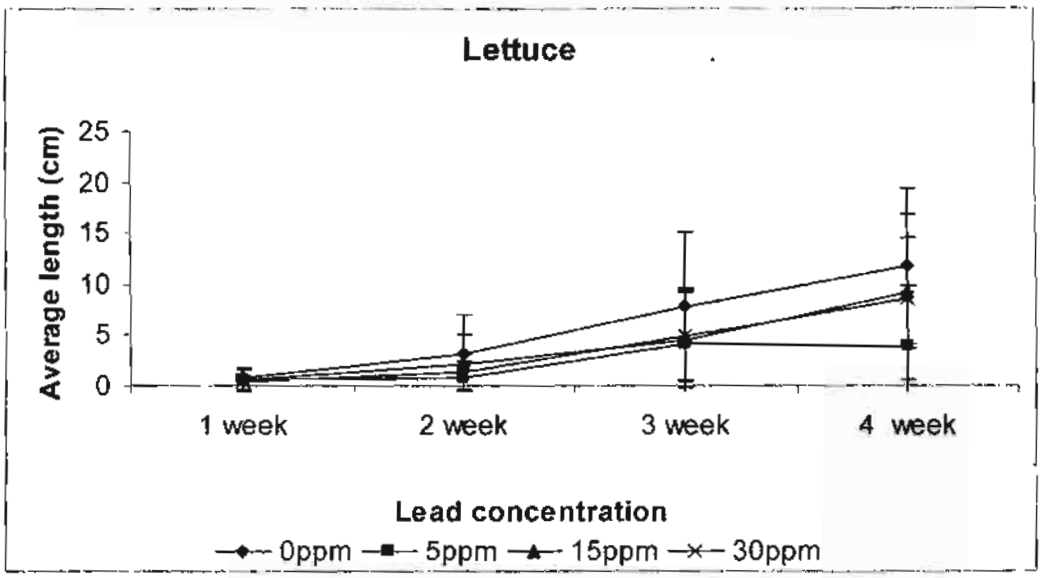


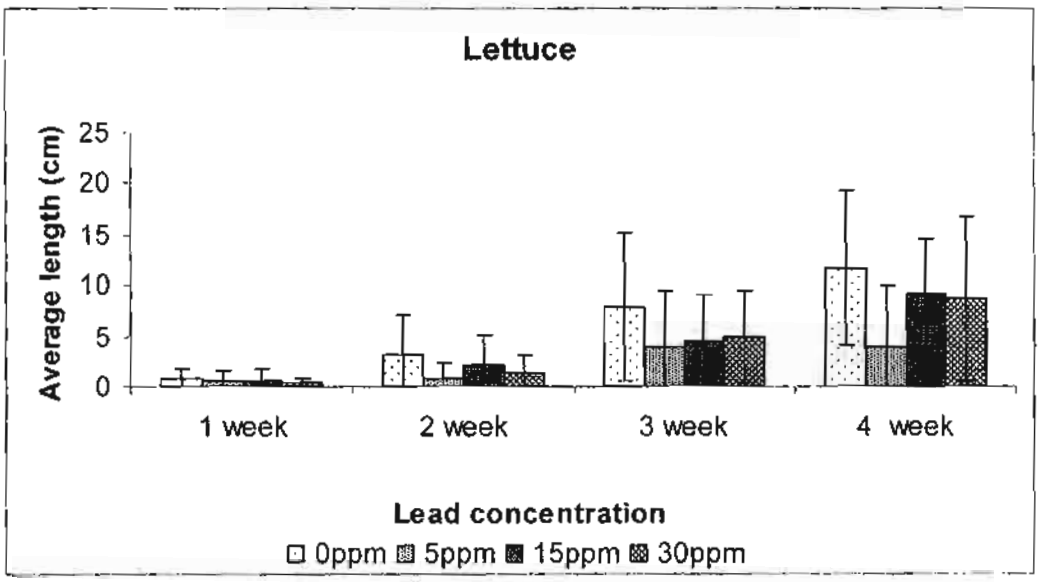


Figure 11: Column and line chart types for average length of lettuce showed no significant difference (P>0.05) after four week exposure to lead any concentration. Values represent the mean ±SD of five replicate samples.

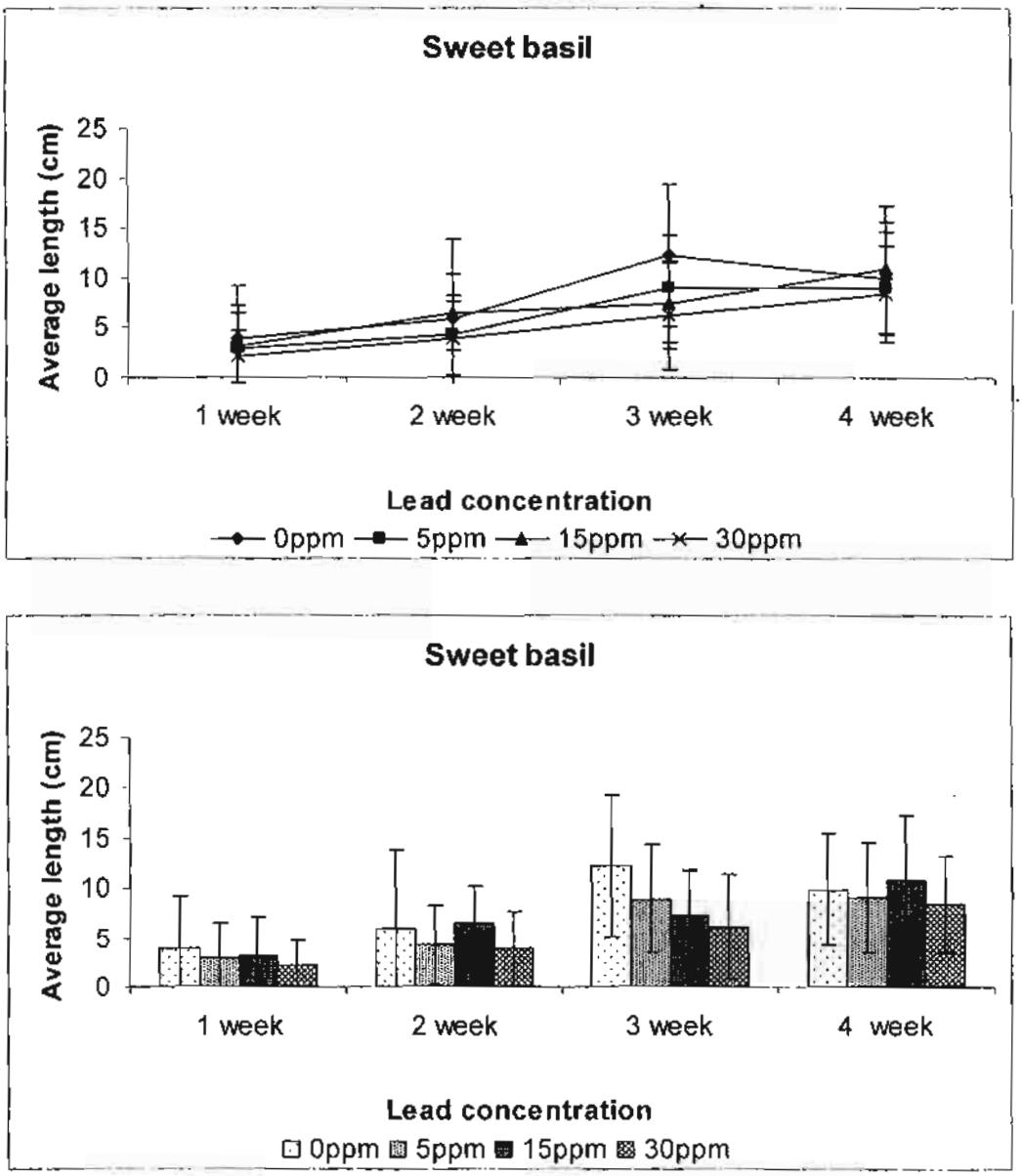


Figure 12: Column and line chart types for average length of sweet basil showed no significant difference (P>0.05) after four week exposure to lead any concentration. Values represent the mean ±SD of five replicate samples.

