus montrouzieri* Mulsant also known as mealybug ladybird or mealybug destroyer consumes a larger proportion of its prey/food needed for its development from egg to pupa during fourth instar (Reddy et al., 1991). Feeding on Cd contaminated mealybugs can increase the Cd body burden of 4th instar *C. montrouzieri* larvae which can be transferred to adult stage (Green et al., 2003). The influence of metamorphosis on Cd concentration in *C. montrouzieri* adults and Cd transfer from food consumed during larval stage to adults has also not been reported to date.

In this context, the current investigation was carried out to assess the magnitude of Cd transfer in a soil-plant-mealybug-ladybird system on two different host plants. Tomato (*Solanum lycopersicum*) and egg plant (*Solanum melongena*) were used as model plants because of their adaptability to widespread climatic conditions, large biomass and their use as food by humans. Apart from this assessments were also made of the potential for *C. montrouzieri* to regulate the Cd body burden of newly emerged adults through sequestration in pupal exuviae. The main objectives of this work were: a) to know the effect of host plants on extent of Cd transfer from soil to plant-pest-predator food chain; b) to assess that whether the quantities of transferred Cd were bioaccumulated or biominimized at different levels of food chain, and c) to assess the possibility of any sub-lethal effects of Cd transfer across the food chain by observing the changes in dry weights of different organism in response to different Cd concentrations.

2. Materials and methods

2.1. Chemical and reagents

All the chemical and reagents used in this study were of standard analytical grade and all the chemicals were supplied by Genstar Chemicals, China.

2.2. Insect cultures

D. neobrevipes was maintained on tomato plants following the method of Qin et al. (2011) at Key laboratory of Bio-Pesticide innovation and application of Guangdong Province, South China Agricultural University, Guangzhou, P.R. China. Briefly, 100 reproductively active females of *D. neobrevipes* were used to start colonies at 26 ± 1 °C, 75–90% R.H, and a photoperiod of 14:10 (L: D) h. The insects were reared for two generations. Gravid females from the second generation were placed in a rearing-box (box length 9.0 cm, width 6.3 cm, height 5.0 cm) and the nymphs produced them were used for further experiments.

C. montrouzieri adults were collected from the experimental area of the South China Agricultural University, Guangzhou, Guangdong, China, during 2015. Before the experiment, the beetles were reared for several generations on *D. neobrevipes* under laboratory conditions at 26 ± 2 °C, 60–80% relative humidity (RH) and a light: dark photoperiod of 14:10 h.