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RESEARCH ARTICLE

Effects of Chemical Fertilizer and Some Bacterial Formulations on Growing Medium and Plant Heavy Metal Content in Poinsettia Cultivation

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ABSTRACT

High amount of chemical fertilizers and various pesticides are used in the cultivation of poinsettia. This study was conducted to compare the amount of heavy metals (Zn, Cu, Pb and Cd (mg kg^{-1}) and B (mg kg^{-1}) metalloid) accumulated by the use of different bacterial formulations and chemical fertilizers in the cultivation of poinsettia. The research was conducted in climate controlled research greenhouse conditions between July 2015 and July 2017. In the study, rooted cuttings of poinsettia (*Euphorbia pulcherrima* Willd.ex Klotzsch cv. Christmas Eve) were used as plant material. The applications were created as BI (*Paenibacillus polymyxa* TV-12E + *Pseudomonas putida* TV-42A + *Pantoea agglomerans* RK-79), BII (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-92 + *Bacillus subtilis* TV- 17C), BIII (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-92 + *Kluyvera cryocrescens* TV-113C), BIV (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-79 + *Bacillus megaterium* TV-6D), CF [the full amount of commonly used chemical fertilizer (150 g $100L^{-1}$)], BI+CF, BII+CF, BIII+CF, BIV+CF (by combining with 50% the reduced amount of chemical fertilizer by (75 g $100L^{-1}$)) and control (uninoculated). The highest Zn, Cu, Pb and Cd (mg kg^{-1}) amounts were obtained from BIV application in growth medium. According to CF and control applications, BI+CF application was determined as reducing in the Zn amount of leaf samples of plants 14.47% and 15.70%, respectively. BI application was determined as reducing in the Cd amount of leaf samples of plants 26.58% and 54.69%, respectively when compared to CF and control applications. The highest amount of Pb was determined in plant root samples.

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Introduction

Heavy metal pollution is increasing in day by day due to industrialization in all over world. Different agricultural activities like usage of agrochemicals and different industrial activities like waste disposal and deposition of urban sewage sludge accumulate huge amounts of heavy metals to the growth medium and can disrupt human food and environment safety (Saleh et al., 2004). Metals such as zinc, iron, copper, nickel and manganese play important roles as beneficial or essential micronutrients of microorganisms (Olson et al., 2001; Sakamoto and Bryant, 2001). However, a high concentration of metal ions in growth medium shows serious effects on microbial communities by decreasing diversity and total microbial biomass and changing the community structure (Khan et al., 2009). Therefore, microbial communities are useful indicators of the effect of contamination on growth medium health (Mishra et al., 2008). Bacteria in heavy metal-

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contaminated growth medium is firstly exposed to the heavy metal stress. Also, to have a functional role in remediation, the bacteria must overcome the heavy metal stress. It is known that microorganisms tolerate heavy metals by immobilizing metals on cell surfaces or transforming metals into less toxic forms, for example by acidification, precipitation and oxidation-reduction (Ma et al., 2011).

Rhizosphere is the root surrounding region and has many types of active groups of bacteria (Villacieros et al., 2003) termed as "PGPR" (Plant Growth Promoting Rhizobacteria) (Khatoon et al., 2014). PGPR inhabits in around the root and useful for plant with the enhancement of growth by way of two mechanisms: First is the direct mechanisms such as nitrogen fixation, increasing in availability of nutrients to the plant, growth-regulating agents production, production of plant vitamins and hormones such as gibberllin and cytokinin. The second is the indirect mechanisms includes make iron available, antibiotics synthesis, competing with root inhabiting species (Glick et al., 1999; Verma et al., 2015), causing systemic resistance, and promoting plant resistance to stress conditions caused by non-living factors (Glick et al., 1998). Pal et al., (2004) bacteria developed various resistance mechanisms to adopt the metal contaminated environment.

The solubility of heavy metals in soil is limited due to complexing with organic matter, sorption on clays and oxides, and precipitation as carbonates, hydroxides, and phosphates. This problem can be controlled (Naidu and Harter, 1998) and increase in solubility may be achieved by adding plant growth-promoting rhizobacteria (PGPR) to the soil. Previous studies have also been found no changes or decreases in plant growth and yield with increases in the heavy metal uptake of various plants (Turan and Angin, 2004; Turan and Esringu, 2007; Angin et al., 2008; Pezzarossa et al., 2009; Gullap et al., 2014).