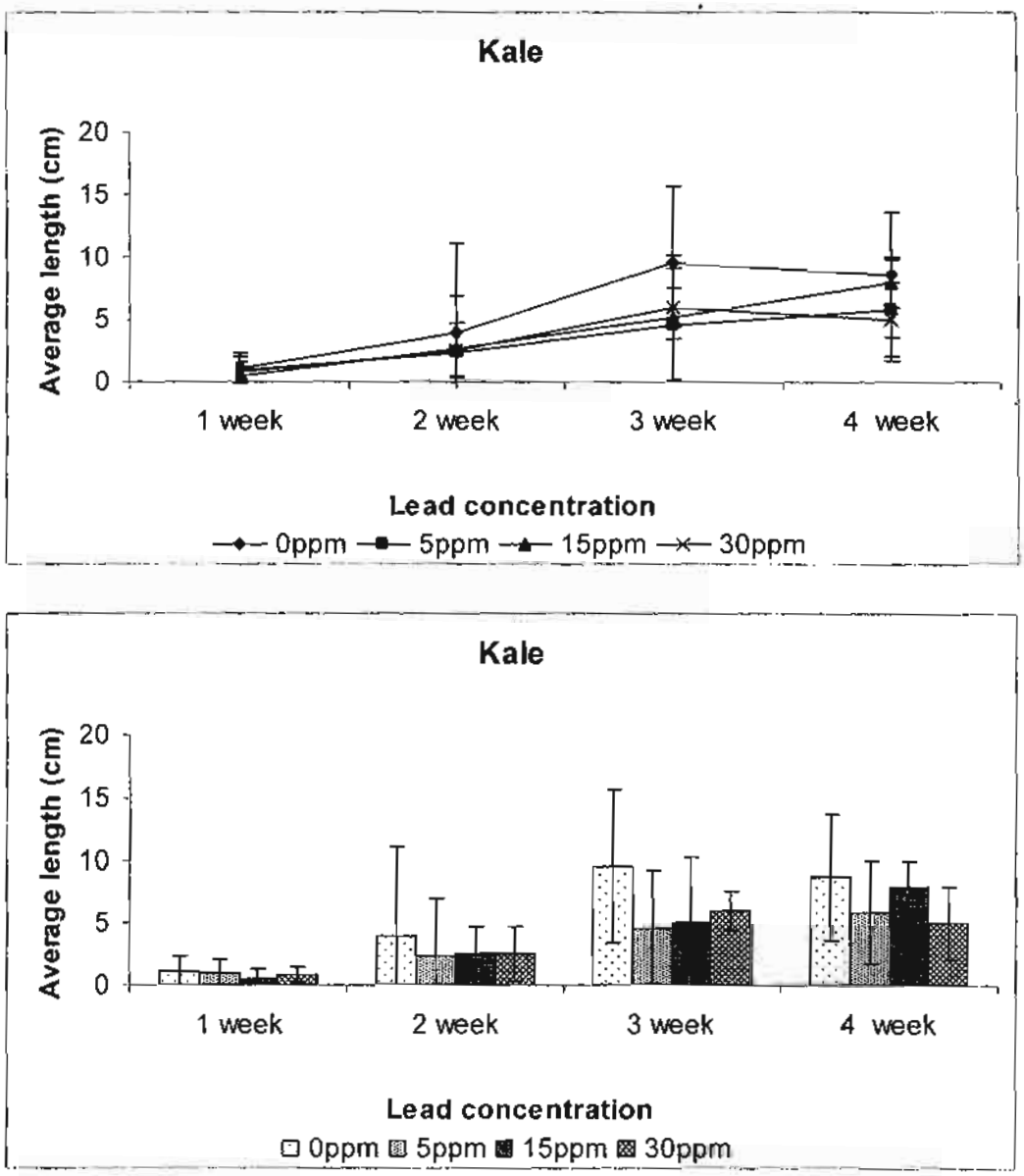
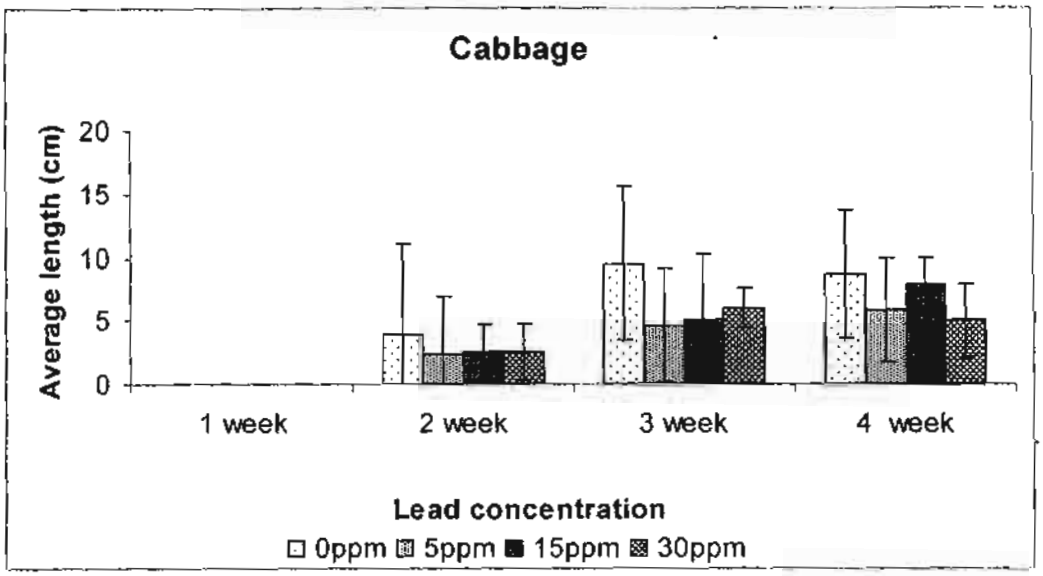


Figure 13: Column and line chart types for average length of kale showed no significant difference ($P>0.05$) after four week exposure to lead any concentration. Values represent the mean ±SD of five replicate samples.



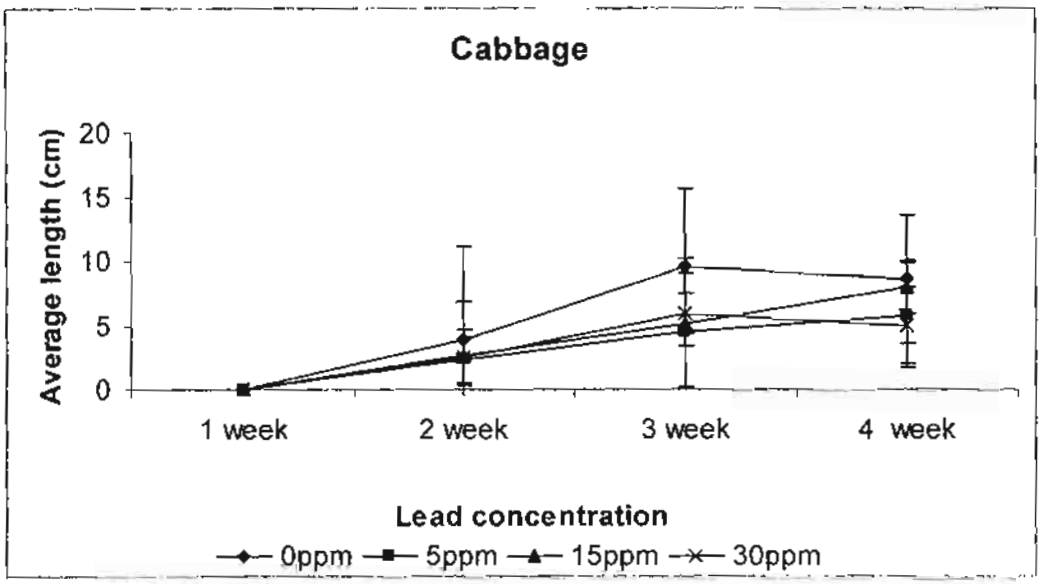


Figure 14: Column and line chart types for average length of cabbage showed no significant difference (P>0.05) after four week exposure to lead any concentration. Values represent the mean ±SD of five replicate samples.

4.3 Plant physiological changes

The seedling still grew in the presence of high concentrations of lead. However, the subsequent seedlings growth (after the breakage of seed coat) was severely inhibited at much lower concentrations of lead.

Mung bean, cucumber, morning glory, sweet basil, lettuce, kale, tomato, cabbage, holy basil, and bird pepper are dicotyledonous plants. In many dicots the primary roots continues to elongate and forms the taproot. Many smaller branch roots may grow from the taproot (Martin and Rene, 2006). The effect of lead on root growth was observed as a decrease in the growth of vegetables during taproot elongation, with increasing lead concentration (from 5 mg kg-1 to 30 mg kg-1). The taproot growth was decreased after exposure to lead at 5 mg kg-1, 15 mg kg-1 and 30 mg kg-1 of lead concentrations as compared to the control.

EDTA was added to completely dissolve the lead nitrate solution. EDTA also caused easier and higher rate of translocation of lead to the shoot as compared to other parts of the plants as research done by Andrew D. Vassil and Co. in Indian mustard. EDTA destroys the physiological barrier(s) in roots by removal of stabilizing Zn^{2+} and Ca^{2+} from the plasma membrane. The primary effect of lead toxicity in plants is a rapid inhibition of root growth, probably due to the inhibition of cell division in the root tip (Lee Y, 2000). So in this study Pb and EDTA may play an importance role in decreasing a taproots elongation.

This result indicated that lead had negatively effects on root elongation of mung bean, cucumber, morning glory, sweet basil, lettuce, kale, tomato, cabbage, holy basil, and bird pepper. The vegetables were not tolerant to lead toxicity even at low (5 mg kg-1) concentrations.

Afterward, each plant samples were analysed for its lead accumulated content by using either flame atomic absorption spectrophotometer or graphite furnace atomic absorption spectrophotometer, depending on the amount of lead present in the samples. Plants which were treated with lead concentrations of 5, 15 and 30 mg kg^{-1} *in vitro* for four weeks of exposure, lead concentration was determined. Results were focused on uptake and accumulation of lead in plants, Relative Growth Rate (RGR) and Bioaccumulation coefficient (BC) of the plants.

4.1 Study of uptake and accumulation of lead in plants

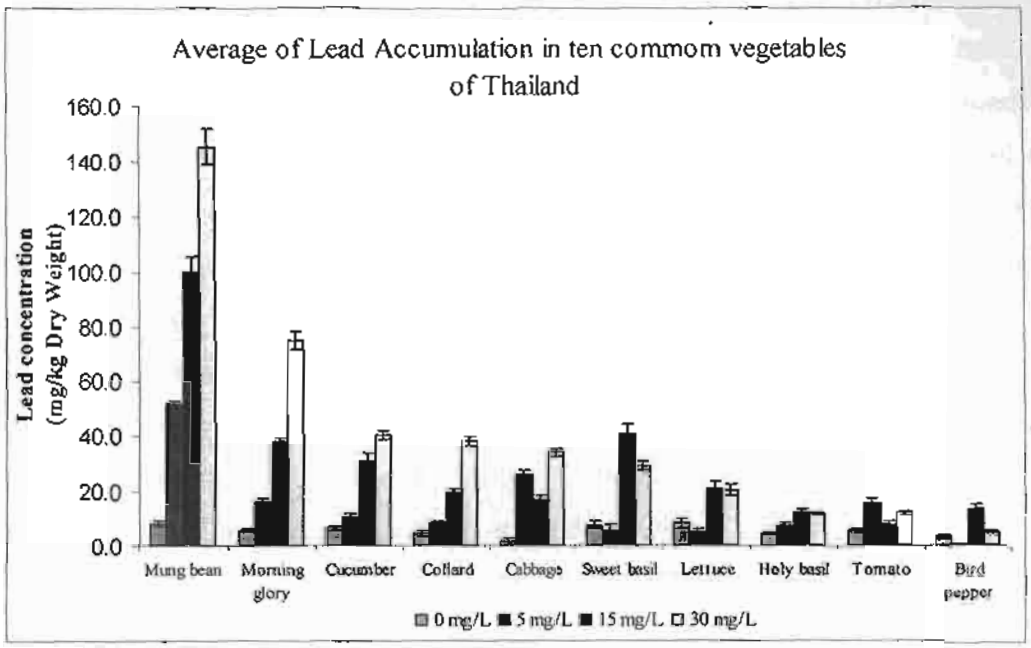


Figure 15: Average of lead accumulation in ten common vegetables of Thailand. Values represent the mean ± SD of three replicate samples at week 4.

