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CADMIUM AND ZINC REMOVAL BY SOME CUT FLOWER PLANTS

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จากปัญหาสภาพการปนเปื้อนของแคดเมียมและสังกะสีในดินและพืชที่บ้านพะเด๊ะ อ.แม่สอด จังหวัดตาก จึงมีแนวคิดในการนำพืชตัดดอกได้แก่ เบญจมาศ (Chrysanthemum (*Dendranthema difflora*)) ดาวเรือง (Marigold (*Tagetes erecta* L.)) และบานไม่รู้โรย (Globe amaranth (*Gomphrena globosa* L.)) ไปปลูกในพื้นที่ดังกล่าว เพื่อช่วยดูดดึงแคดเมียมและสังกะสีออกจากดิน ทั้งยังสามารถนำดอกไปใช้ประโยชน์ได้

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาผลของแคดเมียมและสังกะสีที่ระดับความเข้มข้นต่างๆ ต่อการเจริญเติบโตของเบญจมาศ (*D. difflora*)) ดาวเรือง (*T. erecta* L.) และบานไม่รู้โรย (*G. globosa* L.) โดยวัดจากความสูง ความยาวข้อ ขนาดเส้นผ่านศูนย์กลาง และน้ำหนักแห้ง เปรียบเทียบปริมาณแคดเมียมและสังกะสีที่พืชสะสมไว้ในส่วนต่างๆ ได้แก่ ราก ลำต้น ใบ และดอก ตลอดจนประสิทธิภาพในการดูดดึงแคดเมียมและสังกะสี (%) โดยจะทำการปลูกพืชทั้ง 3 ชนิดในกระถางที่มีการใส่สารประกอบ $Cd(NO_3)_2.4H_2O$ ที่ระดับความเข้มข้น 0, 20, 40, 60, 80 และ 100 mg Cd/kg soil หรือ $Zn(NO_3)_2.6H_2O$ ที่ระดับความเข้มข้น 0, 50, 100, 150, 200 และ 250 mg Zn/kg soil และ Ethylenediaminetetraacetic acid (EDTA) 0.1 g/kg soil เมื่อพืชออกดอกจะทำการเก็บเกี่ยวและนำมาวิเคราะห์หาปริมาณแคดเมียมและสังกะสีที่สะสมไว้ในส่วนต่างๆ ของพืช

ผลการศึกษาพบว่าดาวเรือง (*T. erecta* L.) และบานไม่รู้โรย (*G. globosa* L.) สามารถเจริญเติบโตได้ดีกว่าเบญจมาศ (*D. difflora*) โดยดาวเรือง (*T. erecta* L.) และบานไม่รู้โรย (*G. globosa* L.) มีการเจริญเติบโตปรกติและสามารถให้ดอกได้ในทุกความเข้มข้น ขณะที่เบญจมาศ (*D. difflora*) ที่ปลูกในดินที่ผสม $Cd(NO_3)_2.4H_2O$ แสดงอาการแคระแกรนและมีช่วงข้อสั้นที่ความเข้มข้น 20, 40, 60, 80 และ 100 mg Cd/kg soil ตลอดจนเกิดอาการใบซีดเหลืองเล็กน้อยที่ความเข้มข้น 100 mg Cd/kg soil ส่วนเบญจมาศ (*D. difflora*) ที่ปลูกในดินที่ผสม $Zn(NO_3)_2.6H_2O$ แสดงอาการใบไหม้และเกิดจุดสีน้ำตาลที่ใบที่ความเข้มข้น 50, 100, 150, 200 และ 250 mg Zn/kg soil ตลอดจนเกิดอาการดอกแห้งตายที่ความเข้มข้น 200 และ 250 mg Zn/kg soil พืชทั้งสามชนิดมีแนวโน้มในการสะสมแคดเมียมและสังกะสีในใบและลำต้นมากกว่าราก โดยพบว่าที่ความเข้มข้น 100 mg Cd/kg soil และที่ความเข้มข้น 250 mg Zn/kg soil ดาวเรือง (*T. erecta* L.) มีประสิทธิภาพในการดูดดึงแคดเมียมและสังกะสีออกจากดินมากที่สุด ซึ่งมีค่า 0.019% และ 0.042% ตามลำดับ จากการศึกษาสามารถสรุปได้ว่าดาวเรือง (*T. erecta* L.) และบานไม่รู้โรย (*G. globosa* L.) มีศักยภาพในการนำไปใช้ในพื้นที่เนื่องจากมีประสิทธิภาพในการดูดดึงโลหะหนักและสามารถให้ดอกได้ในทุกความเข้มข้นของการทดลอง

สาขาวิชา วิทยาศาสตร์สิ่งแวดล้อม ลายมือชื่อนิสิต พรอำภา สุรภักดี

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PORN-UMPA SURABHUKDI: CADMIUM AND ZINC REMOVAL BY SOME CUT FLOWER PLANTS. THESIS ADVISOR: ASSOC. PROF. THARES SRISATIT, Ph.D., 189 pp.

From the problem statement of cadmium and zinc contamination in soil and plants in Pha Tae village, Mae Sot district, Tak Province. So it leads to an idea to use some cut flower plants such as chrysanthemum (*Dendranthema difflora*), marigold (*Tagetes erecta* L.) and globe amaranth (*Gomphrena globosa* L.) to cultivate in this area to uptake of cadmium and zinc from contaminated soil, moreover by product is cut flowers for the commercial purposes.

The objective of this research is the study on the effects of cadmium and zinc at different levels to the growth of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.), that determined by height, internodes length, diameter of stem and dry weight. Comparing the amount of cadmium and zinc accumulation in roots, stems, leaves and flowers including their efficiencies of cadmium and zinc removal (%) in different species of plant. Three plant species were cultivated by using treated soil with $Cd(NO_3)_2.4H_2O$ at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil or $Zn(NO_3)_2.6H_2O$ at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil and ethylenediaminetetraacetic acid (EDTA) at 0.1 g/kg soil was added for chelation. Until flowering stage, the plants were harvested and the amount of cadmium and zinc accumulate in various parts of plants will be analyzed.

The results showed that marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) better grew up than chrysanthemum (*D. difflora*). Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew normally and could produce flowers under all concentrations, while chrysanthemum (*D. difflora*) which grew in soil with the compositions of $Cd(NO_3)_2.4H_2O$ exhibited abnormal characteristics such as stunted and could not produce flowers at concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, moreover a mild chlorosis appeared at concentration of 100 mg Cd/kg soil and chrysanthemum (*D. difflora*) which grew in soil with the compositions of $Zn(NO_3)_2.6H_2O$ exhibited abnormal characteristics such as scorching in leaves and necrosis at concentrations of 50, 100, 150, 200 and 250 mg Zn/kg soil, moreover death of the flowers appeared at concentrations of 200 and 250 mg Zn/kg soil. The results indicated that all plants tended to accumulate cadmium and zinc in leaves and stems more than roots. Furthermore, at cadmium concentration of 100 mg Cd/kg soil and zinc concentrations of 250 mg Zn/kg soil, marigold (*T. erecta* L.) was more effective to remove cadmium and zinc from the soil at 0.019% and 0.042%, respectively. The results concluded that marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were suitable species for phytoremediation of contaminated soil because of their efficiencies in heavy metals removal and able to produce flowers under all concentrations.

Field of Study Environmental Science Student's Signature Pornumpa Surabhukdi

Academic Year 2006 Advisor's Signature T. Srisatit

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CHAPTER I

INTRODUCTION

1.1 Background

Soil contamination by heavy metals is a great worldwide concern. Sources of metals in the environment originate from both natural geochemical processes (weathering of ultramafic rocks) and anthropogenic sources such as residues from metalliferous mining, the metal smelting industry, combustion of fossil fuel, agriculture use of pesticides, fertilizers and sewage sludges (Alloway, 1997).

Cadmium (Cd) and zinc (Zn) are two widespread harmful heavy metals. Cadmium contamination in the environment is mainly from anthropogenic sources (Furgusson, 1990). Non-ferrous metal mine can be a significant source of local cadmium contamination, particularly those which exploit zinc and lead (Pb) ores. Cadmium is closely related to zinc and will be found wherever zinc is found in nature (Fulkerson and Goeller, 1973). It is obtained as a by product from smelting of sulfide ore minerals. The most abundant sources of cadmium are the ZnS minerals aphalerite, wurzite and secondary minerals such as $ZnCO_3$ which typically contain 0.2-0.4% cadmium concentration up to 5% cadmium can be found. (Pollution Control Department, 2004).

In Thailand, the major zinc production is in Tak Province (Theerapunsatien, 1995). In Mae Sot district, cadmium contamination is discovered in soil and rice by International Water Management Institute (IWMI). The first phase of the study (from 1998-2000) was done in the most potentially polluted area where water was naturally supplied by Mae Tao Creek in which sediment was suspected of having high contamination of cadmium (Figure 1-1).

It was concluded that source of cadmium contamination was high level in soil, but no sufficient evidences to confirm that whether cadmium was from natural zinc mineralized area or contamination by zinc mining activities, flooded or eroded into natural and man-made water supplies which was, then, irrigated into rice paddy fields. Cadmium was eventually transferred from soil into rice. Results showed that cadmium

levels in 154 soil samples ranged from 3.4–284 mg Cd/kg soil which was 1.13–94 times European Economic Community (EEC) Maximum Permissible (MP) soil cadmium concentration of 3.0 mg Cd/kg soil and 1,800 times the Thai standard of 0.15 mg Cd/kg soil. Moreover, rice samples from 90 fields were found to be contaminated with cadmium ranging from 0.1 to 4.4 mg/kg rice while the mean background Thai rice cadmium concentrations was 0.043±0.019 mg/kg rice. (Pollution Control Department, 2004).

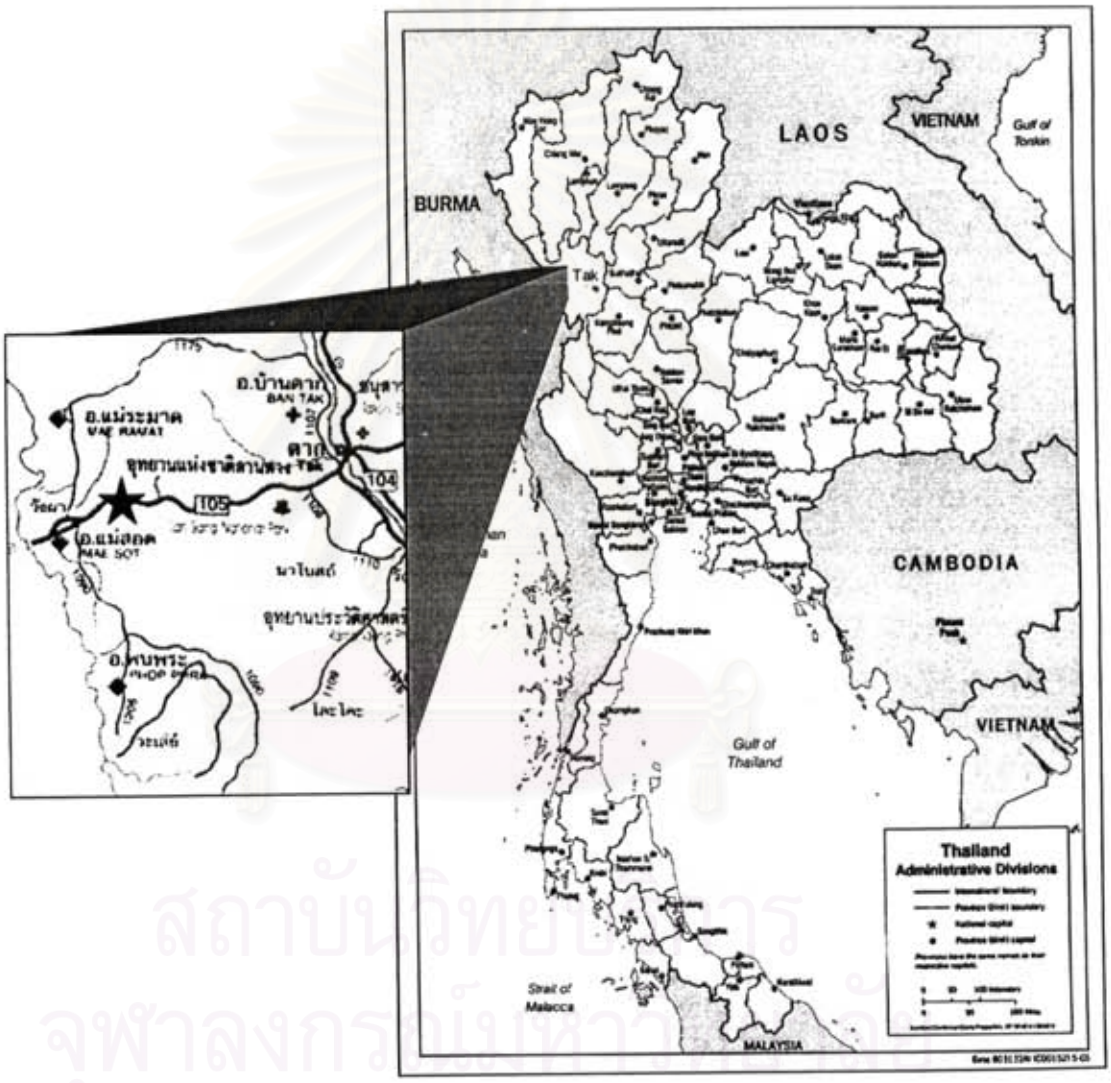

Figure 1-1 Mae Sot district, Tak Province, Thailand

Source: Adapted from Chanthachot et al., 2005

The second phase of the study, from 2001 – 2003, was expanded to cover the downstream part of Mae Tao Creek. Cadmium level in soil samples was found to be 72

times European Union (EU) standard and 80 % of rice samples were contaminated with cadmium at the level higher than Food and Agriculture Organization (FAO) and Japanese standards. This concentration of cadmium could lead to 2.8-11 times higher than the Joint FAO/WHO Expert Committee on Food Additives (JECFA) Provisional Tolerable Weekly Intake (PTWI) of 7 μg Cd / kg body weight (BW) per week. (Simmons et al., 2005). While toxicologists from Chiang Mai University Medical School and Japanese cadmium experts from Kanazawa Medical University started a research project to assess the effect of cadmium on kidneys, the major target organ of cadmium. It is expected that a 10-year surveillance is needed to reduce health risks among 800 people, who had high urinary cadmium level (> 5 μg/g creatinine) and were at risk of having cadmium-induced renal failure.

There are many methodologies to alleviate or minimize heavy metals that have been contaminated in soil, such as by removing or replacement the contaminated sites. However, the cost such management is rather high and difficult for general practice. The removing of heavy metals by plants has been recommended for experiment due to its relatively low cost. The method is phytoremediation, many researches have proved that it is one of the most efficient tools for improving environmentally contaminated sites (Terry and Bañuelos, 2000).

An idea to use some cut flower plants such as chrysanthemum (*Dendranthema difflora*), marigold (*Tagetes erecta* L.) and globe amaranth (*Gomphrena globosa* L.) to grow in the stated area for helping the uptake of cadmium and zinc from contaminated soil, moreover by product is to cut the flowers for the commercial purposes.

But the low solubility of heavy metals in soil is often a limiting factor in metal extraction by plants (Huang et al., 1997). Increasing metal solubility in soil and the bioavailability of metals to the plant are important to phytoextraction of heavy metals from contaminated soil. Chelating compounds have been used in soils and nutrient solutions to increase the solubility of metal in soil for the plants. So in this study, the use of ethylenediaminetetraacetic acid (EDTA) was introduced as chelating agent applied to the contaminated soil to enhance metal accumulation in plant species.

1.2 Objectives

1.2.1 To study the effects of cadmium and zinc at different levels on the growth of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) determined by height, internodes length, diameter of stem and dry weight.

1.2.2 To compare the amount of cadmium and zinc accumulation in roots, stems, leaves and flowers of the above plant species.

1.2.3 To compare the efficiency of cadmium and zinc removal in different species of plant.

1.3 Hypothesis

1.3.1 Cadmium and zinc accumulation in plants would be increasing when the concentration of cadmium and zinc increasing in soil.

1.3.2 Cadmium and zinc accumulation in plants would affect on plants growth.

1.3.3 Roots, stems, leaves and flowers would accumulate cadmium and zinc in different concentrations.

1.3.4 Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) would accumulate cadmium and zinc in different concentrations.

1.4 Scope of study

1.4.1 The cut flower plants used in the study were chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.).

1.4.2 The three plant species were cultivated using soil treated with $Cd(NO_3)_2.4H_2O$ at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil or $Zn(NO_3)_2.6H_2O$ at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil and

ethylenediaminetetraacetic acid (EDTA) at 0.1 g/kg soil was added for chelation. There were three replicates of each treatment in completely randomize design (CRD).

1.4.3 Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were grown under natural light and ambient temperature. Until flowering stage, the plants were harvested and the amount of cadmium and zinc accumulation in roots, stems, leaves and flowers will be analyzed.

1.4.4 Study the effects of cadmium and zinc at different levels on the growth of plants, moreover the amount of cadmium and zinc accumulation in various parts of each plant, and the efficiency of cadmium and zinc removal in plants were compared.

1.5 Anticipated benefits

1.5.1 This study can identify the level of contamination of cadmium and zinc in various parts of the cut flower plants.

1.5.2 The results can identify the plant species with the high potential to use for phytoremediation of contaminated soil.

1.5.3 This method can be implemented in the contaminated sites in order to create the appropriate agriculture for the local farmer.

CHAPTER II

LITERATURE REVIEWS

'Heavy metal' is refers to metals with a density greater than a certain value of usually 5 or 6 g cm^{-3}. It is not alkali and alkaline earth and it atomic number is between 23-92 in row of 4 to 7th of elements periodic (Figure 2-1) (Panitchasukpatana, 1997).

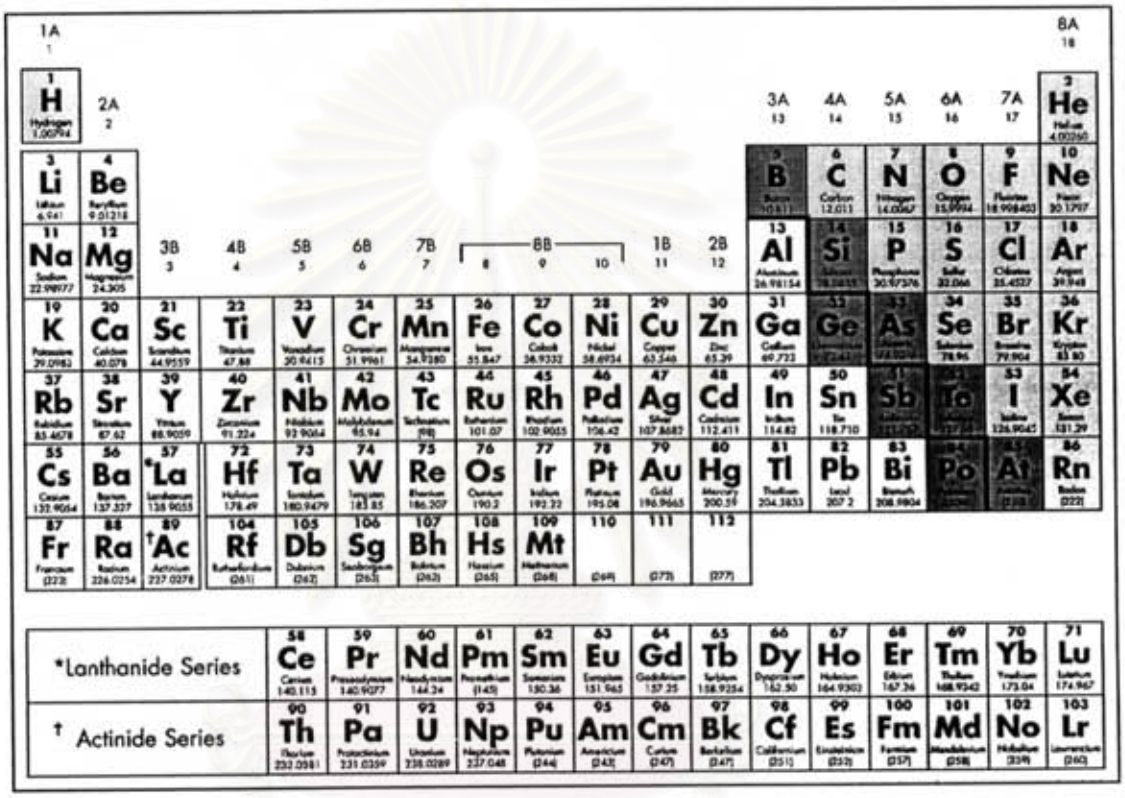

Figure 2-1 Periodic table of the elements

Source: Scerri, 2006

Heavy metals occur from both natural sources and human activities. When heavy metals contaminate the soil, they release to environment, including water, groundwater and air. Generally, the toxic substances cause serious problem. The substances that exist in soil for a long time and plants cannot uptake are, for example, lead (Pb), mercury (Hg). Besides, there are toxic substances that can exist in soil for a short period and is soluble, which can be uptaken by plants. These toxic substances are cadmium (Cd), boron (Br), nickel (Ni) and zinc (Zn). Then heavy metals get into food chain. These substances can cause serious environmental problems (Figure 2-2).

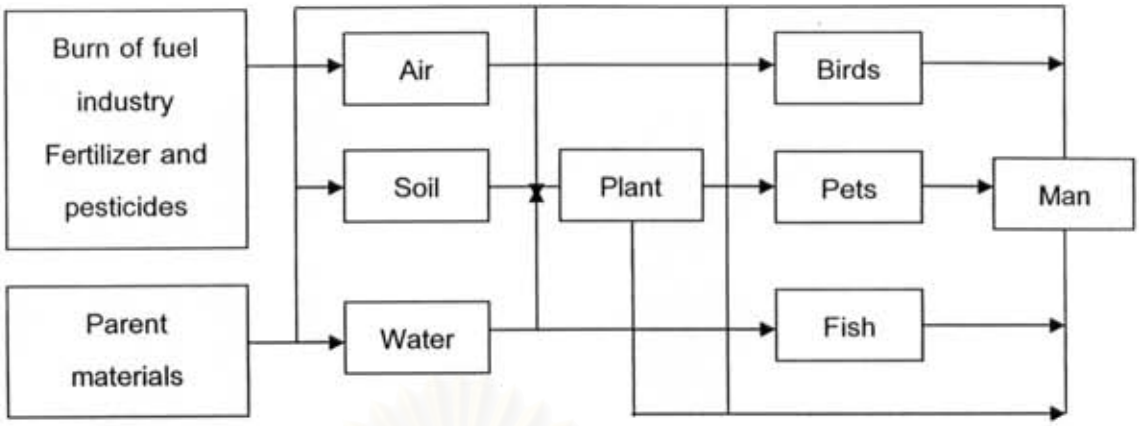

Figure 2-2 The cycling of heavy metals in soils and ecosystems.

Source: Brandy, 1984

2.1 Cadmium

2.1.1 Properties of cadmium

Cadmium (Cd) belongs to the group 2B of the Periodic Table of the elements and is a relatively rare metal, being 67th in order of elemental abundance. It is closely associated with zinc (Zn) in its geochemistry. (Alloway, 1995). Cadmium occurs in the earth's crust at an average concentration of 0.2 mg/kg. Cadmium is classified as a soft acid, preferentially complexing with sulfides, often as greenockite (a hexagonal crystalline form of cadmium sulfide), hawleyite (a cubic crystalline from of cadmium sulfide), sphalerite (zinc sulfide) and otavite (a mineralized form of calcium carbonate). Cadmium is considerable of environmental and health significance because of its increasing mobilization and toxicity to many life forms (Moore, 1991).

Cadmium (atomic number 48; relative atomic mass 122.40) is a metallic element belonging, together with zinc and mercury. It is rarely found in a pure state. It is present in various types of rocks and soils and in water, as well as in coal and petroleum. Among these natural sources, zinc, lead and copper ores are the main sources of cadmium. The average natural abundance of cadmium in the earth's crust has most often been reported from 0.1–0.5 ppm, but much higher and much lower values have also been cited depending on a large number of factors. Igneous and metamorphic rocks tend to show lower values, from 0.02 to 0.2 ppm whereas sedimentary rocks have much higher values, from 0.1 to 25 ppm. Naturally, zinc, lead

and copper ores, which are mainly sulfides and oxides, contain even higher levels, 200 to 14,000 ppm for zinc ores and around 500 ppm for typical lead and copper ores. The raw materials for iron and steel production contain approximately 0.1 to 5.0 ppm, while those for cement production contain about 2 ppm. Fossil fuels contain 0.5 to 1.5 ppm cadmium, but phosphate fertilizers contain from 10 to 200 ppm cadmium (Cook and Morrow, 1995).

Cadmium exists in many forms. The most common forms are elemental cadmium, cadmium carbonate, cadmium chloride, cadmium oxide, cadmium sulfate and cadmium sulfide (Table 2-1).

Table 2-1 Physical and chemical properties of cadmium compounds

Cadmium compounds	Physical and chemical properties					
	Empirical formula	Relative atomic or molecular mass	Relative density	Melting point (°C)	Boiling point (°C)	Water solubility (g/litre)
Cadmium	Cd	112.41	8.642	320.9	765	insoluble
Cadmium chloride	$CdCl_2$	183.32	4.047	568	960	1400 (20 °C)
Cadmium acetate	$C_4H_6CdO_4$	230.50	2.341	256	decomposes	Very soluble
Cadmium oxide	$Cd(OH)_2$	128.40	6.95	< 1426	900-1000 (decomposes)	insoluble
Cadmium hydroxide	CdO	146.41	4.79	300 (decomposes)		0.0026 (26 °C)
Cadmium sulfide	CdS	144.46	4.82	1750		0.0013 (18 °C)
Cadmium sulfate	$CdSO_4$	208.46	4.691	1000		755 (0 °C)
Cadmium sulfite	$CdSO_3$	192.46		decomposes		slightly soluble

Source: Adapted from ATSDR, 1993

Cadmium can form a number of salts. Its mobility in the environment and effects on the ecosystem depend to a great extent on the nature of these salts. Since there is no evidence that organocadmium compounds, where the metal is covalently bound to carbon, occur in nature, only inorganic cadmium salts will be discussed. Cadmium may occur bound to proteins and other organic molecules and form salts with organic acids, but in these form, it is regarded as inorganic (Hirsch and Banin, 1990).

Cadmium has a relatively high vapor pressure. Its vapor is oxidized rapidly in air to produce cadmium oxide. When reactive gases or vapor, such as carbon dioxide, water vapor, sulfur dioxide, sulfur trioxide or hydrogen chloride are present, the vapor reacts to produce cadmium carbonate, hydroxide, sulfite, sulfate or chloride, respectively. These salts may be formed in stacks and emitted to the environmental. Some of the cadmium salts, such as the sulfide, carbonate or oxide, are practically insoluble in water. However, these can be converted to water soluble salts in nature under the influence of oxygen and acids; the sulfate, nitrate and halogenates are soluble in water (Alloway, 1995).

2.1.2 Sources of cadmium

Thailand, cadmium has been produced since 1890, it is obtained as a by product from smelting of sulfide ore minerals in which it has substituted for some of the zinc. The most abundant sources of cadmium are the ZnS minerals aphalerite and wurzite and secondary minerals, such as $ZnCO_3$ which typically contain 0.2-0.4% cadmium although concentration of up to 5% cadmium can be found. (Pollution Control Department, 2004). Its principle uses are as protecting planting on steel, in various alloys, in pigments (for plastics, enamels and glazes) as a stabilizer for plastic, in Ni-Cd-dry-cell batteries and other miscellaneous uses including photovoltaic cells and control roots for nuclear reactors (Alloway, 1995). The cadmium pollution of the soils and environment has been rapidly increasing in recent decades as a result of rising consumption of cadmium by industry. The disposal of water containing cadmium, such as the incineration of plastic containers and batteries, sewage sludge application to land. Phosphatic and fertilizers are important cadmium contents vary. Their continual

use has led to significant increases in the cadmium contents of many agricultural soils (Alloway, 1997).

2.1.3 Uses of cadmium

Cadmium has a limited number of applications but within these ranges the metal is used in a large variety of consumer and industrial materials. The following comments describe the nature of the principal applications of cadmium in six categories:

Cadmium is used as the anode in nickel-cadmium batteries. These batteries are rechargeable, have a long lifetime of approximately 3,000 cycles and a low self-discharge rate, operate over a wide temperature range and can deliver maximal current with a low-voltage drop. The chief disadvantages of nickel-cadmium batteries are their low energy density and their high cost. They are used as sealed cells in radios, alarm systems, emergency lighting, pacemakers, calculators, motor starters, walki-talkies, portable appliances and tools. Large vented units are used in buses, diesel engines, aircraft, spacecraft, military applications and standby power and lighting systems (Nriagu, 1980).

Almost all cadmium plating is done by electrodeposition, although some plating and coating is also done by vacuum deposition, dipping or spraying. In electrolysis on metal objects made of steel, iron, copper, brass and other alloys to prevent corrosion. The cadmium layer provides good solder ability and conducts electricity well, is highly ductile and provides good corrosion resistance to tropical atmospheres, saltwater and alkaline substances. Cadmium has the ability to protect steel, to which it is anodic, through sacrificial corrosion (Hirsch and Banin, 1990).

Certain cadmium compounds are coloring agents in a variety of products, chiefly in plastics but also including coated fabrics, textiles, rubber, glass, pains, enamels, ceramic glazer, printing inks and artist's colors. The colors, which range from yellow to red, are produced by mixtures of cadmium sulfide and cadmium selenide (red) or of cadmium sulfide with zinc sulfide (yellow). Cadmium pigments have good hiding power and color intensity, do not bleed, are resistant to degradation by light,

basic substances, and H_2S and are heat stable up to about 6,000°C (Hirsch and Banin, 1990).

Mixture of cadmium and barium combined with organic acid anions is used as heat stabilizers in plastics to retard degradation due to elevated temperatures. These stabilizers offer some protection against light induced degradation as well. Because of the toxicity of cadmium, the FAD has ruled that cadmium stabilizers cannot be incorporated into plastics used for food packaging (Alloway, 1995).

Alloys of cadmium have found use in a variety of applications. Metals such as bismuth, lead and selenium have been combined with cadmium to produce low melting point alloys that are used in fire detection and fire door release devices, smolds for casting plastics, and as safety plugs in compressed gas cylinders. Such alloys usually contain less than 20% cadmium. Bearing made of cadmium combined with nickel, copper or silver have greater heat resistance and can run at higher speeds than selenium or lead bearing, but use of such bearing has declined since World War II (Alloway, 1997).

Cadmium is used in certain pesticides both in agriculture and in nonagricultural applications. Because cadmium is effective in absorbing neutrons, it has been used to make control rods for nuclear reactors. Cadmium is also used in smoke detection devices, in solar cells, in photocell, and as a component of the phosphores in television tubes, X-ray screens and luminescent dials. Small concentrations of cadmium are found in virtually all fossil fuels. Concentrations in coal as high as 1-2 mg/L have been reported, but typical levels in oil are found in the range 0.1-0.5 mg/L. Roughly 6 billion tons of fossil fuels are burned each year and the concomitant release of cadmium to the atmosphere amounts to about 670 tons (Edward, 2002).

2.1.4 Cadmium in soil

The major factors governing cadmium speciation, adsorption and distribution in soils are pH, soluble organic matter content, hydrous metal oxide content, clay content, type of organic and inorganic ligands and competition from other metal ions (OECD, 1994).

The uptake of cadmium into plants generally depends upon the availability of the metal in soil solution. The soil pH and composition, particularly the nature of soil clays, the organic matter content and obviously, the soil cadmium level affect this availability. The relationship between soil cadmium level and plant uptake is not a simple one because of the wide variety of soil characteristics that affect the extent of cadmium uptake (WHO, 1992).

2.1.5 Cadmium and plants relationship

Cadmium is one of the most dangerous heavy metal due to its high mobility and the small concentration at which its effects on plants. The primary mechanism of cadmium removal from water is precipitation with sulfides and plant up take. Certain plants seem to have affinity for cadmium and will show elevated levels in all portions of the plant. In most cases, metal uptake is in the root and rhizome, with a minor amount moving to the leaves and stems (Moral et al, 1994).

When a plant dies, the metals remain in the sediment unless physically disturbed. The roots of lettuce released much more of their absorbed cadmium for translocation to the shoots than other crops (ryegrass and orchardgrass) (Javis, Jones and Hopper, 1976). The greater translocation is due to active transport or lack of metal absorption to fixed or soluble chelators in the root or perhaps due to the exchange with the calcium, manganese and zinc moving through the root (John, Van Laerhoven and Bjerring, 1976). Cadmium was easily transported to aerial parts of tomato and was not detected in fruits (Moral et al, 1994).

In general, broadleaf plants such as swiss chard and lettuce accumulate more cadmium than grasses and plant leaves and stems accumulate more than seeds (Baghour et al, 2001). On the contrary, Mckenna, Chaney and William (1993) reported higher cadmium concentration in older leaves of lettuce and spinach. The potential accumulation of cadmium in old leaves could not be solely due to the transpiration rate. Metal-binding peptides were present in older leaves in higher amounts than in younger leaves in tobacco, and cadmium was transported into the vacuoles as a mean of detoxification (Vogeli-Lange and Wanger, 1990).

The most general symptoms are stunting and chlorosis. Chlorosis from excessive cadmium appears to be due to a direct or an indirect interaction with foliar iron. Chaney and Giordano (1977) stress that it is not possible to rely on the onset of visible symptoms of cadmium toxicity to act as a warning when food crops have accumulated excessive amounts of metals, such as cadmium, which could be hazardous to health.

Relatively large concentrations of cadmium can accumulate in edible portions without the plant showing symptoms of stress. Acute cadmium toxicity is manifested by leaves chlorosis, wilting and stunted growth, but is rarely found. Many cases of toxicity on heavy metal-polluted soils are due to excesses of other elements present in far higher concentrations. Overnell (1975) reported that 0.01-0.1 mg/L cadmium reduced the concentration of ATP and chlorophyll in many species, and decreased oxygen production. Root, Miller and Koeppe (1975) felt that cadmium-induced chlorosis in corn leaves could be due to changes in Fe:Zn ratios. Mitchell, Bingham and Page (1978) found the order of toxicity to wheat and lettuce plants on acid soil to be cadmium>nickel>zinc.

2.2 Zinc

2.2.1 Properties of zinc

Zinc (Zn) is the first element in group 2B in the periodic table; it is one of the most common elements in the earth's crust. Zinc is occurs in the earth's crust at an average concentration of 76 mg/kg, making it the 24th most abundant element. The principal ores are sulfides, such as sphalerite, wurtzite (cubic and hexagonal ZnS, respectively), carbonate (known as smithsonite or clamine, $ZnCO_3$) and silicate (willemite, Zn_2SiO_4). The solubility of zinc is controlled in natural wares by adsorption on mineral surfaces, carbonate equilibrium and organic complexes (Moore, 1991).