The objective of this work is to study the effect of different bacteria formulations, chemical fertilizer and their combinations on heavy metals content of poinsettia (*Euphorbia pulcherrima* Willd.ex Klotzsch cv. Christmas Eve) plant and the growth medium.

Materials and Methods

The research was conducted in climate controlled research greenhouse between July 2015 and July 2017. In the study, rooted cuttings of poinsettia (*Euphorbia pulcherrima* Willd.ex Klotzsch cv. Christmas Eve) were used as plant material. The cultivation medium was prepared by mixing peat in ratio of 2: 1 and pumice as volume (Anonymous, 2010; Anonymous, 2015). Plants were planted in 3.5 liter plastic pots. The applications were created as formulation 1 (*Paenibacillus polymyxa* TV-12E + *Pseudomonas putida* TV-42A + *Pantoea agglomerans* RK-79), formulation 2 (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-92 + *Bacillus subtilis* TV-17C), formulation 3 (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-92 + *Kluyvera cryocrescens* TV-113C), formulation 4 (*Bacillus megaterium* TV-91C + *Pantoea agglomerans* RK-79 + *Bacillus megaterium* TV-6D) (Table 1), the full amount of commonly used chemical fertilizer (100% CF) and by combining the reduced amount of chemical fertilizer by 50% with each bacterial formulation. Bacterial formulations were inoculated in the rooted cuttings of the poinsettia by dipping method and they were planted in pots filled with appropriate growing medium. The study was designed as 3 replicates in randomized experimental design with 1 (variety) x10 (application) x2 (years) in randomized parcel trial design.

Table 1. Bacterial isolates used in the study and some biochemical properties (Kotan et al., 2009; Kotan et al., 2010)

Isolate No	MIS Diagnosis Result	SIM	Location	Host	Nitrogen	Phosphate	Siderophore
RK-79	*Pantoea agglomerans*	0.762	Erzurum	Apple	+	+	-
TV-12E	*Paenibacillus polymyxa*	0.551	Van	Poaceae	S+	+	-
TV-17C	*Bacillus subtilis*	0.677	Van	Raspberry	S	W+	-
TV-6D	*Bacillus megaterium*	0.750	Van	Poaceae	+	+	-
TV-42A	*Pseudomonas putida*	0.113	Van	Poaceae	W+	W+	+
TV-91C	*Bacillus megaterium*	0.474	Van	Poaceae	+	W+	-
TV-113C	*Kluyvera cryocrescens*	0.688	Van	Garlic	+	+	-
RK-92	*Pantoea agglomerans*	0.889	Erzurum	Pear	+	S	-

(SIM: Similarity index, S: Strong +, W: Weak +; +: Positive, -: Negative)

After planting of rooted cuttings in pots, two different types of fertilizer in a form that can be completely dissolved in water were applied to the pot groups to be applied chemical fertilizer at the determined different doses. These are comprised from "White 15-0-19 + 9CaO + 2MgO + TE, NPK ratio 4: 0: 5" (white composite fertilizer, granule, containing nitrogen, potassium, calcium, magnesium, boron, zinc, iron, copper, magnesium, molybdenum and manganese) and "Blue 18-11-18 + 2.5MgO, NPK ratio 3: 2: 3" (blue composite fertilizer, granule, containing nitrogen, phosphorus, potassium, magnesium, boron, zinc, iron, copper, molybdenum and manganese). These two different chemical fertilizers were given in specified amounts with the irrigation water consecutively (Kofranek et al., 1963; Faust et al., 2001; Anonymous, 2015). The recommended dose (150 g 100 L^{-1}) of these fertilizers for pots, flower beds and all covered seedlings was used in this study.

After 110-120 days from bacterial inoculation, in measurements of heavy metals were made on 10 samples from each application. The amount of heavy metals (Zn, Cu, Pb and Cd (mg kg^{-1}) and B (mg kg^{-1}) metalloid) in the plant leaves, plant roots and growth medium samples was determined. Plant samples (leaf and root) were oven-dried at 68 °C for 48 h and were then ground. Cu, Zn, Pb and Cd were determined by atomic absorption spectrometry using the methods of AOAC (1990). Boron was determined, after dry-ashing of plant samples, spectrophotometrically at 550 nm by the curcumin method (Odom, 1992).