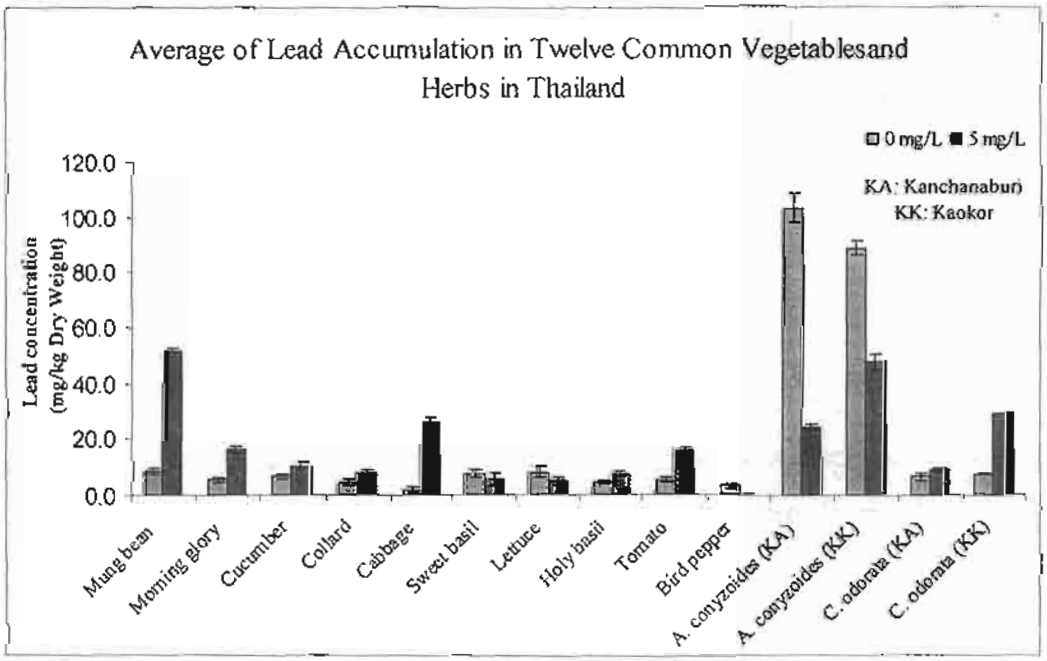


Figure 16: Average of lead accumulation in twelve common vegetables and herbs of Thailand. Values represent the mean ± SD of three replicate samples at week 4. (KK: Kaokor, KA: Kanchanaburi)

In this study, we investigated the lead accumulation in each cultivar of twelve common vegetables and herbs from a common medium which contained various concentrations of lead compounds. Concentration of lead which plants accumulated was determined by flame atomic absorption spectrometry (FAAS) technique and graphite furnace atomic absorption spectrometry (GFAAS) technique. Due to the limit detection of FAAS, some plants that had lead content lower than 0.02 mg kg-1 used in this study were determined by GFAAS that can be used for detection the lead content in plant samples with lead content higher than 1 µg kg-1. Lead was accumulated in plant by transfer the lead metal from root to plant shoot. Most of the plant samples were accumulated lead rise from lower concentration to higher concentration of lead compounds. The plants also increasing accumulated lead compounds when the exposure day was rising. Lead had effect on seed germination of *Sonchus arvensis* due to their low biomass production. The heavy metal analysis of *S. arvensis* could not perform the test. The highest lead accumulation was found in the forth week of lead exposed. Most of the plants showed highest accumulation at 30 mg kg-1 of lead concentration in the media. From the result at week 4 (Figure 15), they can be categorized into three groups of plants according to level of lead accumulations: high, moderate and low lead. Mung bean (145.2 mg kg^{-1} DW) and morning glory (74.7 mg kg^{-1} DW) demonstrated significantly in high lead content among ten common vegetables. The moderate lead accumulations are cucumber (40.1 mg kg^{-1} DW), collard (38.1 mg kg^{-1} DW), cabbage (33.7 mg kg^{-1} DW) and sweet basil (29.1 mg kg^{-1} DW). The low lead accumulations were lettuce (20.2 mg kg^{-1} DW), holy basil (11.7 mg kg^{-1} DW), tomato (11.9 mg kg^{-1} DW) and bird pepper (5.1 mg kg^{-1} DW). Lead metal accumulation by *A. conyzoides* and *C. odorata* were summarized in Figure 16 compared to ten common vegetables.

In Figure 16, both populations of *A. conyzoides* at week 4, the accumulation of lead was higher in control than to 5 mg kg-1 of lead treated and non contaminated site (Kaokor) had higher lead accumulated than the contaminated site (Kanchanaburi). Where as the both population of *C. odorata* at week 4, demonstrated the high level of lead accumulation of lead in contaminated site as compared to non contaminated site with 5 mg kg-1 treated lead compound was higher accumulated than control.

In this study, we found that relative growth rate (RGR) of plant at week 4 was inverse proportion to the concentration of lead contamination. Lead concentration was not significantly affected to the growth of plants (Figure 17). Some plants can be developed themselves to tolerate the toxic of lead and capable to growth with increasing their biomass. However, from the results interpreted that all treated plants continued to develop new leaves and roots. At week 4, *A. conyzoides* had developed their sensitivity to lead exposure in contaminated site.

RGR of *A. conyzoides* at contaminated site (Kanchanaburi) was higher than those in non contaminated site (Kaokor). In *C. odorata*, the non contaminated site (Kaokor) was shown higher relative growth rate than the contaminated site (Kanchanaburi) (Figure 18).

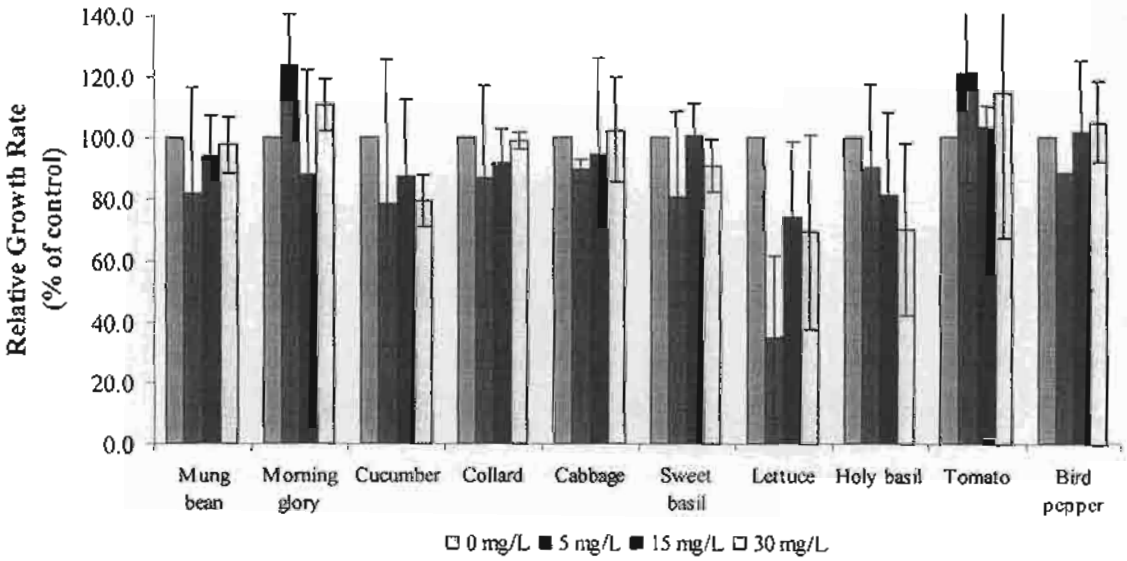


Figure 17: Effect of lead on average of relative growth rate (RGR) in ten common vegetables of Thailand. Values represent the mean ± SD of three replicate samples.

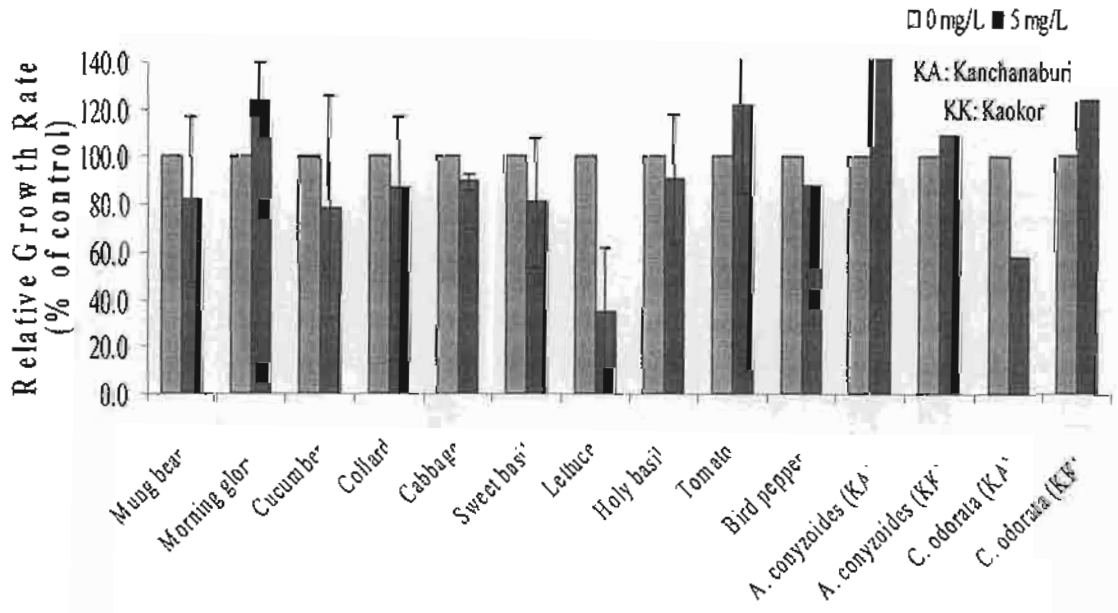


Figure 18: Effect of lead on average of relative growth rate (RGR) in twelve common vegetables and herbs of Thailand. Values represent the mean ± SD of three replicate samples. (KK: Kaokor, KA: Kanchanaburi)