Pure zinc (atomic number 30; atomic weight 65.38) is a bluish-white and lustrous when polished. It is brittle at ordinary temperatures but malleable at 100 to 150°C. It is a fair conductor of electricity and burns in air at high red heat with evolution of white clouds of the oxide. It exhibits superplasticity. Neither zinc nor zirconium is

ferromagnetic, but $ZrZn_2$ exhibits ferromagnetism at temperatures below 35°K. It has unusual electrical, thermal, optical and solid-state properties that have not been fully investigated (WHO, 2001). Naturally occurring zinc contains five stable isotopes. Sixteen other unstable have very short half-lives (Lide, 1991).

2.2.2 Sources of zinc

Zinc is one of the most common elements in the earth's crust. It is present in nearly all foods. Also found naturally in air, soil and water. The average abundance of zinc in the earth's crust is 76 mg/kg; in soil, 25 to 68 mg/kg; in streams, 20 μg/L, and groundwater, <0.1 mg/L (Nriagu and Pacyna, 1988).

The total of zinc discharged to freshwater from anthropogenic sources comes to 77-373 x 10^3 metric tons per year (Nriagu and Pacyna, 1988). There are several major sources including the discharge of domestic wastewater, coal-burning power plants, manufacturing processes involving metals and atmospheric fallout. Approximately 34% of all emissions of zinc to the atmosphere come from natural sources, the remainder originating from metal production, burning of coal and oil and fertilizer and cement production (Nriagu and Pacyna, 1988; Nriagu, 1989).

The major sources of zinc in soils are the zinc sulfide minerals such as sphalerite (sulfide) and wurtzite, and to lesser extent minerals such as smithsonites ($ZnCO_3$) (carbonate), willemite (Zn_2SiO_4), zincite (ZnO), zinkosite ($ZnSO_4$), franklinite ($ZnFe_2O_4$) (zinc, manganese, iron oxide) and hopeite ($Zn_3(PO_4)_2.4H_2O$) (Table 2-2). Zinc supplementation of soil is achieved using sewage sludge or fertilizers. Zinc was added to the soils in the form of zinc nitrate or sewage sludge.

2.2.3 Uses of zinc (Burch, Hanh, and Sullivan, 1975)

Zinc is necessary to modern living and in tonnage produced, stands fourth among all metals in world production-being exceeded only by iron, aluminum and copper. Zinc is also a necessary element for proper growth and development of humans, animals and plants; it is the second most common trace metal, after iron, naturally found in the human body.

Table 2-2 Common zinc compounds and their uses

Compounds	Uses
Zinc acetate	Wood preserving, mordant, glazes, reagent.
Zinc carbonate	Pigment, feed additive, manufacture of porcelains, pottery, rubber.
Zinc chloride	Deodorant, disinfectant, wood preservative, fireproofing, soldering flux, cement, mordant, petroleum refining, textile treatment, vulcanizing rubber, solvent for cellulose, manufacture of activated carbon, paper, glues, and dye.
Zinc chromate (VI),	Pigment in paint, oil, varnish, linoleum, rubber.
Zinc cyanide	Electroplating, removing NH_2 from gas.
Zinc fluoride	Fluoridation of organic compounds, glazes, enamels, wood preserving, electroplating; manufacture of phosphors for fluorescent lights.
Zinc oxide (flowers of zinc, zinc white, philosopher's wool)	Pigments, cements, glass, tires, glue, matches, white ink, reagent, photocopy paper, flame retardant, semiconductor, fungicide, cosmetics, dental cements.
Zinc phosphide	Rodenticide
Zinc silicate	Television screens, neon lights.
Zinc stearate	Tablet and rubber manufacture; cosmetic and pharmaceutical powders; ointments, waterproofing, releasing agent in the manufacture of plastics.
Zinc sulfate (zinc vitriol, white vitriol)	Mordant, wood preserving, paper bleaching, reagent, manufacture of Zn salts, electrodeposition of Zn.
Zinc sulfide (zinc blende)	Pigment (manufacture of luminous dials, X-ray and television screen).

Source: WHO, 2001

The metal is employed to form numerous alloys with other metals. Brass, nickel silver, typewriter metal, commercial bronze, spring bronze, German silver, soft solder and aluminum solder are some of the more important alloys. Large quantities of zinc are used to produce die casting, which are used extensively by the automotive, electrical and hardware industries. An alloy called Prestal, consisting of 78% zinc and 22% aluminum, is reported to be almost as strong as steel and as easy to mold as plastic. The alloy is said to be so moldable that it can be molded into form using inexpensive ceramics or cement die casts.

Zinc is also used extensively to galvanize other metals such as iron to prevent corrosion. Zinc oxide is a unique and very useful material for modern civilization. It is widely used in the manufacture of paint, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, storage batteries, textiles, electrical equipment and other products. Lithopone, a mixture of zinc sulfide and barium sulfate, is an important pigment. Zinc sulfide is used in making luminous dials, X-ray, TV screens and fluorescent light.

Zinc is an essential element in the growth of human beings and animals. Test showed that zinc-deficient animals require 50% more food to gain the same weight as an animal supplied with sufficient zinc.

Zinc is not considered to be toxic, but when freshly formed zinc oxide (ZnO) is inhaled a disorder known as the Oxide shakes or zinc chills sometimes occurs. Where zinc oxide is encountered, recommendations include providing good ventilation to avoid concentration exceeding 5 mg/m^3, (time-weighed over an 8-hour exposure, 40-hour work/week). Some of the occupations involving exposure to zinc and zinc compounds are alloy makers, embalmers, petroleum refinery workers and welders.

2.2.4 Zinc in soil

The major attenuation mechanisms for zinc are adsorption, cation exchange, and precipitation. Zinc is a common cation in soil systems. The pH of the leachate-soil system is crucial factor in zinc removal, reflecting the influence of dominant hydrolysis species on both the affinity for soil colloids and the solubility of zinc (Burch, Hanh and Sullivan, 1975).

Zinc availability decreases as a result of increasing pH (Figure 2-3). The attenuation of zinc was found to increase rapidly for a pH change from 2-8 with a significant rise around 6-8 (Griffin, Hale and Shay, 1976). Precipitation of zinc with a variety of anions including sulfide, phosphate, carbonate and silicate has also been found to be important in zinc immobilization. Experimental results suggest that the removal of zinc is also dependent on clay type and cation-exchange capacity (Frost and Griffin, 1977). Organic matter improves zinc immobilization (Folett and Lindsay, 1971;

Norvell, 1972). Soil material favoring attenuation of zinc including clays, organic material, hydrous metal oxides and free lime. Zinc attenuation will be most favored by an alkaline condition. In general, mobility of zinc in a clayey environment is low (Frost and Griffin, 1977).

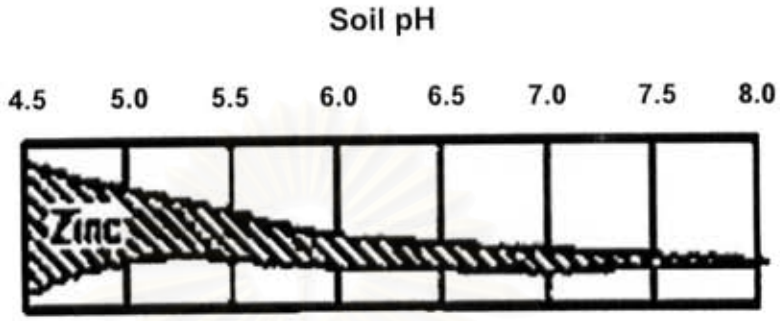

Figure 2-3 Zinc availability decreases as a result of increasing pH

Source: Prapreatdham, 1995

2.2.5 Zinc and plants relationship

Zinc ions have been absorbed through the roots and have been transported to the xylem vessels, there is the possibility of movement throughout the whole plant. The rate and extent of movement within plants depends on the metal concerned, the plant organ and the age of the plant. About root absorption, the extent to which elements are translocated decreases in the order Cd>B>Zn>Cu>Pb (Chaney, 1993).

Zinc toxicity affects general physiological processes, e.g., transpiration, respiration and photosynthesis, and plant development in general can be visibly inhibited. Stunted growth, leaf epinasty and chlorosis of the younger leaves are striking symptoms of strong zinc toxicity. However, at lower degrees of zinc toxicity these visible symptoms are less pronounced or can even be absent, whereas at the cellular level several processes are affected, owing to increases in local metal concentrations. Several mechanisms of metal action at the physiological and biochemical level have been described (Chaney, 1993; Vangronsvels and Clijsters, 1994).

2.3 Relationship of heavy metal and soil

The soil is a dynamic system, subject to short-term fluctuation, such as variations in moisture status, pH and redox conditions, and also undergoing gradual alterations in response to change in management and environment factors. These changes in soil properties affect the form and bioavailability of metals and need to be considered in decisions on the management of polluted soils or the used of soils for disposal of waste materials. Soil can show marked spatial variability in physical and chemical properties at the macro-and micro-scales, thus emphasizing the need for thorough sampling to include the range of variation in parameters at any site investigated soil properties influence movement and exist of heavy metal in soil, such as soil pH, soil texture, organic matter and cation exchange capacity (Alloway, 1995).

2.3.1 Soil pH

Soil pH is the logarithm of the hydrogen ion (H^+) concentration in soil colloidal, which the scale serves as a measure of acidity, neutral and alkalinity. The pH of soil applies to the negative logarithm of the hydrogen ion activity; $pH = - \log [H^+]$. The soil is acidity pH lower 7, pH 7 at neutrality and alkalinity is pH upper 7 (Mclaren and Cameron, 1996). This property is the pre-eminent factor controlling the chemical behavior of metals and many other important processes in the soil. In general, heavy metal cations are the most mobile under acid conditions and increasing the pH by liming usually reduces their bioavailability (Figure2-4). The pH is result to soluble condition of metals in soil. General, that pH in soil has little or no direct effect on plants growth (Taechapinyawat, 1994), but the level of pH can control soluble substance in soil such as toxic substance which is toxic to plants, and it can control microorganism activities that there effect to plants growth.

2.3.2 Soil texture

Soil texture is the relative properties of the different size groups or separates. The rate and extent of many important physical and chemical reactions in soils are governed by texture. Because it determines amount of surface on which the reactions can occur, water holding capacity, aeration and soil strength (Millar, Turk and

Foth, 1965). Clay particles tend to be plate-shaped, rather than spherical, and very small in size with a large surface area per gram, because the specific surface of clay is many times greater than that of sand or silt, a gram of clay adsorption is function of surface area. Metals are more available in sandy soils than in clayey soils, where they are firmly retained on the surface of clay minerals (Eriksson, 1989). They may form two types of complexes on clay surfaces: outer-sphere ion-exchange complexes on the basal plane, and coordination complexes with SiOH or AlOH groups exposed at the edge of the silicate layers. Other minerals, including amorphous hydroxides and oxides, gibbsite, and allophone clay adsorb metals, reduce their mobility in soil (Zachara et al, 1993).

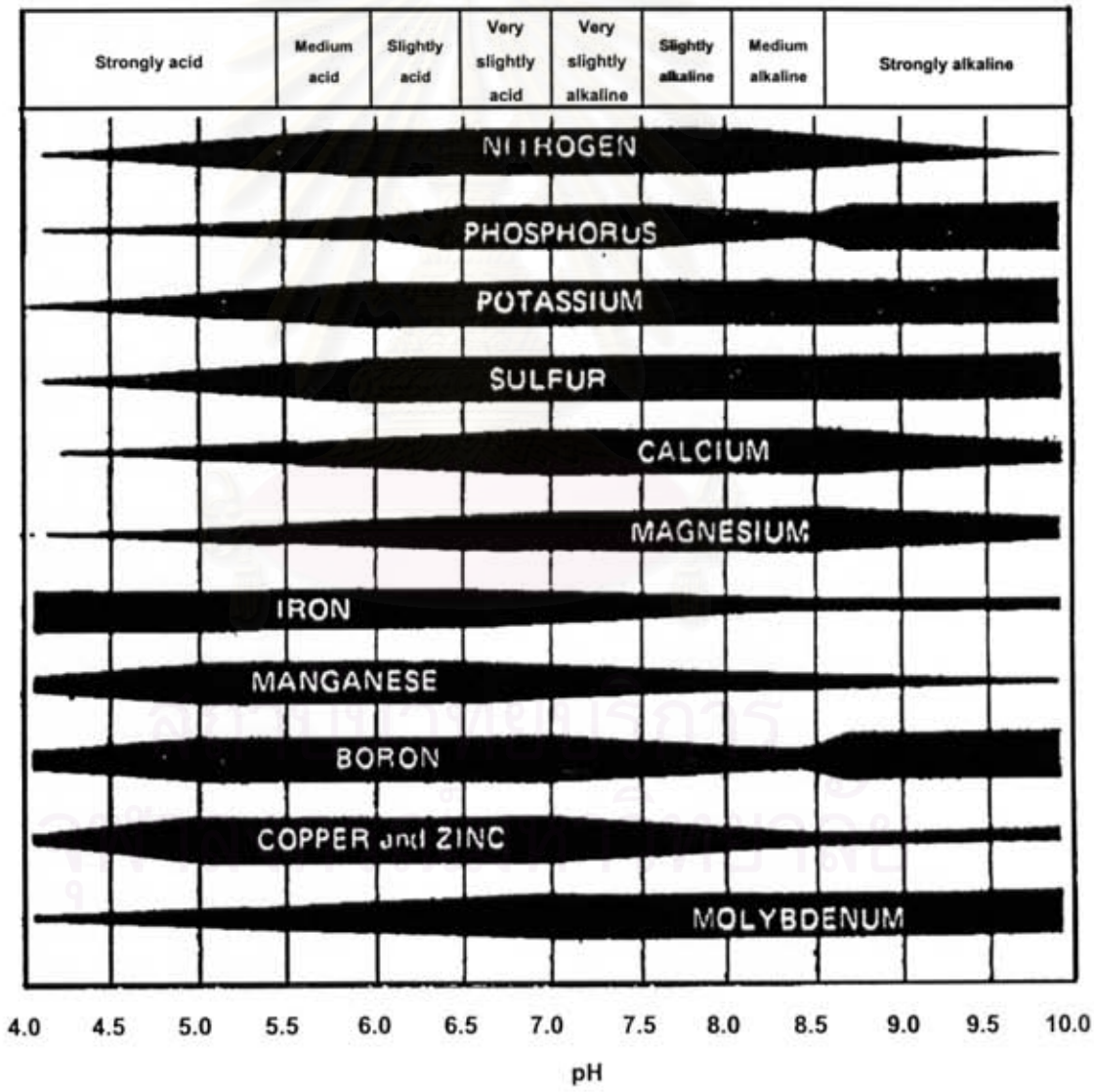

Figure2-4 Relationship of plant nutrient availability to soil pH

Source: Prapreatdham, 1995

2.3.3 Organic matter

Organic matter is organic compound, which has complex variables structure. The organic matter had decomposed from plants and animals residues under go extensive alternative in the soil, and included organic compound that root exudate, and microorganism were analyzed. Organic matter in the soil is important to chemical, physical and biological of soils properties. There is relative about level of fertility, production, cation exchange capacity, soil pH and ecosystem. Metals can be immobilized by precipitated or adsorbed organic matter, or maintained in the soil solution as soluble organic complexes with low molecule weight compounds (e.g., organic and fulvic acids). The presence of high amounts of insoluble organic matter in soil is negatively correlated with plant uptake (Haghiri, 1974).

2.3.4 Cation Exchange Capacity

The cation Exchange Capacity (CEC) is a function of clay and organic matter contents in soil, controls the availability of trace elements. Cation exchange capacity (CEC) of soil is defined as the sum of positive (+) charges of the adsorbed cations that a soil can adsorb at a specific pH. The CEC is the sum of (+) charges of all adsorbed cations. The CEC is commonly expressed as centimoles of positive charge per kilogram [c mol (+)/kg], also written as cmol/kg, of oven dry soil. In general, an increase in CEC decreases uptake of metals by plants (Tyler and Mcbride, 1982).

2.4 Relationship of heavy metal and plant

The factors affecting the amounts of metal absorbed by a plant are those controlling:

2.4.1 The concentrations and speculation of the metal in the soil solution

2.4.2 The movement of metal from the bulk soil to the root surface

2.4.3 The transport of the metal from the root surface into the root

2.4.4 Its translocation from the root to the shoot

Heavy ions have been absorbed through plant roots and have been transported to the xylem vessels, there is the possibility of movement throughout the whole plant.

About root absorption, the extent to which elements are translocated decreases in the order Cd>B>Zn>Cu>Pb (Chaney, 1993).

Plant uptake of mobile ions present in the soil solution is largely determined by the total quantity of this ion in the soil but in the case of strongly adsorbed ions, absorption is more dependent upon the amount of root produced. Absorption of heavy metals by plant roots can be by both passive and active (metabolic) processes. Passive (non-metabolic) uptake involves diffusion of ions in the soil solution into the root endodermis. On the other hand, active uptake takes place against a concentration gradient but requires metabolic energy and can therefore be inhibited by toxins. The mechanisms appear to differ between metals. The absorption mechanisms can vary for different metal ions, but ions that are absorbed into the root by the same mechanisms are like to compete with each other (Alloway, 1995).

Metal uptake by plants depends on metal bioavailability in the soil, and particularly on the supply from less plant-available fractions. The most important metal pools in soils include exchangeable and organically bound metals. Availability to plants is governed by dynamic equilibrium involving these fractions, rather than by the total metals content. In addition the plant may modify rhizosphere conditions through processes such as production of metal-solubilising root exudates or alternation of pH (Adriano, 2001; Puschenreiter et al., 2003; Wenzel et al., 2003). Soil pH is an important factor controlling metal mobility and availability. Usually the mobility of many metals increases with a decrease in soil pH (Kabata-Pendias and Pendias, 1992). Iyengar, Martens and Miller (1998) found that exchangeable zinc generally increases in soils with pH decreasing.

Relative differences in the uptake of metal ions between plant species and cultivates is genetically controlled and can be due to various factors, including surface area of the root, root CEC, root exudates and the rate of evapotranspiration. The transfer coefficient is the metal concentration in the soil. Although numerous soil and plants factors can affect the accumulation of metals in plants, the values given are intended as guides to the order of magnitude of the transfer coefficients and not precise values (Huang et al, 1997).

High concentrations of heavy metals in plants depend on the plant species, plant age, time of heavy metal exposure and also the light regime. The most widely described effects of metal toxicity in plants are inhibited root growth, depressed shoot and leaf growth and general of the young leaves (Das, Samantary and Rout, 1997). Heavy metals exert their harmful effects to plant in many ways for example is growth rate. Growth rate of plant can easily be studied for phytotoxicity. Angela et al. (1999) reported that cadmium can inhibit growth rate of *Brassica juncea* at 25 μM $CdNO_3$ at 5, 24, 48, 72 and 96 hours. They found a decline in growth rate only 24 hours after the onset of cadmium exposure. After 48 and 72 hours, growth rates were only about 25% and 60% respectively, as compared to that of control plant. This report indicates that cadmium can induce reduction in growth rate. Growth reduction in response to cadmium-stress was also reported for *Phaseolus vulgaris* (Poschenrieder, Gunse and Barcelo, 1989) and for various Brasica species after exposure to excess zinc or copper (Ebbs and Kochian, 1997). In addition, chlorosis, necrosis and significant decrease in crop yields are the major visual symptoms of metal toxicity in plants (Tarradellas, Bitton and Rossel, 1997).

The symptoms of cadmium toxicity are easily identifiable. In plants, the most general symptoms are stunting and chlorosis may appear to be iron deficiency and the interaction of toxic metals and irons have been studied for many years. Chlorosis from excess cadmium appears to be due to a direct or an indirect interaction with foliar iron (Das, Samantary and Rout, 1997). Zinc toxicity is first expressed in reduced root growth, a parameter that is used routinely in testing zinc-resistance in plants (Schat, Vooijs and Kuiper, 1996). In higher plants the toxicity of zinc increases with exposure time, therefore increasing zinc concentration in the plant and translocation from root to shoot (Davies, 1993; Sheppard et al., 1993).

2.5 Phytoremediation (U.S.EPA., 1998)

Phytoremediation is the name given to a set of technologies that uses plants to remediate contaminated sites. It uses living plants for *in situ* and *ex situ* remediation of contaminated soil, sludges, sediments and groundwater through contaminant removal, degradation or stabilization. It can be used to remediate various contaminants including metals, pesticides, solvents, explosives, petroleum hydrocarbons, polycyclic aromatic

hydrocarbons and landfill leachates. The U.S.EPA.'s Brownfields Technology Primer: selecting and using phytoremediation for site cleanup definition of the seven types of phytoremediation and their application is listed below.

2.5.1 Phytoextraction

Phytoextraction, also called phytoaccumulation, refers to the uptake of a contaminant by plant roots and the translocation of that contaminant into the aboveground portion of the plants; the contaminant generally is removed by harvesting the plants. Certain plants called hypoaccumulators absorb unusually large amounts of metals comparison to other plants and the ambient metals concentration. These plants are selected and planted at a site based on the type of metals present and other site conditions. This technology is applied most often to soil or water contaminated with metals. The planting and harvesting of plants may be repeated as necessary to bring soil contaminant levels down to allowable limits. A plan may be required to deal with the plant waste.

2.5.2 Phytodegradation

Phytodegradation, also called phytotransformation, is the breakdown of contaminants take up by the plant through metabolic processes within the plant, or the breakdown of the contaminants external to the plant through the effect of compounds (such as enzymes) produced by the plant. Pollutants are degraded, used as nutrients and incorporated into the plant tissues. In some cases, metabolic intermediate or end products are re-released to the environment depending on the contaminant and plant species.

2.5.3 Phytostabilization

Phytostabilization is the use of certain plant species to immobilize contaminants in the soil and groundwater through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone of plant and physical stabilization of soils. This process reduces the mobility of the contaminant and prevents migration to the groundwater or air. This technique can be used to re-establish

a vegetative cover at sites where natural vegetation is lacking due to high metal concentrations.

2.5.4 Phytovolatilization

Phytovolatilization is the uptake and transpiration of a contaminant by a plant, which releases the contaminant to the atmosphere from the plant. Phytovolatilization occurs as growing trees and other plants take up water and the organic and inorganic contaminant. Some of these contaminants can pass through the plants to the leaves and volatilize into the atmosphere at comparatively low concentrations. Many organic compounds transpired by plant are subject to phytodegradation.

2.5.5 Rhizodegradation

Rhizodegradation, also called phytostimulation, rhizosphere biodegradation, enhanced rhizosphere biodegradation, or plant-assisted bioremediation/degradation, is the breakdown of contaminants in the soil through microbial activity that is enhanced by the presence of the root zone.

2.5.6 Rhizofiltration

Rhizofiltration is the adsorption or precipitation of contaminants onto plant roots or the absorption of contaminants into the roots when contaminants are in solution surrounding the root zone. The plans are raised in greenhouses hydroponically (with their roots in water rather than in soil). Once a large root system has been developed, contaminant water is diverted and brought in contact with the plants or the plants are moved and floated in the contaminated water. The plants are harvested and disposed as he roots become saturated with contaminants.

2.6 Role of soil amendments in metal phytoextraction

Plants growth on heavy-metal-contaminated soils generally do not accumulate high levels of the targeted metals in the plant tissue, the major limitations to the

phytoextraction of heavy metals are the low metal bioavailability in the soil and the poor metal translocation from roots to shoots. The application of soil amendments (such as synthetic chelates and organic acids) could increase metal desorption from soil to soil solution and metal translocation from roots to shoots. (Raskin, 1997; U.S.EPA., 1998; Raskin and Ensley, 2000).

The availability of metal in the soil for plant uptake is another limitation for successful phytoremediation. However, since metals may be bound too tightly to soil components, genetic potential to accumulate metals does not always translate into effective phytoextraction (Raskin, 1997). The low solubility of heavy metals in the soil is often a limiting factor in phytoextraction by plant. A key to the success of metal phytoextraction is to increase and maintain metal concentration in the soil solution (Raskin and Ensley, 2000). Increasing metal solubility in soil and bioavailability of metals to the plants by chelating agent are important to phytoextraction of heavy metals from contaminated soils (Blaylock et al., 1997). Chelates and other chemical compounds have been used in soils and nutrient solution to increase the solubility of metals in plant growth media and could significantly increase metal accumulation in plants (Blaylock et al., 1997; Huang et al., 1997).

2.6.1 Chelating agent

A chelating agent is a substance whose molecules can form several bonds to a single metal ion. A chelate is a chemical compound composed of a metal ion and a chelating agent. Many essential biological chemicals are chelates. Chelates play important roles in oxygen transport and in photosynthesis. Furthermore, many biological catalysts (enzymes) are chelates. In addition to their significance in living organisms, chelates are also economically important, both as products in themselves and as agents in the production of other chemicals (Huang et al, 1997). Metal chelators and other soil amendments, which release metals to plant roots and facilitate metal uptake and translocation are extremely effective in improving phytoextraction in the field and make this process cost effective (Raskin, 1997) (Figure2-5).

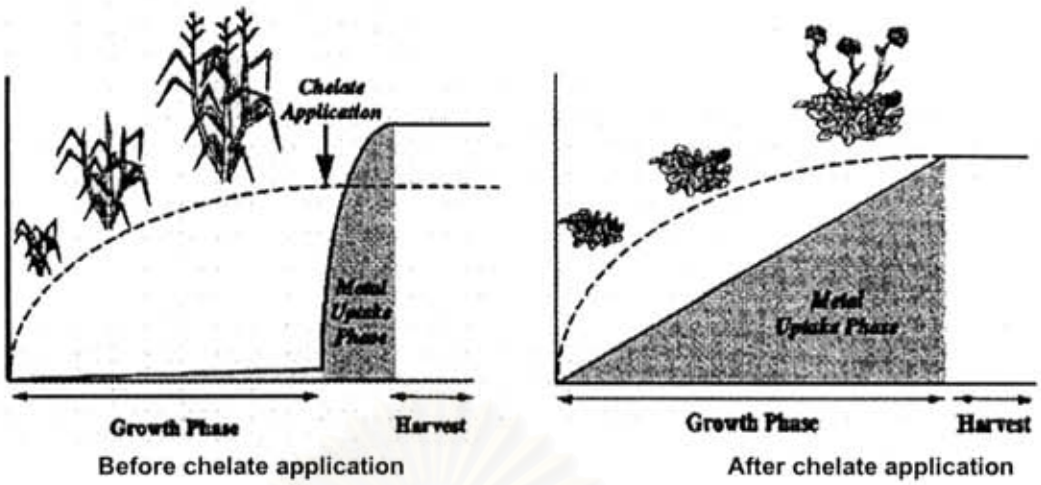

Figure 2-5 Metal phytoextraction by adding chelating agent

Source: Raskin, 1997

2.6.2 Ethylenediaminetetraacetic acid (EDTA) (Alloway, 1995)

Ethylenediaminetetraacetic acid (EDTA) is a versatile chelating agent. It can form four or six bonds with a metal ion, and it forms chelates with both transition-metal ions and main-group ions. EDTA is frequently used in soaps and detergents, because it forms complexes with calcium and magnesium ions. These ions are in hard water and interfere with the cleaning action of soaps and detergents. The EDTA binds to them, sequestering them and preventing their interference. In the calcium complex, $[Ca\ (EDTA)]^{2}$, EDTA is a tetradentate ligand, and chelation involves the two nitrogenatoms and two oxygen atoms in separate carboxyl ($-COO^{-}$) groups (Figure 2-6).

EDTA is also used extensively as a stabilizing agent in the food industry. Food spoilage is often promoted by naturally-occurring enzymes that contain transition-metal ions. These enzymes catalyze the chemical reactions that occur during spoilage.

2.6.3 Mechanisms of soil-amendment (Panyakhan, 2003)

Major limiting factors for phytoextraction of metals from contaminated soils are the lower metal bioavailability in the soil and poor metal translocation from roots to shoots. Application of soil amendments could partially eliminate these limiting

steps in the metal phytoextraction. There are several mechanisms involved in the soil amendment triggered metal hyperaccumulation in plants.

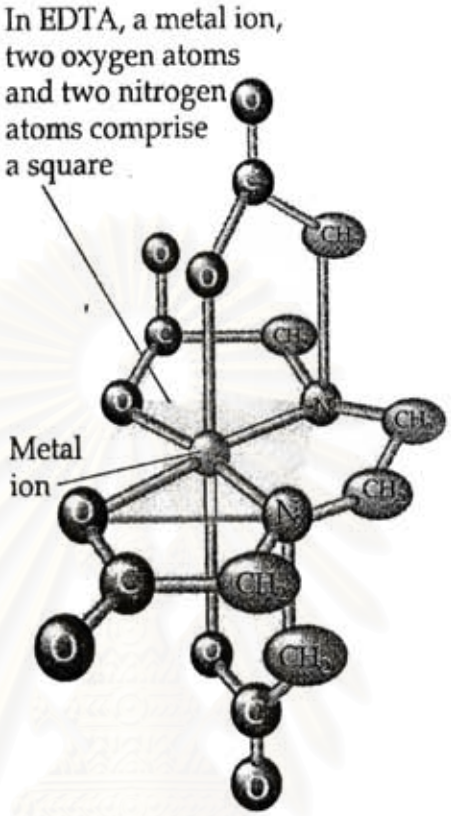

Figure 2-6 Chemical structure of Ethylenediaminetetraacetic acid (EDTA)

Source: Alloway, 1995

First, the increase in metal level in soil solution is required, soil-amendment-induced surge of metal concentration in soil solution could be the chelation between metals and the chelating compounds.

Second, chelating compounds could buffer metal activity near the root surface and thus maintain a constant supplying of free metal to the uptake sites of roots.

Third, the complex of metal chelate could be directly absorbed by roots and translocate to shoots. Finally, it may also be possible that chelating compounds at

higher levels alter plant ion transport system and/or root-cell membrane structure such that metal uptake and translocation are facilitated.

2.7 Chrysanthemum (*Dendranthema difflora*) (Dong et al, 2007)

Scientific name: *Dendranthema difflora*

Common Names: Chrysanthemum

Family: Compositae

Figure 2-7 Chrysanthemum (*D. difflora*)

Source: Dong et al, 2007

Chrysanthemums (*D. difflora*) are natives of China, Japan, northern Africa, and southern Europe. Their flowers come in every color except blue. Their blooms come in a huge variety of shapes and sizes. Some are spherical in shape and have incurved petals at the center. Some have tubular-shaped petals of unequal length with little hooks at the end. Spoon chrysanthemums have rather flat petals that are spoon-shaped

at the end. Anemone chrysanthemums have fairly flat, thin petals with shorter tubular petals in the center. Large plants of this variety tend to become straggly, so it is smart to lift the clumps every year or two and separate them (Figure 2-7).

Chrysanthemums can be easily grown in all climates, well-ventilated atmosphere and require a well drained soil and good sunlight. It can propagate or multiply from seeds or tender cuttings. The seeds can be sown directly in the garden anytime except winter or they can be started indoors for earlier blooms. Space the plants 20-40 cm apart depending on the variety. The plants will spread out and become bushy. Water deeply and regularly, especially in hot weather. It can be grown in an informal border on the ground or in pots in a equal mixture of sand, soil and compost. Mulching (spreading a mixture of wet leaves to enrich the soil) between plants will help to conserve moisture.

2.8 Marigold (*Tagetes erecta* L.) (Sreekera and Raghava, 2003)

Scientific name: *Tagetes erecta* L.

Common Names: Marigold

Family: Compositae

Marigolds (*T. erecta* L.) are natives of Mexico and South America, but perfectly hardy in all countries, and easy to grow. Marigold is a fast growing annual herb which grows to almost 6-12 inches tall and produces single, semi double, fluffy double or crested flowers, depending on the species and variety. The pinnate leaves with toothed, lance-shaped leaflets are aromatic (Figure 2-7). This bushy plant with around 20 to 30 species, have a long flowering period and the colors range from orange, yellow, gold, cream to apricot. Marigolds are categorized into three groups: French, African and triploid marigolds. The French marigolds (*T. patula*) are small bushy plants that are about 15-30 cm in height. The flowers are up to 5 cm across and are composed of a dense arrangement of "rays" that come in yellow, orange and a unique bronze color. The French marigolds bloom continuously until cut down by frost. The African marigolds (*T. erecta* L.), also called American marigolds or marigold, are tall stout plants that grow to 90 cm in height. They have larger blossoms and a shorter flowering period than their French cousins - remove faded flowers to encourage a second flush of bloom. The triploid marigolds are sterile hybrids obtained by crossing the French with the African species. These triploids are non-stop bloomers with impressive 7.6 cm flower heads in

clear warm colors of gold, yellow, red and russet. The leaves of all marigolds are dark green, deeply divided and have a somewhat unpleasant, aromatic fragrance.

Figure 2-8 Marigold (*T. erecta* L.)

Source: Sreekera and Raghava, 2003

Marigold can be easily grown in all climates, well-ventilated atmosphere and require a well drained soil and good sunlight. It can be propagated or multiplied from seeds or tender cuttings. The seeds can be sown directly in the garden anytime except winter or they can be started indoors for earlier blooms. Space the plants 20-40 inches apart depending on the variety. The plants will spread out and become bushy. Watering deeply and regularly is required, especially in hot weather. It can be grown in an informal border on the ground or in pots in an equal mixture of sand, soil and compost. Mulching (spreading a mixture of wet leaves to enrich the soil) between plants will help to conserve moisture. Marigold does not need specific care. They are rarely disturbed by insects or diseases and can tolerate dry conditions and full sun. Pinching young

plants promotes bushy growth. Deadheading of spent flowers and faded leaves greatly enhances the plant's appearance during flowering. If growing as cut flowers, pinch out terminal buds to encourage laterals. The plant can be kept indoor during heavy rains as too much water will wilt the plant.

Marigold is a common garden plant found throughout the world. They are often used as cut flowers and as a bedding plant, as well as for edging, backgrounds. Common but colorful, inexpensive and easy to germinate and grow, there are varieties available in a wide range of heights, hues and flower forms. The rugged marigolds are perfect for containers where they combine well with other plants. Plant marigolds in the vegetable garden where they are said to discourage certain insect pests.

2.9 Globe amaranth (*Gomphrena globosa* L.) (Jones and Sheard, 1977)

Scientific name: *Gomphrena globosa L.*

Common Names: globe amaranth, gomphrena, bachelor's buttons

Family: Amaranthaceae

Globe amaranth *(G. globosa L.)* is native to Panama and Guatemala in Central America. These are annual flowering plants that are found wild in tropical countries, which is an annual bedding plant that grows 30-60 cm tall with a spread of about 30 cm. Taller plants may need staking. The branched stems are erect and stiff and the plant has a bushy appearance (Figure 2-8).

The narrow green leaves are opposite, oblong, 10-15 cm long, and wooly-white when young, becoming sparsely white-hairy as they age. Clover-like flowerheads, 3.8 cm long, are borne on upright spikes. The tiny, white true flowers within the flowerheads are rather inconspicuous and insignificant, only being visible close up. It is the bright magenta bracts arranged in globose, stiff, papery bracts that form the bulk of the structure and provide the real show. The individual flower heads occur on each plant ranging in colors from purple, lavender, rose, red, orange and white.