At the end of the experiment, growth medium samples were taken from the rhizosphere area, comprised of 3 samples from each application, to represent each application from the cultivation medium. Zn and Cu quantities absorbable by the plant were determined by reading ICP-OES in the percolators extracted according to DTPA method (Lindsay and Norwell, 1978). Total Pb, Cd and B were determined according to AOAC (1990).

Data were treated by the analysis of variance by using the SPSS version 20.0 statistical software package (SPSS Inc., Chicago, IL, USA). For the significance level, 5% has been set to be the maximum acceptable limit to be considered as a significant result.

Results and Discussion

Zinc has effects on nitrogen metabolism, seed maturation and starch formation in plants. It is an important component of various metabolic enzymes and is in the group of immobilized elements in plants; plants need a constant supply of zinc for optimum growth. In addition, it is involved in the metabolism of hormones (auxin) that promote plant growth (Balashouri, 1995; Gardiner and Miller, 2008; Kosesakal and Unal, 2009; McCauley et al., 2009). The amount of zinc in the green leaves varied between 41.21 mg kg^{-1} and 60.03 mg kg^{-1} according to the applications. In terms of application averages, the highest average value for the amount of zinc was determined in BIV application. The lowest level was obtained from BI+CF application (Table 2).

Table 2. The amount of Zn mg kg^{-1} in the green and bract leaf, plant root and growth medium samples

Applications	**Soluble Zn (mg kg^{-1})**			
	Green Leaf	**Bract**	**Root**	**Growth medium**
Control	48.52 cd***	50.46 bc***	59.16 a***	1.79 g***
CF	48.18 cd	51.78 bc	53.68 bcd	2.57 de
BI	49.94 c	48.52 bc	49.34 e	3.20 b
BI+CF	41.21 e	48.95 bc	51.81 de	2.49 de
BII	47.66 cd	50.31 bc	56.32 abc	2.62 de
BII+CF	43.42 de	47.92 c	53.93 bcd	2.26 f
BIII	57.21 ab	52.14 b	58.34 a	2.66 d
BIII+CF	52.59 bc	43.36 d	52.53 cde	2.42 ef
BIV	60.03 a	56.56 a	57.01 ab	3.46 a
BIV+CF	51.96 c	56.03 a	56.85 ab	2.98 c
Mean	50.07	50.60	54.90	2.64

* P ≤0.05; ** P≤0.01; *** P≤0.001; ns: not significant (P≥0.05). The numbers in one column having the same letter are not significantly different

According to the general application mean, the highest mean value for the amount of zinc from the bract leaf samples was determined in BIV (56.56 mg kg^{-1}) and BIV + CF (56.03 mg kg^{-1}). The amount of zinc in the bract leaves varied between 43.36 mg kg^{-1} 56.56 mg kg^{-1} according to the applications (Table 2). Zn contents of plants are normally between 5-100 mg kg^{-1}, and toxicities are usually seen at values above 400 mg kg^{-1} (Mengel and Kirkby, 2001; Güzel et al., 2002; Marschner, 2008). According to these findings, the amount of zinc in the leaves obtained from this study was found to be sufficient or in the appropriate range. Zinc uptake efficiency of plants can vary based on plant varieties, even different genotypes of the same variety (Karaman et al., 2012). In general, the amount of zinc determined in BIV bacterial formulation application may be formed by the effects of some organic compounds. Indeed, some organic compounds, such as the amino acid secreted by the roots of certain plants, decrease level of the pH in the plant's root rhizosphere; so that plant nutrients such as the zinc, manganese, iron and phosphorus can be converted into more soluble and obtainable forms (Marschner, 2008). Di Simine et al. (1998) and Fasim et al. (2002) have documented with the findings that the insoluble Zn compounds are dissolved by bacteria. In this context, the results obtained from the present study can be explained by this finding.

In the experiment, the highest average value in terms of the amount of zinc available for poinsettia roots was determined in control and BIII applications. The amount of zinc taken from root samples varied between 49.34 mg kg^{-1} and 59.16 mg kg^{-1} according to the applications (Table 2). Aliyeva (2014) stated that the Zn concentration in the roots of *Chlamydotis undulata* is always higher than that of the leaves. The Zn amounts obtained in this study are in the normal range according to the range specified by Mengel and Kirkby (2001), Güzel et al. (2002) and Marschner (2008). Also, Di Simine et al. (1998) and Fasim et al. (2002) have shown that the Zn compounds, slow dissolving zinc in soil are dissolved by bacteria. They proved that the dissolution of Zn by microorganisms useful and economical. With these findings, the findings of this study can be supported. The amount of zinc that can be taken from the cultivation media samples varied between 2.26 mg kg^{-1}-3.46 mg kg^{-1} according to the general average of the applications. The highest amount of zinc was taken from BIV application while the lowest available zinc content was obtained from BII+CF application (Table 2).