4.3 Bioaccumulation coefficient (BC)

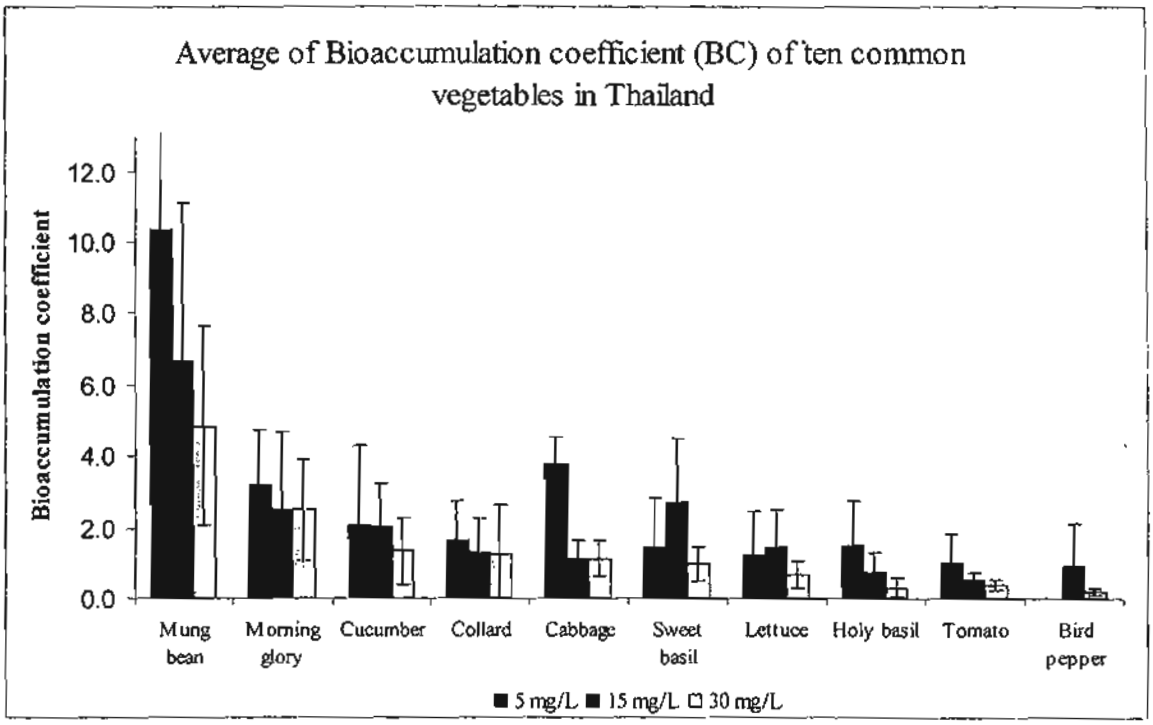


Figure 19: Average of bioaccumulation coefficient (BC) of ten common vegetables of Thailand. Values represent the mean ± SD of three replicate samples at week 4.

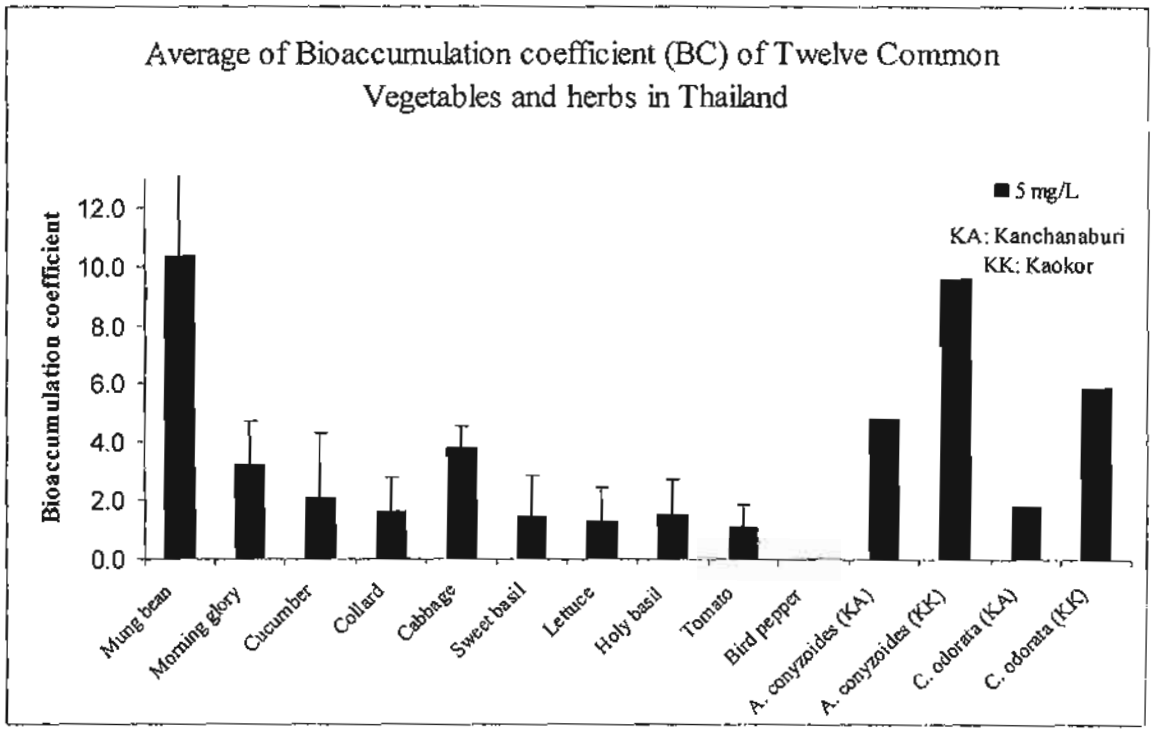


Figure 20: Average of bioaccumulation coefficient (BC) of twelve common vegetables and herbs of Thailand. Values represent the mean ± SD of three replicate samples at week 4. (KK: Kaokor, KA: Kanchanaburi)

The BC at week 4 in each vegetable had same trend decreasing from low concentration of lead accumulation to high lead accumulation. The highest BC in each vegetable increased from mung bean > morning glory > cucumber > collard > cabbage > sweet basil > lettuce > holy basil > tomato > bird pepper (Figure 20). The highest BC for lead in each vegetable was 10.3, 3.2, 2.1, 1.6, 3.8, 2.7, 1.5, 1.0, 1.5, and 0.9 respectively. At 5 mg kg-1 of lead treated in week 4 of *A. conyzoides* and *C. odorata* in contaminated site (Kanchanaburi) were shown lower than the noncontaminated site (Kaokor) (Figure 20).

Markert (1994) gave the values of metal concentration of normal plant with which the uptakes in a species could be compared, and showed that the normal compositions of lead in plant are 1 mg kg^{-1} DW. Lead is a non-essential element and can be toxic to photosynthesis (Skórzyñska-Polit and Baszyñski, 1997), chlorophyll synthesis (Stobart et al., 1985) abd antioxidase enzyme (Somashekaraiah et al., 1992). In this study, all vegetables and herbs showed abnormal lead concentration in their tissue. In general, the mean level of lead in plants collected increased with the increased concentration of lead in media. Numerous studies have demonstrated that heavy metal concentration in plants is a function of heavy metal content in the environment (Xiong, 1998).

There are three indicators to define a lead hyperaccumulator: (1) the concentration of lead in plant shoots > 1000 mg kg^{-1} (Barker and Brooks, 1989); (2) the concentration of lead in shoots is 10-500 times more than that in plants from non-polluted areas (Pb 5 mg kg^{-1}) (Shen and Liu, 1998); (3) the TF or shoot:root ratio >1 (Barker and Brooks, 1989, Baker et al., 1994). In this study, although the translocation factor (TF) or shoot:root ratio was not determined but with two above indicators can evaluated that all ten common vegetables could not be considered as hyperaccumulator. The highest lead accumulation was mung bean (145.2 mg kg^{-1} DW) or 0.014% of lead in total weight of plant.

In the soil, the bioavailability of lead is quite low due to low solubility of most lead compounds, and the readily precipitation of lead by sulfate and phosphate at the root system (Baker et al., 2000). Arvik and Zimdahl (1974) indicated that Pd uptake did not require any energetic exposure. Lead can be taken up from the surrounding solution against concentration gradients and deposited in large amounts in the roots (Wierzbicka, 1987). Heavy metals are transported from roots to shoots in terrestrial plants to different parts. Different metals are different motile and within a plant, lead is less motile than extents other Cu, Zn, and Cd (Greger, 2004).

Most of the shoot accumulation was found in stems but not pass though leaves. Lead deposition in the cell membrane and cell wall (Sahi et al., 2002). There was no report of plants

with ability to solubilize lead from the soil metrix which lead in nature is insoluble form (Blaylock and Huang, 2000).These knowledge can be explained that lead will not pass through leaves. The vegetables that consumed only leaves and fruits (tomato, bird pepper) can be consumed. However, lead may present in fruit vegetables such as tomato but in very less amount. Even though the seed of mung bean that people consumed as sweet seed mung bean soup, the lead may pass through the seed in very little amount because the lead was heavy molecule and mostly accumulate in root (Hussein, Obuid-Allah et al. 2006)

The results in sweet basil confirm the understanding that high heavy metal concentrations in the growth medium may increase metal accumulation in plant tissue, but not in the essential oil, which is the final marketable product (Zheljazkov and Warman 2003). It can imply that sweet-basil could be grown as an essential oil crop in contaminated soil without a risk of contamination of the end product, the essential oil.