There are no serious insect or disease problems. Good drainage is essential but little fertilizer or water is necessary to produce a massive display. Although mature plants exhibit good drought resistance, plants grow best with regular moisture.

Figure 2-9 Globe amaranth (*G. globosa* L.)

Source: Jones and Sheard, 1977

Globe amaranths are used in annual beds and borders. In masses, the round flowerheads produce an interesting texture and their bright colors last late into the season. Their low stature makes them well suited for edging around taller plantings. Globe amaranth is often grown in containers on the porch or deck. The conelike flowerheads are beautiful in dried arrangements and will hold their shape and color indefinitely. To grow globe amaranth for cut flowers or dried arrangements, plant closely together to force longer stems. Cut the stems just as the heads are beginning to open and hang upside down in a warm, dark place to dry.

2.10 Review of the studies

The research of phytoremediation of a contaminant by heavy metals and its toxicity are reviewed, it was found that various kinds of plant had been used to remediate heavy metals in contaminated condition for instance, aquatic plants (e.g. marsh pennywort (*Hydrocotyle umbellate*) and aquatic ferns (*Salvinia cucullata*)), vegetable (e.g. kale (*Brassica oleracea* var. *alboglaba*) and Kangkong (*Ipomoea aquatica* Forsk)), weeds (e.g. False daisy (*Eclipta prostrate* L.) and swollen finger grass (*Chloris barbata* Sw.)) and flowering plants (e.g. Sunflower (*Helianthus annuus*))., all relevant researches are listed below.

Somboon (1999) studied the distribution of cadmium and zinc in soil from zinc mining activity: a case study of zinc mine, Mae Sot district, Tak Province. It was concluded that zinc mining activity distributes cadmium and zinc into the watershed, especially the downstream area by water transportation. Due to the result, two alternatives for the management of soil pollution are proposed as follows 1) For the management of land and water from mining activity, it is recommended that roof should be constructed to cover stockpile and gangue minerals, and that the surrounding area be fenced in order to protect the stockpile and gangue minerals from being grained by rainfall. 2) The mitigation of soil pollution can be carried out by increasing pH in the uncultivated land, while cultivated land should have organic matter added in order to reduce the solubility of cadmium and zinc, or the land should not be planted with root crops or edible crops.

Chanthachot et al (2005) studied the analysis of heavy metals namely: arsenic, manganese, cadmium, scandium, thorium, chromium, zinc, cobalt, cerium and iron in soil along Mae Tao River, Tak Province were determined using Instrumental Neutron Activation Analysis. The samples from 12 locations were collected during 15-19 November 2004. Arsenic, cadmium, chromium, cobalt, thorium, scandium and cerium were found in the range of 4-92 µg/g. While manganese were found in the range of 100-1,052 µg/g, zinc were found in the range of <25-1,652 µg/g and iron were found in the range of 10,300-25,100 µg/g. Results show that the concentration of cadmium, zinc and arsenic are higher than the European Maximum Permissible Levels for Agricultural Soil.

Sripachote (2006) studied the distribution and fractionation of cadmium and zinc in the contaminated soil at Pha Te village, Mae sot district, Tak Province. The results revealed that in most area, soil had sandy clay loam throughout depth, the exception was 0-20 cm of lowland and control with clay loam and loam was detected. Soil pH ranged from 5.35-8.22 and same or less constant throughout the depth. Organic matter (OM) and CEC content were 1.5-4.9% and 9.7-20 cmol(+) Kg^{-1} respectively of them. Both OM and CEC had trend to decrease with depth. Total cadmium (Cd) and zinc (Zn) at lowland and waterlogged highland were higher than acceptable limits of EU while these found on the other locations were lower. Distributions of them decreased with depth. Average contents soil surface of them from each location were 27 mg Cd/kg and 550 mg Zn/kg (lowland) 23 mg Cd/kg and 536 mg Zn/kg (waterlogged highland). Sediment soil which 0-10 cm depth was sampled, had 70 mg Cd/kg and 1,326 mg Zn/kg. While highland, forest and control soils contained 0.34-2.59 mg Cd/kg and 14-272 mg Zn/kg. Total Cd had relation with total Zn (R^2=0.950). More than 50% of fractionation Cd from lowland and waterlogged highland was the carbonate bound. While for highland, forest and control the residual fraction dominated (>60%). And this fraction increased with depth. For fractionation Zn of these location, the Fe&Mn oxide-bound and residual fractions somewhat similar (approximately 31-34%). For the sediments, the Fe&Mn oxide-bound Cd and Zn dominated (52 and 44%, respectively). Available Cd had relation with carbonated-bound fraction (R^2=0.912). Available Zn had relation with Fe&Mn oxide-bound fraction (R^2=0.822).

Srisatit, Kosakul and Dhitivara (2003) studied the efficiency of arsenic removal from soil by *Vetiveria zizanioides* (Linn.) Nash and *Vetiveria nemoralis* (Balansa) A. Camus. The ideal characteristics of plant species to use to remove toxic contaminants from soil should be as following: high biomass, short life span and able to tolerate and accumulate high concentration of contaminants. Vetiver is a kind of perennial grass with strong ecological adaptability and large biomass and is easy to manage and grow at different soil conditions. It has great potential for various applications including hillside soil and water conservation, sustainable agriculture, fixing sandy river banks and pollution control, and it was found that the accumulation of arsenic in roots of both vetiver grasses was higher than in leaves.

Srisatit and Tambamroong (2006) studied phytoextraction of arsenic from contaminated soil by *Colocasia esculenta* (Linn.) Schott; taro and wild taro. It was found that the accumulation of arsenic in both plants can be enhanced through the application of EDTA to the soil. EDTA could enhance the accumulation of arsenic in both plants in all most concentration. With the maximum of 61.63% enhanced the accumulation for taro in the concentration of 400 mg As/kg soil at day 40 and 53.28% for wild taro in the concentration of 200 mg As/kg soil at day 100. And it was found that the accumulation of arsenic in roots of taro and wild taro was higher than in leaves.

Faisatjatham (2006) studied the efficiency of *Vetiveria zizanioides* (Linn.) Nash (Surat Thani ecotype) and *Vetiveria nemoralis* (Balansa) A. Camus (Prachuabkirikhan ecotype) in cadmium and zinc removal from soil. It was found that the accumulation of cadmium and zinc in roots of both vetiver grasses was higher than in leaves. Amount of both heavy metals accumulation in Surat Thani ecotype was more than in Prachuabkirikhan ecotype. The highest efficiency of cadmium removal of Surat Thani ecotype was 4.63% in treatment of 50 mg Cd/kg soil and 1.02% in treatment of 500 mg Zn/kg soil while, the highest efficiency of cadmium removal of Prachuabkirikhan ecotype was 4.10% in treatment of 50 mg Cd/kg soil and 0.91% in treatment of 500 mg Zn/kg soil was found that EDTA addition is a factor influencing on heavy metal uptake variation at all experiment time and all of ecotypes.

Baryla et al (2001) studied about leaves chlorosis in oilseed rape plants (*Brassica napus* Linn.) grown on cadmium-polluted soil: causes and consequences for photosynthesis and growth. It was found that *Brassica napus* Linn. (oilseed rape) was grown from seeds on a reconstituted soil contaminated with cadmium (100 mg Cd/kg soil), resulting in a marked chlorosis of the leaves which was investigated using a combination of biochemical, biophysical and physiological methods. Spectroscopic and chromatographic analyses of the photosynthetic pigments indicated that chlorosis was not due to a direct interaction of Cd with the chlorophyll biosynthesis pathway. In addition, mineral deficiency and oxidative stress were apparently not involved in the pigment loss. Leaves chlorosis were attributable to a marked decrease in the chloroplast density caused by a reduction in the number of chloroplasts per cell and a change in cell size, suggesting that Cd interfered with chloroplast replication and cell division.

Panyakhan (2003) studied the toxicity of cadmium and zinc on growth, chlorophyll contents and accumulation of aquatic plant (*Hydrocotyle umbellate*). He found that cadmium and zinc effected to significant decrease in relative growth, biomass productivity and chlorophyll content when the exposure times and concentrations of both metals were increased. The toxicity symptoms of H. *umbellate* exposed to cadmium and zinc at different concentrations and exposure times showed stunted growth and chlorosis in leaves, some plants died at higher concentrations of metals. The symptoms were more severe at higher metal concentrations.

Phetsombat (2003) studied the toxicity and accumulation of cadmium and lead in the aquatic fern, *Salvinia cucullata*. He found that the toxicity symptoms of *S. cucullata* exposed to cadmium and lead were chlorosis in leaves. The accumulation study showed that there was a significant increase when the exposure time and metal concentration were increased.

Chen and Cutright (2001) studied the effect of EDTA (ethylenediaminetriacetic acid) and HEDTA (*N*-(2-hydroxyethyl)-ethylenediaminetriacetic acid) on cadmium, chromium, and nickel uptake by *Helianthus annuus*. It was found that EDTA at the rate of 0.5g/kg significantly increased the shoot concentrations of cadmium and nickel from 34 and 15 to 115 and 17 mg/kg, respectively. The total removal efficiency for EDTA was 59 µg/plant. HEDTA resulted in a total metal uptake of 42 µg/plant. This research demonstrated that cadmium had greater accumulated in the shoot than root and the results also showed that chelator toxicity reduced the plant's biomass.

Turgut, Pepe and Cutright (2004) studied the effect of EDTA and Citric acid (CA) on phytoremediation of Cd, Cr, and Ni from soil using *Helianthus annuus*, two different concentrations of the chelators were studied for enhancing the uptake and translocation of heavy metals from a silty-clay-loam soil. It was found that when 0.1 g/kg CA was used the highest total metal uptake was only 0.65 mg, while EDTA at a concentration of 0.1 g/kg yielded the best results achieving a total metal uptake of ~0.73 mg which experiment plants had more Cd in stems and leaves.

Turgut, Pepe and Cutright (2005) studied the effect of EDTA on *Helianthus annuus* uptake, selectivity, and translocation of heavy metals when grown in Ohio

(sandy-loam), New Mexico (silty-loam) and Colombia soils (sandy-clay-loam), which used of two EDTA concentrations for enhancing the bioavailability of cadmium, Chromium and nickel in three natural soils. It was found that plants grown in the Ohio soil had a higher uptake that the resulted in a selectivity and total metal content of cadmium>chromium>>nickel and 0.73 mg for 0.1 g EDTA /kg soil and treated plants had more Cd in stems and leaves. The study evaluated the mobile metal fraction with and without EDTA determined that the chelator was capable of overcoming mass transfer limitations associated with the expandable clay fraction in the soils.

Sampanpanish (2005) studied about chromium removal by phytoremediation and biosorption with weed plant in 6 species. He found that some weed plants accumulated chromium in leave≥stem>root such as *Pluchea indica* and *Amaranthus viridis*, so *Pluchea indica* is greater Cr(VI) accumulation and absorption than the other plants which occurred mainly in leaves, stems, and roots at 73, 35 and 29 mg Cr/kg, respectively.

CHAPTER III

MATERIAL AND METHODOLOGY

The objectives of this study were to (1) observe the effects of cadmium and zinc at different levels on the growth of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) determined by height, internodes length, diameter of stem, and dry weight, (2) compare the amount of cadmium and zinc accumulate in roots, stems, leaves and flowers and (3) compare the efficiency of cadmium and zinc removal in different species of plant. The experimental study in laboratory scale and methodology are as follows.

3.1 Equipments and Materials

3.1.1 Equipments

1. Atomic absorption spectrophotometer (AAS)
2. Oven
3. Hood
4. pH meter
5. Analytical Balance 4 digits
6. Hot plate
7. Blender, mortar and pestle
8. Filter paper (Whatman no.42)
9. Glass Containers
    - 9.1 Beaker
    - 9.2 Erlenmeyer Flask
    - 9.3 Volumetric Flask
    - 9.4 Cylinder
    - 9.5 Glass Funnel
    - 9.6 Volumetric pipette
10. Chemical reagents use for analysis; $Cd(NO_3)_2.4H_2O$, $Zn(NO_3)_2.6H_2O$, Ethylenediaminetetraacetic acid (EDTA), Sulfuric acid (H_2SO_4), Nitric acid (HNO_3)

3.1.2 Materials for experimental plants cultivate

1. Seeds of marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.), and seedlings of chrysanthemum (*D. difflora*)
2. Commercial soil 162 kg.
3. Plastic pots (6 inches diameter, 5 inches depth) and plastic bags
5. Spoon, fork and spade
6. Scissors and knife

3.2 Experimental set up

3.2.1 Experimental design

Completely randomize design (CRD) was used in this experiment. Pot culture experiments were cultivated using soil treated with $Cd(NO_3)_2.4H_2O$-EDTA or $Zn(NO_3)_2.6H_2O$-EDTA. Cadmium treatments were cadmium concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil and zinc treatments were zinc concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil (Table 3-1; see calculation in appendix A). There were 6 treatments of each experiment and for comparison, an untreated control. Three replicates of each treatment were performed. Therefore, the total of experiments was 108 units.

Table 3-1 The amounts of $Cd(NO_3)_2.4H_2O$ and $Zn(NO_3)_2.6H_2O$ in soil

Cadmium concentrations (mg Cd/kg soil)	The amounts of $Cd(NO_3)_2.4H_2O$ (g/pot)	Zinc concentrations (mg Zn/kg soil)	The amounts of $Zn(NO_3)_2.6H_2O$ (g/pot)
0	0	0	0
20	0.0823	50	0.3411
40	0.1646	100	0.6823
60	0.2470	150	1.0234
80	0.3292	200	1.3645
100	0.4115	250	1.7057

3.2.2 Soil preparation

Soil in this experiment was commercial soil, which was purchased from Chatuchak Sunday's market, Bangkok. Then soil was thoroughly mixed to homogeneous, air dried at room temperature, passed by screening with a 2 mm sieve. The soil was then characterized to obtain the properties (Table 3-2). The air dried soil was uniformly mixed with appropriate amounts of $Cd(NO_3)_2.4H_2O$ in order to add 0, 20, 40, 60, 80 and 100 mg Cd/kg soil or $Zn(NO_3)_2.6H_2O$ in order to add 0, 50, 100, 150, 200 and 250 mg Zn/kg soil. Then ethylenediaminetetraacetic acid (EDTA) was added at 0.1 g/kg soil for chelation and placed in pots (1.5 kg).

Table 3-2 Physical and chemical characteristics of the soil

Soil properties	Methods
Soil moisture	Gravimetic Method (Gardner, 1965)
pH	pH Meter Method (Peech, 1965)
Soil texture sand : silt : clay (%)	Hydrometer Method (ASTM, 1961)
CEC (meq/100g)	Amonium acetate Method (Attanant, Janjareansuk and Jittakanont, 1999)
Total Organic Matter (%)	Walky-Black Method (Walky and Black,1934)
Nitrogen (%)	Kjeldahl Method (Bremner, 1965)
Potassium (ppm)	Flame photometer (Peech, 1965)
Phosphorus (ppm)	$HClO_4$ Digestion (Jackson, 1967)
Cadmium and zinc (mg/kg soil DW)	HNO_3 and H_2SO_4 acid Digestion (U.S.EPA., 1982)

3.2.3 Plants preparation

Seeds of marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were purchased from Chatuchak Sunday's market, Bangkok, while seedlings of chrysanthemum (*D. difflora*) were taken from Nakhon Rachasima. Both of seeds and seedlings were cultivated in the soil for 2 weeks, but only uniform seedlings with similar weight and size were allowed to grow in each pot, then separated seedling in two parts;

3.2.3.1 Part I for measuring height and dry weight, and analyzing cadmium and zinc accumulations in plants before start the experiment.

3.2.3.2 Part II for growing in pot. There was one seedling per pot and the pots were placed in a net house shade to protect from rain water leaching. Plants were grown under natural light and ambient temperature in order to keep all plants under natural conditions as similar as possible. No artificial fertilizers were added to the soil during the course of the experiment.

3.3 Plants growth observation and harvesting

The growth of plants was determined by height, internodes length and diameter of stem, which observed and recorded every seven days from beginning to the end of experiment. Until flowering stage, the plants were carefully harvested without damaging the roots (Table 3-3). They were washed in water to remove dust and soil mineral particles and separated into roots, stems, leaves and flowers and dried in an oven at 70°C for 3 days.

Table 3-3 Date for harvesting

Plants	Start	Harvesting
Chrysanthemum (*D. difflora*)	23 Jan 2006	3 May 2006
Marigold (*T. erecta* L.)	5 Oct 2005	5 Dec 2005
Globe amaranth (*G. globosa* L.)	19 Jan 2006	20 Mar 2006

3.4 Sample preparation and analysis

Dried samples were weighed and milled with mortar and pestle before analysis. The crushed samples were digested by acidic mixture of HNO_3:H_2SO_4 according to United States Environment Protection Agency (USEPA) Method 3030 (US EPA-3030, 1982) and analyzed with atomic absorption spectrophotometer (AAS). The detection limit obtainable with the extraction procedure and atomic absorption analysis was 0.01 mg/l for cadmium and 0.03 mg/l for zinc.

3.5 Data analysis

3.5.1 The growth of plants

The growth of plants was determined by height, internodes length and diameter of stem. All plant parameters were calculated from cumulative height, cumulative internodes length and cumulative diameter of stem from beginning to the end of experiment. Moreover, dry weight was determined when plants were harvested.

3.5.2 Cadmium and zinc accumulation in plants

Cadmium and zinc accumulation in plants were calculated by amount of heavy metals in each part of the plants (mg) per dry weight (kg). For example; cadmium, It's calculated as follow.

$$\text{Cadmium accumulations in each part of the plants (mg/kg)} = \frac{\text{Amount of cadmium in each part of the plants (mg)}}{\text{Dry weight (Kg)}}$$

3.5.3 The efficiency of cadmium and zinc removal in plants (%)

The efficiency of cadmium and zinc removal in plants (%) was calculated from total heavy metals accumulation in plant (mg) per amount of heavy metals concentration in pot (mg). For example; cadmium, It's calculated as follow.

$$\text{Cadmium in plants \%} = \frac{\text{Total amount of cadmium in plants (mg)} \times 100}{\text{Amount of cadmium concentration in pot (mg)}}$$

3.6 Statistical analysis

Statistical comparison of means was done by an analysis of variance (one way ANOVA). Differences among treatments were compared by Duncan multiple range test (DMRT). All of the statistical significance were set at the level of $\rho<0.01$. The data presented are means ± S.D. (standard deviation).

CHAPTER IV

RESULTS AND DISCUSSIONS

The study of cadmium and zinc removal from contaminated soil by some cut flower plants aimed to observe the effect of cadmium and zinc at different levels on the growth of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) determined by height, internodes length, diameter of stem and dry weight. Compare the amount of cadmium and zinc accumulation in roots, stems, leaves and flowers, moreover to compare the efficiency of cadmium and zinc removal in different species of plant. The results are shown in 9 parts as follows,

- The properties of soil
- The properties of plants
- General observation of plants
- The effects of cadmium on plants growth
- The effects of zinc on plants growth
- Cadmium accumulation in various parts of plants
- Zinc accumulation in various parts of plants
- The efficiency of cadmium accumulation in plants (%)
- The efficiency of zinc accumulation in plants (%)

4.1 The properties of soil

The soil used in this experiment was commercial soil, which was purchased from Chatuchak Sunday's market, Bangkok. The properties of soil are shown in Table 4-1.

Table 4-1 The properties of soil

Soil properties	Result	Methods
Soil moisture (air dry) (oven dry)	20.08 % 22.54 %	Gravimertic Method
pH	5.66	pH Meter Method (soil:water = 1:2)
sand : silt : clay (%)	40.78: 32.68: 26.54	Hydrometer Method
Soil texture	loam	Hydrometer Method
CEC (meq/100g soil)	17.76	Amonium acetate Method
Total Organic Matter (%)	9.54	Walky – Black Method
Nitrogen (%)	2.93	Kjeldahl Method
Potassium (ppm)	276.17	Flame photometer
Phosphorus (ppm)	384.86	$HClO_4$ Digestion
Cadmium (mg/kg soil DW)	ND	HNO_3 and H_2SO_4 acid Digestion
Zinc (mg/kg soil DW)	107.59	HNO_3 and H_2SO_4 acid Digestion

Note : ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

4.2 The properties of plants

Seeds of marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were purchased from Chatuchak Sunday's market, Bangkok, while seedlings of chrysanthemum (*D. difflora*) were taken from Nakhon Rachasima. The properties of plants are shown in Table 4-2.

Table 4-2 The properties of plants

Seedlings	Dry weight (g)	Height (g)	Concentration	
			Cadmium (mg Cd/kg)	Zinc (mg Zn/kg)
Chrysanthemum (*D. difflora*)	1.57±0.02	13.07±1.62	ND	0.09±0.01
Marigold (*T. erecta* L.)	1.01±0.13	15.10±0.30	ND	0.14±0.03
Globe amaranth (*G. globosa* L.)	1.27±0.01	13.37±1.63	ND	0.05±0.01

Note : Each value is the mean of triplicate ± S.D.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

After analyzed for the amount of cadmium and zinc accumulation in plants, it was found that all three plant species were non-detectable for cadmium, while zinc accumulation in plants was in the range from 0.05 - 0.14 mg Zn/kg.

4.3 General observation of plants

During the experimental period, chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could survive under all conditions of cadmium and zinc concentration in soil. The growth parameters; height, internodes length, and diameter of stem of all plants were increased by time during the experimental period.

4.3.1 The growth of plants under condition of cadmium contamination in soil

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could survive under all conditions of cadmium concentration in soil (Appendix B). However, visual toxicity symptoms also indicated the intensity of stress. The reduction of growth in all plants showed when cadmium concentration was increased in soil, at level of 20, 40, 60, 80 and 100 mg Cd/kg soil.

Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could survive under all conditions of cadmium in soil. Although the growth in plants was reduced by the stress of cadmium, both of them looked healthy. The leaves were green and could produce colorful flowers at all cadmium concentrations.

Toxicity symptoms from cadmium in plants were obviously seen in chrysanthemum (*D. difflora*). It was found that chrysanthemum (*D. difflora*) could survive under all conditions of cadmium concentration in soil. At cadmium concentration of 20, 40, 60, 80 and 100 mg Cd/kg soil exhibited abnormal characteristics such as stunted, shortening of internodes and could not produce flowers, moreover a mild chlorosis appeared at cadmium concentration of 100 mg Cd/kg soil.

4.3.2 The growth of plants under condition of zinc contamination in soil

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could survive under all conditions of zinc concentration in soil (Appendix B). However, visual toxicity symptoms also indicated the intensity of stress. The increase of growth in all plants showed when zinc concentration was increased in soil, at level of 50, 100, 150, 200 and 250 mg Zn/kg soil.

Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could survive under all conditions of zinc concentration in soil and grown up normally as well as control, both of them looked healthy. The leaves were green and could produce colorful flowers at all zinc concentrations.

Toxicity symptoms from zinc in plants were obviously seen in chrysanthemum (*D. difflora*). It was found that chrysanthemum (*D. difflora*) could survive and produced colorful flowers under all conditions of zinc concentration in soil. At zinc concentration of 50, 100, 150, 200 and 250 mg Zn/kg soil exhibited abnormal characteristics such as scorching in leaves and necrosis, moreover death of the flowers appeared at zinc concentration of 200 and 250 mg Zn/kg soil.

4.4 The effects of cadmium on plants growth

The growth of plants such as height, internodes length diameter of stem and dry weight were measured under cadmium concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil. In addition, the growth data in each pot was measured in every 7 days during the experimental period (Appendix C).

4.4.1 Chrysanthemum (*D. difflora*)

The effects of cadmium on the growth of chrysanthemum (*D. difflora*) are shown in Table 4-3.

Table 4-3 The effects of cadmium on the growth of chrysanthemum (*D. difflora*)

Cadmium concentrations (mg Cd/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$38.12^{a} \pm 9.34$	$0.63^{a} \pm 0.42$	$0.26^{a} \pm 0.04$	$8.56^{a} \pm 2.23$
20	$14.37^{b} \pm 1.65$	$0.53^{a} \pm 0.42$	$0.26^{ab} \pm 0.04$	$7.22^{ab} \pm 0.67$
40	$14.42^{b} \pm 2.94$	$0.47^{a} \pm 0.31$	$0.25^{ab} \pm 0.07$	$6.70^{ab} \pm 0.98$
60	$12.52^{b} \pm 3.40$	$0.47^{a} \pm 0.35$	$0.21^{ab} \pm 0.04$	$6.06^{ab} \pm 0.60$
80	$8.67^{b} \pm 2.72$	$0.43^{a} \pm 0.25$	$0.20^{ab} \pm 0.05$	$4.95^{b} \pm 0.55$
100	$7.85^{b} \pm 1.10$	$0.43^{a} \pm 0.31$	$0.18^{b} \pm 0.04$	$4.60^{b} \pm 0.78$
F-value	**21.79**	**0.14**	**3.91**	**4.80**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

In consideration of the growth of chrysanthemum (*D. difflora*), the results of height were 38.12, 14.37, 14.42, 12.52, 8.67 and 7.85 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest height (38.12 cm) was found at the control and the lowest height (7.85 cm) was found at 100 mg Cd/kg soil. The results of internodes length were 0.63, 0.53, 0.47, 0.47, 0.43 and 0.43 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest internodes length (0.63 cm) was found at the control and the lowest internodes length

(0.43 cm) was found at 80 and 100 mg Cd/kg soil. The results of diameter of stem were 0.26, 0.26, 0.25, 0.21, 0.20 and 0.18 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest diameter of stem (0.26 cm) was found at the control and 80 Cd/kg soil, the lowest diameter of stem (0.18 cm) was found at 100 mg Cd/kg soil. Moreover, the results of dry weight were 8.56, 7.22, 6.70, 6.06, 4.95 and 4.60 g at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest dry weight (8.56 g) was found at the control and the lowest dry weight (4.95 g) was found at 100 mg Cd/kg soil.

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight decreased when cadmium concentration was increased in soil. Moreover, there were significant decreases ($\rho<0.01$) between the height, diameter of stem and dry weight of control and treatment plants (Appendix D).

4.4.2 Marigold (*T. erecta* L.)

The effects of cadmium on the growth of marigold (*T. erecta* L.) are shown in Table 4-4.

Table 4-4 The effects of cadmium on the growth of marigold (*T. erecta* L.)

Cadmium concentrations (mg Cd/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$16.77^{a} \pm 1.25$	$0.43^{a} \pm 0.06$	$0.26^{a} \pm 0.05$	$7.19^{a} \pm 0.30$
20	$15.87^{a} \pm 1.16$	$0.30^{ab} \pm 0.10$	$0.23^{a} \pm 0.09$	$6.73^{ab} \pm 0.43$
40	$15.83^{a} \pm 2.71$	$0.27^{ab} \pm 0.06$	$0.22^{a} \pm 0.10$	$6.48^{bc} \pm 0.18$
60	$15.43^{a} \pm 0.15$	$0.23^{b} \pm 0.06$	$0.19^{a} \pm 0.04$	$6.24^{bc} \pm 0.09$
80	$15.23^{a} \pm 2.53$	$0.17^{b} \pm 0.12$	$0.17^{a} \pm 0.03$	$6.04^{bc} \pm 0.09$
100	$13.57^{a} \pm 1.51$	$0.13^{b} \pm 0.06$	$0.17^{a} \pm 0.13$	$5.85^{c} \pm 0.17$
F-value	**0.92**	**6.56**	**0.45**	**10.95**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

In consideration of the growth of marigold (*T. erecta* L.), the results of height were 16.77, 15.87, 15.83, 15.43, 15.23 and 13.57 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest height (16.77 cm) was found at the control and the lowest height (13.57 cm) was found at 100 mg Cd/kg soil. The results of internodes length were 0.43, 0.30, 0.27, 0.23, 0.17 and 0.13 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest internodes length (0.43 cm) was found at the control and the lowest internodes length (0.13 cm) was found at 100 mg Cd/kg soil. The results of diameter of stem were 0.26, 0.23, 0.22, 0.19, 0.17 and 0.17 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest diameter of stem (0.26 cm) was found at the control and the lowest diameter of stem (0.17 cm) was found at 80 and 100 mg Cd/kg soil. Moreover, the results of dry weight were 7.19, 6.73, 6.48, 6.24, 6.04 and 5.85 g at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest dry weight (7.19 g) was found at the control and the lowest dry weight (5.85 g) was found at 100 mg Cd/kg soil.

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight decreased when cadmium concentration was increased in soil. Moreover, there were significant decreases ($\rho<0.01$) between the internodes length and dry weight of control and treatment plants (Appendix D).

4.4.3 Globe amaranth (*G. globosa* L.)

The effects of cadmium on the growth of globe amaranth (*G. globosa* L.) are shown in Table 4-5. In consideration of the growth of globe amaranth (*G. globosa* L.), the results of height were 27.53, 24.47, 24.37, 22.67, 16.40 and 15.97 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest height (27.53 cm) was found at the control and the lowest height (15.97 cm) was found at 100 mg Cd/kg soil. The results of internodes length were 0.43, 0.40, 0.33, 0.30, 0.23 and 0.20 cm at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest internodes length (0.43 cm) was found at the control and the lowest internodes length (0.20 cm) was found at 100 mg Cd/kg soil. The results of diameter of stem were 0.10, 0.10, 0.09, 0.07, 0.06 and 0.03 cm at the concentrations of

0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest diameter of stem (0.10 cm) was found at the control and 20 mg Cd/kg soil, the lowest internodes length (0.03 cm) was found at 100 mg Cd/kg soil. Moreover, the results of dry weight were 8.63, 7.50, 7.30, 7.00, 6.84 and 6.86 g at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest dry weight (8.63 g) was found at the control and the lowest dry weight (6.84 g) was found at 100 mg Cd/kg soil.

Table 4-5 The effects of cadmium on the growth of globe amaranth (*G. globosa* L.)

Cadmium concentrations (mg Cd/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$27.53^{a} \pm 6.96$	$0.43^{a} \pm 0.15$	$0.10^{a} \pm 0.05$	$8.63^{a} \pm 1.38$
20	$24.47^{a} \pm 3.52$	$0.40^{a} \pm 0.17$	$0.10^{a} \pm 0.05$	$7.50^{a} \pm 0.51$
40	$24.37^{a} \pm 3.96$	$0.33^{a} \pm 0.15$	$0.09^{a} \pm 0.08$	$7.30^{a} \pm 1.00$
60	$22.67^{a} \pm 2.15$	$0.30^{a} \pm 0.00$	$0.07^{a} \pm 0.07$	$7.00^{a} \pm 1.05$
80	$16.40^{a} \pm 3.73$	$0.23^{a} \pm 0.12$	$0.06^{a} \pm 0.01$	$6.84^{a} \pm 0.77$
100	$15.97^{a} \pm 3.31$	$0.20^{a} \pm 0.00$	$0.03^{a} \pm 0.01$	$6.86^{a} \pm 0.40$
F-value	**3.33**	**1.50**	**1.16**	**2.09**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight decreased when cadmium concentration was increased in soil. However, there was no significant difference between the treatment plants and the control ($\rho<0.01$) (Appendix D).

In summation of the effects of cadmium under 6 concentrations (0, 20, 40, 60, 80 and 100 mg Cd/kg soil) on the growth parameters, height, internodes length, diameter of stem and dry weight of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.). The results of all plants showed in the same direction; the growth tended to decrease when cadmium concentration was increased in soil. Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew better than chrysanthemum (*D. difflora*). Both of them looked healthy. Leaves were green and could

produce colorful flowers under all cadmium concentrations. While toxicity symptoms of cadmium in plants were obviously seen in chrysanthemum (*D. difflora*). Although chrysanthemum (*D. difflora*) could survive under all cadmium concentrations in soil, it exhibited abnormal characteristics such as stunted, shortening of internodes and could not produce flowers at concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, moreover a mild chlorosis appeared at concentration of 100 mg Cd/kg soil (Appendix B).

Cadmium contents in the plants caused reduction of plants growth as well as toxicity symptoms. A decline of growth could be due to the decrease in the cellular volume, and the level of photosynthetic pigments (Leborans and Novillo, 1996). It was also some reported that cadmium led to a loss of membrane integrity of plant tissue (Sen, Mondal and Mondal, 1987).

Visual toxicity symptoms also indicated the intensity of cadmium stress were obviously seen in chrysanthemum (*D. difflora*), which exhibited abnormal characteristics. Especially, a mild chlorosis appeared at concentration of 100 mg Cd/kg soil. Possible caused of chlorosis due to poor drainage and nutrient deficiencies in the plant. Chlorosis from excess cadmium appears may be due to a direct or an indirect interaction with foliar iron (Das, Samantary and Rout, 1997)

It was suggested that cadmium concentrations in soil (e.g. 20, 40, 60, 80 and 100 mg Cd/kg soil) were more than the critical level of cadmium in soil that could affect on plants growth and exhibited toxicity symptoms (1-3 mg Cd/kg soil) (Panitchasukpatana, 1997). The toxicity symptoms in each plant were difference depended on plants ability to tolerate, absorb and accumulate of heavy metals (Alloway, 1995).

4.5 The effects of zinc on plants growth

The growth of plants such as height, internodes length diameter of stem and dry weight were measured under zinc concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil. In addition, the growth data in each pot was measured in every 7 days during the experimental period (Appendix C).

4.5.1 Chrysanthemum (*D. difflora*)

The effects of zinc on the growth of chrysanthemum (*D. difflora*) are shown in Table 4-6.

Table 4-6 The effects of zinc on the growth of chrysanthemum (*D. difflora*)

Zinc concentrations (mg Zn/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$29.63^{b} \pm 6.43$	$0.47^{a} \pm 0.15$	$0.22^{a} \pm 0.03$	$6.31^{d} \pm 0.66$
50	$39.93^{ab} \pm 4.97$	$0.50^{a} \pm 0.46$	$0.22^{a} \pm 0.05$	$7.44^{cd} \pm 0.94$
100	$42.13^{ab} \pm 4.69$	$0.53^{a} \pm 0.40$	$0.24^{a} \pm 0.06$	$9.11^{bcd} \pm 1.14$
150	$43.43^{ab} \pm 5.53$	$0.60^{a} \pm 0.26$	$0.26^{a} \pm 0.03$	$9.69^{bc} \pm 0.96$
200	$43.98^{ab} \pm 3.01$	$0.60^{a} \pm 0.17$	$0.30^{a} \pm 0.03$	$11.06^{ab} \pm 1.42$
250	$46.33^{a} \pm 3.65$	$0.67^{a} \pm 0.32$	$0.31^{a} \pm 0.07$	$13.38^{a} \pm 0.61$
F-value	**3.76**	**0.15**	**3.61**	**17.34**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

In consideration of the growth of chrysanthemum (*D. difflora*), the results of height were 29.63, 39.93, 42.13, 43.43, 43.98 and 46.33 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest height (46.33 cm) was found at 250 mg Zn/kg soil and the lowest height (29.63 cm) was found at the control. The results of internodes length were 0.47, 0.50, 0.53, 0.60, 0.60 and 0.67 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest internodes length (0.67 cm) was found at 250 mg Zn/kg soil and the lowest

internodes length (0.47 cm) was found at the control. The results of diameter of stem were 0.22, 0.22, 0.24, 0.26, 0.30 and 0.31 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest diameter of stem (0.22 cm) was found at 200 and 250 mg Zn/kg soil, the lowest diameter of stem (0.31 cm) was found at the control. Moreover, the results of dry weight were 6.31, 7.44, 9.11, 9.69, 11.06 and 13.38 g at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest dry weight (13.38 g) was found at 250 mg Zn/kg soil and the lowest dry weight (6.31 g) was found at the control.