Copper (Cu) in plants is important for plant health, plant growth and development. It is involved in the formation and composition of the cell wall, thus affecting lignification (Marschner, 1995). Copper is effective in protein and carbohydrate metabolism. It has a role in symbiotic nitrogen fixation (McCauley et al., 2009; Kacar, 2015). In this study, the highest amount of soluble copper in green leaf samples was found in BII application (15.35 mg kg^{-1}) while the lowest soluble copper content was determined in the control (13.14 mg kg^{-1}) application. It was found that the differences between the amount of copper in the bract leaf samples were not statistically significant (Table 3).

The effect of PGPR depends on bacterial strains and population, plant bacterial strain combination, plant genotype, evaluated growth parameters and environmental conditions (Çakmakçı et al., 2006; 2007; Sahin et al., 2004). Cu uptake depends on the amount of soluble Cu in the soil (Turan and Köse, 2004). It was determined that the applications on the amount of copper taken from root samples were not significant (Table 3). The highest available copper value 2.43 mg kg^{-1} BIV application while the lowest available copper was obtained from control application with 1.66 mg kg^{-1} in the growing medium (Table 3). It was determined that *Burkholderia pyrrocinia* 13/4, *Paenibacillus macquariensis* 59/8, *Pantoea agglomerans* 5/8, *Stenotrophomonas maltophilia* 21/1 ve *Lysobacter enzymogenes enzymogenes* 9/8 isolates had positive effects on plant vegetative development and nutrient contents (Ertürk et al., 2010).

Table 3. Findings of Cu (mg kg^{-1}) in the green and bract leaf, plant root and growth medium samples of poinsettia

Applications	Soluble Cu (mg kg^{-1})			
	Green Leaf	Bract	Root	Growth medium
Control	13.14 d*	12.91 ns	12.48 ns	1.66 e***
CF	13.73 bcd	12.74	12.61	2.02 d
BI	14.79 abc	13.20	12.38	2.14 bcd
BI+CF	14.76 abc	12.09	13.29	2.16 bcd
BII	15.35 a	11.95	12.74	2.09 cd
BII+CF	15.14 ab	11.99	12.63	2.20 bc
BIII	13.48 cd	12.39	13.33	2.11 cd
BIII+CF	13.77 bcd	12.88	13.80	2.08 cd
BIV	14.13 abcd	12.13	13.23	2.43 a
BIV+CF	15.03 ab	12.58	13.98	2.25 b
Mean	14.33	12.49	13.05	2.11

In green leaf samples, the highest amount of Pb was taken from CF application while the lowest amount of Pb was determined in BIV application. BI, BII, BIII, BIII+CF and BIV+CF applications were in the same statistical group with BIV application. The maximum amount of soluble Pb in the bracts is in control (0.39 mg kg^{-1}) and CF (0.41 mg kg^{-1}) applications while the lowest soluble Pb amount was determined in BIV (0.24 mg kg^{-1}) (Table 4). Pb affects plant growth (Wang et al., 2007) in a harmful way by inhibiting many physiological processes (Sinha et al., 2006; Ruley et al., 2004). The amount of Pb obtained from this study is very low. It was observed that this amount was not at the level of toxic effect or at a level that would prevent plant growth and development.

Table 4. The effects of the applications on soluble Pb values of the green and bract leaf, plant root and growth medium samples of poinsettia

Applications	Soluble Pb (mg kg^{-1})			
	Green Leaf	Bract	Root	Growth medium
Control	0.42 bc***	0.39 a***	0.36 ab***	0.18 f***
CF	0.50 a	0.41 a	0.40 a	0.26 cd
BI	0.34 de	0.33 b	0.33 bc	0.20 ef
BI+CF	0.44 ab	0.28 bcd	0.34 bc	0.19 ef
BII	0.31 de	0.28 bcd	0.24 e	0.19 ef
BII+CF	0.37 cd	0.29 bc	0.27 de	0.26 cd
BIII	0.30 de	0.25 cd	0.27 de	0.22 de
BIII+CF	0.30 de	0.28 bcd	0.29 cde	0.27 bc
BIV	0.27 e	0.24 d	0.28 cde	0.30 b
BIV+CF	0.31 de	0.33 b	0.32 bcd	0.51 a
Mean	0.35	0.31	0.31	0.26