Lead was not significantly effect on relative growth rate in all ten common vegetables. But lead showed significantly effect on shoot and root length extension in bird pepper, tomato, mung bean and holy basil (Piemyoo S., 2005). The genotypic differences in accumulation between cultivars are important. In this study, all crops were grown at the same location so it is expected that the deposition would have been relatively similar. In the view of the relatively high accumulation of lead shown by mung bean and morning glory, these species would not be suitable for edible vegetables that cultivar in contaminated area.

For health consequences of lead in edibles, after lead is ingested, it can only adversely affect health if it is absorbed. Adults absorb approximately 11% of ingested lead (USFDA, 1998), and excrete approximately 50-60% of that ingested over the short term (at a half-life of approximately 20 days) and an additional 25% over many months. The residual lead accumulates in mineralizing tissues (i.e. bones and teeth). Children can absorb lead from 30-75% of ingested lead (USFDA, 1998) and infant can excrete only approximately 5μg kg^{-1} day^{-1} (Ziegler et al., 1978). Accumulation of lead in women of child bearing age is problematic, as transfer of lead to the fetus can occur, and lead stored to bone is mobilized during pregnancy (hence, made available to transfer to the fetus) (Gomaa et al., 2002). Diets laden with urban-grown herbs may substantially contribute to a person's lead burden. For example, if a person were to consume as little as 1 tablespoon of dried cilantro (weighing approximately 1.75 g), with a lead concentration of 49 mg of lead per gram dry weight of sample, they would be ingesting 85.75 mg of lead. As a result, this value would contribute to their total body burden of lead, for it exceeds the US FDA's recommended Provisional Total Tolerable Intake Levels (PTTIL) for all age groups, which are defined at 6 mg lead/day for children up to 6 years of age, 15 mg

leady/day for children 7 years and older, 25 mg lead/day for pregnant woman and 75 mg lead/day for other adults (US FDA, 1993). In 1991, the Centre for Disease Control and Prevention, Atlanta, United States of America provided guideline of lead poisoning in blood lead levels is equal or more than 10 microgram per deciliter (US EPA, 2001).

However, the level of safe lead concentration in edible vegetable is not clearly identified. It is because of many factors influences such as amount of vegetables that people consumed and times that people consumed in each species of plants. However, United States Food and Drug Administration defined the range of lead concentration in vegetable that can be safe for consumption. It is ranging from 15-40 ppm of lead that accumulated in plant (US FDA, 1993).

These results indicate that the vegetables that lead had less effect on growth and still low accumulation are lettuce, sweet basil, cabbage and collard respectively.

The contrast pattern of Bioaccumulation coefficient and lead accumulation pattern, Kim et al. (2003) suggested such discrepancies arise due to variation in heavy metal concentration, form of metal present and plant species.

The ecotype differences in *A. conyzoides* and *C. odorata* were showed significantly different in lead accumulation in plant in both contaminated site (Karnjanburi) and non contaminated site (Kaokor). *A. conyzoides* from (Kaokor) developed themselves to accumulate lead more than the species from contaminated site (Karnjanaburi). P. Tanhan (2007) indicate that *C. odorata* was that hyperaccumulator but in the study, the genotypic different effect the accumulation of the plant. However, *C. odorata* has certain detoxification mechanisms within the tissue, which allow plants to accumulate such high amount of lead (Greger, 2004). It may be recognized that the medium lead treated instead of soil field, probably gave rise to enhanced uptake (Alexander P.D., 2006).

Because urban gardening is a wide spread activity with potential health impacts. The following lists recommendations urban gardeners may elect to follow so to lower risks associated with gardening.

Recommendations for urban gardeners (M.E. Finster et al., 2003)
• Survey the property to determine the potential lead hazards, extent of the contamination and location of high-risk areas.
• Plan to locate fruit and vegetable gardens away from buildings, especially if peeling paint is evident and sites where sludge with heavy metals was applied.
• Do not grow food crops in a soil that is contaminated to levels greater than 400 ppm.

• Analyze lead concentration in soil samples from areas where vegetable gardens exist or are planned.

• Instead, use either containers or construct raised beds, with a semi-permeable barrier between the clean and contaminated soil.

• Where container or raised bed gardening is not possible, fruiting crops should be grown.

• Root vegetables, leafy greens and herbs should not be planted in contaminated soils.

• Test new topsoil before using it and annually retest the garden soil to monitor for recontamination.

• Do not use plants grown in contaminated soils for compost.

• Use mulch or a weed tarp in garden beds to reduce the potential for aerial soil dust deposition or soil splash up on crops.

The risk of gardening in lead contaminated soil is both from the lead contamination of the edibles and the practices that might promote ingestion of lead contaminated soil (e.g. oral behaviors, soil track-in to the home).While there are no federal standards or guidelines for soil lead concentration for home gardening, it is recommend that all food crops-should be grown in a soil in which the lead concentration is less that 400 ppm, the current US regulatory soil hazard standard that is considered safe for child play (USEPA, 2001). However, the gardener should recognize that any regulatory cutoff point does not ensure safety and keep in mind that background soil lead contamination levels are less than one-tenth this suggested 400 ppm soil hazard level (Shacklette and Boerngen, 1984).

Moreover, it is important that plants grown in contaminated soils are not used for compost, for this would result in lead recycling within a garden since most plants were shown to accumulate lead to some extent, particularly within their roots. Due to concern about directly ingesting lead from soil adhered to the leaves, fruits or roots of crops, it is important to remove outer leaves of leafy greens, peel vegetables when possible, and thoroughly wash all items with a detergent before consumption. Finally, when consumed the vegetables, it is recommended that wash the vegetables with 1% vinegar solution (2.5 tablespoons per gallon) for 15 min to dissolved lead contaminated on the surface skin of vegetables.

References

Alexander, P. D., B. J. Alloway, et al. (2006). "Genotypic variations in the accumulation of Cd, Cu, Pb and Zn exhibited by six commonly grown vegetables." Environmental Pollution 144(3): 736-745.

Alvarado MC, Zsigmond LM, Kovács I, Csépl A, Koncz C, Szabados LM (2003) Gene trapping with firefly luciferase in *Arabidopsis*:tagging of stress-responsive genes. Plant Physiol 134:18-27.

Andrew D. Vassil, Yoram Kapulnik, Ilya Raskin, and David E. Salt. 1998. The Role of EDTA in Lead Transport and Accumulation by Indian Mustard. Plant Physiol. 117: 447–453.

Antosiewicz D.M. 1992. Adaptation of plants to environment polluted with heavy metals. Acta Soc. Bot. Pol. 61: 281–299.

APHA, AWWA, WEF, 1998. Standard Methods for the Examination of Water and Wastewater. The association, Washington DC.

Arvik, J.H., Zimdahl, R.L., 1974. The induce of temperature, pH, and metabolic inhibitors on uptake of lead by plant roots. J. Environ. Qual. 3, 374--376.

Baker AJM, Brooks RR (1989) Terrestrial higher plants which hyperaccumulate metallic elements- a review of their distribution, ecology and phytochemistry. Biorecovery 1:81-126.

Baker, A.J.M., McGrath, S.P., Sidoli, C.M.D., Reeves, R.D., 1994. The possibility of in situ heavy metals decontamination of polluted soils using crops of metal-accumulating plants. Resour. Conserv. Recyl. 11, 41–49.

Baker AJM, Whiting SN (2002) In search of the Holy Grail- a further step in understanding metal hyperaccumulation. New Phytol. 155:1-4

Baker R, Simpson FS (1998) Cleanup Order Issued to Chrome Crankshaft. Sacramento, CA, California Environmental Protection Agency, Department of Toxic Substances Control:1-2, http://www.dtsc.ca.gov/SiteCleanup/Chrome_Crankshaft/NEWS_1998_Chrome_Crankshaft_Cleanup_Order_t-21-98.pdf

Birnbaum K, Shasha DE, Wang JY, Jung JW, Lambert GM, Galbraith DW, Benfey PN (2003) A gene expression map of the *Arabidopsis* root. Science 302:1956-60.

Bizily SP, Kim T, Kandasamy MK, Meagher RB (2003) Subcellular targeting of methylmercury lyase enhances its specific activity for organic mercury detoxification in plants. Plant Physiol 131:463-471.

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

Blaylock MJ, Huang JW, Elless MP, Edenspace Systems Corporation (2001) Phytoremediation of Arsenic in Soil. Annual International Conference on Soils, Sediments and Waters.

Body, P.E., P.R. Dolan, and D.E. Mulcahy (1991) Environmental lead: A review. Crit. Rev. Eviron. Control 20:299-310.

Brooks RR, Lee J, Reeves RD, Jaffré T (1977) Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. J Geochem Explor 7:49-77.

Chaney RL, Angle JS Li YM, Baker AJM (1999) Method for phytomining of nickel, cobalt and other metals from soil. U.S. Patent No. 5944872 (continuation in-part of US Patent 5711784 issued Jan. 27, 1998)

Clemens S, Palmgren MG, Kramer U (2002) A long way ahead: understanding and engineering plant metal accumulation. Trends Plant Sci 7:309-315.

Dushenkov D. 2003. Trends in phytoremediation of radionuclides. Plant and Soil. 249: 167-175.

Eltrop L., Brown G., Joachim O., Brinkmann K. 1991. Lead tolerance of Betula and Salix in the mining area of Mechernich/Germany. Plant Soil. 131: 275-285.

Ensley B (2000) Rationale for use of phytoremediation. In: Raskin I, Ensley B (eds) Phytoremediation of toxic metals: Using plants to clean up the environment. Wiley Interscience, NewYork, pp 3-12.

Freeman JL, Persans MW, Nieman K, Albrecht C, Peer WA, Pickering IJ, Salt DE (2004) Increased glutathione biosynthesis plays a role in nickel tolerance in *Thlaspi* nickel hyperaccumulators. Plant Cell 16:2176-2191.