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight increased when zinc concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between the height and dry weight of control and treatment plants (Appendix D).

4.5.2 Marigold (*T. erecta* L.)

The effects of zinc on the growth of marigold (*T. erecta* L.) are shown in Table 4-7.

Table 4-7 The effects of zinc on the growth of marigold (*T. erecta* L.)

Zinc concentrations (mg Zn/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$18.50^{a} \pm 0.30$	$0.13^{b} \pm 0.06$	$0.19^{a} \pm 0.15$	$6.20^{b} \pm 0.44$
50	$18.80^{a} \pm 0.52$	$0.20^{ab} \pm 0.00$	$0.26^{a} \pm 0.04$	$6.50^{b} \pm 0.29$
100	$19.67^{a} \pm 0.74$	$0.27^{ab} \pm 0.06$	$0.28^{a} \pm 0.05$	$6.93^{ab} \pm 0.38$
150	$20.50^{a} \pm 2.18$	$0.37^{a} \pm 0.12$	$0.28^{a} \pm 0.07$	$7.38^{ab} \pm 0.12$
200	$20.63^{a} \pm 0.55$	$0.37^{a} \pm 0.15$	$0.28^{a} \pm 0.03$	$7.77^{ab} \pm 0.40$
250	$21.07^{a} \pm 2.42$	$0.40^{a} \pm 0.10$	$0.33^{a} \pm 0.01$	$8.26^{a} \pm 1.02$
F-value	**1.55**	**5.81**	**1.30**	**5.64**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

In consideration of the growth of marigold (*T. erecta* L.), the results of height were 18.50, 39.93, 42.13, 43.43, 43.98 and 46.33 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest height (46.33 cm) was found at 250 mg Zn/kg soil and the lowest height (18.50 cm) was found at the control. The results of internodes length were 0.13, 0.20, 0.27, 0.37, 0.37 and 0.40 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest internodes length (0.40 cm) was found at 250 mg Zn/kg soil and the lowest internodes length (0.13 cm) was found at the control. The results of diameter of stem were 0.19, 0.26, 0.28, 0.28, 0.28 and 0.33 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest diameter of stem (0.33 cm) was found at 250 mg Zn/kg soil and the lowest diameter of stem (0.19 cm) was found at the control. Moreover, the results of dry weight were 6.20, 6.50, 6.93, 7.38, 7.77 and 8.26 g at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest dry weight (8.26 g) was found at 250 mg Zn/kg soil and the lowest dry weight (6.20 g) was found at the control.

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight increased when zinc concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between the internodes length and dry weight of control and treatment plants (Appendix D).

4.5.3 Globe amaranth (*G. globosa* L.)

The effects of zinc on the growth of globe amaranth (*G. globosa* L.) are shown in Table 4-8. In consideration of the growth of globe amaranth (*G. globosa* L.), the results of height were 22.20, 23.00, 23.80, 24.23, 27.43 and 28.27 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest height (28.27 cm) was found at 250 mg Zn/kg soil and the lowest height (22.20 cm) was found at the control. The results of internodes length were 0.30, 0.40, 0.43, 0.47, 0.50 and 0.60 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest internodes length (0.60 cm) was found at 250 mg Zn/kg soil and the lowest internodes length (0.30 cm) was found at the control. The results of diameter of stem were 0.05, 0.06, 0.12, 0.12, 0.15 and 0.17 cm at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest diameter of stem

(0.17 cm) was found at 250 mg Zn/kg soil and the lowest diameter of stem (0.05 cm) was found at the control. Moreover, the results of dry weight were 6.33, 6.90, 7.24, 8.71, 9.19 and 9.57 g at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest dry weight (9.57 g) was found at 250 mg Zn/kg soil and the lowest dry weight (6.33 g) was found at the control.

Table 4-8 The effects of zinc on the growth of globe amaranth (*G. globosa* L.)

Zinc concentration (mg Zn/kg soil)	Growth parameters			
	Height (cm)	Internodes length (cm)	Diameter of stem (cm)	Dry weight (g)
0	$22.20^{a} \pm 3.01$	$0.30^{a} \pm 0.26$	$0.05^{a} \pm 0.03$	$6.33^{b} \pm 1.53$
50	$23.00^{a} \pm 2.70$	$0.40^{a} \pm 0.26$	$0.06^{a} \pm 0.01$	$6.90^{ab} \pm 1.15$
100	$23.80^{a} \pm 5.14$	$0.43^{a} \pm 0.21$	$0.12^{a} \pm 0.04$	$7.24^{ab} \pm 0.59$
150	$24.23^{a} \pm 2.91$	$0.47^{a} \pm 0.38$	$0.12^{a} \pm 0.04$	$8.71^{ab} \pm 0.69$
200	$27.43^{a} \pm 7.49$	$0.50^{a} \pm 0.20$	$0.15^{a} \pm 0.10$	$9.19^{ab} \pm 1.08$
250	$28.27^{a} \pm 7.38$	$0.60^{a} \pm 0.46$	$0.17^{a} \pm 0.05$	$9.57^{a} \pm 0.87$
F-value	**0.62**	**0.36**	**3.14**	**4.85**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

The results of plant growth were compared with control. It was found that the height, internodes length, diameter of stem and dry weight increased when zinc concentration was increased in soil. Moreover, there was significant increase ($\rho<0.01$) between the dry weight of control and treatment plants (Appendix D).

In summation of the effects of zinc under 6 concentrations (0, 50, 100, 150, 200 and 250 mg Cd/kg soil) on the growth parameters, height, internodes length, diameter of stem and dry weight of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.). The results of all plants showed in the same direction; the growth tended to increase when zinc concentration was increased in soil. Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew better than chrysanthemum (*D. difflora*). Both of them could grow normally as well as control, looked healthy. Leaves were green and could produce colorful flowers under all zinc

concentrations. While toxicity symptoms of zinc in plants were obviously seen in chrysanthemum (*D. difflora*). Although chrysanthemum (*D. difflora*) could survive and produced colorful flowers under all zinc concentrations in soil, it exhibited abnormal characteristics such as scorching in leaves and necrosis at concentration of 50, 100, 150, 200 and 250 mg Zn/kg soil, moreover death of the flowers appeared at concentration of 200 and 250 mg Zn/kg soil (Appendix B).

Zinc contents in the plants caused increases of plant growth, the effect on the growth of plants could be due to the fact that zinc is an essential micronutrient for plant growth.

Visual toxicity symptoms also indicated the intensity of zinc stress were obviously seen in chrysanthemum (*D. difflora*), which exhibited abnormal characteristics. Especially, scorching in leaves and necrosis appeared at zinc concentration of 50, 100, 150, 200 and 250 mg Zn/kg soil. Possible caused of scorching in leaves and necrosis due to plants accumulated excessive amount of zinc and poor drainage.

It was suggested that zinc concentration in soil (e.g. 100, 150, 200 and 250 mg Zn/kg soil) were more than critical level of zinc in soil that could affect on plants growth and exhibited toxicity symptoms (60 mg Zn/kg soil) (Panitchasukpatana, 1997). The toxicity symptoms in each plant were difference depended on plants ability to tolerate, absorb and accumulated of heavy metals (Alloway, 1995).

4.6 Cadmium accumulation in various parts of plants

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were separated into 4 parts, roots, stems, leaves and flowers and then analyzed for the amount of cadmium in each part, it was determined into milligram cadmium per kilogram dry weight (mg Cd/kg).

4.6.1 Chrysanthemum (*D. difflora*)

Cadmium accumulation in various part of chrysanthemum (*D. difflora*) is shown in Table 4-9.

Table 4-9 Cadmium accumulation in various parts of chrysanthemum (*D. difflora*)

Cadmium concentrations (mg Cd/kg soil)	Cadmium accumulation				F-value
	Roots (mg Cd/kg)	Stems (mg Cd/kg)	Leaves (mg Cd/kg)	Flowers (mg Cd/kg)	
0	ND^{c}	ND^{b}	ND^{b}	ND	
20	0.36^{bcA} ± 0.08	0.45^{bA} ± 0.08	0.59^{abA} ± 0.29	-	**1.24**
40	0.70^{abA} ± 0.09	1.00^{aA} ± 0.25	1.07^{aA} ± 0.29	-	**2.35**
60	0.84^{abA} ± 0.27	1.15^{aA} ± 0.26	1.10^{aA} ± 0.37	-	**0.86**
80	0.89^{aA} ± 0.11	1.15^{aA} ± 0.21	1.27^{aA} ± 0.32	-	**2.08**
100	0.91^{aA} ± 0.29	1.27^{aA} ± 0.26	1.35^{aA} ± 0.27	-	**2.12**
F-value	**11.50**	**22.81**	**9.83**	-	

Note : There was no flower datas because at cadmium concentrations of 20, 40, 60, 80 and 100 Mg Cd/kg soil, plants could not produce flowers but except control.

: Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of cadmium accumulation in each part of chrysanthemum (*D. difflora*), the amounts of cadmium accumulation in roots were 0.36, 0.70, 0.84, 0.89 and 0.91 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in roots (0.91 mg Cd/kg) was found at 100 mg Cd/kg soil and the lowest amount of cadmium accumulation in roots (0.36 mg Cd/kg) was found at 20 mg Cd/kg soil. The amounts of cadmium accumulation in stems were 0.45, 1.00, 1.15, 1.15 and 1.27 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in stems (1.27 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in stems (0.45 mg Cd/kg) was found at 20 mg Cd/kg soil, moreover the amounts of cadmium accumulation in leaves were 0.59, 1.07, 1.10, 1.27 and 1.35 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in leaves (1.35 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in leaves (0.59 mg Cd/kg) was found at 20 mg Cd/kg soil.

Then the results of the amounts of cadmium accumulation in each part of plants were compared with control, it was found that cadmium content in roots, stems and leaves increased when cadmium concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots and stems of control and treatment plants (Appendix E).

In consideration of the amounts of cadmium accumulation in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil. It was found that at concentration of 20 mg Cd/kg soil; cadmium accumulation in roots, stems and leaves were 0.36, 0.45 and 0.59 mg Cd/kg, respectively. At concentration of 40 mg Cd/kg soil; cadmium accumulation in roots, stems and leaves were 0.70, 1.00 and 1.07 mg Cd/kg, respectively. At concentration of 60 mg Cd/kg soil; the amount of cadmium accumulation in stems was more than leaves a little, the results of cadmium accumulation in roots, stems and leaves were 0.84, 1.15 and 1.10 mg Cd/kg, respectively. At concentration of 80 mg Cd/kg soil; cadmium accumulation in roots, stems and leaves were 0.89, 1.15, 1.27 mg Cd/kg, respectively. Moreover, at concentration of 100 mg Cd/kg soil, the highest concentration level of cadmium accumulation in 0.91, 1.27 and 1.35 mg Cd/kg, respectively.

Then the amounts of cadmium accumulation in roots, stems and leaves in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil were compared, the highest cadmium accumulation observed in the leaves and stems more than roots. However, there was no significant difference between the amounts of cadmium accumulation in the part of plants ($\rho<0.01$) (Appendix F).

4.6.2 Marigold (*T. erecta* L.)

Cadmium accumulation in various parts of marigold (*T. erecta* L.) is shown in Table 4-10.

Table 4-10 Cadmium accumulation in various parts of marigold (*T. erecta* L.)

Cadmium concentrations (mg Cd/kg soil)	Cadmium accumulation				F-value
	Roots (mg Cd/kg)	Stems (mg Cd/kg)	Leaves (mg Cd/kg)	Flowers (mg Cd/kg)	
0	ND^{d}	ND^{d}	ND^{b}	ND^{c}	
20	$0.10^{cA}\pm0.05$	$0.25^{cdA}\pm0.16$	$0.33^{bA}\pm0.38$	$0.12^{cA}\pm0.08$	**0.83**
40	$0.13^{bcC}\pm0.02$	$0.48^{bcB}\pm0.04$	$0.82^{bA}\pm0.17$	$0.19^{cC}\pm0.02$	**37.13**
60	$0.14^{bcC}\pm0.00$	$0.52^{bcB}\pm0.05$	$0.91^{bA}\pm0.10$	$0.22^{cC}\pm0.05$	**99.06**
80	$0.18^{abC}\pm0.02$	$0.66^{bB}\pm0.16$	$1.04^{bA}\pm0.01$	$0.53^{bB}\pm0.06$	**52.56**
100	$0.24^{aB}\pm0.06$	$1.16^{aB}\pm0.29$	$2.56^{aA}\pm1.08$	$0.79^{aB}\pm0.24$	**9.01**
F-value	**23.72**	**28.04**	**11.55**	**33.69**	

Note : Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of cadmium accumulation in each part of marigold (*T. erecta* L.), the amount of cadmium accumulation in roots were 0.10, 0.13, 0.14, 0.18 and 0.24 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg

Cd/kg soil, respectively. The highest amount of cadmium accumulation in roots (0.24 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in roots (0.10 mg Cd/kg) was found at 20 mg Cd/kg soil. The amounts of cadmium accumulation in stems were 0.25, 0.48, 0.52, 0.66 and 1.16 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in stems (1.16 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in stems (0.25 mg Cd/kg) was found at 20 mg Cd/kg soil. The amounts of cadmium accumulation in leaves were 0.33, 0.82, 0.91, 1.04 and 2.56 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in leaves (2.56 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in leaves (0.33 mg Cd/kg) was found at 20 mg Cd/kg soil, moreover the amounts of cadmium accumulation in flowers were 0.12, 0.19, 0.22, 0.53 and 0.79 mg Cd/kg soil at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in flowers (0.79 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in flowers (0.12 mg Cd/kg) was found at 20 mg Cd/kg soil.

Then the results of the amounts of cadmium accumulation in each part of plants were compared with control, it was found that cadmium content in roots, stems, leaves and flowers increased when cadmium concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots, stems, leaves and flowers of control and treatment plants (Appendix E).

In consideration of the amounts of cadmium accumulation in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil. It was found that at concentration of 20 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.10, 0.25, 0.33 and 0.12 mg Cd/kg, respectively. At concentration of 40 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.13, 0.48, 0.82 and 0.19 mg Cd/kg, respectively. At concentration of 60 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.14, 0.52, 0.91 and 0.22 mg Cd/kg, respectively. At concentration of 80 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.18, 0.66, 1.04 and 0.53 mg Cd/kg, respectively. Moreover, at concentration of 100 mg Cd/kg soil, the highest concentration level of

cadmium accumulation in roots, stems, leaves and flowers were 0.24, 1.16, 2.56 and 0.79 mg Cd/kg, respectively.

Then the amounts of cadmium accumulation in roots, stems leaves, and flowers in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil were compared, the highest cadmium accumulation observed in the leaves more than stems, flowers and roots, respectively. Moreover, there were significant differences between the amounts of cadmium accumulation in the part of plants at concentrations of 40, 60, 80 and 100 mg Cd/kg soil ($\rho<0.01$) (Appendix F).

4.6.3 Globe amaranth (*G. globosa* L.)

Cadmium accumulation in various parts of globe amaranth (*G. globosa* L.) is shown in Table 4-11.

Table 4-11 Cadmium accumulation in various parts of globe amaranth (*G. globosa* L.)

Cadmium concentrations (mg Cd/kg soil)	Cadmium accumulation				F-value
	Roots (mg Cd/kg)	Stems (mg Cd/kg)	Leaves (mg Cd/kg)	Flowers (mg Cd/kg)	
0	ND^{b}	ND^{b}	ND^{c}	ND^{b}	
20	0.24^{aB} ±0.06	0.47^{aA} ±0.05	0.51^{bA} ±0.06	0.15^{aB} ±0.02	**35.30**
40	0.28^{aBC} ±0.07	0.51^{aAB} ±0.15	0.71^{abA} ±0.11	0.17^{aC} ±0.04	**16.50**
60	0.31^{aBC} ±0.05	0.52^{aB} ±0.13	0.88^{abA} ±0.12	0.18^{aC} ±0.02	**33.51**
80	0.33^{aB} ±0.01	0.55^{aAB} ±0.08	0.96^{abA} ±0.37	0.19^{aB} ±0.02	**9.35**
100	0.34^{aB} ±0.06	0.60^{aB} ±0.06	1.10^{aA} ±0.28	0.20^{aB} ±0.03	**21.04**
F-value	**29.44**	**15.61**	**12.93**	**26.15**	

Note : Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of cadmium accumulation in each part of globe amaranth (*G. globosa* L.), the amount of cadmium accumulation in roots were 0.24, 0.28, 0.31, 0.33 and 0.34 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in roots (0.34 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in roots (0.24 mg Cd/kg) was found at 20 mg Cd/kg soil. The amounts of cadmium accumulation in stems were 0.47, 0.51, 0.52, 0.55 and 0.60 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in stems (0.60 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in stems (0.47 mg Cd/kg) was found at 20 mg Cd/kg soil. The amounts of cadmium accumulation in leaves were 0.51, 0.71, 0.88, 0.96 and 1.10 mg Cd/kg at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in leaves (1.10 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in leaves (0.51 mg Cd/kg) was found at 20 mg Cd/kg soil, moreover the amounts of cadmium accumulation in flowers were 0.15, 0.17, 0.18, 0.19 and 0.20 mg Cd/kg soil at the concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, respectively. The highest amount of cadmium accumulation in flowers (0.10 mg Cd/kg) was found at 100 Cd/kg soil and the lowest amount of cadmium accumulation in flowers (0.15 mg Cd/kg) was found at 20 mg Cd/kg soil.

Then the results of the amounts of cadmium accumulation in each part of plants were compared with control, it was found that cadmium content in roots, stems, leaves and flowers increased when cadmium concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots, stems, leaves and flowers of control and treatment plants (Appendix E).

In consideration of the amounts of cadmium accumulation in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil. It was found that at concentration of 20 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.24, 0.47, 0.51 and 0.15 mg Cd/kg, respectively. At cadmium concentration of 40 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.28, 0.51, 0.71 and 0.17 mg Cd/kg, respectively. At cadmium concentration of 60 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.31, 0.52, 0.88 and

0.18 mg Cd/kg, respectively. At cadmium concentration of 80 mg Cd/kg soil; cadmium accumulation in roots, stems, leaves and flowers were 0.33, 0.55, 0.96 and 0.19 mg Cd/kg, respectively. Moreover, at cadmium concentration of 100 mg Cd/kg soil, the highest concentration level of cadmium accumulation in roots, stems, leaves and flowers were 0.34, 0.60, 1.10 and 0.20 mg Cd/kg, respectively.

Then the amounts of cadmium accumulation in roots, stems leaves, and flowers in each concentration, 20, 40, 60, 80 and 100 mg Cd/kg soil were compared, the highest cadmium accumulation observed in the leaves more than stems, roots and flowers, respectively. Moreover, there were significant differences between the amounts of cadmium accumulation in the part of plants at concentrations of 20,40, 60, 80 and 100 mg Cd/kg soil ($\rho<0.01$) (Appendix F).

In summation of cadmium accumulation in various parts of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.), the results of all plants showed in the same direction; the amount of cadmium accumulation in plants increased when cadmium concentration was increased in soil. Chrysanthemum (*D. difflora*) tended to accumulate cadmium in leaves and stems more than roots, respectively (leaves≥stems>roots), marigold (*T. erecta* L.) tended to accumulate cadmium in leaves more than stems, flowers and roots, respectively (leaves>stems> flowers>roots), moreover globe amaranth (*G. globosa* L.) tended to accumulate cadmium in leaves more than stems, roots and flowers, respectively (leaves>stems>roots>flowers). Therefore, the results of cadmium accumulation in all plants showed in the same direction; plants tended to accumulate cadmium in leaves and stems more than roots and flowers.

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) tended to accumulate cadmium in shoot, it could be due to cadmium is a high mobility in soil, cadmium is one of heavy metals which readily transport to plants shoot and the application of EDTA could increase the uptake of heavy metals into plant (Chen and Cutright, 2001).

The similar results had been reported that lettuce (Plant of *Lactuca sp.*) accumulated cadmium and more distributed in leaves than in roots (Inmaculada *et al*,

2002). Turgut, Katie Pepe and Cutright (2005) found that EDTA (at 0.1 g/kg soil) effected on dwarf sunspot sunflower (*Helianthus annuus*) for uptake and translocation of cadmium, which more cadmium accumulated in leaves than in roots. Moreover, Faisatjatham (2006) was reported that the accumulation of cadmium and zinc in roots of *Vetiveria zizanioides* (Linn.) Nash and *Vetiveria nemoralis* (Balansa) A. Camus was higher than in leaves and the similar results reported by Srisatit and Tambamroong (2006), showing that the accumulation of arsenic in roots of *Colocasia esculenta* (Linn.) Schott; taro and wild taro was higher than in leaves. The bioavailability of soil cadmium for uptake by plants roots depended on the root morphology as well as physicochemical soil properties such as pH, organic matter content, and soil texture (Youn-joo, 2003).

It was suggested that marigold (*T. erecta* L.) was the highest in cadmium accumulation. The difference in the ability of plants to accumulate heavy metals could be due to difference in their root morphology (Schierup and Lorsen, 1981), from the observation, root weights of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were nearly, but marigold (*T. erecta* L.) had a lot of roots in the small size, so it has roots surface for uptake cadmium more than another, and this reason could explain the difference of cadmium accumulation in plants.

4.7 Zinc accumulation in various parts of plants

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were separated into 4 parts, roots, stems, leaves and flowers and then analyzed for the amount of zinc in each part, it was determined into milligram zinc per kilogram dry weight (mg Zn/kg).

4.7.1 Chrysanthemum (*D. difflora*)

Zinc accumulation in various parts of chrysanthemum (*D. difflora*) is shown in Table 4-12.

Table 4-12 Zinc accumulation in various parts of chrysanthemum (*D. difflora*)

Zinc concentrations (mg Zn/kg soil)	Zinc accumulation				F-value
	Roots (mg Zn/kg)	Stems (mg Zn/kg)	Leaves (mg Zn/kg)	Flowers (mg Zn/kg)	
0	0.31^{cAB} ±0.04	0.34^{bAB} ±0.09	0.59^{bA} ±0.21	0.21^{bB} ±0.06	**5.18**
50	0.37^{bcA} ±0.03	0.55^{bA} ±0.25	0.78^{bA} ±0.23	0.29^{bA} ±0.10	**4.58**
100	0.51^{bcA} ±0.18	0.86^{abA} ±0.23	1.28^{bA} ±0.43	0.53^{abA} ±0.29	**4.33**
150	0.63^{bcA} ±0.22	1.09^{abA} ±0.58	1.65^{bA} ±0.65	0.64^{abA} ±0.10	**3.41**
200	0.87^{abA} ±0.17	1.64^{aA} ±0.06	1.95^{bA} ±0.72	0.84^{aA} ±0.23	**6.18**
250	1.31^{aB} ±0.44	1.77^{aB} ±0.43	3.58^{aA} ±0.75	0.87^{aB} ±0.10	**17.92**
F-value	**10.68**	**8.35**	**9.97**	**7.53**	

Note : Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of zinc accumulation in each part of chrysanthemum (*D. difflora*), the amounts of zinc accumulation in roots were 0.31, 0.37, 0.51, 0.63, 0.87 and 1.31 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and

250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in roots (1.31 mg Zn/kg) was found at 250 mg Zn/kg soil and the lowest amount of zinc accumulation in roots (0.31 mg Zn/kg) was found at the control. The amounts of zinc accumulation in stems were 0.34, 0.55, 0.86, 1.09, 1.64 and 1.77 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in stems (1.77 mg Zn/kg) was found at 250 Zn /kg soil and the lowest amount of zinc accumulation in stems (0.34 mg Zn/kg) was found at the control. The amounts of zinc accumulation in leaves were 0.59, 0.78, 1.28, 1.65, 1.95 and 3.58 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in leaves (3.58 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in leaves (0.59 mg Zn/kg) was found at the control, moreover the amounts of zinc accumulation in flowers were 0.21, 0.29, 0.53, 0.64, 0.84 and 0.87 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in flowers (0.87 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in flowers (0.21 mg Zn/kg) was found at the control.

Then the results of the amounts of zinc accumulation in each part of plants were compared with control, it was found that zinc content in roots, stems, leaves and flowers increased when zinc concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots stems, leaves and flowers of control and treatment plants (Appendix E).

In consideration of the amounts of zinc accumulation in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil. It was found that at concentration of 0 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.31, 0.34, 0.59 and 0.21 mg Zn/kg, respectively. At concentration of 50 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were mg 0.37, 0.55, 0.78 and 0.29 Zn/kg, respectively. At concentration of 100 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.51, 0.86, 1.28 and 0.53 mg Zn/kg, respectively. At concentration of 150 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.63, 1.09, 1.65 and 0.64 mg Zn/kg, respectively. At concentration of 200 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.87, 1.64, 1.95 and 0.84 mg Zn/kg, respectively. Moreover, at

concentration of 250 mg Zn/kg soil; the highest concentration level of zinc accumulation in roots, stems, leaves and flowers were 1.31, 1.77, 3.58 and 0.87 mg Zn/kg, respectively.

Then the amounts of zinc accumulation in roots, stems, leaves and flowers in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil were compared, the highest zinc accumulation observed in the leaves more than stems, roots and flowers, respectively. Moreover, there were significant differences between the amounts of cadmium accumulation in the part of plants at concentrations of 0 and 250 ($\rho<0.01$) (Appendix F).

4.7.2 Marigold (*T. erecta* L.)

Zinc accumulation in various parts of marigold (*T. erecta* L.) is shown in Table 4-13.

Table 4.13 Zinc accumulation in various parts of marigold (*T. erecta* L.)

Zinc concentrations (mg Zn/kg soil)	Zinc accumulation				F-value
	Roots (mg Zn/kg)	Stems (mg Zn/kg)	Leaves (mg Zn/kg)	Flowers (mg Zn/kg)	
0	0.51^{dB} ±0.19	0.82^{dB} ±0.17	2.08^{dA} ±0.61	0.87^{dB} ±0.13	**12.65**
50	0.63^{dC} ±0.08	1.13^{dB} ±0.12	3.09^{dA} ±0.28	1.13^{cdB} ±0.14	**121.21**
100	0.87^{cdB} ±0.26	1.37^{cdB} ±0.18	4.20^{cdA} ±0.41	1.27^{cdB} ±0.25	**85.09**
150	1.20^{bcC} ±0.12	1.90^{bcB} ±0.18	5.11^{cA} ±0.36	1.49^{bcBC} ± 0.16	**195.29**
200	1.45^{bB} ±0.08	2.24^{bB} ±0.35	7.55^{bA} ±0.96	1.80^{bB} ±0.22	**91.01**
250	2.19^{aB} ±0.34	3.32^{aB} ±0.71	10.64^{aA} ±1.77	3.05^{aB} ±0.34	**47.68**
F-value	**53.39**	**35.49**	**43.34**	**53.50**	

Note : Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of zinc accumulation in each part of marigold (*T. erecta* L.), the amounts of zinc accumulation in roots were 0.51, 0.63, 0.87, 1.20, 1.45 and 2.19 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in roots (2.19 mg Zn/kg) was found at 250 mg Zn/kg soil and the lowest amount of zinc accumulation in roots (0.51 mg Zn/kg) was found at the control. The amounts of zinc accumulation in stems were 0.82, 1.13, 1.37, 1.90, 2.24 and 3.32 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in stems (3.32 mg Zn/kg) was found at 250 mg Zn /kg soil and the lowest amount of zinc accumulation in stems (0.82 mg Zn/kg) was found at the control. The amounts of zinc accumulation in leaves were 2.08, 3.09, 4.20, 5.11, 7.55 and 10.64 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in leaves (10.64 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in leaves (2.08 mg Zn/kg) was found at the control, moreover, the amounts of zinc accumulation in flowers were 0.87, 1.13, 1.27, 1.49, 1.80 and 3.05 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in flowers (3.05 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in flowers (0.87 mg Zn/kg) was found at the control.

Then the results of the amounts of zinc accumulation in each part of plants were compared with control, it was found that zinc content in roots, stems, leaves and flowers increased when zinc concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots stems, leaves and flowers of control and treatment plants (Appendix E).

In consideration of the amounts of zinc accumulation in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil. It was found that at concentration of 0 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.51, 0.82, 2.08 and 0.87 mg Zn/kg, respectively. At zinc concentration of 50 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were mg 0.63, 1.13, 3.09 and 1.13 Zn/kg, respectively. At zinc concentration of 100 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.87, 1.37, 4.20 and 1.27 mg Zn/kg, respectively. At zinc concentration of 150 mg Zn/kg soil; zinc accumulation in

roots, stems, leaves and flowers were 1.20, 1.90, 5.11 and 1.49 mg Zn/kg, respectively. At zinc concentration of 200 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 1.45, 2.24, 7.55 and 1.80 mg Zn/kg, respectively. Moreover, at zinc concentration of 250 mg Zn/kg soil; the highest concentration level of zinc accumulation in roots, stems, leaves and flowers were 2.19, 3.32, 10.64 and 3.05 mg Zn/kg, respectively.

Then the amounts of zinc accumulation in roots, stems, leaves and flowers in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil were compared, the highest zinc accumulation observed in the leaves more than stems, flowers and roots, respectively. Moreover, there were significant differences between the amounts of cadmium accumulation in the part of plants at concentrations of 0, 50, 100, 150, 200 and 250 ($\rho<0.01$) (Appendix F).

4.7.3 Globe amaranth (*G. globosa* L.)

Zinc accumulation in various parts of globe amaranth (*G. globosa* L.) is shown in Table 4-14.

Table 4-14 Zinc accumulation in various parts of globe amaranth (*G. globosa* L.)

Zinc concentrations (mg Zn/kg soil)	Zinc accumulation				F-value
	Roots (mg Zn/kg)	Stems (mg Zn/kg)	Leaves (mg Zn/kg)	Flowers (mg Zn/kg)	
0	0.54^{eA} ±0.28	0.17^{eA} ±0.04	0.38^{dA} ±0.16	0.07^{bA} ±0.01	**4.98**
50	0.84^{deA} ±0.09	0.62^{deA} ±0.22	0.75^{dA} ±0.48	0.13^{bA} ±0.03	**4.07**
100	1.03^{cdA} ±0.03	1.07^{cdA} ±0.22	1.34^{cdA} ±0.46	0.18^{bB} ±0.03	**11.79**
150	1.39^{cB} ±0.32	1.67^{bcAB} ±0.30	2.41^{bcA} ±0.56	0.26^{bC} ±0.02	**18.73**
200	1.91^{bAB} ±0.18	2.07^{bAB} ±0.49	3.81^{abA} ±1.23	0.48^{abB} ±0.03	**12.45**
250	2.38^{aB} ±0.12	3.91^{aA} ±0.39	4.70^{aA} ±0.89	0.97^{aB} ±0.48	**27.49**
F-value	**55.26**	**62.16**	**29.79**	**9.06**	

Note : Consider in each row to compare the amount of cadmium accumulation in each part at various concentrations level.

: Consider in each column to compare the amount of cadmium accumulation in various parts at the same concentration level.

: ND was stand for non determination because heavy metals concentration were lower than

detection limit (Cd; 0.01 mg/l, Zn; 0.03 mg/l).

: Each value is the mean of triplicate ± S.D.

: The same small alphabet on the right corner in each row and the same capital alphabet on the right corner in each column means there is no significant difference ($\rho<0.01$).

In consideration of the amounts of zinc accumulation in each part of globe amaranth (*G. globosa* L.), the amounts of zinc accumulation in roots were 0.54, 0.84, 1.03, 1.39, 1.91 and 2.38 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in roots (2.38 mg Zn/kg) was found at 250 mg Zn/kg soil and the lowest amount of zinc accumulation in roots (0.54 mg Zn/kg) was found at the control. The amounts of zinc accumulation in stems were 0.17, 0.62, 1.07, 1.67, 2.07 and 3.91 mg Zn/kg with the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in stems (3.31 mg Zn/kg) was found at 250 Zn /kg soil and the lowest amount of zinc accumulation in stems (0.17 mg Zn/kg) was found at the control. The amounts of zinc accumulation in leaves were 0.38, 0.75, 1.34, 2.41, 3.81 and 4.70 mg Zn/kg with the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in leaves (4.70 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in leaves (0.38 mg Zn/kg) was found at the control, moreover, the amounts of zinc accumulation in flowers were 0.07, 0.13, 0.18, 0.26, 0.48 and 0.97 mg Zn/kg at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil, respectively. The highest amount of zinc accumulation in flowers (0.97 mg Zn/kg) was found at 250 Zn/kg soil and the lowest amount of zinc accumulation in flowers (0.07 mg Zn/kg) was found at the control.

Then the results of the amounts of zinc accumulation in each part of plants were compared with control, it was found that zinc content in roots, stems, leaves and flowers increased when zinc concentration was increased in soil. Moreover, there were significant increases ($\rho<0.01$) between roots stems, leaves and flowers of control and treatment plants (Appendix E).

In consideration of the amounts of zinc accumulation in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil. It was found that at concentration of 0 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.54, 0.17, 0.38 and 0.07 mg Zn/kg, respectively. At zinc concentration of 50 mg

Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 0.84, 0.62, 0.75 and 0.13 mg Zn/kg, respectively. At zinc concentration of 100 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 1.03, 1.07, 1.34 and 0.18 mg Zn/kg, respectively. At zinc concentration of 150 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 1.39, 1.67, 2.41 and 0.26 mg Zn/kg, respectively. At zinc concentration of 200 mg Zn/kg soil; zinc accumulation in roots, stems, leaves and flowers were 1.91, 2.07, 3.81 and 0.48 mg Zn/kg, respectively. Moreover, at zinc concentration of 250 mg Zn/kg soil, the highest concentration level of zinc accumulation in roots, stems, leaves and flowers were 2.38, 3.91, 4.70 and 0.97 mg Zn/kg, respectively.

Then the amounts of zinc accumulation in roots, stems, leaves and flowers in each concentration, 0, 50, 100, 150, 200 and 250 mg Zn/kg soil were compared, the highest zinc accumulation observed in the leaves more than stems, roots and flowers, respectively. Moreover, there were significant differences between the amounts of cadmium accumulation in the part of plants at concentrations of 100, 150, 200 and 250 ($\rho<0.01$) (Appendix F).