The effect of the applications in terms of the amount of soluble Pb in the root samples ($P \leq 0.001$) was significant. The highest amount of soluble Pb was taken from CF (0.40 mg kg^{-1}) application while the lowest amount of soluble Pb (0.24 mg kg^{-1}) was determined in BII application. BII+CF and BIII applications were in the same statistical group with BII application (Table 4). Pb accumulates in stem cells in many plants. Since the plant takes Pb from the soil, the Pb content in the root is related to the amount of Pb in the soil (Raskin and Ensley, 1999). Determination of the maximum Pb content in 100% chemical fertilizer and 50% reduced chemical fertilizer applications is also consistent with this determination. Value of the highest soluble Pb in the growing media samples was determined in BIV+CF application (0.51 mg kg^{-1}) while the lowest soluble Pb amount was obtained in control (0.18 mg kg^{-1}) application. BI, BII and BI+CF applications were in the same statistical group with control (Table 4).

Boron, which is a micro plant nutrient, plays an important role in plant cell wall formation, reproduction of plant tissues, transport of sugars through cell membranes, biosynthesis of carbohydrates, nucleic acid, amino acid and protein synthesis. Boron also activates some dehydrogenase enzymes (Stangoulis et al., 2001; McCauley et al., 2009). The highest amount of boron content in poinsettia green leaf samples was found in BIV+CF application while the lowest boron content was obtained from the control application. Control application and BII application were statistically found in the same group. The amount of boron in the bract leaf was determined as the highest average in BIV+CF application. The lowest boron level was determined in the control application and control application is in the same group with CF and BI applications (Table 5). In general, the amount of boron nutrients required for the development of many plants is between 6 and 60 ppm (Jones and Jacobsen, 2001; Epstein and Bloom, 2005). The highest boron content for root samples was obtained from BIV+CF application. The lowest boron content for root samples was obtained from control and BI applications (Table 5). Microelements such as Ca, Mo and B play an important role in the pigmentation and growth of bracts of poinsettia (Arreola et al., 2008). The highest available boron value was obtained from BIII+CF application (0.86 mg kg^{-1}). The lowest available boron amounts were obtained from CF (0.46 mg kg^{-1}), control (0.47 mg kg^{-1}), BI+CF (0.50 mg kg^{-1}) and BI (0.53 mg kg^{-1}) (Table 5). Zulueta-Rodriguez et al. (2014) reported that *Pseudomonas putida* rhizobacterium was effective in increasing in the coloration and anthocyanin pigmentation of poinsettia varieties.

Table 5. The effects of the applications on soluble B values of the green and bract leaf, plant root and growth medium samples of poinsettia

Applications	Soluble B (mg kg^{-1})			
	Green Leaf	Bract	Root	Growth medium
Control	21.28 e ***	21.84 e***	22.72 d***	0.47 d***
CF	24.08 cd	23.57 de	24.06 cd	0.46 d
BI	24.34 cd	22.87 de	23.15 d	0.53 d
BI+CF	23.79 cd	27.40 bc	26.45 bc	0.50 d
BII	22.50 de	27.20 c	26.28 bc	0.61 c
BII+CF	26.72 ab	29.27 b	27.52 b	0.64 c
BIII	24.26 cd	24.52 d	24.56 cd	0.72 b
BIII+CF	26.03 bc	27.56 bc	24.81 cd	0.86 a
BIV	26.97 ab	29.05 bc	27.43 b	0.73 b
BIV+CF	28.51 a	32.05 a	31.22 a	0.71 b
Mean	24.85	26.53	25.82	0.62

Table 6. Findings of Cd (mg kg^{-1}) in the green and bract leaf, plant root and growth medium samples of poinsettia