Garcia G, Faz A, Cunha M (2004) Performance of *Piptatherum miliaceum* (Smilo grass) in edaphic Pb and Zn phytoremediation over a short growth period. Int Biodeter & Biodeg 54:245-250.

Gomaa A, Hu H, Bellinger D, Schwartz J, Tsaih SW, Gonzalez-Cossio T, Schnaas L, Peterson K, Aro A, Hernandez-Avila M.Maternal bone lead as an independent risk factor for fetal neurotoxicity: a prospective study. J Pediatr. 2002.110:110–118.

Greger, M., 2004. Metal availability, uptake, transport and accumulation in plants. In: Prasad, M.N.V. (Ed.), Heavy Metal Stress in Plants from Biomolecules to Ecosystems, second ed. Springer-Verlag, Berlin, pp. 1–27.

Gstoettner EM, Fisher NS (1995) Accumulation of cadmium, chromium and zinc by the moss *Sphagnum papillosum* Lindle. Water Air Soil Pollut. 93:321-330.

Hall JL (2002) Cellular mechanisms for heavy metal detoxification and tolerance. J Exp Bot 53:1-11.

Huang JW., Chen J., Berti WB., Cunningham SD. 1997. Phytoremediation of lead-contaminated soils: role of synthetic cheates in lead phytoextraction. Environ. Sci. Technol. 31: 800-805.

Hussein, M. A., A. H. Obuid-Allah, et al. (2006). "Seasonal variation in heavy metal accumulation in subtropical population of the terrestrial isopod, *Porcellio laevis*." Ecotoxicology and Environmental Safety. 63(1): 168-174.

Jones L.H.P., Clement C.R., Hopper M.J. 1973. Lead uptake from solution by perennial ryegrass and its transport from roots to shoots. Plant Soil. 38: 403–414.

Kumar P, Dushenkov V, Motto H, Raskin I (1995) Phytoextraction - the use of plants to remove heavy-metals from soils. Environ Sci Technol. 29:1232-1238.

Kupper H, Lombi E, Zhao FJ, McGrath SP (2000) Cellular compartmentation of cadmium and zinc in relation to other elements in the hyperaccumulator *Arabidopsis halleri*. Planta 212:75-84.

Kupper H, Zhao F, McGrath SP (1999) Cellular compartmentation of zinc in leavesof the hyperaccumulator *Thlaspi caerulescens*. Plant Physiol. 119:305-311.

Lee Y., Eun SO., Youn HS. 2000. Lead disturbs microtubule organization in the root meristem of Zea mays. Physiol. Plant. 110: 357-365.

Leon V. Kochian. 2000. Phytoremediation: Using Plants to Clean Up Soils. Plant Biological and Molecular Processes, an ARS National Program, and Agricultural Research.

Ma L.Q., Komar K.M., Tu C., Zhang W., Cai Y., and Kenelley E.D. 2001. Bioremediation: A fern that hyperaccumulates arsenic. Nature. 409-579.

Markert, B., 1994. Plant as biomonitors-potential advantages and problems. In: Adriano, D.C., Chen, Z.S., Yang, S.S. (Eds). Biogeochemistry of Trace Elements. Sci. Tech. Lett., Northwood, NY, pp. 601–603.

Magorzata Wierzbicka, Jolanta Obidzin´ska. 1998. The effect of lead on seed imbibition and germination in different plant species. Plant Science. 137: 155–171.

Martin Cocks and Rene Frans: http://www.botany.uwc.ac.za/ecotree/index.htm (April 18, 2006)
McGrath SP, Zhao FJ (2003) Phytoextraction of metals and metalloids from contaminated soils. Curr Opin Biotechnol 14:277-282.

McIntyre T. 2003. Phytoremediation of heavy metals from soils. Adv Biochem Eng Biotechnol. 78: 97–123.

Meharg A, Macnair M (1992a) Genetic correlation between arsenate tolerance and the rate of influx of arsenate and phosphate in *Holcus lanatus* L. Heredity 69:336-341.

Meharg A, Macnair M (1992b) Suppression of the high-affinity phosphate-uptake system: a mechanism of arsenate tolerance in *Holcus lanatus* L. J Exp Botany 43:519-524.

Mengel K., Kirkby E.A. 1980. Principles of Plant Nutrition. International Potash Institute. Norblaufen-Bern. Switzerland.

Mitch M.L. 2002. Phytoextraction of Toxic Metals: A Review of Biological Mechanisms. Published in J. Environ. Qual. 31: 109–120.

Nanda-Kumar, P.B.A., Dushenkov, V., Motto, H., Raskin, I., 1995. Phytoextraction: the use of plants to remove heavy metals from soils. Environ. Sci. Technol. 29, 1232–1238.

Newman L, Strand S, Choe N, Duffy J, Ekuan G, Ruszaj M, Shurtleff B, Wilmoth J, Heilman P, Gordon M (1997) Uptake and biotransformation of trichloroethylene by hybrid poplars. Environ Sci Tech 31:1062-1067.

Ng BH, Anderson JW (1979) Light-dependent incorporation of selenite and sulphite into selenocysteine and cysteine by isolated pea chloroplasts. Phytochemistry 18:573-580.

Pallavi S., Rama S.D. 2005. Lead toxicity in plants. Plant Physiol. 17(1): 35-52.

Pendias A., Kabata-Pendias A. 1984. Trace Elements in Soils and Plants. CRC Press Inc, Florida, pp. 154-163.

Peer, W. A., I. R. Baxter, et al. (2006). Phytoremediation and hyperaccumulator plants. Topics in Current Genetics. M. J. Tamas and Enrico. 14: 299-340.

Pence NS, Larsen PB, Ebbs SD, Letham DL, Lasat MM, Garvin DF, Eide D, Kochian LV (2000) The molecular physiology of heavy metal transport in the Zn/Cd hyperaccumulator *Thlaspi caerulescens*. Proc Natl Acad Sci USA 97:4956-4960.

Pendias A., Kabata-Pendias A. 1984. Trace Elements in Soils and Plants. CRC Press Inc, Florida, pp. 154-163.

Pickering IJ, Wright C, Bubner B, Ellis D, Persans MW, Yu EY, George GN, Prince RC, Salt DE (2003) Chemical form and distribution of selenium and sulfur in the selenium hyperaccumulator *Astragalus bisulcatus*. Plant Physiol 131:1460-1467.

Pilon M, Owen JD, Garifullina GF, Kurihara T, Mihara H, Esaki N, Pilon-Smits EA (2003). Enhanced selenium tolerance and accumulation in transgenic Arabidopsis expressing a mouse selenocysteine lyase. Plant Physiol 131:1250-1257

Raskin I., Kumar P.B.A.N., Dushenkov S., Salt D.E. 1994. Bioconcentration of heavy metals by plants. Curr Opin Biotechnol. 5: 285-290.

Reeves RD, Baker AJM (2000) Metal-accumulating plants. In: Raskin I, Ensley, BD (eds) Phytoremediation of toxic metals: Using plants to clean up the environment. John Wiley & Sons, Inc, New York, pp. 193-229.

Robinson B, Fernandez J, Madejon P, Maranon T, Murillo JM, Green S, Clothier B (2003) Phytoextraction: an assessment of biogeochemical and economic viability. Plant Soil 249:117-125.

Rupali D., Dibyendu S. 2004. Effective integration of soil chemistry and plant molecular biology in phytoremediation of metals: An Overview Environmental Geosciences. 11: 53-63.

Raskin I., Smith R.D., Salt D.E. 1997. Phytoremediation of metals: using plants to remove pollutants from the environment. Curr Opin Biotechnol. 8: 221–6.

Rupali D., Dibyendu S. 2004. Effective integration of soil chemistry and plant molecular biology in phytoremediation of metals: An overview. Environmental Geosciences. 11: 53-63.

Salt D.E., Blaylock M., Nanda Kumar P.B.A., Dushenkov V., Ensley B.D., Raskin I. 1995. Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. Biotechnol. 13: 468-474.

Salt D.E., Pickering I.J., Prince R.C., Gleba D., Dushenkov S., Smith R.D., Raskin I. 1997. Metal accumulation by aquacultured seedlings of Indian mustard. Environ. Sci. Technol. 31(6): 1636-1644.

Salt D.E., Smith R.D., Raskin I. 1998. Phytoremediation. Annu. Rev. Plant Physiol. Plant Mol. Biol. 49: 643-668.

Skórzyńska-Polit, E., Baszyński, T., 1997. Difference on sensitivity of the photosynthetic apparatus in Cd-stressed runner bean plants in relation to their age. Plant Sci. 128, 11-21.

Steve P McGrath, Fang-Jie Zhao. 2003. Phytoextraction of metals and metalloids from contaminated soils. Curr Opin Biotechnol. 14: 277–282.

Peer, W. A., I. R. Baxter, et al. (2006). Phytoremediation and hyperaccumulator plants. Topics in Current Genetics. M. J. Tamas and Enrico. 14: 299-340.

Pence NS, Larsen PB, Ebbs SD, Letham DL, Lasat MM, Garvin DF, Eide D, Kochian LV (2000) The molecular physiology of heavy metal transport in the Zn/Cd hyperaccumulator *Thlaspi caerulescens*. Proc Natl Acad Sci USA 97:4956-4960

Pendias A., Kabata-Pendias A. 1984. Trace Elements in Soils and Plants. CRC Press Inc, Florida, pp. 154-163

Pickering IJ, Wright C, Bubner B, Ellis D, Persans MW, Yu EY, George GN, Prince RC, Salt DE (2003) Chemical form and distribution of selenium and sulfur in the selenium hyperaccumulator *Astragalus bisulcatus*. Plant Physiol 131:1460-1467

Piemyoo S., 2005. Effects of lead concentrations on germination and development of common vegetables in Thailand, Assumption Univeristy, Thialand.

Pilon M, Owen JD, Garifullina GF, Kurihara T, Mihara H, Esaki N, Pilon- Smits EA (2003). Enhanced selenium tolerance and accumulation in transgenic Arabidopsis expressing a mouse selenocysteine lyase. Plant Physiol 131:1250-1257.