In summation of the zinc accumulation in various parts of chrysanthemum (*D. difflora*), marigold (*T. erecta* L) and globe amaranth (*G. globosa* L.), the results of all plants showed in the same direction; the amount of zinc accumulation in plants increased when zinc concentration was increased in soil. Chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.) tended to accumulate zinc in leaves more than stems, roots and flowers, respectively (leaves>stems>roots>flowers), moreover marigold (*T. erecta* L.) tended to accumulate zinc in leaves more than stems, flowers and roots, respectively (leaves>stems> flowers>roots). Therefore, the results of zinc accumulation in all plants showed in the same direction; plants tended to accumulate zinc in leaves and stems than roots and flowers.

Chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) tended to accumulate zinc in shoot, due to zinc is a high mobility in soil, zinc is one of heavy metals which readily transport to plants shoot and the application of EDTA could increase the uptake of heavy metals into plant (Chen and Cutright, 2001).

The similar results had been reported by Reeves and Baker (1984) that Halacsy (*Thlaspi goesingense*) taken from calcareous soil was grew on a serpentine soil and extremely high concentrations of nickel (Ni), zinc (Zn), cobalt (Co) and manganese (Mn) were accumulated in the above-ground dry matter. Chahal and Ahluwalia (2004) revealed that highest amount of zinc was accumulated in shoot portion of groundnut plant and declined severely at 75 days of plant growth. Maximum zinc translocation from the shoot portion to fruits occurred between 50 and 75 days of growth period. Kellera, Hammera and Kayserb (2003) found that the total amount of cadmium and zinc extracted by *Thlaspi caerulescens* and *Salix viminalis* were significantly higher in leaves than stems, highlighting the necessity to collect leaves as well as shoots. Moreover, Faisatjatham (2006) was reported that the accumulation of cadmium and zinc in roots of *Vetiveria zizanioides* (Linn.) Nash and *Vetiveria nemoralis* (Balansa) A. Camus was higher than in leaves and the similar results reported by Srisatit and Tambamroong (2006), showing that the accumulation of arsenic in roots of *Colocasia esculenta* (Linn.) Schott; taro and wild taro was higher than in leaves. The bioavailability of soil cadmium for uptake by plants roots depended on the root morphology as well as physicochemical soil properties such as pH, organic matter content, and soil texture (Youn-joo, 2003).

It was suggested that marigold (*T. erecta* L.) was the highest in zinc accumulation. The difference in the ability of plants to accumulate heavy metals could be due to difference in their root morphology (Schierup and Lorsen, 1981), from the observation, root weights of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were nearly, but marigold (*T. erecta* L.) had a lot of roots in the small size, so it has roots surface for uptake zinc more than another, and this reason could explain the difference of zinc accumulation in plants.

4.8 The efficiency of cadmium removal in plants (%)

The efficiency of cadmium removal in plants (%) were calculated from total cadmium accumulation in plant (mg) per amount of cadmium concentration in pot (mg) and presented as percentage of cadmium in plants (Table 4-15).

Table 4-15 The efficiency of cadmium removal in plants (%)

Cadmium concentrations (mg Cd/kg soil)	% Cadmium in plants		
	chrysanthemum (*D. difflora*)	marigold (*T. erecta* L.)	globe amaranth (*G. globosa* L.)
20	0.033^{a}±0.00	0.018^{a}±0.02	0.034^{a}±0.00
40	0.031^{a}±0.01	0.018^{a}±0.00	0.021^{b}±0.00
60	0.021^{ab}±0.00	0.012^{a}±0.00	0.015^{bc}±0.00
80	0.014^{b}±0.00	0.012^{a}±0.00	0.012^{c}±0.00
100	0.011^{b}±0.00	0.019^{a}±0.00	0.010^{c}±0.00
F-value	**6.96**	**0.70**	**16.18**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.01$).

The efficiency of cadmium removal in chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.) were in range of 0.011%-0.033% and 0.010%-0.034%, respectively. The highest efficiency of cadmium removal in chrysanthemum (*D. difflora*) (0.033%) and globe amaranth (*G. globosa* L.) (0.034%) were found at 20 mg Cd/kg soil and the lowest efficiency of cadmium removal in chrysanthemum (*D. difflora*) (0.011%) and globe amaranth (*G. globosa* L.) (0.010%) were found at 100 mg Cd/kg soil. The results of the efficiency of cadmium removal in plants were compared. It was found that the efficiency of cadmium removal in chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.) decreased when cadmium concentration was increased in soil. Moreover, there were significant decreases at concentration of 60, 80, 100 ($\rho<0.01$) (Appendix G).

Concerning on the efficiency of cadmium removal in marigold (*T. erecta* L.) was in range of 0.012%-0.019%. The highest efficiency of cadmium removal in marigold

(*T. erecta* L.) (0.019%) was found at 100 mg Cd/kg soil and the lowest efficiency of cadmium removal in marigold (*T. erecta* L.) (0.012%) was found at 60 and 80 mg Cd/kg soil. However, there was no significant difference between the treatment plants ($\rho<0.01$) (Appendix G).

In summation of the efficiency of cadmium removal in plants, it was found that at the highest cadmium concentration; 100 mg Cd/kg soil, marigold (*T. erecta* L.) was more effective in remove cadmium from the soil than chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.), respectively. Therefore, the results indicated that marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were suitable species for phytoremediation uses in the cadmium-contaminated soil because of their efficiencies in cadmium removal, moreover marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could certainly tolerate to toxic from cadmium and produce colorful flowers under all cadmium concentrations.

It was suggested that the efficiency of cadmium removal was reduced in chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.) due to the cadmium phytotoxicity, cadmium concentrations in soil (e.g. 20, 40, 60, 80 and 100 mg Cd/kg soil) were more than the critical level of cadmium in soil that could affect on plants growth and exhibited toxicity symptoms (1-3 mg Cd/kg soil) (Panitchasukpatana, 1997). Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) better grew up than chrysanthemum (*D. difflora*). Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew normally and could produce flowers under all concentrations, while chrysanthemum (*D. difflora*) exhibited abnormal characteristics such as stunted, shortening of internodes and could not produce flowers at concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, moreover a mild chlorosis appeared at cadmium concentration of 100 mg Cd/kg soil.

4.9 The efficiency of zinc removal in plants (%)

The efficiency of zinc removal in plants (%) were calculated from total zinc accumulation in plant (mg) per amount of zinc concentration in pot (mg) and presented as percentage of zinc in plants (Table 4-15).

Table 4-16 The efficiency of zinc removal in plants (%)

Zinc concentrations (mg Zn/kg soil)	% Zinc in plants		
	chrysanthemum (*D. difflora*)	marigold (*T. erecta* L.)	globe amaranth (*G. globosa* L.)
50	0.020^{ab} ±0.00	0.052^{a} ±0.00	0.022^{a} ±0.01
100	0.024^{ab} ±0.00	0.046^{ab} ±0.01	0.024^{a} ±0.01
150	0.018^{b} ±0.00	0.032^{b} ±0.00	0.022^{a} ±0.00
200	0.020^{ab} ±0.00	0.034^{b} ±0.00	0.026^{a} ±0.00
250	0.027^{a} ±0.00	0.042^{ab} ±0.00	0.030^{a} ±0.00
F-value	**2.02**	**3.12**	**0.51**

Note : Each value is the mean of triplicate ± S.D.

: The same alphabet on the right corner in each row means there is no significant difference ($\rho<0.05$).

The efficiency of zinc removal in chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were in range of 0.018%-0.027%, 0.032%-0.052% and 0.022%-0.030%, respectively. The highest efficiency of zinc removal in chrysanthemum (*D. difflora*) (0.027%) and globe amaranth (*G. globosa* L.) (0.030%) were found at 250 mg Zn/kg soil, and the highest efficiency of zinc removal in marigold (*T. erecta* L.) (0.052%) was found at 50 mg Zn/kg soil. The lowest efficiency of zinc removal in chrysanthemum (*D. difflora*) (0.018%) and marigold (*T. erecta* L.) (0.032%) were found at 150 mg Zn/kg soil. The lowest efficiency of zinc removal in globe amaranth (*G. globosa* L.) (0.022%) was found at 50 and 150 mg Zn/kg soil.

The results of the efficiency of zinc removal in plants were compared. It was found that the efficiency of cadmium removal in chrysanthemum (*D. difflora*) and marigold (*T. erecta* L.) fluctuated, moreover the efficiency of zinc removal in globe

amaranth (*G. globosa* L.) was no significant difference between the treatment plants ($\rho<0.01$) (Appendix G).

In summation of the efficiency of zinc removal in experimental plants, it was found that at the highest zinc concentration; 250 mg Zn/kg soil, marigold (*T. erecta* L.) was more effective in remove zinc from the soil than globe amaranth (*G. globosa* L.) and chrysanthemum (*D. difflora*), respectively. Therefore, the results indicated that marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were suitable species for phytoremediation uses in the zinc-contaminated soil because of their efficiencies in zinc removal, moreover marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could certainly tolerate to toxic from zinc and produce colorful flowers under all zinc concentrations.

It was suggested that zinc concentrations in soil (e.g. 100, 150, 200 and 250 mg Zn/kg soil) were more than critical level of zinc in soil that could affect on plants growth and exhibited toxicity symptoms (60 mg Zn/kg soil) (Panitchasukpatana, 1997). Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) better grew up than chrysanthemum (*D. difflora*). Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew normally and could produce flowers under all concentrations, while chrysanthemum (*D. difflora*) exhibited abnormal characteristics such as scorching in leaves and necrosis at concentrations of 50, 100, 150, 200 and 250 mg Zn/kg soil, moreover death of the flowers appeared at concentrations of 200 and 250 mg Zn/kg soil.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 The effects of cadmium on plants growth

The results of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) showed in the same direction; the growth tended to decrease when cadmium concentration was increased in soil. Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew better than chrysanthemum (*D. difflora*). Both of them looked healthy. Leaves were green and could produce colorful flowers under all cadmium concentrations. While toxicity symptoms of cadmium in plants were obviously seen in chrysanthemum (*D. difflora*). Although chrysanthemum (*D. difflora*) could survive under all cadmium concentrations in soil, it exhibited abnormal characteristics such as stunted, shortening of internodes and could not produce flowers at concentrations of 20, 40, 60, 80 and 100 mg Cd/kg soil, moreover a mild chlorosis appeared at concentration of 100 mg Cd/kg soil.

5.1.2 The effects of zinc on plants growth

The results of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) showed in the same direction; the growth tended to increase when zinc concentration was increased in soil. Marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) grew better than chrysanthemum (*D. difflora*). Both of them could grow normally as well as control, looked healthy. Leaves were green and could produce colorful flowers under all zinc concentrations. While toxicity symptoms of zinc in plants were obviously seen in chrysanthemum (*D. difflora*). Although chrysanthemum (*D. difflora*) could survive and produced colorful flowers under all zinc concentrations in soil, it exhibited abnormal characteristics such as scorching in leaves and necrosis at concentration of 50, 100, 150, 200 and 250 mg Zn/kg soil, moreover death of the flowers appeared at concentration of 200 and 250 mg Zn/kg soil.

5.1.3 Cadmium accumulation in various parts of plants

The results of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) showed in the same direction; the amount of cadmium accumulation in plants increased when cadmium concentration was increased in soil.

Chrysanthemum (*D. difflora*) tended to accumulate cadmium in leaves and stems more than roots, respectively (leaves≥stems>roots), marigold (*T. erecta* L.) tended to accumulate cadmium in leaves more than stems, flowers and roots, respectively (leaves>stems> flowers>roots), moreover globe amaranth (*G. globosa* L.) tended to accumulate cadmium in leaves more than stems, roots and flowers, respectively (leaves>stems>roots>flowers). Therefore, the results of cadmium accumulation in all plants showed in the same direction; plants tended to accumulate cadmium in leaves and stems more than roots and flowers. Moreover, marigold (*T. erecta* L.) was the highest in cadmium accumulation.

5.1.4 Zinc accumulation in various parts of plants

The results of chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) showed in the same direction; the amount of zinc accumulation in plants increased when zinc concentration was increased in soil.

Chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.) tended to accumulate zinc in leaves more than stems, roots and flowers, respectively (leaves>stems>roots>flowers), moreover marigold (*T. erecta* L.) tended to accumulate zinc in leaves more than stems, flowers and roots, respectively (leaves>stems> flowers>roots). Therefore, the results of zinc accumulation in all plants showed in the same direction; plants tended to accumulate zinc in leaves and stems more than roots and flowers. Moreover, marigold (*T. erecta* L.) was the highest in zinc accumulation.

5.1.5 The efficiency of cadmium and zinc removal in plants (%)

At the highest cadmium concentration; 100 mg Cd/kg soil, marigold (*T. erecta* L.) was more effective in remove cadmium from the soil than chrysanthemum (*D. difflora*) and globe amaranth (*G. globosa* L.), respectively. Moreover, at the highest zinc concentration; 250 mg Zn/kg soil, marigold (*T. erecta* L.) was more effective in remove zinc from the soil than globe amaranth (*G. globosa* L.) and chrysanthemum (*D. difflora*), respectively.

From the problem statement of soil degradation due to heavy metals contamination, this study has proposed to use some cut flower plants such as chrysanthemum (*D. difflora*), marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) to uptake cadmium and zinc from the contaminated soil into the harvestable tissue, meanwhile increase local's income. The results was found that the three plant species had capabilities to uptake contaminated heavy metals in soil and indicated that marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) were good as cadmium and zinc accumulators. The calculation of the amount of cadmium and zinc concentration in flowers was provided by Paull methodology (Souther, 2005) for assessed health risk of dermal and dermal-to-oral exposures. The results were lower than acceptable limits of Provisional Tolerable Weekly Intake (PTWI) (7 µg Cd/kg body weight/week for cadmium and 25 µg Zn/kg body weight/week for zinc) (Simmons et al., 2005) (Appendix H). Moreover, plants could certainly tolerate to toxic from cadmium and zinc and could produce colorful flowers under all heavy metals concentrations. Therefore, marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.) could be useful in the remediation of the contaminated soil. They can be used as economical plants instead of the existing plants that farmer cultivated in this time.

5.2 Recommendations

5.2.1 Plants diseases and insects were effected plants and stopped the growth, so this study should have errors.

5.2.2 Preparation of contaminated soil with heavy metals. Soil was mixed with the standard heavy metals by hands. The concentration mixture among soil and heavy metals might not be well mixed, so this study should have errors.

5.2.3 The ions contained in soil may affect the uptake of studied heavy metal. Therefore, when comparing the effects of metal, it should be aware of the nutrient background.

Suggestions for the future;

- Provide cadmium and zinc contaminations were not phytotoxicity in marigold (*T. erecta* L.) and globe amaranth (*G. globosa* L.), so it should be cultivated with higher heavy metals concentrations.

- To study the factor influence on uptake heavy metals of cut flower plants, such as selection other cut flowering plants, selection other soil series, increasing the period of the experiment, cutting stem to stimulate the re-growth of cut flower plants.

- To study the capacity of other cut flower plants that can uptake heavy metals contaminated in the soil.

- It should be follow up the unused parts of plants such as leaves, stems and roots in waste management and elimination.

REFERENCES

Adriano, D. C. 2001. **Trace elements in the terrestrial environment, biochemistry and risks of metal**. 2nd eds. Berlin, Heidelberg, New York: Springer-Verlag.

Alloway, B. J. 1995. **Soil processes and the behavior of heavy metals: Heavy metals in soils**. 2nd ed. New York: Blackie and Professional.

Alloway, B.J. 1997. Cadmium. In Alloway, B.J. (ed.). **Heavy Meatals in Soil**. 2nd eds. London: UK Black Academic and Professional.

Angela, H. K., Schafer, H. J., Heiss, S., Walter, C., and Rausch, T. 1999. Cadmium exposure in *Brassica juncea* causes a decline in transpiration rate and leaf expansion without effect on photosynthesis. **Exp. Bot**. 50: 1827-1835.

ASTM American Society for Testing and Materials. 1961. Tentative method for grain-size analysis of soils. In ASTM (ed). **The 1961 Book of ASTM Standards, part 4. Am. Soc. Testing Meter**, pp. 1272-1283. Philadelphia.

ATSDR Agency for Toxic Substances and Disease Registry. 1993. **Toxicological profile for cadmium and references cited**. U.S.: Department of Health & Human Services.

Attanant, T., Janjareansuk J., and Jittakanont, S. 1999. Handbook and exercise of soil and plants analysis. Bangkok: Department of Pedology, Faculty of Agriculture, Kasetsart University.

Baghour, M., Diego, A. M., Gemma, V., Joaquin, H., Nicolas, C., and Luis, R. 2001. Phytoextraction of cadmium and lead and physiological effects in potato plants (*Solanum tuberosum* var. Spunta): importance of root temperature. **J Agric Food Chem**. 49: 5356-5363.

Baryla, A., Carrier, P., Franck, F., Columb, C., Sakut, M., and Havaux, M. 2001. Leaf chlorosis in oilseed rape plants (*Brassica napus*) grown on cadmium-polluted soil: causes and consequences for photosynthesis and growth. **Planta**. 212: 696-709.

Blaylock, M. J., Salt, D. E., Dushenkov, S., Zakharova, O., Gussman, C., Kapulnik, Y., Ensley, B. D., and Raskin, I. 1997. Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents. **Environ. Sci. Technol**. 31: 860-865.

Brandy, N. Y. 1984. Soils and chemical pollution. In: Brandy, N.Y. (ed). **The nature and properties of soils**. New York: Macmillan Pub. Co.

Bremner, J. N. 1965. Total nitrogen. In: Black C. A. (ed), **Method of soil analysis, part 2. Agronomy No. 9 Am. Soc. Agron**, pp. 1149-1237. USA. Wisconsin: Medison.

Burch, R.E., Hanh, H.K.J. and Sullivan, J.F.1975. Newer aspects of the role of zinc, manganese and copper in human nutrition. **Clin. Chem**. 21: 501-520.

Chahal, R. S., and Ahluwalia, S. P. S. 2004. Neutroperiodism in different varieties of groundnut with respect to zinc and its uptake as affected by phosphorus application. **Plant and Soil**. 47: 541-546.

Chaney, R. L. 1993. Zinc phytotoxicity. In: Robson, A.D. (ed). **Zinc in Soil and Plants, Proceedings of the International Symposium on 'Zinc in Soils and Plants'. University of Western Australia, 27-28 September, 1993**, pp. 135-140. Kluwer: Pordrecht.

Chaney, R. L., and Giordano G. M. 1977. Microelements as related to plat deficiencies and toxicities. In: Elliot L. F., Stevenson, F. J. (ed). **Soils for management and utilization of organic wastes and wastewaters**, pp. 233-280. Wisconsin: Madison.

Chanthachot, W., Busamongkol, A., Khuntong, S., Peripart, R., and Loaharojanapanal, S. 2005. Analysis of heavy metals in soil along Mae Tao River, Tak province by neuclear technique. In **31st Congress on Science and Technology of Thailand at Suranaree University of Technology, 18 – 20 October 2005**, pp. 130-133. Thailand: Nakhon Rachasima, Suranaree University of Technology.

Chen, H., and Cutright, T. J. 2001. EDTA and HEDTA effects on Cd, Cr, and Ni uptake by *Helianthus annuus*. **Chemosphere**.45: 21-28.

Cook, M., and Morrow, H. 1995. **Anthropogenic Sources of Cadmium in Canada, National Workshop on Cadmium Transport into Plant**. Canada: John Wiley and Son.

Das, P., Samantary, S., and Rout, G. R. 1997. Studies on cadmium toxicity in plants: A review. **Environ. Saf**. 33: 38-43.

Davies, B. E. 1993. Radish as and indicator plant for derelict land: uptake of zinc at toxic concentrations. **Common Soil. Sci. Technol**. 6: 518-522.

Dong. L., Wang, J., Deng, C., and Shen X. 2007. Gas chromatography-mass spectrometry following pressurized hot water extraction and solid phase microextraction for quantification of eucalypetol, camphor, and borneol in Chrysanthemum flowers. **J Sep Sci**. 1: 86-89.

Ebbs, S. D., and Kochian, L. V. 1997. Toxicity of zinc and copper to Brassica species: implications for phytoremediation. **Environ. Qual**. 26:776-781.

Edward, A. L. 2002. **Pollution: an introductory text**. 3rd eds. Canada: John Wiley and Son.

Eriksson, J. E. 1989. The influence of pH, soil type and time on adsorption and uptake by plants of Cd added to the soil. **Water, Air Soil Pollut**. 48: 317.

Faisatjatham, S. 2006. **Efficiency of *Vetiveria zizanioides* (Linn.) Nash (Surat Thani ecotype) and *Vetiveria nemoralis* (Balansa) A. Camus (Prachuabkirikhan ecotype) in cadmium and zinc removal from soil**. Master's thesis, Inter-department of environment Science, Graduate School, Chulalongkorn University.

Follett, R. H., and Lindsay, W. L. 1971. **Soil Sci. Soc. Am. Proc**. 35: 600–602.

Frost, R. R., and Griffin, R. A. 1977. Effect of pH on adsorption of arsenic and selenium from landfill leachate by clay minerals. **Soil Sci. Soc. Am. J**. 41: 53–57.

Fulkerson, W., and Goeller, H. E. 1973. **Cadmium the Dissipated Element**. Oxford: Oak Ridge National Laboratory.

Furgusson, J. E. 1990. **The Heavy Elements: Chemistry, Environmental Impact and Health Effects**. Oxford: Pergamon Press.

Gardner, W.H. 1965. Water content. In Black C. A. (ed.). **Method of Soil Analysis, part 1. Agronomy No. 9 Am. Soc. Agron**, pp. 82-127. USA. Wisconsin: Medison.

Griffin, G. J., Hale M. G., and Shay, F. J. 1976. Nature and quantity of sloughed organic matter produced by roots of axenic peanut plants. **Soil Biol Biochem**. 8: 29-32.

Haghiri, F. 1973. Cadmium uptake by plants. **J. Environ. Qual**. 2: 93-96.

Haghiri, F. 1974. Plant uptake of cadmium as influenced by cation exchange capacity, organic matter, zinc and soil temperature. **J. Environ. Qual**. 3:180.

Hirsch, D. and, Banin, A. 1990. Cadmium speciation in soil solution. **J.Environ.Qual**. 19: 366-372.

Huang, J. W., Chen, J. J., Berti, W. R., and Cunningham, S. D. 1997. Phytoremediation of lead from contaminated soils: Role of synthetic chelates in lead phytoextraction. **Environ. Sci. Technol**. 31: 800-805.

Inmaculada, R., Elvira, E., Juan, J., Agustin, G., (2002). **Cadmium uptake and subcellular distribution in plants of *Lactuca sp.* Cd-Mn interaction**. Spain: Facultad de Ciencias, Universidad Autonomoa de Madrid, Madrid.

Iyengar, S. S., Martens, D. C., and Miller, W. P. 1998. Distribution and plant availability of zinc fraction. **Soil Sci Soc Am J**. 45: 735-9.

Jackson, M. L. 1967. **Soil Analysis**. Eaglewood Cliffs, New Jersey: Prentice Hall. Inc.

Javis, S. C., Jones L. H. P., Hopper M. J. 1976. Cadmium uptake from solution by plants and its transport from roots to shoots. **Plant Soil**. 44: 179-191.

John, M. K., Van Laerhoven, C. J., Bjerring, J. H. 1976. Effect of a smelter complex on the regional distribution of Cd, Pb an Zn in litters and soil horizons. **Arch. Environ. Contam. Toxical.** 4: 456-468.

Jones, R. W., and Sheard, R. W. 1977. Differential effect of irradiance and nutrient nitrate on the relationship of in vivo and in vitro nitrate reductase assay in chlorophyllous tissues. **Plant physio**. 4: 535-539.

Kabata-Pendias, A., and Pendias, H. 1992. **Trace elements in soils and plants**. Boca Raton, Florida: CRC Press, Inc.

Kellera, C., Hammera, D., and Kayserb, A. 2003. Phytoextraction of Cd and Zn with *Thlaspi caerulescens* and *Salix viminalis* in field trials. In Kellera, C., Hammera, D., and Kayserb, A. (ed). **COST 837 Workshop on "Phytoremediation of toxic metals"**, pp. 34. Sweden: Department of Botany, Stockholm University.

Leborans, G. F., and Novillo, A. 1996. Toxicity and bioaccumulation of cadmium in *Olishodiscus leteus* (Raphidophyceal) **Water Res**. 1:57-62.

Lide, D. R. 1991. Physical constants of inorganic compounds. In: Lide D. R. (ed). **CRC Handbook of Chemistry and Physics. A ready-reference book of chemical and physical data**, pp. 4/116-4/118. Boca Raton, Florida: CRC Press, Inc.

Mckenna I. M., Chaney R. L., and William, F. M. 1993. The effects of cadmium and zinc interactions on the accumulation and tissue distribution of zinc and cadmium in lettuce and spinach. **Environ Pollut**. 79:113-120.

Mclaren, R. G., and Cameron, K. C. 1996. **Soil science**. 2nd ed. Auckland: Oxford University.

Millar, C. E., Turk, L. M., and Foth, H. D. 1965. **Fundamental of soil science**. New York: John Wiley and Son.

Mitchell, G. A., Bingham, F. T., and Page, A. L. 1978. Yield and metal composition of lettuce and wheat grown on soils amended with sewage sludge enriched with cadmium, copper, nickel and zinc. **J Environ Qual**. 7: 165-171.

Moore, J. W. 1991. **Inorganic Contaminants of Surface Water Research and Mornitoring Priotities**. New York: Springer-Verlag.

Moral, R., Palacios, G., Gomez, I., Navarro-Pedreno, J., Mataix, J. 1994. Distribution and accumulation of heavy metals (Cd, Ni and Cr) in tomato plant. **Fresen Environ Bull**. 3:395-399.

Norvell, W. A. 1972. Equilibria of metal chelates in soil solution. In: Mortvedt, J. J., Giordano, P. M., and Lindsay, W. L. (ed). **Micronutrients in Agriculture**. pp 115–138. Wisconsin: Madison.

Nriagu, J. O. 1980. Production, uses and properties of cadmium. In: Nriagu, J. O. (ed), **Cadmium in the Environment**, Vol. 1. New York: Wiley-Interscience.

Nriagu, J. O., 1989. A global assessment of natural sources of atmospheric trace metals. **Nature**. 333: 47-49.

Nriagu, J. O., and Pacyna, J. M. 1988. Quantitative assessment of worldwide contamination of air, water and soil by trace metals. **Nature**. 333: 134-139.

Organisation for Economic Co-operation and Development (OECD). 1994. **Risk Reduction Monograph No.5: Cadmium**. France: OECD Environment directorate.

Overnell, J. 1975. The effect of some heavy metal ions on phytosynthesis in a freshwater alga. **Pestic Biochem Physiol**. 5:19-26.

Panitchasukpatana, S. 1997. **Soil pollution from chemicals substances**. 2nd eds. Bangkok: Kasetsart University.

Panyakhan, S. 2003. **Cadmium and Zinc Toxicity on Growth, Chlorophyll contents and Accumulation of *Hydrocotyle umbellate* L.** Master's thesis, Environment Biology, Graduate Studies, Mahidol University.

Peech, M. 1965. Soil pH by glass electrode pH meter, Method of soil analysis (part 2). **Amer. Soc. of Agro**. 60: 914-925.

Phetsombat, S. 2003. **Toxicity and Bioaccumulation of Cadmium and Lead in *Salvinia cucullata* Roxb.** Master's thesis, Environment Biology, Graduate Studies, Mahidol University.

Pollution Control Department. 2004. **Summary of Environmental Samplings in Mae Sot after cadmium contamination**. Bangkok: Ministry of Natural Resources and Environment, Thailand.

Poschenrieder, C., Gunse, B., and Barcelo, J. 1989. Influence of cadmium on water relations, stomatal resistance and abscisic acid content in expanding bean leaves. **Plant Physiol**. 90: 1365-1371.

Prapreatdham, P. 1995. **Plant controlling factors in soilless culture system**, 2-1-2-11. Bangkok: Department of Pedology, Faculty of Agriculture, Kasetsart University.

Puschenreiter, M., Wieczorek, S., Horak, O., and Wenzel, W. W. 2003. Chemical changes in the rhizophere of metal hyperaccumulator and excluder *thlaspi* species. **J Plant Nutr Soil Sci**. 166: 579-84.

Raskin, I. 1997. **Phytoremediation: using plants to remove pollutants from the environment**. NJ: American Society of Plant Physiologists.

Raskin, I., and Ensley, B. D. 2000. **Phytoremediation of toxic metals: Using plants to clean up the environment**. New York: A Wiley-interscience publication.

Reeves, R. D., and Baker, A. J. M. 1984. Studies on metal uptake by plants from serpentine and non-serpentine populations of *Thlaspi goesingense* Halacsy (Cruciferae). **New Phytologist**. 98: 191-204.

Root, R. A., Miller, R. J., and Koeppe, D. E. 1975. Uptake of cadmium-its toxicity, and effect on the iron ratio in hydroponically grown corn. **J Environ Qual**. 4: 473-476.

Sampanpanish, P. 2005. **Chromium removal by phytoremediation and biosorption**. Doctoral dissertation, Inter-department of environment Science, Graduate School, Chulalongkorn University.

Scerri, E. R. 2006. **The periodic table: Its story and significance**. Oxford: Oxford University Press.

Schat, H., Vooijs, R., and Kuiper, E. 1996. Identical major gene loci for heavy metal tolerances that have independently evolved in different local populations and subspecies of Silene vulgaris. **Evolution**. 50: 1888-1895.

Schierup, H., and Lorsen, V. J. 1981. Macrophyte cycling of Zn, Cu, Pb and Cd in the littoral zone of a polluted and a non-polluted lake. I. Availability, uptake and translocation of heavy metals in *Phragmites australis* (Cav.). **Trin. Aquatic Bot**. 11: 179-210.

Sen, A. K., Mondal, N. G., and Mondal, S. 1987. Studies of uptake and toxic effects of Cr (VI) on *Pistia stratiotes*. **Wat. Sci. Tech**. 19: 119-127.

Sheppard, S. C., Evenden, W. G., Abboud, S. A., and Stephenson, M. 1993. A plant life cycle bioassay for contaminated soil, with comparison to other bioassays: mercury and zinc. **Arch. Environ. Contam. Toxicol**. 25: 27-35.

Simmons, R. W., Pongsakul, P., Saiyasitpanich, D., and Klinphoklap, S. 2005. Elevated levels of cadmium and zinc in paddy soils and elevated levels of cadmium in

rice grain downstream of a zinc mineralized area in Thailand: Implications for public health. **Environmental Geochemistry and Health**. 27: 501-511.

Somboon, P. 1999. **Distribution of Cadmium and Zinc in Soil from Zinc Mining Activity: a Case Study of Zinc Mine, Mae Sot District, Tak Province**. Master's thesis, Technology of Environmental Planning for Rural Development, Graduate Studies, Mahidol University.

Souther, T. G. 2005. Dermal exposure risk screening calculation. Ohio: Geomatrix Consultants, Inc.

Sreekera, C., and Raghava, S. P. 2003. Exploitation of heterosis for carotenoid content in Marigold (*Tagetes erecta* L.) and its correlation with esterase polymorphism. **Theor Appl Genet**. 4: 771-776.

Sriprachote, A. 2006. **Distribution of cadmium in contaminated soil**. Master's thesis, Inter-department of environment Science, Graduate School, Chulalongkorn University.

Srisatit, T., Kosakol, T., and Dhitivara, D. 2003. Efficiency of arsenic removal from soil by *Vetiveria zizanioides* (Linn.) Nash and *Vetiveria nemoralis* (Balansa) A. Camus. **Science Asia**. 29: 291-296.

Srisatit, T., and Tambamroong, W. 2006. Phytoextraction of arsenic from contaminated soil by *Colocasia esculenta* (Linn.) Schott; taro and wild taro. In **The International Forum in Natural Treatment and Hazardous Substance Management (NTHSM 2006) May 29-30, 2006**. Thailand: Khon Kaen, Khon Kean university.

Taechapinyawat, S. 1994. **Botany**. 3rd ed. Bangkok: Ruakeaw.

Tarradellas, J., Bitton, G., and Rossel, D. 1997. **Soil Ecotoxicology**. Boca Raton, Florida: CRC Press, Inc.

Terry, N., and Bañuelos, G. 2000. **Phytoremediation of contaminated soil and water**. Boca Rotan: Lewis.

Theerapunsatien, S. 1995. **Cadmium and Zinc in Water. Sediments and Mussel Hyriopsis myersiana of the Ping River**. Master's thesis, Inter-department of environment Science, Graduate School, Chulalongkorn University.

Turgut, C., Pepe, M. K., and Cutright, T. J. 2004. The effect of EDTA and citric acid on phytoremediation of Cd, Cr, and Ni from soil using *Helianthus annuus*. **Environmental Pollution**. 131: 147-154.

Turgut, C., Pepe, M. K., and Cutright, T. J. 2005. The effect of EDTA on *Helianthus annuus* uptake, selectivity, and translocation of heavy metals when grown in Ohio, New Mexico and Colombia soils. **Chemosphere**. 58: 1087-1095.

Tyler, L. D., and Mcbride M. B. 1982. Influence of Ca, pH, and humic acid on Cd uptake, **Plant and soil**. 64: 259.

U.S.EPA. United States Environment Protection Agency .1982. **Second edition. Test Methods for Evaluating Solid Waste**. Washington, D.C.: U.S. Department of Commerce.

U.S.EPA. United States Environment Protection Agency. 1989. Risk assessment guidance for superfund. In, USEPA (ed). **Human health evaluation manual (part A)**, pp.1-89. Ohio: Cincinnati.

U.S.EPA. United States Environment Protection Agency. 1998. **A citizen's guide** to **phytoremediation**. Ohio: Cincinnati.

Vangronsvels, J., and Clijsters, H. 1994. Toxic effects of metals. In: Farago, M. (ed). **Plants and the Chemical Elements**, pp. 149-177. VCH: Weinheim.

Vogeli-Lange, R., and Wanger, G. L. 1990. Subcellular localization of cadmium and cadmium-binding peptides in tobacco leaves. **Plant Physiol**. 92: 1086-1093.

Walkley, A., and Black, C. A. 1934. An examination of degradation methods for determining soil organic matter: a proposed modification of the chromic acid titration method. **Soil Sci**. 37: 29-35.

Wenzel, W. W., Bunkowki, M., Puschenreiter, M., and Horak, O. 2003. Rhizosphere characteristics of indigenously growing nickel hyperaccumulator and excluder plants on serpentine soil. **Emviron Pollut**. 123: 131-8.

WHO (World Health Organization). 2001. **Environmental Health Criteria-221, zinc: environmental aspects**. Finland: World Health Organization.

WHO (World Health Organization). 1992. **Environmental Health Criteria-135, cadmium: environmental aspects**. Finland: World Health Organization.

Youn-Joo, A. 2004. Soil ecotoxicity assessment using cadmium sensitive plant. **Environmental Pollution**. 127: 21-26.