Applications	Soluble Cd (mg kg^{-1})			
	Green Leaf	Bract	Root	Growth medium
Control	1.58 e***	1.55 de***	1.31 de ***	0.24 f***
CF	2.56 a	2.36 a	2.27 a	0.34 e
BI	1.16 g	1.14 g	1.12 f	0.37 cd
BI+CF	1.95 bc	1.38 f	1.60 bc	0.42 bcd
BII	1.35 f	1.47 ef	1.12 f	0.40 cde
BII+CF	2.07 b	1.81 b	1.76 b	0.47 ab
BIII	1.35 f	1.21 g	1.24 ef	0.39 cd
BIII+CF	1.84 cd	1.68 c	1.73 b	0.47 ab
BIV	1.38 f	1.20 g	1.46 cd	0.45 ab[c]
BIV+CF	1.70 de	1.63 cd	1.66 b	0.50 a
Mean	1.69	1.54	1.53	0.40

According to the applications, cadmium values varied between 1.16 mg kg^{-1} and 2.56 mg kg^{-1} in the green leaf samples of poinsettia while the available cadmium values in the bract leaves ranged from 1.14 mg kg^{-1} to 2.36 mg kg^{-1}. In green leaf samples, the highest available cadmium level was found in CF application and the lowest available cadmium amount was found in BI application. The least amount of cadmium in the bracts was determined in BI, BIII and BIV applications (Table 6). Cadmium is a heavy metal cation that causes phytotoxicity in plants (Shah and Dubey, 1998a, 1998b). As a result of this study, the highest Cd content was determined in plant leaves grown with 100% chemical fertilizer application. It can be said that it is expected to obtain less Cd amount in bacterial formulation applications, based on previous studies. Burd et al. (1998) reported that inoculation of seeds of canola and indian mustard with the strain *Kluyvera ascorbata* SUD165, one of the plant growth promoting rhizobacteria, protected plants against to Ni, Pb and Zn toxicity by producing 1-aminocyclopropane-1-carboxylate (ACC) deaminase enzyme and siderophore. It has been reported that various PGPR strains have the ability to immobilize Cd in nutrient medium (Belimov et al., 1998) and soil (Pishchik et al., 2002) as well as providing resistance to Cd (Belimov et al., 2005). As a result of this study, no indication of Cd's toxic effect was observed in any application. Plant capacities, such as depositing heavy metals and tolerating excess, are special characteristic of the plant species (Baker, 1987; Antosiewicz, 1992). According to the findings of these researchers, it can be concluded that the capacity of poinsettia to accumulate Cd heavy metal is low. The highest amount of cadmium in root samples was determined in CF (2.27 mg kg^{-1}) application. The lowest available cadmium content was obtained from BII and BI (1.12 mg kg^{-1}) (Table 6).

As a result of this study, the highest Cd content was determined in plant roots grown with 100% chemical fertilizer application. The toxic level of Cd may be due to natural soil properties, applications such as agricultural, manufacturing, mining, or the use of metals contained in pesticides and fertilizers in agricultural soils (Radotić et al., 2000). Since less Cd content obtained from BI, BIII and BIV bacterial formulations in the leaf samples and from the BI and BII bacterial formulations in the root samples, it was caused to be considered as ecological applications of these bacterial formulations in the present study. The highest available cadmium value in growing media samples was 0.53 mg kg^{-1} BIV+CF application while the lowest available cadmium amounts were obtained from control application with 0.24 mg kg^{-1} (Table 6). As a result of this study, no indication of Cd's toxic effect was observed in any application.

High amount of chemical fertilizers and various pesticides are used in the cultivation of poinsettia. Such applications may result in the increase in heavy metals particularly Cd, Pb, and As (Nouri et al. 2008; Atafar et al., 2010). Long-term use of excessive chemical fertilizers and organic manures in the bare vegetable field and the greenhouse vegetable field contributed to the accumulation of heavy metals in the soils (Huang and Jin, 2008). High fertilizer applications and acid atmospheric deposition, combined with insufficient liming, may also cause a decrease in pH and thus increase in heavy metal availability, aggravating the problem of deteriorating food quality, metal leaching, and impacting on soil organisms (De Vries et al., 2002).

In conclusion, plants inoculated with plant growth-promoting rhizobacteria have helped to taken from growth medium having heavy metals in growth medium. Some heavy metal resistant to bacteria are predicted to able to useful for enhancement of plant growth with recolonization of plant's rhizosphere region in metal polluted soil. For this purpose, more bacterial strains should be tested and the resistance characteristics of the bacteria to heavy metals should be identified and tested on poinsettia and other ornamental plants in further studies.

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