Reeves RD, Baker AJM (2000) Metal-accumulating plants. In: Raskin I, Ensley, BD (eds) Phytoremediation of toxic metals: Using plants to clean up the environment. John Wiley & Sons, Inc, New York, pp 193-229.

Robinson B, Fernandez J, Madejon P, Maranon T, Murillo JM, Green S, Clothier B (2003) Phytoextraction: an assessment of biogeochemical and economic viability. Plant Soil 249:117-125

Rupali D., Dibyendu S. 2004. Effective integration of soil chemistry and plant molecular biology in phytoremediation of metals: An Overview Environmental Geosciences. 11: 53-63

Sahi SV, Bryant NL, Sharma NC, Singh SR (2002) Characterization of a lead hyperaccumulator shrub, *Sesbania drummondii*. Environ Sci Technol 36:4676-4680

Salt DE, Kramer U (2000) Mechanisms of metal hyperaccumulation in plants. In: Raskin I, Ensley B (eds) Phytoremediation of Toxic Metals. John Wiley and Sons Inc., New York, pp 231-246

Salt D.E., Smith R.D., Raskin I. 1998. Phytoremediation. Annu. Rev. Plant Physiol. Plant Mol. Biol. 49: 643-668

Schnoor J, Licht L, Mccutcheon S, Wolfe N, Carreira L (1995) Phytoremediation of organic and nutrient contaminants. Environ Sci Technol 29:A318-A323

Schnoor J (1997) Phytoremediation: ground water remediation technologies analysis center evaluation report TE-98-01, 37

Schroder P, Harvey PJ, Schwitzguebel JP (2002) Prospects for the phytoremediation of organic pollutants in Europe. Environ Sci Pollut Res Int 9:1-3

Shacklette HT, Boerngen JG.Pr ofessional Paper 1270. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States, 1984, p.105.

Shen, Z.G., Liu, Y.L., 1998. Progress in the study on plants that hyperaccumulate heavy metal, Plant Physiol. Comp. 34, 133-139

Skórzyñska-Polit, E., Baszyñski, T., 1997. Difference on sensitivity of the photosynthetic apparatus in Cd-stressed runner bean plants in relation to their age. Plant Sci. 128, 11-21.

Somashekaraiah, B.V., Padmaja, K., Prasad, A.R.K., 1992. phytotoxicity of cadmium ions on germinating seeding of mung bean (*Phaseolus vulgaris*): involvement of lipid peroxidase in chlorophyll degradation. Physiol, Planta. 85, 85-89.

Song J, Zhao FJ, Luo YM, McGrath SP, Zhang H (2004) Copper uptake by *Elsholtzia splendens* and *Silene vulgaris* and assessment of copper phytoavailability in contaminated soils. Environ Pollut 128:307-315.

Stobart, A.K., Griffiths, W.T., Ameen-BuKhara, I., Sherwood, R.P., 1985. The effect of Cd^{2+} on the biosynthesis of chlorophyll in leaves of barley. Physiol, Planta. 63, 293-298.

Suresh B, Ravishankar G (2004) Phytoremediation - A novel and promising approach for environmental clean-up. Crit Rev Biotech 24:97-124.

Tanhan, P., M. Kruatrachue, et al.(2007). Uptake and accumulation of cadmium, lead and zinc by siam weed [*Chromolaena odorata* (L.) King & Robinson] Chemosphere 68(2): 323-329.

Todd A.C., Wetmur J.G., Moline J.M., Godbold J.H., Levin S.M., Landrigan P.J. 1996. Unraveling the chronic toxicity of lead: an essential priority for environmental health. Environ Health Perspec. 104: 141-146.

US EPA (United States Environmental Protection Agency). Lead: Identification of Dangerous Levels of Lead: Final Rule. Federal Register, 2001, 40 CRF Part 745.

US FDA (United States Food and Drug Administration).Danger of Lead Still Linger. FDA Consumer Magazine. January–February, 1998.

US FDA (United States Food and Drug Administration). Guidance document for lead in shellfish.W ashington, DC: Center for Food Safety and Applied Nutrition, 1993.

Van Assche F., Clijsters H. 1990. Effects of metals on enzymes activity in plants. Plant Cell Environ. 13: 195-206.

Vogel-Mikus K, Drobne D, Regvar M (2005) Zn, Cd and Pb accumulation and arbuscular mycorrhizal colonisation of pennycress *Thlaspi praecox* Wulf. (Brassicaceae) from the vicinity of a lead mine and smelter in Slovenia. Environ Pollut 133:233-242.

Xiaoe Yang, Ying Feng, Zhenli He, Peter J. Stoffella. 2005. Molecular mechanisms of heavy metal hyperaccumulation and Phytoremediation. Journal of Trace Elements in Medicine and Biology. 18: 339–353.

Wierzbicka, M., 1987. Lead translocation and localization in *Allium cepa* roots. Can. J. Bot. 65, 1851–1860.

Wong JWC, Lai KM, Su DS, Fang M (2001) Availability of heavymetals for *Brassica chinensis* grown in an acidic loamy soil amended with a domestic and an industrial sewage sludge. Water Air Soil Pollut 128:339-353

Wu J, Hsu F, Cunningham S (1999) Chelate-assisted Pb phytoextraction: Pb availability, uptake, and translocation constraints. Environ Sci Tech. 33:1898-1904

Xiaoe Yang, Ying Feng, Zhenli He, Peter J. Stoffella, 2005. Molecular mechanisms of heavy metal hyperaccmulation and phytoremediation. Journal of Trace Elements in Medicine and Biology. 18: 339-353.

Xiong, Z.T., 1998. Lead uptake and effects on seed germination and plant growth in a Pb hyperaccumulator *Brassica pekinensis* Rupr. B. Environ. Contam. Toxicol. 60, 285–291.

Zimdahl RL. 1976. Entry and movement in vegetation of lead derived from air and soil sources. APCA J. 26: 656–660.

Appendix A

Media formulation

The compositions of White (1963) used in tissue culture medium to study effects of lead on germination and development of common vegetables.

Table A-1: Compositions of nutrient solution in the media
(Modified White 1963)

Stock No.	Compounds	Amount (g/50ml)	Stock	Used (ml/l)
1	KNO_3	0.8	200x	5
	$Ca(NO_3)_2$	2		
2	$MgSO_4.7H_2O$	7.2	200x	5
3	$MnSO_4.4\ H_2O$	0.053	200x	5
	$ZnSO_4.7\ H_2O$	0.030		
	$Fe(SO_4)_3$	0.035		
	Na_2SO_4	2		
4	KCl	1.3	400x	2.5
	KI	0.015		
	H_3BO_3	0.030		
5	$NaH_2.PO_4.H_2O$	0.186	200x	5
6	Glycine	0.009	600x	1.66
	Nicotinic acid	0.015		
	Vitamin B_1	0.003		
	Vitamin B_6	0.030		

Appendix B

Percentage of seed germination

Table B-1: Percentage of seed germinations in four week cultures

Species	Lead concentration			
	0mg kg-1	5mg kg-1	15mg kg-1	30mg kg-1
Mung bean	100	100	100	100
Cucumber	85	70	75	50
Morning glory	70	80	55	80
Sweet basil	65	70	75	70
Lettuce	70	50	65	65
Kale	85	80	75	85
Tomato	95	100	100	80
Cabbage	66.67	80	73.33	66.67
Holy basil	80	80	86.67	73.33
Bird pepper	80	60	80	90

Table B-2: Statistic analysis of percent mung bean germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.000[a]	3	.000	.	.
Intercept	400.000	1	400.000	.	.
TRT	.000	3	.000	.	.
Error	.000	12	.000		
Total	400.000	16			
Corrected Total	.000	15			

a. R Squared = . (Adjusted R Squared = .)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	.00	.00	1.000	.[a]	.
		15ppm	.00	.00	1.000	.[a]	.
		30ppm	.00	.00	1.000	.[a]	.
	5ppm	0ppm	.00	.00	1.000	.[a]	.
		15ppm	.00	.00	1.000	.[a]	.
		30ppm	.00	.00	1.000	.[a]	.
	15ppm	0ppm	.00	.00	1.000	.[a]	.
		5ppm	.00	.00	1.000	.[a]	.
		30ppm	.00	.00	1.000	.[a]	.
	30ppm	0ppm	.00	.00	1.000	.[a]	.
		5ppm	.00	.00	1.000	.[a]	.
		15ppm	.00	.00	1.000	.[a]	.

Based on observed means.

a. Range values cannot be computed.

Table B-3: Statistic analysis of percent cucumber germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.500[a]	3	2.167	3.467	.051
Intercept	196.000	1	196.000	313.600	.000
TRT	6.500	3	2.167	3.467	.051
Error	7.500	12	.625		
Total	210.000	16			
Corrected Total	14.000	15			

a. R Squared = .464 (Adjusted R Squared = .330)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	.75	.56	.205	-.47	1.97
		15ppm	.50	.56	.389	-.72	1.72
		30ppm	1.75*	.56	.009	.53	2.97
	5ppm	0ppm	-.75	.56	.205	-1.97	.47
		15ppm	-.25	.56	.663	-1.47	.97
		30ppm	1.00	.56	.099	-.22	2.22
	15ppm	0ppm	-.50	.56	.389	-1.72	.72
		5ppm	.25	.56	.663	-.97	1.47
		30ppm	1.25*	.56	.045	3.20E-02	2.47
	30ppm	0ppm	-1.75*	.56	.009	-2.97	-.53
		5ppm	-1.00	.56	.099	-2.22	.22
		15ppm	-1.25*	.56	.045	-2.47	-3.20E-02

Based on observed means.

*. The mean difference is significant at the .05 level.