Zachara, J. M., Smith, S.C., Resch, C.T., and Cowan, C.E. 1993. Cadmium sorption on specimen and soil smectites in sodium and calcium electrolytes. **Soil Sci. Soc. Am. J**. 57: 1491.

APPENDICES

APPENDIX A

The calculation of the amounts of heavy metals in soil

The amount of $Cd(NO_3)_2.4H_2O$ was calculated as follows: For example; at cadmium concentration of 20 mg Cd/kg soil, 1 kg of soil treated with cadmium concentration of 20 mg Cd. This experiment used 1.5 kg soil/pot, therefore 1.5 kg of soil treated with cadmium concentration of 1.5 x 20 = 30 mg Cd.

112.41 g weight of Cd composed of $Cd(NO_3)_2.4H_2O$ weight 308.41 g, therefore, 30 mg weight of Cd composed of $Cd(NO_3)_2.4H_2O$ weight (30x308.41)/112.41 = 82.30 mg. With this calculation, it can work out the formula amount of $Cd(NO_3)_2.4H_2O$ and $Zn(NO_3)_2.6H_2O$;

$$\text{The amounts of } Cd(NO_3)_2.4H_2O = \frac{\text{Soil wt x Cadmium concentration x } Cd(NO_3)_2.4H_2O \text{ wt}}{\text{Cadmium wt}}$$

$$\text{The amounts of } Zn(NO_3)_2.6H_2O = \frac{\text{Soil wt x Zinc concentration x } Zn(NO_3)_2.6H_2O \text{ wt}}{\text{Zinc wt}}$$

Note :

The molecular weight of Cd = 112.41, then its weight is 112.41 g.
The molecular weight of Zn = 65.38, then its weight is 65.38 g.
The molecular weight of N = 14
The molecular weight of O = 16
The molecular weight of H = 1
The molecular weight of $Cd(NO_3)_2.4H_2O$ = 308.41, then its weight is 308.41 g.
The molecular weight of $Zn(NO_3)_2.6H_2O$ = 297.38, then its weight is 297.38 g.
This experiment used 1.5 kg soil/pot

The soil treated with $Cd(NO_3)_2.4H_2O$ at the concentrations of 0, 20, 40, 60, 80 and 100 mg Cd/kg soil or $Zn(NO_3)_2.6H_2O$ at the concentrations of 0, 50, 100, 150, 200 and 250 mg Zn/kg soil

APPENDIX B

The effects of cadmium and zinc on plants growth

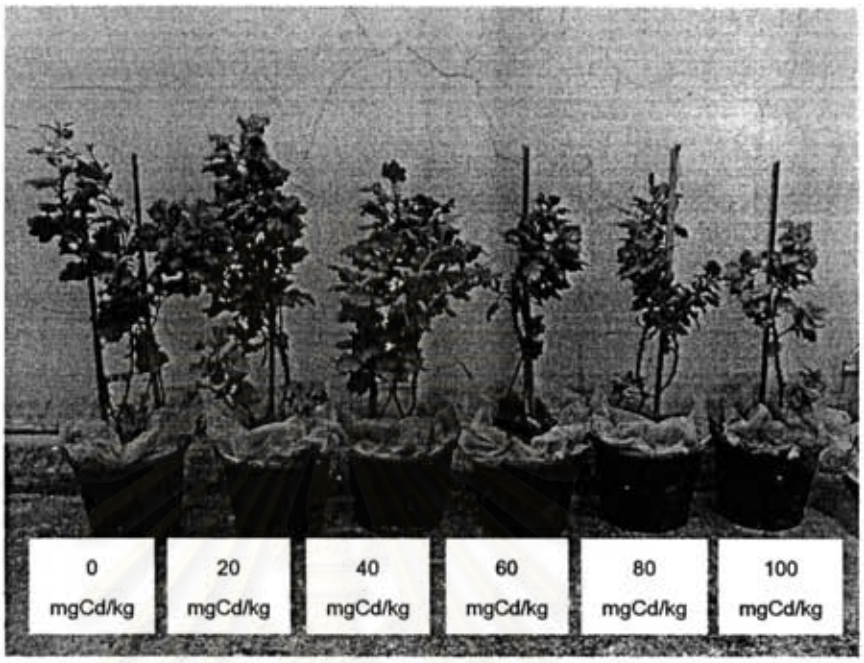

Figure B-1 The effects of cadmium on the growth of chrysanthemum (*D. difflora*)

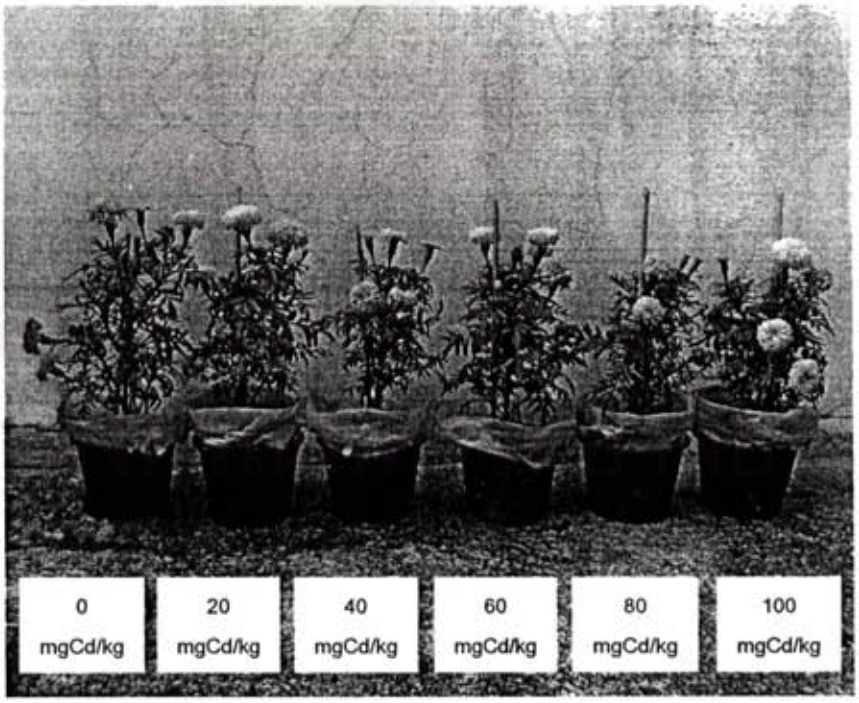

Figure B-2 The effects of cadmium on the growth of marigold (*T. erecta* L.)

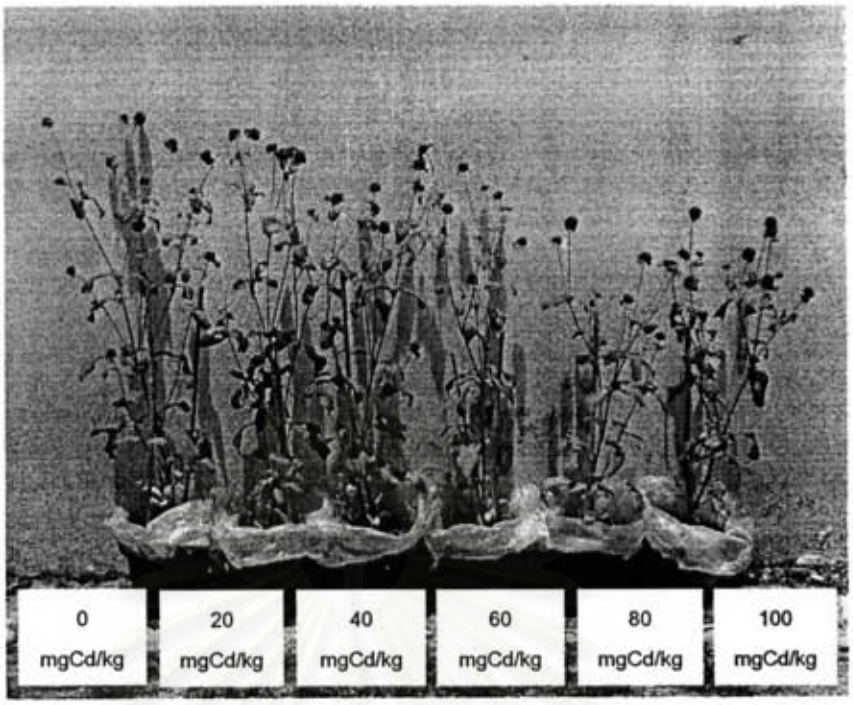

Figure B-3 The effects of cadmium on the growth of globe amaranth (*G. globosa* L.)

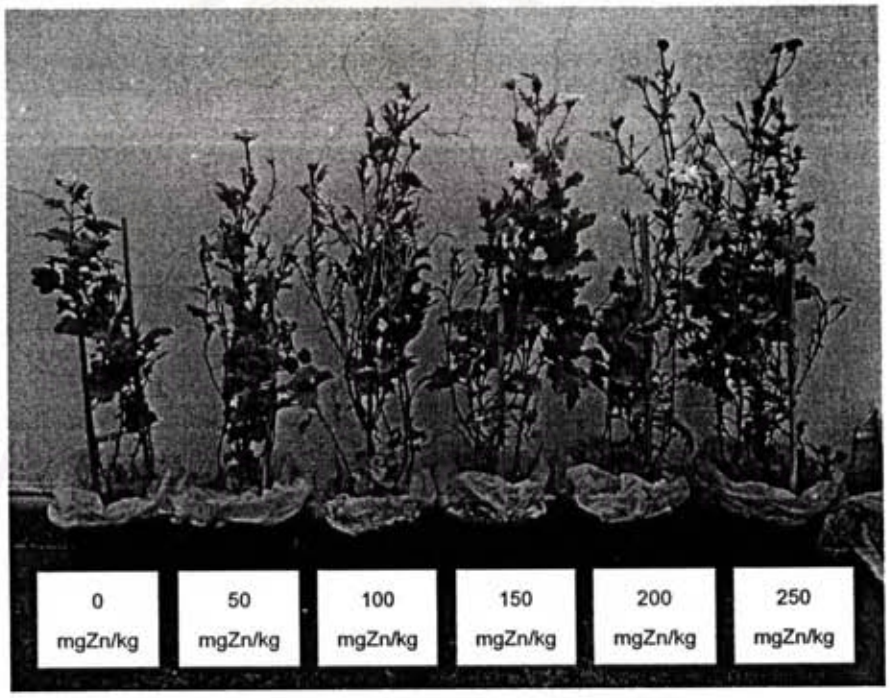

Figure B-4 The effects of zinc on the growth of chrysanthemum (*D. difflora*)

Figure B-5 The effects of zinc on the growth of marigold (*T. erecta* L.)

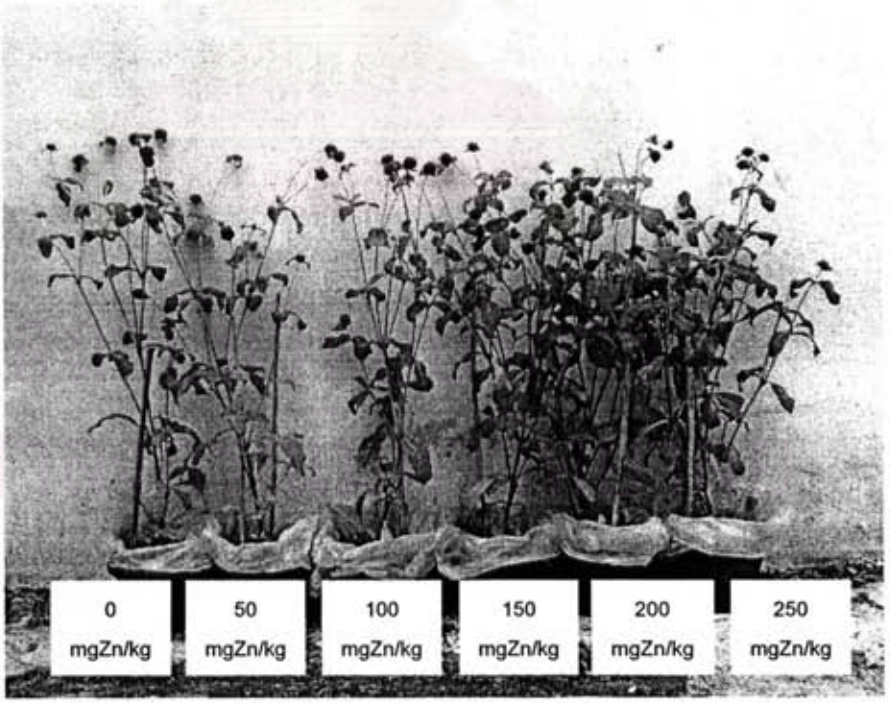

Figure B-6 The effects of zinc on the growth of globe amaranth (*G. globosa* L.)

Appendix C

The growth data of plants under condition of cadmium and zinc contamination in soil

Table C-1 height data of chrysanthemum (*D. difflora*) under condition of cadmium and zinc contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period														Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Cd 0/1	4.50	9.65	14.10	17.50	20.35	22.90	25.45	27.30	29.20	31.20	32.00	33.30	34.10	34.10	29.60
Cd 0/2	10.10	17.40	23.35	28.50	33.50	37.55	41.80	44.25	50.10	53.00	55.30	57.00	58.00	58.20	48.10
Cd 0/3	7.50	12.25	17.10	21.50	25.60	28.90	31.10	34.15	37.80	40.30	42.00	43.20	44.10	44.15	36.65
Cd 20/1	7.80	11.40	13.30	15.15	17.00	17.80	18.50	19.30	20.40	21.00	22.15	23.00	23.50	23.90	16.10
Cd 20/2	9.30	11.55	13.65	14.45	15.60	16.80	17.50	18.40	19.35	19.95	22.70	23.10	23.40	23.40	14.10
Cd 20/3	8.75	10.45	12.25	14.10	15.30	16.25	17.45	18.60	19.30	19.80	20.30	21.00	21.60	21.65	12.90
Cd 40/1	3.20	6.65	9.80	11.25	13.65	15.10	16.40	17.20	18.00	18.50	19.00	19.90	21.00	21.00	17.80
Cd 40/2	13.60	16.30	18.35	19.30	20.60	21.35	22.10	22.90	23.25	23.85	24.40	25.50	26.00	26.10	12.50
Cd 40/3	8.60	10.35	12.80	14.65	15.80	16.70	17.15	17.95	18.60	19.15	20.00	21.00	21.55	21.55	12.95
Cd 60/1	6.20	8.80	10.10	10.95	11.85	12.65	13.50	14.00	14.65	15.00	15.65	16.00	16.30	16.30	10.10
Cd 60/2	7.40	10.25	13.55	15.40	17.10	19.30	20.40	21.60	22.05	22.40	23.00	23.30	23.80	23.80	16.40
Cd 60/3	7.00	9.95	11.35	12.50	13.65	14.80	15.70	16.50	17.05	17.25	17.50	17.80	18.05	18.05	11.05
Cd 80/1	6.20	7.80	8.35	9.60	10.10	10.60	11.05	11.70	12.10	12.40	12.80	13.00	13.20	13.20	7.00
Cd 80/2	5.70	7.35	9.45	10.30	11.20	12.85	14.30	15.10	16.00	16.35	16.80	17.10	17.50	17.50	11.80
Cd 80/3	6.15	7.15	8.30	9.25	10.05	10.80	11.40	11.80	12.20	12.55	12.85	13.05	13.35	13.35	7.20
Cd 100/1	5.80	6.60	7.90	8.55	9.40	10.20	10.85	11.50	12.00	12.35	12.75	13.00	13.20	13.20	7.40
Cd 100/2	6.10	7.00	8.85	9.65	10.25	11.05	11.85	12.55	13.65	14.05	14.35	14.70	15.00	15.20	9.10
Cd 100/3	5.65	6.75	7.90	8.75	9.65	10.00	10.30	10.80	11.15	11.55	12.00	12.30	12.60	12.70	7.05

Table C-2 Internodes length data of chrysanthemum (*D. difflora*) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period														Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Cd 0/1	0.80	0.85	0.85	0.90	0.95	1.00	1.05	1.05	1.10	1.10	1.10	1.10	1.10	1.10	0.30
Cd 0/2	0.90	0.95	1.00	1.25	1.40	1.65	1.75	1.85	1.95	1.95	2.00	2.00	2.00	2.00	1.10
Cd 0/3	0.90	0.95	0.95	1.00	1.20	1.25	1.30	1.35	1.35	1.40	1.40	1.40	1.40	1.40	0.50
Cd 20/1	0.70	0.75	0.75	0.85	0.90	1.00	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.40
Cd 20/2	1.60	1.65	1.65	1.70	1.75	1.75	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	0.20
Cd 20/3	1.20	1.20	1.25	1.35	1.50	1.65	1.80	1.95	2.10	2.15	2.20	2.20	2.20	2.20	1.00
Cd 40/1	0.70	0.70	0.75	0.80	0.90	0.95	1.00	1.05	1.05	1.10	1.10	1.10	1.10	1.10	0.40
Cd 40/2	0.70	0.70	0.70	0.75	0.80	0.80	0.85	0.90	0.90	0.90	0.9	0.90	0.90	0.90	0.20
Cd 40/3	1.00	1.05	1.05	1.20	1.35	1.50	1.65	1.70	1.75	1.75	1.80	1.80	1.80	1.80	0.80
Cd 60/1	1.00	1.00	1.00	1.05	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.10
Cd 60/2	2.00	2.05	2.05	2.15	2.25	2.35	2.40	2.45	2.45	2.50	2.50	2.50	2.50	2.50	0.50
Cd 60/3	0.80	0.80	0.85	1.00	1.20	1.45	1.55	1.55	1.60	1.60	1.60	1.60	1.60	1.60	0.80
Cd 80/1	0.70	0.70	0.75	0.9	1.15	1.25	1.30	1.35	1.35	1.40	1.40	1.40	1.40	1.40	0.70
Cd 80/2	0.50	0.50	0.50	0.55	0.60	0.65	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.20
Cd 80/3	1.60	1.60	1.65	1.85	1.90	1.95	1.95	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0.40
Cd 100/1	1.00	1.00	1.05	1.2	1.35	1.40	1.45	1.45	1.50	1.50	1.50	1.50	1.50	1.50	0.50
Cd 100/2	1.60	1.60	1.65	1.8	1.95	2.15	2.20	2.25	2.25	2.30	2.30	2.30	2.30	2.30	0.70
Cd 100/3	1.20	1.20	1.20	1.25	1.25	1.25	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	0.10

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Table C-3 Diameter of stem data of chrysanthemum (*D. difflora*) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period														Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Cd 0/1	0.3000	0.3350	0.3715	0.4000	0.4415	0.4600	0.4755	0.4800	0.4955	0.5000	0.5250	0.5300	0.5300	0.5300	0.2300
Cd 0/2	0.3200	0.3655	0.4075	0.4400	0.4735	0.5085	0.5255	0.5345	0.5400	0.5550	0.5600	0.5650	0.5700	0.5700	0.2500
Cd 0/3	0.2800	0.3250	0.3555	0.3895	0.4250	0.4650	0.5000	0.5315	0.5550	0.5700	0.5750	0.5800	0.5800	0.5800	0.3000
Cd 20/1	0.4000	0.4365	0.4695	0.4900	0.5215	0.5400	0.5600	0.5700	0.5850	0.6125	0.6500	0.6550	0.6550	0.6550	0.2550
Cd 20/2	0.3000	0.3315	0.3555	0.3700	0.3895	0.4150	0.4300	0.4435	0.4615	0.4875	0.5000	0.5005	0.5100	0.5150	0.2150
Cd 20/3	0.3200	0.3750	0.4150	0.4495	0.4800	0.5250	0.5550	0.5745	0.5935	0.6055	0.6100	0.6150	0.6150	0.6150	0.2950
Cd 40/1	0.3700	0.3750	0.3950	0.4200	0.4535	0.4705	0.4815	0.4950	0.5150	0.5255	0.5300	0.5350	0.5350	0.5350	0.1650
Cd 40/2	0.2550	0.2850	0.3250	0.3600	0.4050	0.4315	0.4600	0.4855	0.5185	0.5300	0.5350	0.5400	0.5400	0.5400	0.2850
Cd 40/3	0.2825	0.3225	0.3565	0.3800	0.4185	0.4400	0.4750	0.5000	0.5305	0.5495	0.5545	0.5625	0.5675	0.5675	0.2850
Cd 60/1	0.2100	0.2150	0.2400	0.2650	0.2895	0.3135	0.3285	0.3555	0.3665	0.3700	0.3800	0.3895	0.4000	0.4100	0.2000
Cd 60/2	0.2450	0.2750	0.2900	0.3235	0.3450	0.3595	0.3655	0.3950	0.4135	0.4200	0.4285	0.4300	0.4300	0.4300	0.1850
Cd 60/3	0.1975	0.2195	0.2315	0.2650	0.2900	0.3250	0.3495	0.3600	0.3850	0.4000	0.4455	0.4495	0.4500	0.4500	0.2525
Cd 80/1	0.3000	0.3250	0.3550	0.3700	0.3850	0.3900	0.3955	0.3985	0.4200	0.4300	0.4350	0.4400	0.4400	0.4400	0.1400
Cd 80/2	0.2800	0.3150	0.3495	0.3700	0.3955	0.4205	0.4495	0.4600	0.4825	0.4915	0.5000	0.5000	0.5000	0.5000	0.2200
Cd 80/3	0.2600	0.2900	0.3250	0.3655	0.3925	0.4250	0.4400	0.4550	0.4750	0.4800	0.4955	0.5000	0.5000	0.5000	0.2400
Cd 100/1	0.3700	0.3955	0.4250	0.4565	0.4715	0.4800	0.4835	0.4875	0.4900	0.4950	0.5000	0.5000	0.5000	0.5000	0.1300
Cd 100/2	0.2800	0.3100	0.3345	0.3675	0.3800	0.4000	0.4150	0.4250	0.4400	0.4450	0.4555	0.4600	0.4600	0.4600	0.1800
Cd 100/3	0.2950	0.3150	0.3455	0.3785	0.4000	0.4235	0.4550	0.4845	0.5000	0.5050	0.5100	0.5100	0.5100	0.5100	0.2150

Table C-4 Dry weight data of chrysanthemum (*D. difflora*) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Cd 0/1	7.160
Cd 0/2	11.128
Cd 0/3	7.382
Cd 20/1	7.886
Cd 20/2	6.552
Cd 20/3	7.212
Cd 40/1	7.609
Cd 40/2	6.815
Cd 40/3	5.664
Cd 60/1	5.795
Cd 60/2	5.647
Cd 60/3	6.750
Cd 80/1	5.571
Cd 80/2	4.520
Cd 80/3	4.773
Cd 100/1	4.961
Cd 100/2	5.137
Cd 100/3	3.711

Table C-5 Height data of marigold (*T. erecta* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	15.40	21.40	27.40	28.30	29.20	29.80	30.80	31.60	16.20
Cd 0/2	12.80	23.40	27.90	28.20	29.10	30.10	30.60	31.00	18.20
Cd 0/3	14.20	21.60	27.40	28.70	29.00	29.50	30.00	30.10	15.90
Cd 20/1	13.20	21.00	26.70	26.90	27.80	29.80	30.10	30.40	17.20
Cd 20/2	12.10	21.80	23.00	24.40	25.90	26.50	26.80	27.20	15.10
Cd 20/3	12.40	21.90	23.20	24.70	25.00	26.20	27.40	27.70	15.30
Cd 40/1	11.10	21.60	24.10	25.40	26.00	26.80	27.00	27.20	16.10
Cd 40/2	10.80	16.40	22.90	25.60	26.80	27.00	28.80	29.20	18.40
Cd 40/3	14.00	20.20	23.50	24.90	25.40	26.70	26.90	27.00	13.00
Cd 60/1	11.20	22.00	23.10	24.30	25.40	26.00	26.30	26.50	15.30
Cd 60/2	12.50	22.00	24.00	25.40	26.50	27.10	28.00	28.10	15.60
Cd 60/3	15.00	20.80	25.40	26.80	28.90	29.30	29.70	30.40	15.40
Cd 80/1	11.40	17.80	19.90	20.70	21.50	23.60	24.20	24.70	13.30
Cd 80/2	14.50	20.50	23.80	24.70	25.80	26.60	27.50	28.80	14.30
Cd 80/3	10.20	20.10	24.70	25.90	26.60	27.30	28.00	28.30	18.10
Cd 100/1	13.00	21.50	25.00	25.70	26.30	27.00	27.60	28.30	15.30
Cd 100/2	14.10	20.20	24.30	25.60	25.90	26.30	26.40	26.60	12.50
Cd 100/3	14.40	16.60	22.90	23.90	25.10	26.30	27.20	27.30	12.90

Table C-6 Internodes length data of marigold (*T. erecta* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	2.20	2.30	2.40	2.50	2.55	2.60	2.60	2.60	0.40
Cd 0/2	2.50	2.65	2.75	2.90	2.95	3.00	3.00	3.00	0.50
Cd 0/3	2.20	2.40	2.50	2.55	2.60	2.60	2.60	2.60	0.40
Cd 20/1	2.30	2.45	2.60	2.65	2.65	2.70	2.70	2.70	0.40
Cd 20/2	2.40	2.50	2.55	2.55	2.60	2.60	2.60	2.60	0.20
Cd 20/3	2.30	2.45	2.50	2.55	2.55	2.60	2.60	2.60	0.30
Cd 40/1	2.10	2.25	2.30	2.35	2.35	2.40	2.40	2.40	0.30
Cd 40/2	2.10	2.20	2.35	2.35	2.40	2.40	2.40	2.40	0.30
Cd 40/3	2.10	2.15	2.25	2.25	2.30	2.30	2.30	2.30	0.20
Cd 60/1	2.40	2.50	2.55	2.60	2.60	2.60	2.60	2.60	0.20
Cd 60/2	2.30	2.45	2.55	2.55	2.60	2.60	2.60	2.60	0.30
Cd 60/3	2.30	2.35	2.45	2.50	2.50	2.50	2.50	2.50	0.20
Cd 80/1	1.90	2.00	2.10	2.15	2.20	2.20	2.20	2.20	0.30
Cd 80/2	2.00	2.05	2.05	2.10	2.10	2.10	2.10	2.10	0.10
Cd 80/3	2.40	2.40	2.45	2.45	2.50	2.50	2.50	2.50	0.10
Cd 100/1	2.30	2.40	2.45	2.50	2.50	2.50	2.50	2.50	0.20
Cd 100/2	1.90	1.95	2.00	2.00	2.00	2.00	2.00	2.00	0.10
Cd 100/3	1.70	1.75	1.75	1.80	1.80	1.80	1.80	1.80	0.10

Table C-7 Diameter of stem data of marigold (*T. erecta* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	0.405	0.440	0.505	0.555	0.580	0.615	0.650	0.655	0.250
Cd 0/2	0.470	0.490	0.530	0.570	0.615	0.645	0.670	0.675	0.205
Cd 0/3	0.400	0.465	0.525	0.585	0.635	0.675	0.700	0.710	0.310
Cd 20/1	0.325	0.395	0.460	0.535	0.585	0.620	0.650	0.655	0.330
Cd 20/2	0.530	0.570	0.600	0.635	0.670	0.690	0.700	0.700	0.170
Cd 20/3	0.375	0.425	0.460	0.495	0.520	0.545	0.570	0.570	0.195
Cd 40/1	0.425	0.460	0.490	0.525	0.560	0.590	0.620	0.620	0.195
Cd 40/2	0.585	0.605	0.645	0.685	0.700	0.715	0.720	0.725	0.140
Cd 40/3	0.420	0.490	0.550	0.615	0.660	0.715	0.740	0.745	0.325
Cd 60/1	0.415	0.495	0.545	0.610	0.620	0.635	0.655	0.655	0.240
Cd 60/2	0.550	0.590	0.620	0.655	0.680	0.695	0.710	0.715	0.165
Cd 60/3	0.505	0.545	0.585	0.620	0.640	0.655	0.675	0.675	0.170
Cd 80/1	0.455	0.475	0.515	0.550	0.585	0.595	0.610	0.610	0.155
Cd 80/2	0.605	0.665	0.605	0.730	0.765	0.790	0.810	0.810	0.205
Cd 80/3	0.495	0.535	0.570	0.615	0.625	0.640	0.655	0.655	0.160
Cd 100/1	0.555	0.615	0.615	0.615	0.615	0.620	0.625	0.635	0.080
Cd 100/2	0.360	0.435	0.500	0.560	0.615	0.650	0.675	0.680	0.320
Cd 100/3	0.490	0.515	0.535	0.560	0.580	0.595	0.600	0.600	0.110

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Table C-8 Dry weight data of marigold (*T. erecta* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Cd 0/1	6.993
Cd 0/2	7.532
Cd 0/3	7.047
Cd 20/1	6.853
Cd 20/2	6.253
Cd 20/3	7.080
Cd 40/1	6.299
Cd 40/2	6.662
Cd 40/3	6.493
Cd 60/1	6.190
Cd 60/2	6.340
Cd 60/3	6.176
Cd 80/1	6.109
Cd 80/2	6.073
Cd 80/3	5.941
Cd 100/1	5.671
Cd 100/2	5.893
Cd 100/3	6.000

Table C-9 Height data of globe amaranth (*G. globosa* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	18.00	26.30	32.55	38.05	43.45	48.60	51.50	53.20	35.20
Cd 0/2	19.00	25.90	30.35	34.40	37.30	38.55	39.65	40.60	21.60
Cd 0/3	12.20	18.25	25.45	30.00	34.00	36.60	37.20	38.00	25.80
Cd 20/1	10.10	18.85	23.50	26.05	28.40	29.10	29.95	30.50	20.40
Cd 20/2	10.70	18.20	24.80	29.45	32.10	35.60	36.80	37.00	26.30
Cd 20/3	16.50	21.35	27.50	32.15	36.25	39.60	42.30	43.20	26.70
Cd 40/1	11.70	19.75	25.65	29.90	34.80	36.95	37.90	40.50	28.80
Cd 40/2	19.10	27.10	31.30	34.75	37.20	39.20	41.00	42.20	23.10
Cd 40/3	11.80	17.85	24.30	27.65	29.10	31.70	32.60	33.00	21.20
Cd 60/1	17.60	43.75	48.95	52.40	55.15	57.15	57.90	38.20	20.60
Cd 60/2	18.60	25.55	30.65	34.05	38.45	41.60	43.20	43.50	24.90
Cd 60/3	17.00	25.55	31.10	33.35	35.20	37.10	38.30	39.50	22.50
Cd 80/1	12.30	17.50	21.30	25.85	27.45	29.50	30.30	31.10	18.80
Cd 80/2	17.20	19.20	22.10	25.25	27.30	28.80	29.00	29.30	12.10
Cd 80/3	11.10	17.15	21.80	24.30	26.45	27.30	28.50	29.40	18.30
Cd 100/1	15.00	49.00	52.05	54.45	56.20	57.10	57.35	27.50	12.50
Cd 100/2	17.90	22.80	25.55	28.90	31.40	33.05	33.90	34.20	16.30
Cd 100/3	15.20	21.15	25.80	28.60	31.25	33.95	34.25	34.30	19.10

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Table C-10 Internodes length data of globe amaranth (*G. globosa* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	2.30	2.45	2.60	2.65	2.70	2.70	2.70	2.70	0.40
Cd 0/2	2.00	2.30	2.45	2.55	2.55	2.60	2.60	2.60	0.60
Cd 0/3	2.50	2.65	2.75	2.80	2.80	2.80	2.80	2.80	0.30
Cd 20/1	2.50	2.60	2.75	2.85	2.90	2.95	3.00	3.00	0.50
Cd 20/2	2.60	2.70	2.75	2.75	2.80	2.80	2.80	2.80	0.20
Cd 20/3	2.60	2.75	2.85	2.90	2.95	3.05	3.10	3.10	0.50
Cd 40/1	3.40	3.50	3.55	3.60	3.60	3.60	3.60	3.60	0.20
Cd 40/2	2.80	2.95	3.10	3.20	3.25	3.30	3.30	3.30	0.50
Cd 40/3	3.20	3.35	3.45	3.45	3.50	3.50	3.50	3.50	0.30
Cd 60/1	2.20	2.35	2.45	2.45	2.50	2.50	2.50	2.50	0.30
Cd 60/2	2.20	2.30	2.40	2.45	2.45	2.50	2.50	2.50	0.30
Cd 60/3	2.10	2.25	2.35	2.40	2.40	2.40	2.40	2.40	0.30
Cd 80/1	2.30	2.45	2.50	2.55	2.60	2.60	2.60	2.60	0.30
Cd 80/2	2.40	2.55	2.65	2.70	2.70	2.70	2.70	2.70	0.30
Cd 80/3	2.40	2.45	2.45	2.50	2.50	2.50	2.50	2.50	0.10
Cd 100/1	1.90	2.00	2.05	2.05	2.10	2.10	2.10	2.10	0.20
Cd 100/2	1.90	1.95	2.05	2.10	2.10	2.10	2.10	2.10	0.20
Cd 100/3	1.80	1.95	1.95	2.00	2.00	2.00	2.00	2.00	0.20

Table C-11 Diameter of stem data of globe amaranth (*G. globosa* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Experimental period								Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Cd 0/1	0.520	0.565	0.590	0.605	0.605	0.610	0.610	0.610	0.090
Cd 0/2	0.450	0.510	0.545	0.570	0.585	0.595	0.600	0.600	0.150
Cd 0/3	0.400	0.435	0.455	0.455	0.460	0.460	0.460	0.460	0.060
Cd 20/1	0.620	0.655	0.670	0.675	0.680	0.680	0.680	0.680	0.060
Cd 20/2	0.410	0.450	0.470	0.480	0.480	0.485	0.485	0.485	0.075
Cd 20/3	0.480	0.535	0.580	0.610	0.625	0.635	0.635	0.635	0.155
Cd 40/1	0.430	0.450	0.465	0.470	0.470	0.470	0.470	0.470	0.040
Cd 40/2	0.510	0.535	0.550	0.560	0.565	0.565	0.565	0.565	0.055
Cd 40/3	0.420	0.465	0.515	0.555	0.580	0.600	0.605	0.610	0.190
Cd 60/1	0.530	0.535	0.540	0.540	0.540	0.540	0.540	0.540	0.010
Cd 60/2	0.465	0.505	0.520	0.530	0.535	0.535	0.535	0.535	0.070
Cd 60/3	0.450	0.495	0.535	0.560	0.575	0.580	0.585	0.590	0.140
Cd 80/1	0.530	0.565	0.570	0.575	0.575	0.575	0.575	0.575	0.045
Cd 80/2	0.540	0.585	0.605	0.605	0.610	0.610	0.610	0.610	0.070
Cd 80/3	0.470	0.515	0.520	0.525	0.525	0.525	0.525	0.525	0.055
Cd 100/1	0.455	0.465	0.465	0.470	0.470	0.470	0.470	0.470	0.015
Cd 100/2	0.530	0.545	0.555	0.560	0.565	0.570	0.570	0.570	0.040
Cd 100/3	0.680	0.695	0.705	0.705	0.710	0.710	0.710	0.710	0.030

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Table C-12 Dry weight data of globe amaranth (*G. globosa* L.) under condition of cadmium contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Cd 0/1	9.791
Cd 0/2	9.008
Cd 0/3	7.105
Cd 20/1	7.117
Cd 20/2	8.075
Cd 20/3	7.307
Cd 40/1	8.298
Cd 40/2	6.308
Cd 40/3	7.285
Cd 60/1	7.532
Cd 60/2	5.764
Cd 60/3	7.624
Cd 80/1	7.698
Cd 80/2	6.230
Cd 80/3	6.584
Cd 100/1	7.328
Cd 100/2	6.594
Cd 100/3	6.883

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Table C-13 Height data of chrysanthemum (*D. difflora*) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period														Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Zn 0/1	6.50	10.50	16.75	21.70	25.40	28.20	31.90	34.30	37.50	39.40	41.70	42.00	42.20	42.20	35.70
Zn 0/2	12.90	16.40	20.25	23.40	25.65	26.90	28.95	30.70	32.00	34.00	34.80	35.20	35.70	35.80	22.90
Zn 0/3	8.70	12.45	18.65	22.70	26.10	29.55	32.30	34.30	36.40	37.20	38.00	38.50	38.80	39.00	30.30
Zn 50/1	9.45	16.60	23.20	30.40	35.25	39.85	43.00	46.50	49.20	51.00	52.90	53.20	53.45	53.45	44.00
Zn 50/2	4.10	11.95	18.30	23.5	27.50	30.50	33.20	34.20	35.00	36.90	37.80	38.30	38.50	38.50	34.40
Zn 50/3	11.50	17.80	23.35	28.90	34.70	39.45	44.50	47.10	49.00	50.70	51.30	52.00	52.60	52.90	41.40
Zn 100/1	10.50	15.55	26.40	29.80	34.70	38.10	41.20	44.20	46.15	47.30	49.00	49.90	50.70	51.10	40.60
Zn 100/2	8.40	16.75	25.50	31.25	36.40	40.80	44.95	47.35	50.05	52.30	53.70	55.00	55.60	55.80	47.40
Zn 100/3	7.30	15.70	21.30	26.85	30.85	34.90	37.55	39.80	42.45	43.00	44.20	45.00	45.50	45.70	38.40
Zn 150/1	4.00	11.00	17.20	23.80	27.60	30.45	34.55	37.30	39.00	40.40	40.90	41.10	41.50	41.60	37.60
Zn 150/2	7.50	15.20	22.25	28.45	33.70	38.60	42.10	46.65	49.40	52.45	54.30	55.50	56.00	56.10	48.60
Zn 150/3	5.75	12.30	17.70	23.80	27.90	31.15	35.30	39.00	43.35	46.55	48.35	49.80	49.85	49.85	44.10
Zn 200/1	8.40	16.30	23.10	28.55	33.35	37.70	40.80	42.90	45.00	47.10	48.20	48.80	49.10	49.10	40.70
Zn 200/2	7.50	15.90	23.50	29.85	33.55	37.10	41.10	43.25	47.70	50.35	52.00	53.20	54.00	54.10	46.60
Zn 200/3	6.95	13.30	20.90	25.70	30.45	36.00	40.10	44.50	47.25	49.10	50.65	51.20	51.60	51.60	44.65
Zn 250/1	9.20	16.10	24.80	31.50	37.65	41.30	45.00	49.75	52.60	54.40	56.00	57.30	58.60	58.80	49.60
Zn 250/2	5.80	11.60	16.80	21.40	26.70	30.80	34.45	38.20	41.25	44.30	46.10	47.50	48.00	48.20	42.40
Zn 250/3	6.50	12.85	20.95	27.30	33.45	39.50	43.35	46.00	48.30	51.00	52.10	53.20	53.50	53.50	47.00

Table C-14 Internodes length data of chrysanthemum (*D. difflora*) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period														Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Zn 0/1	0.60	0.75	0.80	0.90	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.50
Zn 0/2	1.10	1.10	1.20	1.35	1.35	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	0.30
Zn 0/3	1.10	1.20	1.35	1.45	1.55	1.60	1.65	1.70	1.70	1.70	1.70	1.70	1.70	1.70	0.60
Zn 50/1	1.00	1.05	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.10
Zn 50/2	0.70	0.75	0.80	0.95	1.05	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.40
Zn 50/3	0.50	0.55	0.6	0.75	0.9	1.1	1.3	1.45	1.45	1.5	1.5	1.5	1.5	1.5	1.00
Zn 100/1	1.00	1.05	1.10	1.30	1.45	1.50	1.55	1.55	1.60	1.60	1.60	1.60	1.60	1.60	0.60
Zn 100/2	1.60	1.60	1.65	1.70	1.95	2.10	2.25	2.35	2.40	2.45	2.45	2.50	2.50	2.50	0.90
Zn 100/3	1.4	1.4	1.45	1.45	1.45	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	0.10
Zn 150/1	0.80	0.85	0.90	1.00	1.15	1.25	1.25	1.25	1.30	1.30	1.30	1.30	1.30	1.30	0.50
Zn 150/2	1.00	1.05	1.30	1.55	1.70	1.80	1.85	1.85	1.90	1.90	1.90	1.90	1.90	1.90	0.90
Zn 150/3	0.70	0.80	0.95	0.95	1.00	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	0.40
Zn 200/1	1.00	1.00	1.10	1.25	1.35	1.40	1.45	1.45	1.50	1.50	1.50	1.50	1.50	1.50	0.50
Zn 200/2	1.60	1.60	1.70	1.90	1.95	1.95	2.00	2.05	2.05	2.10	2.10	2.10	2.10	2.10	0.50
Zn 200/3	0.80	1.00	1.20	1.45	1.55	1.55	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	0.80
Zn 250/1	0.70	0.80	1.00	1.20	1.30	1.30	1.35	1.40	1.40	1.45	1.50	1.50	1.50	1.50	0.80
Zn 250/2	1.00	1.20	1.45	1.70	1.80	1.85	1.85	1.90	1.90	1.90	1.90	1.90	1.90	1.90	0.90
Zn 250/3	1.10	1.20	1.25	1.30	1.35	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	0.30

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Table C-15 Diameter of stem data of chrysanthemum (*D. difflora*) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period														Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	9th week (cm)	10th week (cm)	11th week (cm)	12th week (cm)	13th week (cm)	14th week (cm)	
Zn 0/1	0.3150	0.3250	0.3450	0.3750	0.4250	0.4400	0.4650	0.4900	0.5100	0.5250	0.5350	0.5450	0.5550	0.5550	0.2400
Zn 0/2	0.4000	0.4250	0.4550	0.4800	0.5150	0.5400	0.5550	0.5650	0.5750	0.5800	0.5850	0.5850	0.5900	0.5900	0.1900
Zn 0/3	0.3000	0.3415	0.3885	0.4250	0.4500	0.4715	0.4750	0.4800	0.4900	0.5000	0.5050	0.5100	0.5150	0.5150	0.2150
Zn 50/1	0.3325	0.3625	0.4150	0.4455	0.4700	0.495	0.5245	0.5550	0.5700	0.5850	0.6000	0.6050	0.6050	0.6100	0.2775
Zn 50/2	0.3300	0.3650	0.3955	0.4100	0.4355	0.4595	0.4785	0.4900	0.4950	0.5000	0.5050	0.5050	0.5100	0.5100	0.1800
Zn 50/3	0.3500	0.3850	0.4150	0.4300	0.4565	0.4800	0.5000	0.5150	0.5300	0.5445	0.5450	0.5500	0.5520	0.5525	0.2025
Zn 100/1	0.3000	0.3455	0.3674	0.3895	0.5050	0.5200	0.5445	0.5500	0.5650	0.5775	0.5825	0.5925	0.6000	0.6000	0.3000
Zn 100/2	0.3300	0.3550	0.3800	0.4050	0.4250	0.4495	0.4685	0.4800	0.5045	0.5100	0.5150	0.5300	0.5350	0.5350	0.2050
Zn 100/3	0.3000	0.3350	0.3600	0.3850	0.4150	0.4300	0.4400	0.4550	0.4700	0.4800	0.4900	0.4950	0.5000	0.5000	0.2000
Zn 150/1	0.3575	0.3900	0.4150	0.4400	0.4950	0.5200	0.5445	0.5650	0.5755	0.5800	0.6000	0.6100	0.6175	0.6175	0.2600
Zn 150/2	0.3375	0.3700	0.4035	0.4500	0.4995	0.5345	0.5700	0.5955	0.6155	0.6300	0.6400	0.6500	0.6525	0.6525	0.3150
Zn 150/3	0.2850	0.3000	0.3455	0.3895	0.4200	0.4535	0.4705	0.4885	0.5000	0.5250	0.5350	0.5400	0.5450	0.5450	0.2600
Zn 200/1	0.3850	0.3900	0.4355	0.4800	0.5225	0.5725	0.6135	0.6300	0.6550	0.6700	0.6800	0.6850	0.6950	0.7000	0.3150
Zn 200/2	0.3000	0.3400	0.3875	0.4250	0.4655	0.5145	0.5400	0.5725	0.5995	0.6100	0.6200	0.6250	0.6300	0.6300	0.3300
Zn 200/3	0.3000	0.3355	0.3500	0.3950	0.4350	0.4500	0.4800	0.5000	0.5255	0.5300	0.5450	0.5550	0.5600	0.5650	0.2650
Zn 250/1	0.3900	0.4355	0.4895	0.5345	0.5795	0.6150	0.6500	0.6845	0.7050	0.7100	0.7300	0.7500	0.7600	0.7600	0.3700
Zn 250/2	0.3750	0.4255	0.4695	0.4935	0.5365	0.5785	0.6000	0.6225	0.6550	0.6700	0.6800	0.6900	0.6950	0.7000	0.3250
Zn 250/3	0.2900	0.325	0.3465	0.3750	0.4050	0.4200	0.4435	0.4600	0.4895	0.5000	0.5150	0.5200	0.5200	0.5200	0.2300

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Table C-16 Dry weight data of chrysanthemum (*D. difflora*) under condition of zinc contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Zn 0/1	7.036
Zn 0/2	6.141
Zn 0/3	5.757
Zn 50/1	6.651
Zn 50/2	7.200
Zn 50/3	8.475
Zn 100/1	7.816
Zn 100/2	9.515
Zn 100/3	9.985
Zn 150/1	10.687
Zn 150/2	9.622
Zn 150/3	8.764
Zn 200/1	12.647
Zn 200/2	10.281
Zn 200/3	10.118
Zn 250/1	13.831
Zn 250/2	13.624
Zn 250/3	12.662

Table C-17 Height data of marigold (*T. erecta* L.) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	12.40	17.80	23.30	26.80	27.20	29.80	30.10	31.20	18.80
Zn 0/2	13.50	22.40	24.40	27.00	28.90	30.50	31.20	32.00	18.50
Zn 0/3	12.80	21.40	25.10	28.90	29.50	30.20	30.70	31.00	18.20
Zn 50/1	12.40	20.90	24.40	26.70	28.50	30.00	31.10	31.50	19.10
Zn 50/2	13.30	21.00	30.40	35.40	39.80	30.40	31.40	32.40	19.10
Zn 50/3	12.40	21.40	27.70	28.90	29.20	30.10	30.50	30.60	18.20
Zn 100/1	12.50	24.80	27.20	28.30	29.60	30.40	32.40	33.00	20.50
Zn 100/2	12.00	21.40	25.30	27.10	27.70	29.10	30.10	31.40	19.40
Zn 100/3	12.70	21.40	27.50	29.10	29.50	30.60	31.40	31.80	19.10
Zn 150/1	14.90	25.40	27.80	28.40	29.00	30.60	32.30	34.40	19.50
Zn 150/2	14.40	22.40	24.40	26.50	27.90	30.30	31.70	33.40	19.00
Zn 150/3	11.20	21.60	27.20	30.10	31.30	32.40	33.60	34.20	23.00
Zn 200/1	12.40	23.90	25.40	27.30	29.60	30.60	31.90	32.40	20.00
Zn 200/2	12.00	21.40	24.20	26.30	28.70	31.00	32.40	33.00	21.00
Zn 200/3	10.10	20.10	25.60	26.60	27.40	29.50	30.70	31.00	20.90
Zn 250/1	14.30	23.50	24.20	25.30	26.90	30.00	31.80	32.60	18.30
Zn 250/2	10.70	22.40	27.90	28.40	29.20	30.40	32.10	33.50	22.80
Zn 250/3	10.00	26.50	27.90	28.00	28.30	29.70	32.00	32.10	22.10

Table C-18 Internodes length data of marigold (*T. erecta* L.) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	2.50	2.50	2.55	2.55	2.60	2.60	2.60	2.60	0.10
Zn 0/2	2.80	2.85	2.90	3.00	3.00	3.00	3.00	3.00	0.20
Zn 0/3	2.40	2.45	2.45	2.50	2.50	2.50	2.50	2.50	0.10
Zn 50/1	2.00	2.05	2.10	2.15	2.20	2.20	2.20	2.20	0.20
Zn 50/2	2.20	2.20	2.25	2.30	2.35	2.35	2.40	2.40	0.20
Zn 50/3	2.20	2.25	2.35	2.35	2.40	2.40	2.40	2.40	0.20
Zn 100/1	2.10	2.20	2.30	2.35	2.40	2.40	2.40	2.40	0.30
Zn 100/2	2.20	2.30	2.40	2.45	2.45	2.50	2.50	2.50	0.30
Zn 100/3	2.30	2.35	2.40	2.45	2.50	2.50	2.50	2.50	0.20
Zn 150/1	2.10	2.25	2.35	2.45	2.55	2.55	2.60	2.60	0.50
Zn 150/2	2.00	2.10	2.20	2.25	2.30	2.30	2.30	2.30	0.30
Zn 150/3	2.10	2.20	2.30	2.35	2.40	2.40	2.40	2.40	0.30
Zn 200/1	2.60	2.75	2.90	3.05	3.10	3.10	3.10	3.10	0.50
Zn 200/2	2.20	2.35	2.45	2.50	2.55	2.55	2.60	2.60	0.40
Zn 200/3	2.30	2.40	2.45	2.45	2.50	2.50	2.50	2.50	0.20
Zn 250/1	2.10	2.25	2.35	2.45	2.50	2.50	2.50	2.50	0.40
Zn 250/2	2.50	2.70	2.80	2.90	2.95	3.00	3.00	3.00	0.50
Zn 250/3	2.50	2.65	2.70	2.75	2.80	2.80	2.80	2.80	0.30

Table C-19 Diameter of stem data of marigold (*T. erecta* L.) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	0.450	0.490	0.535	0.560	0.585	0.595	0.605	0.610	0.160
Zn 0/2	0.485	0.500	0.525	0.535	0.535	0.540	0.540	0.540	0.055
Zn 0/3	0.435	0.510	0.580	0.645	0.705	0.755	0.765	0.780	0.345
Zn 50/1	0.455	0.515	0.555	0.590	0.630	0.660	0.670	0.670	0.215
Zn 50/2	0.450	0.525	0.570	0.625	0.650	0.675	0.700	0.710	0.260
Zn 50/3	0.430	0.495	0.555	0.615	0.655	0.695	0.720	0.720	0.290
Zn 100/1	0.480	0.525	0.570	0.615	0.645	0.680	0.710	0.715	0.235
Zn 100/2	0.400	0.465	0.525	0.560	0.595	0.625	0.660	0.660	0.260
Zn 100/3	0.435	0.495	0.555	0.620	0.685	0.735	0.765	0.765	0.330
Zn 150/1	0.425	0.470	0.530	0.580	0.645	0.710	0.755	0.760	0.335
Zn 150/2	0.405	0.475	0.535	0.585	0.635	0.670	0.705	0.710	0.305
Zn 150/3	0.500	0.545	0.585	0.625	0.650	0.685	0.705	0.705	0.205
Zn 200/1	0.430	0.485	0.530	0.575	0.600	0.635	0.670	0.680	0.250
Zn 200/2	0.410	0.480	0.555	0.605	0.645	0.680	0.710	0.710	0.300
Zn 200/3	0.410	0.470	0.535	0.585	0.620	0.665	0.705	0.710	0.300
Zn 250/1	0.380	0.455	0.530	0.595	0.640	0.685	0.710	0.710	0.330
Zn 250/2	0.390	0.455	0.520	0.570	0.625	0.675	0.710	0.715	0.325
Zn 250/3	0.360	0.445	0.535	0.605	0.655	0.680	0.700	0.700	0.340

Table C-20 Dry weight data of marigold (*T. erecta* L.) under condition of zinc contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Zn 0/1	5.717
Zn 0/2	6.562
Zn 0/3	6.323
Zn 50/1	6.345
Zn 50/2	6.828
Zn 50/3	6.320
Zn 100/1	6.528
Zn 100/2	6.982
Zn 100/3	7.272
Zn 150/1	7.456
Zn 150/2	7.239
Zn 150/3	7.453
Zn 200/1	7.801
Zn 200/2	7.347
Zn 200/3	8.151
Zn 250/1	9.425
Zn 250/2	7.837
Zn 250/3	7.524

Table C-21 Height data of globe amaranth (*G. globosa* L.) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative height (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	12.00	17.55	23.75	26.25	29.35	30.50	31.00	31.30	19.30
Zn 0/2	11.50	16.35	20.30	24.65	27.30	30.50	32.00	33.50	22.00
Zn 0/3	16.40	22.40	27.40	31.55	35.15	38.30	40.00	41.70	25.30
Zn 50/1	11.40	17.40	21.40	26.80	29.45	31.00	32.50	33.10	21.70
Zn 50/2	11.80	18.80	24.80	28.45	31.55	32.15	32.85	33.00	21.20
Zn 50/3	13.10	19.55	24.15	28.30	32.25	35.20	37.40	39.20	26.10
Zn 100/1	12.00	18.85	23.55	27.95	29.05	30.65	30.80	31.50	19.50
Zn 100/2	12.10	19.10	26.10	31.30	36.30	39.70	40.70	41.60	29.50
Zn 100/3	17.10	22.15	27.95	31.40	34.50	37.20	38.65	39.50	22.40
Zn 150/1	11.80	14.20	19.15	23.70	27.40	30.70	32.50	33.00	21.20
Zn 150/2	18.50	25.05	31.20	35.10	39.80	43.80	45.40	45.50	27.00
Zn 150/3	15.30	21.05	25.30	29.60	33.50	36.30	38.80	39.80	24.50
Zn 200/1	16.00	27.85	33.25	39.40	43.95	47.10	49.90	52.00	36.00
Zn 200/2	11.10	14.15	20.70	25.90	29.65	31.25	32.00	33.20	22.10
Zn 200/3	14.20	50.05	55.40	60.85	63.35	65.95	67.50	38.40	24.20
Zn 250/1	16.10	22.35	27.10	30.00	33.05	35.05	36.20	37.70	21.60
Zn 250/2	17.90	28.05	35.45	42.40	46.30	49.90	52.20	54.10	36.20
Zn 250/3	13.40	20.45	26.95	30.05	34.00	37.70	39.90	40.40	27.00

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Table C-22 Internodes length data of globe amaranth (*G. globosa* L.) under condition of zinc contamination in soil

Zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative internodes length (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	2.20	2.25	2.30	2.35	2.35	2.40	2.40	2.40	0.20
Zn 0/2	2.00	2.10	2.23	2.35	2.45	2.55	2.60	2.60	0.60
Zn 0/3	2.80	2.85	2.85	2.90	2.90	2.90	2.90	2.90	0.10
Zn 50/1	3.80	3.85	3.95	4.00	4.05	4.10	4.10	4.10	0.30
Zn 50/2	3.30	3.40	3.50	3.50	3.50	3.50	3.50	3.50	0.20
Zn 50/3	4.30	4.55	4.70	4.80	4.90	4.95	5.00	5.00	0.70
Zn 100/1	2.90	3.10	3.25	3.35	3.45	3.50	3.50	3.50	0.60
Zn 100/2	2.80	2.90	2.95	2.95	3.00	3.00	3.00	3.00	0.20
Zn 100/3	2.00	2.25	2.35	2.45	2.45	2.50	2.50	2.50	0.50
Zn 150/1	2.20	2.30	2.40	2.45	2.50	2.50	2.50	2.50	0.30
Zn 150/2	2.60	2.70	2.75	2.75	2.80	2.80	2.80	2.80	0.20
Zn 150/3	2.60	2.95	3.10	3.30	3.45	3.45	3.50	3.50	0.90
Zn 200/1	2.20	2.45	2.65	2.75	2.85	2.90	2.90	2.90	0.70
Zn 200/2	2.20	2.30	2.40	2.45	2.50	2.50	2.50	2.50	0.30
Zn 200/3	2.50	2.65	2.80	2.90	2.95	3.00	3.00	3.00	0.50
Zn 250/1	3.40	3.75	3.95	4.20	4.35	4.40	4.40	4.40	1.00
Zn 250/2	3.40	3.45	3.45	3.50	3.50	3.50	3.50	3.50	0.10
Zn 250/3	3.60	3.70	3.85	4.00	4.20	4.25	4.30	4.30	0.70

Table C-23 Diameter of stem data of globe amaranth (*G. globosa* L.) under condition of zinc contamination in soil

zinc contamination (mg Zn/kg soil)	Experimental period								Cumulative diameter of stem (cm)
	1st week (cm)	2nd week (cm)	3rd week (cm)	4th week (cm)	5th week (cm)	6th week (cm)	7th week (cm)	8th week (cm)	
Zn 0/1	0.650	0.675	0.710	0.725	0.735	0.740	0.740	0.740	0.090
Zn 0/2	0.610	0.625	0.635	0.640	0.645	0.650	0.650	0.650	0.040
Zn 0/3	0.530	0.545	0.555	0.555	0.560	0.560	0.560	0.560	0.030
Zn 50/1	0.530	0.550	0.565	0.585	0.595	0.595	0.600	0.600	0.070
Zn 50/2	0.550	0.570	0.585	0.595	0.600	0.600	0.600	0.600	0.050
Zn 50/3	0.560	0.575	0.590	0.605	0.610	0.615	0.615	0.615	0.055
Zn 100/1	0.670	0.695	0.710	0.725	0.735	0.740	0.745	0.750	0.080
Zn 100/2	0.560	0.595	0.625	0.640	0.655	0.660	0.665	0.665	0.105
Zn 100/3	0.550	0.580	0.595	0.705	0.705	0.710	0.710	0.710	0.160
Zn 150/1	0.485	0.515	0.540	0.565	0.585	0.600	0.615	0.620	0.135
Zn 150/2	0.530	0.575	0.600	0.625	0.645	0.660	0.675	0.680	0.150
Zn 150/3	0.580	0.615	0.640	0.650	0.655	0.660	0.660	0.660	0.080
Zn 200/1	0.500	0.585	0.635	0.675	0.715	0.735	0.750	0.755	0.255
Zn 200/2	0.510	0.540	0.575	0.575	0.580	0.580	0.580	0.580	0.070
Zn 200/3	0.650	0.695	0.730	0.755	0.765	0.770	0.775	0.775	0.125
Zn 250/1	0.420	0.495	0.540	0.580	0.615	0.635	0.645	0.650	0.230
Zn 250/2	0.570	0.635	0.670	0.690	0.705	0.710	0.710	0.710	0.140
Zn 250/3	0.610	0.665	0.690	0.730	0.755	0.760	0.760	0.760	0.150

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Table C-24 Dry weight data of globe amaranth (*G. globosa* L.) under condition of zinc contamination in soil

Cadmium contamination (mg Cd/kg soil)	Dry weight (g)
Zn 0/1	7.872
Zn 0/2	6.315
Zn 0/3	4.808
Zn 50/1	6.394
Zn 50/2	6.086
Zn 50/3	8.208
Zn 100/1	7.903
Zn 100/2	6.792
Zn 100/3	7.024
Zn 150/1	8.273
Zn 150/2	8.360
Zn 150/3	9.498
Zn 200/1	9.184
Zn 200/2	8.122
Zn 200/3	10.276
Zn 250/1	10.298
Zn 250/2	9.806
Zn 250/3	8.599

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Appendix D

Statistical analysis of the effects of cadmium and zinc on plants growth

Table D-1 Effects of cadmium on height of chrysanthemum (*D. difflora*)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	4601.602	1	4601.602	142.602	.007
	Error	64.538	2	32.269(a)		
CONC	Hypothesis	1879.964	5	375.993	21.792	.000
	Error	172.536	10	17.254(b)		
REP	Hypothesis	64.538	2	32.269	1.870	.204
	Error	172.536	10	17.254(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset	
		1	2
100.00	3	7.8500	
80.00	3	8.6667	
60.00	3	12.5167	
20.00	3	14.3667	
40.00	3	14.4167	
.00	3		38.1167
Sig.		.105	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 17.254.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-2 Effects of cadmium on internodes length of chrysanthemum (*D. difflora*)

Oneway

ANOVA

INTERNODES LENGTH

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	4.401	1	4.401	72.670	.013
	Error	.121	2	.061(a)		
CONC	Hypothesis	.089	5	.018	.136	.980
	Error	1.319	10	.132(b)		
REP	Hypothesis	.121	2	.061	.459	.645
	Error	1.319	10	.132(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset 1
80.00	3	.4333
100.00	3	.4333
40.00	3	.4667
60.00	3	.4667
20.00	3	.5333
.00	3	.6333
Sig.		.547

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .132.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-3 Effects of cadmium on diameter of stem of chrysanthemum (*D. difflora*)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.908	1	.908	99.482	.010
	Error	.018	2	.009(a)		
CONC	Hypothesis	.017	5	.003	3.909	.032
	Error	.009	10	.001(b)		
REP	Hypothesis	.018	2	.009	10.242	.004
	Error	.009	10	.001(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DAIMETER OF STEM

Duncan[a,b]

CONC	N	Subset	
		1	2
100.00	3	.1750	
80.00	3	.2000	.2000
60.00	3	.2125	.2125
40.00	3	.2450	.2450
20.00	3	.2550	.2550
.00	3		.2600
Sig.		.013	.047

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .001.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-4 Effects of cadmium on dry weight of chrysanthemum (*D. difflora*)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	725.492	1	725.492	832.000	.001
	Error	1.744	2	.872(a)		
CONC	Hypothesis	32.457	5	6.491	4.799	.017
	Error	13.525	10	1.353(b)		
REP	Hypothesis	1.744	2	.872	.645	.545
	Error	13.525	10	1.353(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset	
		1	2
100.00	3	4.6032	
80.00	3	4.9548	
60.00	3	6.0645	6.0645
40.00	3	6.6961	6.6961
20.00	3	7.2167	7.2167
.00	3		8.5565
Sig.		.030	.034

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 1.353.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-5 Effects of cadmium on height of marigold (*T. erecta* L.)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	4296.645	1	4296.645	7515.997	.000
	Error	1.143	2	.572(a)		
CONC	Hypothesis	16.945	5	3.389	.921	.506
	Error	36.817	10	3.682(b)		
REP	Hypothesis	1.143	2	.572	.155	.858
	Error	36.817	10	3.682(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset 1
100.00	3	13.5667
80.00	3	15.2333
60.00	3	15.4333
40.00	3	15.8333
20.00	3	15.8667
.00	3	16.7667
Sig.		.092

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 3.682.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-6 Effects of cadmium on internodes length of marigold (*T. erecta* L.)

Oneway

ANOVA

INTERNODES LENGTH

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.176	1	1.176	111.368	.009
	Error	.021	2	.011(a)		
CONC	Hypothesis	.171	5	.034	6.553	.006
	Error	.052	10	.005(b)		
REP	Hypothesis	.021	2	.011	2.021	.183
	Error	.052	10	.005(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset	
		1	2
100.00	3	.1333	
80.00	3	.1667	
60.00	3	.2333	
40.00	3	.2667	.2667
20.00	3	.3000	.3000
.00	3		.4333
Sig.		.027	.022

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .005.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-7 Effects of cadmium on diameter of stem of marigold (*T. erecta* L.)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.771	1	.771	4173.120	.000
	Error	.000	2	.000(a)		
CONC	Hypothesis	.017	5	.003	.452	.803
	Error	.077	10	.008(b)		
REP	Hypothesis	.000	2	.000	.024	.976
	Error	.077	10	.008(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DAIMETER OF STEM

Duncan[a,b]

CONC	N	Subset 1
100.00	3	.1700
80.00	3	.1733
60.00	3	.1917
40.00	3	.2200
20.00	3	.2317
.00	3	.2550
Sig.		.302

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = .008.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-8 Effects of cadmium on dry weight of marigold (*T. erecta* L.)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	742.435	1	742.435	33606.822	.000
	Error	.044	2	.022(a)		
CONC	Hypothesis	3.573	5	.715	10.953	.001
	Error	.652	10	.065(b)		
REP	Hypothesis	.044	2	.022	.339	.721
	Error	.652	10	.065(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset		
		1	2	3
100.00	3	5.8546		
80.00	3	6.0406	6.0406	
60.00	3	6.2351	6.2351	
40.00	3	6.4847	6.4847	
20.00	3		6.7285	6.7285
.00	3			7.1906
Sig.		.018	.012	.051

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .065.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-9 Effects of cadmium on height of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	8632.980	1	8632.980	1307.037	.001
	Error	13.210	2	6.605(a)		
CONC	Hypothesis	331.347	5	66.269	3.329	.050
	Error	199.043	10	19.904(b)		
REP	Hypothesis	13.210	2	6.605	.332	.725
	Error	199.043	10	19.904(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset 1
100.00	3	15.9667
80.00	3	16.4000
60.00	3	22.6667
40.00	3	24.3667
20.00	3	24.4667
.00	3	27.5333
Sig.		.016

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 19.904.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-10 Effects of cadmium on internodes length of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

INTERNODES LENGTH

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.805	1	1.805	270.750	.004
	Error	.013	2	.007(a)		
CONC	Hypothesis	.125	5	.025	1.500	.273
	Error	.167	10	.017(b)		
REP	Hypothesis	.013	2	.007	.400	.681
	Error	.167	10	.017(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset 1
100.00	3	.2000
80.00	3	.2333
60.00	3	.3000
40.00	3	.3333
20.00	3	.4000
.00	3	.4333
Sig.		.072

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares The error term is Mean Square(Error) = .017.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-11 Effects of cadmium on diameter of stem of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.101	1	.101	17.711	.052
	Error	.011	2	.006(a)		
CONC	Hypothesis	.012	5	.002	1.161	.392
	Error	.021	10	.002(b)		
REP	Hypothesis	.011	2	.006	2.757	.111
	Error	.021	10	.002(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DIAMETER OF STEM

Duncan[a,b]

CONC	N	Subset 1
100.00	3	.0283
80.00	3	.0567
60.00	3	.0733
40.00	3	.0950
20.00	3	.0967
.00	3	.1000
Sig.		.109

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .002.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-12 Effects of cadmium on dry weight of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	972.848	1	972.848	577.366	.002
	Error	3.370	2	1.685(a)		
CONC	Hypothesis	6.937	5	1.387	2.091	.150
	Error	6.636	10	.664(b)		
REP	Hypothesis	3.370	2	1.685	2.539	.128
	Error	6.636	10	.664(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset 1
80.00	3	6.8371
100.00	3	6.8682
60.00	3	6.9732
40.00	3	7.2970
20.00	3	7.4999
.00	3	8.6346
Sig.		.034

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .664.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-13 Effects of zinc on height of chrysanthemum (*D. difflora*)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	30122.851	1	30122.851	20485.929	.000
	Error	2.941	2	1.470(a)		
CONC	Hypothesis	524.516	5	104.903	3.763	.035
	Error	278.804	10	27.880(b)		
REP	Hypothesis	2.941	2	1.470	.053	.949
	Error	278.804	10	27.880(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	29.6333	
50.00	3	39.9333	39.9333
100.00	3	42.1333	42.1333
150.00	3	43.4333	43.4333
200.00	3	43.9833	43.9833
250.00	3		46.3333
Sig.	.	.012	.201

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 27.880.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-14 Effects of zinc on internodes length of chrysanthemum (*D. difflora*)

Oneway

ANOVA

INTERNODES LENGTH

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	5.667	1	5.667	152.254	.007
	Error	.074	2	.037(a)		
CONC	Hypothesis	.083	5	.017	.147	.976
	Error	1.126	10	.113(b)		
REP	Hypothesis	.074	2	.037	.331	.726
	Error	1.126	10	.113(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset 1
.00	3	.4667
50.00	3	.5000
100.00	3	.5333
150.00	3	.6000
200.00	3	.6000
250.00	3	.6667
Sig.		.516

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .113.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-15 Effects of zinc on diameter of stem of chrysanthemum (*D. difflora*)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.217	1	1.217	191.152	.005
	Error	.013	2	.006(a)		
CONC	Hypothesis	.026	5	.005	3.609	.040
	Error	.015	10	.001(b)		
REP	Hypothesis	.013	2	.006	4.351	.044
	Error	.015	10	.001(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DIAMETER OF STEM

Duncan[a,b]

CONC	N	Subset 1
.00	3	.2150
50.00	3	.2200
100.00	3	.2350
150.00	3	.2783
200.00	3	.3033
250.00	3	.3083
Sig.		.022

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .001.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-16 Effects of zinc on dry weight of chrysanthemum (*D. difflora*)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1621.297	1	1621.297	4193.061	.000
	Error	.773	2	.387(a)		
CONC	Hypothesis	95.808	5	19.162	17.335	.000
	Error	11.054	10	1.105(b)		
REP	Hypothesis	.773	2	.387	.350	.713
	Error	11.054	10	1.105(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	6.3114			
50.00	3	7.4421	7.4421		
100.00	3	9.1052	9.1052	9.1052	
150.00	3		9.6908	9.6908	
200.00	3			11.0155	11.0155
250.00	3				13.3788
Sig.		.011	.031	.059	.020

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 1.105.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-17 Effects of zinc on height of marigold (*T. erecta* L.)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	7100.347	1	7100.347	5817.308	.000
	Error	2.441	2	1.221(a)		
CONC	Hypothesis	16.423	5	3.285	1.549	.260
	Error	21.199	10	2.120(b)		
REP	Hypothesis	2.441	2	1.221	.576	.580
	Error	21.199	10	2.120(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset 1
.00	3	18.5000
50.00	3	18.8000
100.00	3	19.6667
150.00	3	20.5000
200.00	3	20.6333
250.00	3	21.0667
Sig.		.078

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 2.120.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-18 Effects of zinc on internodes length of marigold (*T. erecta* L.)

Oneway

ANOVA

INTERNODES LENGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.502	1	1.502	62.884	.016
	Error	.048	2	.024(a)		
CONC	Hypothesis	.171	5	.034	5.811	.009
	Error	.059	10	.006(b)		
REP	Hypothesis	.048	2	.024	4.057	.051
	Error	.059	10	.006(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset	
		1	2
.00	3	.1333	
50.00	3	.2000	.2000
100.00	3	.2667	.2667
150.00	3		.3667
200.00	3		.3667
250.00	3		.4000
Sig.		.069	.015

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .006.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-19 Effects of zinc on diameter of stem of marigold (*T. erecta* L.)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.301	1	1.301	268.258	.004
	Error	.010	2	.005(a)		
CONC	Hypothesis	.034	5	.007	1.300	.338
	Error	.052	10	.005(b)		
REP	Hypothesis	.010	2	.005	.930	.426
	Error	.052	10	.005(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DAIMETER OF STEM

Duncan[a,b]

CONC	N	Subset 1
.00	3	.1867
50.00	3	.2550
100.00	3	.2750
150.00	3	.2817
200.00	3	.2833
250.00	3	.3317
Sig.		.049

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .005.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-20 Effects of zinc on dry weight of marigold (*T. erecta* L.)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	926.049	1	926.049	97223.244	.000
	Error	.019	2	.010(a)		
CONC	Hypothesis	9.130	5	1.826	5.637	.010
	Error	3.239	10	.324(b)		
REP	Hypothesis	.019	2	.010	.029	.971
	Error	3.239	10	.324(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset	
		1	2
.00	3	6.2007	
50.00	3	6.4974	
100.00	3	6.9274	6.9274
150.00	3	7.3829	7.3829
200.00	3	7.7660	7.7660
250.00	3		8.2618
Sig.		.011	.023

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .324.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-21 Effects of zinc on height of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

HEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	11090.569	1	11090.569	759.079	.001
	Error	29.221	2	14.611(a)		
CONC	Hypothesis	90.811	5	18.162	.617	.691
	Error	294.519	10	29.452(b)		
REP	Hypothesis	29.221	2	14.611	.496	.623
	Error	294.519	10	29.452(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

HEIGHT

Duncan[a,b]

CONC	N	Subset 1
.00	3	22.2000
50.00	3	23.0000
100.00	3	23.8000
150.00	3	24.2333
200.00	3	27.4333
250.00	3	28.2667
Sig.		.238

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 29.452.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-22 Effects of zinc on internodes length of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

INTERNODES LENGTH

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	3.645	1	3.645	23.516	.040
	Error	.310	2	.155(a)		
CONC	Hypothesis	.152	5	.030	.360	.865
	Error	.843	10	.084(b)		
REP	Hypothesis	.310	2	.155	1.838	.209
	Error	.843	10	.084(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

INTERNODES LENGTH

Duncan[a,b]

CONC	N	Subset 1
.00	3	.3000
50.00	3	.4000
100.00	3	.4333
150.00	3	.4667
200.00	3	.5000
250.00	3	.6000
Sig.		.273

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .084.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-23 Effects of zinc on diameter of stem of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

DIAMETER OF STEM

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.226	1	.226	49.926	.019
	Error	.009	2	.005(a)		
CONC	Hypothesis	.035	5	.007	3.139	.058
	Error	.022	10	.002(b)		
REP	Hypothesis	.009	2	.005	2.032	.182
	Error	.022	10	.002(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DAIMETER OF STEM

Duncan[a,b]

CONC	N	Subset 1
.00	3	.0533
50.00	3	.0583
100.00	3	.1150
150.00	3	.1217
200.00	3	.1500
250.00	3	.1733
Sig.		.018

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .002.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table D-24 Effects of zinc on dry weight of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

DRY WEIGHT

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1149.083	1	1149.083	1350.920	.001
	Error	1.701	2	.851(a)		
CONC	Hypothesis	26.905	5	5.381	4.851	.016
	Error	11.092	10	1.109(b)		
REP	Hypothesis	1.701	2	.851	.767	.490
	Error	11.092	10	1.109(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

DRY WEIGHT

Duncan[a,b]

CONC	N	Subset	
		1	2
.00	3	6.3317	
50.00	3	6.8956	6.8956
100.00	3	7.2399	7.2399
150.00	3	8.7103	8.7103
200.00	3	9.1939	9.1939
250.00	3		9.5678
Sig.		.012	.017

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = 1.109.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Appendix E

Statistical analysis of cadmium and zinc accumulation in various parts of plans

Table E-1 Cadmium accumulation in roots of chrysanthemum (*D. difflora*)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	6.845	1	6.845	484.860	.002
	Error	.028	2	.014(a)		
CONC	Hypothesis	1.992	5	.398	11.499	.001
	Error	.346	10	.035(b)		
REP	Hypothesis	.028	2	.014	.408	.676
	Error	.346	10	.035(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset		
		1	2	3
.00	3	.0000		
20.00	3	.3613	.3613	
40.00	3		.6951	.6951
60.00	3		.8437	.8437
80.00	3			.8903
100.00	3			.9096
Sig.		.039	.012	.217

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .035.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-2 Cadmium accumulation in stems of chrysanthemum (*D. difflora*)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	12.581	1	12.581	141.048	.007
	Error	.178	2	.089(a)		
CONC	Hypothesis	3.767	5	.753	22.805	.000
	Error	.330	10	.033(b)		
REP	Hypothesis	.178	2	.089	2.700	.115
	Error	.330	10	.033(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0000	
20.00	3	.4515	
40.00	3		.9983
60.00	3		1.1478
80.00	3		1.1506
100.00	3		1.2679
Sig.		.012	.121

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .033.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-3 Cadmium accumulation in leaves of chrysanthemum (*D. difflora*)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	14.471	1	14.471	175.160	.006
	Error	.165	2	.083(a)		
CONC	Hypothesis	3.927	5	.785	9.831	.001
	Error	.799	10	.080(b)		
REP	Hypothesis	.165	2	.083	1.034	.391
	Error	.799	10	.080(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0000	
20.00	3	.5915	.5915
40.00	3		1.0728
60.00	3		1.1036
80.00	3		1.2661
100.00	3		1.3457
Sig.		.028	.013

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .080.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-4 Cadmium accumulation in roots of marigold (*T. erecta* L.)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.310	1	.310	121.416	.008
	Error	.005	2	.003(a)		
CONC	Hypothesis	.099	5	.020	23.721	.000
	Error	.008	10	.001(b)		
REP	Hypothesis	.005	2	.003	3.068	.091
	Error	.008	10	.001(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.0000			
20.00	3		.0953		
40.00	3		.1309	.1309	
60.00	3		.1414	.1414	
80.00	3			.1786	.1786
100.00	3				.2409
Sig.		1.000	.091	.082	.024

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .001.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-5 Cadmium accumulation in stems of marigold (*T. erecta* L.)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	4.696	1	4.696	80.968	.012
	Error	.116	2	.058(a)		
CONC	Hypothesis	2.325	5	.465	28.037	.000
	Error	.166	10	.017(b)		
REP	Hypothesis	.116	2	.058	3.496	.071
	Error	.166	10	.017(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.0000			
20.00	3	.2473	.2473		
40.00	3		.4785	.4785	
60.00	3		.5185	.5185	
80.00	3			.6605	
100.00	3				1.1598
Sig.		.041	.033	.129	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .017.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-6 Cadmium accumulation in leaves of marigold (*T. erecta* L.)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	16.002	1	16.002	48.577	.020
	Error	.659	2	.329(a)		
CONC	Hypothesis	11.723	5	2.345	11.551	.001
	Error	2.030	10	.203(b)		
REP	Hypothesis	.659	2	.329	1.623	.245
	Error	2.030	10	.203(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0000	
20.00	3	.3318	
40.00	3	.8166	
60.00	3	.9076	
80.00	3	1.0401	
100.00	3		2.5611
Sig.		.027	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .203.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-7 Cadmium accumulation in flowers of marigold (*T. erecta* L.)

Oneway

ANOVA

FLOWERS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.704	1	1.704	56.223	.017
	Error	.061	2	.030(a)		
CONC	Hypothesis	1.281	5	.256	33.688	.000
	Error	.076	10	.008(b)		
REP	Hypothesis	.061	2	.030	3.985	.053
	Error	.076	10	.008(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

FLOWERS

Duncan[a,b]

CONC	N	Subset		
		1	2	3
.00	3	.0000		
20.00	3	.1215		
40.00	3	.1890		
60.00	3	.2236		
80.00	3		.5261	
100.00	3			.7862
Sig.		.015	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .008.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-8 Cadmium accumulation in roots of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	1.117	1	1.117	159.136	.006
	Error	.014	2	.007(a)		
CONC	Hypothesis	.245	5	.049	29.443	.000
	Error	.017	10	.002(b)		
REP	Hypothesis	.014	2	.007	4.215	.047
	Error	.017	10	.002(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0000	
20.00	3		.2352
40.00	3		.2826
60.00	3		.3055
80.00	3		.3268
100.00	3		.3449
Sig.		1.000	.013

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .002.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-9 Cadmium accumulation in stems of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	3.528	1	3.528	694.534	.001
	Error	.010	2	.005(a)		
CONC	Hypothesis	.733	5	.147	15.613	.000
	Error	.094	10	.009(b)		
REP	Hypothesis	.010	2	.005	.541	.598
	Error	.094	10	.009(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0000	
20.00	3		.4704
40.00	3		.5147
60.00	3		.5224
80.00	3		.5495
100.00	3		.5994
Sig.		1.000	.164

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .009.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-10 Cadmium accumulation in leaves of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	8.655	1	8.655	127.381	.008
	Error	.136	2	.068(a)		
CONC	Hypothesis	2.369	5	.474	12.927	.000
	Error	.367	10	.037(b)		
REP	Hypothesis	.136	2	.068	1.853	.207
	Error	.367	10	.037(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset		
		1	2	3
.00	3	.0000		
20.00	3		.5057	
40.00	3		.7103	.7103
60.00	3		.8840	.8840
80.00	3		.9588	.9588
100.00	3			1.1017
Sig.		1.000	.022	.042

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .037.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-11 Cadmium accumulation in flowers of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

FLOWERS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.394	1	.394	598.838	.002
	Error	.001	2	.001(a)		
CONC	Hypothesis	.082	5	.016	26.150	.000
	Error	.006	10	.001(b)		
REP	Hypothesis	.001	2	.001	1.044	.387
	Error	.006	10	.001(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

FLOWERS

Duncan[a,b]

CONC	N	Subset	
		1	2
.00	3	.0000	
20.00	3		.1512
40.00	3		.1712
60.00	3		.1823
80.00	3		.1861
100.00	3		.1967
Sig.		1.000	.069

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .001.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-12 Zinc accumulation in roots of chrysanthemum (*D. difflora*)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	8.021	1	8.021	72.853	.013
	Error	.220	2	.110(a)		
CONC	Hypothesis	2.060	5	.412	10.680	.001
	Error	.386	10	.039(b)		
REP	Hypothesis	.220	2	.110	2.854	.105
	Error	.386	10	.039(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset		
		1	2	3
.00	3	.3143		
50.00	3	.3728	.3728	
100.00	3	.5071	.5071	
150.00	3	.6349	.6349	
200.00	3		.8706	.8706
250.00	3			1.3056
Sig.		.092	.016	.022

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .039.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E- 13 Zinc accumulation in stems of chrysanthemum (*D. difflora*)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	19.540	1	19.540	363.565	.003
	Error	.107	2	.054(a)		
CONC	Hypothesis	4.954	5	.991	8.348	.002
	Error	1.187	10	.119(b)		
REP	Hypothesis	.107	2	.054	.453	.648
	Error	1.187	10	.119(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.3434	
50.00	3	.5469	
100.00	3	.8606	.8606
150.00	3	1.0941	1.0941
200.00	3		1.6397
250.00	3		1.7667
Sig.		.032	.013

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .119.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E- 14 Zinc accumulation in leaves of chrysanthemum (*D. difflora*)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	48.324	1	48.324	1931.939	.001
	Error	.050	2	.025(a)		
CONC	Hypothesis	17.551	5	3.510	9.968	.001
	Error	3.522	10	.352(b)		
REP	Hypothesis	.050	2	.025	.071	.932
	Error	3.522	10	.352(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset	
		1	2
.00	3	.5907	
50.00	3	.7810	
100.00	3	1.2755	
150.00	3	1.6484	
200.00	3	1.9505	
250.00	3		3.5848
Sig.		.027	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .352.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-15 Zinc accumulation in flowers of chrysanthemum (*D. difflora*)

Oneway

ANOVA

FLOWERS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	5.765	1	5.765	301.109	.003
	Error	.038	2	.019(a)		
CONC	Hypothesis	1.124	5	.225	7.534	.004
	Error	.298	10	.030(b)		
REP	Hypothesis	.038	2	.019	.641	.547
	Error	.298	10	.030(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

FLOWERS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.2142	
50.00	3	.2927	
100.00	3	.5346	.5346
150.00	3	.6397	.6397
200.00	3		.8435
250.00	3		.8708
Sig.		.018	.050

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .030.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-16 Zinc accumulation in roots of marigold (*T. erecta* L.)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	23.394	1	23.394	168.940	.006
	Error	.277	2	.138(a)		
CONC	Hypothesis	5.809	5	1.162	53.390	.000
	Error	.218	10	.022(b)		
REP	Hypothesis	.277	2	.138	6.363	.016
	Error	.218	10	.022(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.5061			
50.00	3	.6294			
100.00	3	.8698	.8698		
150.00	3		1.1987	1.1987	
200.00	3			1.4456	
250.00	3				2.1907
Sig.		.016	.021	.068	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .022.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-17 Zinc accumulation in stems of marigold (*T. erecta* L.)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	58.091	1	58.091	149.921	.007
	Error	.775	2	.387(a)		
CONC	Hypothesis	12.351	5	2.470	35.488	.000
	Error	.696	10	.070(b)		
REP	Hypothesis	.775	2	.387	5.567	.024
	Error	.696	10	.070(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.8221			
50.00	3	1.1276			
100.00	3	1.3695	1.3695		
150.00	3		1.8978	1.8978	
200.00	3			2.2378	
250.00	3				3.3239
Sig.		.035	.034	.146	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .070.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-18 Zinc accumulation in leaves of marigold (*T. erecta* L.)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	533.662	1	533.662	398.328	.003
	Error	2.680	2	1.340(a)		
CONC	Hypothesis	149.844	5	29.969	43.338	.000
	Error	6.915	10	.692(b)		
REP	Hypothesis	2.680	2	1.340	1.937	.194
	Error	6.915	10	.692(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	2.0823			
50.00	3	3.0878			
100.00	3	4.1989	4.1989		
150.00	3		5.1083		
200.00	3			7.5544	
250.00	3				10.6381
Sig.		.014	.017	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .692.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-19 Zinc accumulation in flowers of marigold (*T. erecta* L.)

Oneway

ANOVA

FLOWERS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	46.174	1	46.174	380.481	.003
	Error	.243	2	.121(a)		
CONC	Hypothesis	9.073	5	1.815	53.495	.000
	Error	.339	10	.034(b)		
REP	Hypothesis	.243	2	.121	3.578	.067
	Error	.339	10	.034(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

FLOWERS

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.8688			
50.00	3	1.1253	1.1253		
100.00	3	1.2699	1.2699		
150.00	3		1.4943	1.4943	
200.00	3			1.8011	
250.00	3				3.0504
Sig.		.029	.041	.069	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .034.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-20 Zinc accumulation in roots of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

ROOTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	32.692	1	32.692	297.517	.003
	Error	.220	2	.110(a)		
CONC	Hypothesis	7.182	5	1.436	55.264	.000
	Error	.260	10	.026(b)		
REP	Hypothesis	.220	2	.110	4.228	.047
	Error	.260	10	.026(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

ROOTS

Duncan[a,b]

CONC	N	Subset				
		1	2	3	4	5
.00	3	.5429				
50.00	3	.8394	.8394			
100.00	3		1.0258	1.0258		
150.00	3			1.3869		
200.00	3				1.9113	
250.00	3					2.3797
Sig.		.048	.187	.021	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .026.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-21 Zinc accumulation in stems of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

STEMS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	45.269	1	45.269	288.732	.003
	Error	.314	2	.157(a)		
CONC	Hypothesis	26.493	5	5.299	62.161	.000
	Error	.852	10	.085(b)		
REP	Hypothesis	.314	2	.157	1.839	.209
	Error	.852	10	.085(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

STEMS

Duncan[a,b]

CONC	N	Subset				
		1	2	3	4	5
.00	3	.1733				
50.00	3	.6174	.6174			
100.00	3		1.0717	1.0717		
150.00	3			1.6745	1.6745	
200.00	3				2.0706	
250.00	3					3.9076
Sig.		.092	.086	.030	.128	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .085.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-22 Zinc accumulation in leaves of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

LEAVES

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	89.590	1	89.590	56.765	.017
	Error	3.157	2	1.578(a)		
CONC	Hypothesis	45.167	5	9.033	29.790	.000
	Error	3.032	10	.303(b)		
REP	Hypothesis	3.157	2	1.578	5.205	.028
	Error	3.032	10	.303(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

LEAVES

Duncan[a,b]

CONC	N	Subset			
		1	2	3	4
.00	3	.3767			
50.00	3	.7498			
100.00	3	1.3372	1.3372		
150.00	3		2.4129	2.4129	
200.00	3			3.8065	3.8065
250.00	3				4.7027
Sig.		.068	.038	.011	.074

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .303.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Table E-23 Zinc accumulation in flowers of globe amaranth (*G. globosa* L.)

Oneway

ANOVA

FLOWERS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	2.199	1	2.199	44.726	.022
	Error	.098	2	.049(a)		
CONC	Hypothesis	1.687	5	.337	9.064	.002
	Error	.372	10	.037(b)		
REP	Hypothesis	.098	2	.049	1.321	.310
	Error	.372	10	.037(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

FLOWERS

Duncan[a,b]

CONC	N	Subset 1	Subset 2
.00	3	.0700	
50.00	3	.1313	
100.00	3	.1811	
150.00	3	.2646	
200.00	3	.4812	.4812
250.00	3		.9691
Sig.		.037	.011

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares.
The error term is Mean Square(Error) = .037.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .01.

Appendix F

Statistical analysis of accumulation of cadmium and zinc in each plant

Table F-1 Cadmium accumulation in chrysanthemum (*D. difflora*)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	.000	2	.000	.	.
	Within Groups	.000	6	.000		
	Total	.000	8			
CONC20	Between Groups	.081	2	.040	1.240	.354
	Within Groups	.195	6	.033		
	Total	.276	8			
CONC40	Between Groups	.240	2	.120	2.346	.177
	Within Groups	.307	6	.051		
	Total	.547	8			
CONC60	Between Groups	.162	2	.081	.861	.469
	Within Groups	.565	6	.094		
	Total	.727	8			
CONC80	Between Groups	.222	2	.111	2.079	.206
	Within Groups	.321	6	.053		
	Total	.543	8			
CONC100	Between Groups	.325	2	.162	2.120	.201
	Within Groups	.459	6	.077		
	Total	.784	8			

Post Hoc Test

Homogeneous Subsets

CONC20

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.3613
stems	3	.4515
leaves	3	.5915
Sig.		.182

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 3.000.

CONC40

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.6951
stems	3	.9983
leaves	3	1.0728
Sig.		.096

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC60

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.8437
leaves	3	1.1036
stems	3	1.1478
Sig.		.285

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC80

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.8903
stems	3	1.1506
leaves	3	1.2661
Sig.		.103

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.9096
stems	3	1.2679
leaves	3	1.3457
Sig.		.112

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Table F-2 Cadmium accumulation in marigold (*T. erecta* L.)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	.000	3	.000	.	.
	Within Groups	.000	8	.000		
	Total	.000	11			
CONC20	Between Groups	.110	3	.037	.829	.514
	Within Groups	.354	8	.044		
	Total	.465	11			
CONC40	Between Groups	.890	3	.297	37.125	.000
	Within Groups	.064	8	.008		
	Total	.954	11			
CONC60	Between Groups	1.082	3	.361	99.056	.000
	Within Groups	.029	8	.004		
	Total	1.111	11			
CONC80	Between Groups	1.141	3	.380	52.557	.000
	Within Groups	.058	8	.007		
	Total	1.199	11			
CONC100	Between Groups	8.834	3	2.945	9.008	.006
	Within Groups	2.615	8	.327		
	Total	11.450	11			

Post Hoc Test

Homogeneous Subsets

CONC20

Duncan[a]

PARTS	N	Subset for alpha = .01
		1
roots	3	.0953
flowers	3	.1215
stems	3	.2473
leaves	3	.3318
Sig.		.231

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC40

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
roots	3	.1309		
flowers	3	.1890		
stems	3		.4785	
leaves	3			.8166
Sig.		.449	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC60

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
roots	3	.1414		
flowers	3	.2236		
stems	3		.5185	
leaves	3			.9076
Sig.		.134	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC80

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
roots	3	.1786		
flowers	3		.5261	
stems	3		.6605	
leaves	3			1.0401
Sig.		1.000	.089	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
roots	3	.2409	
flowers	3	.7862	
stems	3	1.1598	
leaves	3		2.5611
Sig.		.096	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Table F-3 Cadmium accumulation in globe amaranth (*G. globosa* L.)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	.000	3	.000	.	.
	Within Groups	.000	8	.000		
	Total	.000	11			
CONC20	Between Groups	.273	3	.091	35.298	.000
	Within Groups	.021	8	.003		
	Total	.294	11			
CONC40	Between Groups	.522	3	.174	16.500	.001
	Within Groups	.084	8	.011		
	Total	.606	11			
CONC60	Between Groups	.852	3	.284	33.513	.000
	Within Groups	.068	8	.008		
	Total	.919	11			
CONC80	Between Groups	1.024	3	.341	9.351	.005
	Within Groups	.292	8	.037		
	Total	1.316	11			
CONC100	Between Groups	1.420	3	.473	21.036	.000
	Within Groups	.180	8	.022		
	Total	1.600	11			

Post Hoc Test

Homogeneous Subsets

CONC20

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flower	3	.1512	
root	3	.2352	
stem	3		.4704
leaf	3		.5057
Sig.		.078	.420

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC40

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
flowers	3	.1712		
roots	3	.2826	.2826	
stems	3		.5147	.5147
leaves	3			.7103
Sig.		.221	.024	.048

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC60

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
flowers	3	.1823		
roots	3	.3055	.3055	
stems	3		.5224	
leaves	3			.8840
Sig.		.140	.020	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC80

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.1861	
roots	3	.3268	
stems	3	.5495	.5495
leaves	3		.9588
Sig.		.056	.030

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.1967	
roots	3	.3449	
stems	3	.5994	
leaves	3		1.1017
Sig.		.013	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Table F-4 Zinc accumulation in chrysanthemum (*D. difflora*)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	.230	3	.077	5.182	.028
	Within Groups	.118	8	.015		
	Total	.349	11			
CONC50	Between Groups	.421	3	.140	4.575	.038
	Within Groups	.245	8	.031		
	Total	.666	11			
CONC100	Between Groups	1.157	3	.386	4.333	.043
	Within Groups	.712	8	.089		
	Total	1.870	11			
CONC150	Between Groups	2.077	3	.692	3.406	.074
	Within Groups	1.626	8	.203		
	Total	3.703	11			
CONC200	Between Groups	2.786	3	.929	6.184	.018
	Within Groups	1.201	8	.150		
	Total	3.987	11			
CONC250	Between Groups	12.803	3	4.268	17.922	.001
	Within Groups	1.905	8	.238		
	Total	14.708	11			

Post Hoc Test

Homogeneous Subsets

CONC0

Duncan[a]

PART	N	Subset for alpha = .01	
		1	2
flowers	3	.2142	
roots	3	.3143	.3143
stems	3	.3434	.3434
leaves	3		.5907
Sig.		.248	.028

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC50

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
flowers	3	.2927
roots	3	.3728
stems	3	.5469
leaves	3	.7810
Sig.		.013

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
roots	3	.5071
flowers	3	.5346
stems	3	.8606
leaves	3	1.2755
Sig.		.018

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC150

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
roots	3	.6349
flowers	3	.6397
stems	3	1.0941
leaves	3	1.6484
Sig.		.032

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC200

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
flowers	3	.8435
roots	3	.8706
stems	3	1.6397
leaves	3	1.9505
Sig.		.011

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC250

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.8708	
roots	3	1.3056	
stems	3	1.7667	
leaves	3		3.5848
Sig.		.063	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

TableF-5 Zinc accumulation in of marigold (*T. erecta* L.)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	4.334	3	1.445	12.654	.002
	Within Groups	.913	8	.114		
	Total	5.248	11			
CONC50	Between Groups	10.674	3	3.558	121.207	.000
	Within Groups	.235	8	.029		
	Total	10.909	11			
CONC100	Between Groups	21.066	3	7.022	85.089	.000
	Within Groups	.660	8	.083		
	Total	21.726	11			
CONC150	Between Groups	29.544	3	9.848	195.290	.000
	Within Groups	.403	8	.050		
	Total	29.947	11			
CONC200	Between Groups	74.723	3	24.908	91.008	.000
	Within Groups	2.189	8	.274		
	Total	76.912	11			
CONC250	Between Groups	138.396	3	46.132	47.676	.000
	Within Groups	7.741	8	.968		
	Total	146.136	11			

Post Hoc Test

Homogeneous Subsets

CONC0

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
roots	3	.5061	
stems	3	.8221	
flowers	3	.8688	
leaves	3		2.0823
Sig.		.243	1.000

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 3.000.

CONC50

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
roots	3	.6294		
flowers	3		1.1253	
stems	3		1.1276	
leaves	3			3.0878
Sig.		1.000	.987	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
roots	3	.8698	
flowers	3	1.2699	
stems	3	1.3695	
leaves	3		4.1989
Sig.		.075	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC150

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
roots	3	1.1987		
flowers	3	1.4943	1.4943	
stems	3		1.8978	
leaves	3			5.1083
Sig.		.146	.059	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC200

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
roots	3	1.4456	
flowers	3	1.8011	
stems	3	2.2378	
leaves	3		7.5544
Sig.		.113	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC250

Duncan[a]

PART	N	Subset for alpha = .01	
		1	2
roots	3	2.1907	
flowers	3	3.0504	
stems	3	3.3239	
leaves	3		10.6381
Sig.		.213	1.000

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 3.000.

Table F-6 Zinc accumulation in globe amaranth (*G. globosa* L.)

Oneway

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CONC0	Between Groups	.401	3	.134	4.976	.031
	Within Groups	.215	8	.027		
	Total	.615	11			
CONC50	Between Groups	.896	3	.299	4.069	.050
	Within Groups	.587	8	.073		
	Total	1.483	11			
CONC100	Between Groups	2.260	3	.753	11.785	.003
	Within Groups	.511	8	.064		
	Total	2.771	11			
CONC150	Between Groups	7.157	3	2.386	18.728	.001
	Within Groups	1.019	8	.127		
	Total	8.176	11			
CONC200	Between Groups	16.696	3	5.565	12.447	.002
	Within Groups	3.577	8	.447		
	Total	20.273	11			
CONC250	Between Groups	24.696	3	8.232	27.488	.000
	Within Groups	2.396	8	.299		
	Total	27.091	11			

Post Hoc Test

Homogeneous Subsets

CONC0

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
flowers	3	.0700
stems	3	.1733
leaves	3	.3767
roots	3	5429
Sig.		.011

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 3.000.

CONC50

Duncan[a]

PARTS	N	Subset for alpha =.01
		1
flowers	3	.1313
stems	3	.6174
leaves	3	.7498
roots	3	.8394
Sig.		.017

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC100

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.1811	
roots	3		1.0258
stems	3		1.0717
leaves	3		1.3372
Sig.		1.000	.186

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC150

Duncan[a]

PARTS	N	Subset for alpha = .01		
		1	2	3
flowers	3	.2646		
roots	3		1.3869	
stems	3		1.6745	1.6745
leaves	3			2.4129
Sig.		1.000	.353	.035

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC200

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.4812	
roots	3	1.9113	1.9113
stems	3	2.0706	2.0706
leaves	3		3.8065
Sig.		.023	.010

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

CONC250

Duncan[a]

PARTS	N	Subset for alpha = .01	
		1	2
flowers	3	.9691	
roots	3	2.3797	
stems	3		3.9076
leaves	3		4.7027
Sig.		.013	.113

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 3.000.

Appendix G

Statistical analysis of the efficiency of cadmium and zinc removal in plants

Table G-1 The efficiency of cadmium removal in chrysanthemum (*D. difflora*)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.007	1	.007	1428.436	.001
	Error	1.026E-05	2	5.131E-06(a)		
CONC	Hypothesis	.001	4	.000	6.963	.010
	Error	.000	8	4.367E-05(b)		
REP	Hypothesis	1.026E-05	2	5.131E-06	.117	.891
	Error	.000	8	4.367E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% cadmium removal in chrysanthemum

Duncan[a,b]

CONC	N	Subset 1	Subset 2
100.00	3	.0110	
80.00	3	.0138	
60.00	3	.0210	.0210
40.00	3		.0314
20.00	3		.0333
Sig.		.114	.060

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 4.367E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Table G-2 The efficiency of cadmium removal in marigold (*T. erecta* L.)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.004	1	.004	38.055	.025
	Error	.000	2	9.790E-05(a)		
CONC	Hypothesis	.000	4	3.126E-05	.699	.614
	Error	.000	8	4.471E-05(b)		
REP	Hypothesis	.000	2	9.790E-05	2.190	.174
	Error	.000	8	4.471E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% cadmium removal in marigold

Duncan[a,b]

CONC	N	Subset 1
80.00	3	.0121
60.00	3	.0124
40.00	3	.0175
20.00	3	.0182
100.00	3	.0186
Sig.		.296

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 4.471E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Table G-3 The efficiency of cadmium removal in globe amaranth (*G. globosa* L.)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.005	1	.005	457.108	.002
	Error	2.203E-05	2	1.101E-05(a)		
CONC	Hypothesis	.001	4	.000	16.178	.001
	Error	.000	8	1.749E-05(b)		
REP	Hypothesis	2.203E-05	2	1.101E-05	.630	.557
	Error	.000	8	1.749E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% cadmium removal in globe amaranth

Duncan[a,b]

CONC	N	Subset 1	Subset 2	Subset 3
100.00	3	.0103		
80.00	3	.0117		
60.00	3	.0149	.0149	
40.00	3		.0206	
20.00	3			.0342
Sig.		.234	.132	1.000

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 1.749E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Table G-4 The efficiency of zinc removal in chrysanthemum (*D. difflora*)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.007	1	.007	355.917	.003
	Error	3.927E-05	2	1.964E-05(a)		
CONC	Hypothesis	.000	4	4.135E-05	2.021	.184
	Error	.000	8	2.046E-05(b)		
REP	Hypothesis	3.927E-05	2	1.964E-05	.960	.423
	Error	.000	8	2.046E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% zinc removal in chrysanthemum

Duncan[a,b]

CONC	N	Subset 1	Subset 2
150.00	3	.0175	
200.00	3	.0198	.0198
50.00	3	.0200	.0200
100.00	3	.0238	.0238
250.00	3		.0269
Sig.		.150	.110

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 2.046E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Table G-5 The efficiency of zinc removal in marigold (*T. erecta* L.)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.025	1	.025	1386.922	.001
	Error	3.655E-05	2	1.828E-05(a)		
CONC	Hypothesis	.001	4	.000	3.122	.080
	Error	.001	8	6.698E-05(b)		
REP	Hypothesis	3.655E-05	2	1.828E-05	.273	.768
	Error	.001	8	6.698E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% zinc removal in marigold

Duncan[a,b]

CONC	N	Subset 1	Subset 2
150.00	3	.0318	
200.00	3	.0338	
250.00	3	.0420	.0420
100.00	3	.0460	.0460
50.00	3		.0518
Sig.		.081	.197

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 6.698E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Table G-6 The efficiency of zinc removal in globe amaranth (*G. globosa* L.)

Oneway

ANOVA

% removal

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	.009	1	.009	97.301	.010
	Error	.000	2	9.520E-05(a)		
CONC	Hypothesis	.000	4	3.339E-05	.508	.732
	Error	.001	8	6.574E-05(b)		
REP	Hypothesis	.000	2	9.520E-05	1.448	.291
	Error	.001	8	6.574E-05(b)		

a MS(REP)
b MS(Error)

Post Hoc Test

Homogeneous Subsets

% zinc removal in globe amaranth

Duncan[a,b]

CONC	N	Subset 1
50.00	3	.0222
150.00	3	.0224
100.00	3	.0236
200.00	3	.0257
250.00	3	.0303
Sig.		.289

Means for groups in homogeneous subsets are displayed. Based on Type III Sum of Squares The error term is Mean Square(Error) = 6.574E-05.
a Uses Harmonic Mean Sample Size = 3.000.
b Alpha = .05.

Appendix H

Preliminary risk assessment

Paull methodology

The Paull methodology is an adaptation of the EPA risk screening methodology for chemicals in soil and incorporates dermal and dermal-to-oral exposures (Souther, 2005). For the Paull methodology, the theoretical maximum dermal and oral exposure was calculated as follows:

$$D = \frac{Cs \times Cr \times fss \times [((1 - fdo) \times (fder)) + (fdo \times fgi)] \times EF \times ED}{BW \times AT \times fwipe}$$

Note :

D	=	workers Dose (µg/kg/day)
Cs	=	Concentration on surface (µg/cm^2)
Cr	=	surface area Contact Rate (1,680 cm^2/d)
fss	=	transfer rate from surface to skin (0.1)
fdo	=	transfer from dermal to oral (0.05)
fder	=	dermal adsorption fraction (0.01 for inorganics and 0.1 for organics)
fgi	=	oral adsorption efficiency (0.01 for cadmium, 0.2 for zinc) (USEPA, 1989)
EF	=	Exposure Frequency (250 days per year)
ED	=	Exposure Duration (1 year)
BW	=	adult Body Weight (70 kg)
AT	=	Averaging Time (70 years)
Fwipe	=	wipe sample removal frequency (1)

Table H-1 Calculation of cadmium and zinc concentration on surface

Experimental plants	The amounts of cadmium in flowers at concentration of 100 mg Cd/kg soil (mg Cd/kg)	The amounts of zinc in flowers at concentration of 250 mg Zn/kg soil (mg Zn/kg)	Flower surface areas (cm^2)	Concentrations on surface ($\mu g/cm^2$)	
				Cadmium	Zinc
Chrysanthemum	-	0.87	100	-	8.70
Marigold	0.79	3.05	200	3.95	15.25
Globe amaranth	0.20	0.97	100	2.00	9.70

Table H-2 Comparison of the results to Provisional Tolerable Weekly intake (PTWI)

Experimental plants	workers Dose (µg /kg body weight/week)		The Provisional Tolerable Weekly intake (PTWI) (µg /kg body weight/week)
	Cadmium	Zinc	
Chrysanthemum	-	10.171	7 µg Cd/kg body weight/week for cadmium and 25 µg Zn/kg body weight/week for zinc
Marigold	2.373	17.829	
Globe amaranth	1.197	11.340	

BIOGRAPHY

Porn-umpa Surabhukdi was born on 23rd of March 1982 in Ubonrachatani. She started to study at Khon Kean University in 2000 and graduated the Bachelor degree of Environmental Science in 2004 from Faculty of Science. Then, she continued her further education for Master degree at Interdisciplinary Program in Environmental Science, Chulalongkorn University in 2004.