Table B-4: Statistic analysis of percent morning glory germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.188[a]	3	1.396	2.913	.078
Intercept	203.063	1	203.063	423.783	.000
TRT	4.188	3	1.396	2.913	.078
Error	5.750	12	.479		
Total	213.000	16			
Corrected Total	9.938	15			

a. R Squared = .421 (Adjusted R Squared = .277)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	-.50	.49	.327	-1.57	.57
		15ppm	.75	.49	.151	-.32	1.82
		30ppm	-.50	.49	.327	-1.57	.57
	5ppm	0ppm	.50	.49	.327	-.57	1.57
		15ppm	1.25*	.49	.025	.18	2.32
		30ppm	.00	.49	1.000	-1.07	1.07
	15ppm	0ppm	-.75	.49	.151	-1.82	.32
		5ppm	-1.25*	.49	.025	-2.32	-.18
		30ppm	-1.25*	.49	.025	-2.32	-.18
	30ppm	0ppm	.50	.49	.327	-.57	1.57
		5ppm	.00	.49	1.000	-1.07	1.07
		15ppm	1.25*	.49	.025	.18	2.32

Based on observed means.

*. The mean difference is significant at the .05 level.

Table B-5: Statistic analysis of percent sweet basil germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.500[a]	3	.167	.364	.780
Intercept	196.000	1	196.000	427.636	.000
TRT	.500	3	.167	.364	.780
Error	5.500	12	.458		
Total	202.000	16			
Corrected Total	6.000	15			

a. R Squared = .083 (Adjusted R Squared = -.146)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	-.25	.48	.611	-1.29	.79
		15ppm	-.50	.48	.317	-1.54	.54
		30ppm	-.25	.48	.611	-1.29	.79
	5ppm	0ppm	.25	.48	.611	-.79	1.29
		15ppm	-.25	.48	.611	-1.29	.79
		30ppm	.00	.48	1.000	-1.04	1.04
	15ppm	0ppm	.50	.48	.317	-.54	1.54
		5ppm	.25	.48	.611	-.79	1.29
		30ppm	.25	.48	.611	-.79	1.29
	30ppm	0ppm	.25	.48	.611	-.79	1.29
		5ppm	.00	.48	1.000	-1.04	1.04
		15ppm	-.25	.48	.611	-1.29	.79

Based on observed means.

Table B-6: Statistic analysis of percent lettuce germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.250[a]	3	.750	1.636	.233
Intercept	156.250	1	156.250	340.909	.000
TRT	2.250	3	.750	1.636	.233
Error	5.500	12	.458		
Total	164.000	16			
Corrected Total	7.750	15			

a. R Squared = .290 (Adjusted R Squared = .113)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	1.00	.48	.059	-4.30E-02	2.04
		15ppm	.25	.48	.611	-.79	1.29
		30ppm	.25	.48	.611	-.79	1.29
	5ppm	0ppm	-1.00	.48	.059	-2.04	4.30E-02
		15ppm	-.75	.48	.143	-1.79	.29
		30ppm	-.75	.48	.143	-1.79	.29
	15ppm	0ppm	-.25	.48	.611	-1.29	.79
		5ppm	.75	.48	.143	-.29	1.79
		30ppm	.00	.48	1.000	-1.04	1.04
	30ppm	0ppm	-.25	.48	.611	-1.29	.79
		5ppm	.75	.48	.143	-.29	1.79
		15ppm	.00	.48	1.000	-1.04	1.04

Based on observed means.

Table B-7: Statistic analysis of percent kale germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.687[a]	3	.229	.440	.729
Intercept	264.063	1	264.063	507.000	.000
TRT	.688	3	.229	.440	.729
Error	6.250	12	.521		
Total	271.000	16			
Corrected Total	6.937	15			

a. R Squared = .099 (Adjusted R Squared = -.126)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	.25	.51	.633	-.86	1.36
		15ppm	.50	.51	.347	-.61	1.61
		30ppm	.00	.51	1.000	-1.11	1.11
	5ppm	0ppm	-.25	.51	.633	-1.36	.86
		15ppm	.25	.51	.633	-.86	1.36
		30ppm	-.25	.51	.633	-1.36	.86
	15ppm	0ppm	-.50	.51	.347	-1.61	.61
		5ppm	-.25	.51	.633	-1.36	.86
		30ppm	-.50	.51	.347	-1.61	.61
	30ppm	0ppm	.00	.51	1.000	-1.11	1.11
		5ppm	.25	.51	.633	-.86	1.36
		15ppm	.50	.51	.347	-.61	1.61

Based on observed means.

Table B-8: Statistic analysis of percent tomato germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	4
	2	5ppm	4
	3	15ppm	4
	4	30ppm	4

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.250[a]	3	.750	1.200	.352
Intercept	342.250	1	342.250	547.600	.000
TRT	2.250	3	.750	1.200	.352
Error	7.500	12	.625		
Total	352.000	16			
Corrected Total	9.750	15			

a. R Squared = .231 (Adjusted R Squared = .038)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	-.25	.56	.663	-1.47	.97
		15ppm	.00	.56	1.000	-1.22	1.22
		30ppm	.75	.56	.205	-.47	1.97
	5ppm	0ppm	.25	.56	.663	-.97	1.47
		15ppm	.25	.56	.663	-.97	1.47
		30ppm	1.00	.56	.099	-.22	2.22
	15ppm	0ppm	.00	.56	1.000	-1.22	1.22
		5ppm	-.25	.56	.663	-1.47	.97
		30ppm	.75	.56	.205	-.47	1.97
	30ppm	0ppm	-.75	.56	.205	-1.97	.47
		5ppm	-1.00	.56	.099	-2.22	.22
		15ppm	-.75	.56	.205	-1.97	.47

Based on observed means.

Table B-9: Statistic analysis of percent cabbage germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	3
	2	5ppm	3
	3	15ppm	3
	4	30ppm	3

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.917[a]	3	.306	.244	.863
Intercept	154.083	1	154.083	123.267	.000
TRT	.917	3	.306	.244	.863
Error	10.000	8	1.250		
Total	165.000	12			
Corrected Total	10.917	11			

a. R Squared = .084 (Adjusted R Squared = -.260)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	-.67	.91	.486	-2.77	1.44
		15ppm	-.33	.91	.724	-2.44	1.77
		30ppm	.00	.91	1.000	-2.11	2.11
	5ppm	0ppm	.67	.91	.486	-1.44	2.77
		15ppm	.33	.91	.724	-1.77	2.44
		30ppm	.67	.91	.486	-1.44	2.77
	15ppm	0ppm	.33	.91	.724	-1.77	2.44
		5ppm	-.33	.91	.724	-2.44	1.77
		30ppm	.33	.91	.724	-1.77	2.44
	30ppm	0ppm	.00	.91	1.000	-2.11	2.11
		5ppm	-.67	.91	.486	-2.77	1.44
		15ppm	-.33	.91	.724	-2.44	1.77

Based on observed means.

Table B-10: Statistic analysis of percent holy basil germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	3
	2	5ppm	3
	3	15ppm	3
	4	30ppm	3

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.667[a]	3	.222	.242	.864
Intercept	192.000	1	192.000	209.455	.000
TRT	.667	3	.222	.242	.864
Error	7.333	8	.917		
Total	200.000	12			
Corrected Total	8.000	11			

a. R Squared = .083 (Adjusted R Squared = -.260)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	.00	.78	1.000	-1.80	1.80
		15ppm	-.33	.78	.681	-2.14	1.47
		30ppm	.33	.78	.681	-1.47	2.14
	5ppm	0ppm	.00	.78	1.000	-1.80	1.80
		15ppm	-.33	.78	.681	-2.14	1.47
		30ppm	.33	.78	.681	-1.47	2.14
	15ppm	0ppm	.33	.78	.681	-1.47	2.14
		5ppm	.33	.78	.681	-1.47	2.14
		30ppm	.67	.78	.419	-1.14	2.47
	30ppm	0ppm	-.33	.78	.681	-2.14	1.47
		5ppm	-.33	.78	.681	-2.14	1.47
		15ppm	-.67	.78	.419	-2.47	1.14

Based on observed means.

Table B-11: Statistic analysis of percent bird pepper germination in four week cultures

Between-Subjects Factors

		Value Label	N
Pb Con.	1	0ppm	2
	2	5ppm	2
	3	15ppm	2
	4	30ppm	2

Tests of Between-Subjects Effects

Dependent Variable: %Germination

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2.375[a]	3	.792	1.267	.398
Intercept	120.125	1	120.125	192.200	.000
TRT	2.375	3	.792	1.267	.398
Error	2.500	4	.625		
Total	125.000	8			
Corrected Total	4.875	7			

a. R Squared = .487 (Adjusted R Squared = .103)

Post Hoc Tests

Pb Con.

Multiple Comparisons

Dependent Variable: %Germination

	(I) Pb Con.	(J) Pb Con.	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	0ppm	5ppm	1.00	.79	.275	-1.19	3.19
		15ppm	.00	.79	1.000	-2.19	2.19
		30ppm	-.50	.79	.561	-2.69	1.69
	5ppm	0ppm	-1.00	.79	.275	-3.19	1.19
		15ppm	-1.00	.79	.275	-3.19	1.19
		30ppm	-1.50	.79	.131	-3.69	.69
	15ppm	0ppm	.00	.79	1.000	-2.19	2.19
		5ppm	1.00	.79	.275	-1.19	3.19
		30ppm	-.50	.79	.561	-2.69	1.69
	30ppm	0ppm	.50	.79	.561	-1.69	2.69
		5ppm	1.50	.79	.131	-.69	3.69
		15ppm	.50	.79	.561	-1.69	2.69

Based on observed means.

Appendix C

Experimental condition for lead determination with FAAS (Variance SpectrAA 55B)

Working condition	Lead (Pb)
Lamp current	5 mA
Fuel	Acetylene
Support	Air
Flame stoichiometry	Oxidizing
Wavelength	217.0 nm
Slit width	1.0 nm
Optimum working range	0.1-30 µg/ml

Experimental condition for lead determination with GFAAS (GBC UltraZ)

Working condition	Lead (Pb)
Lamp current	10.0 mA
Wavelength	217.0 nm
Slit width	1.0 nm
Gas flow	Argon

GBC UltraZ graphite furnace program

Step number	Final Temp. (C)	Ramp Time (s)	Hold Time (s)	Inert Gas	Aux. Gas	Read	Signal Graphics
Step 1	50	1	4	3	Off	Off	Off
Step 2	Inject Sample						
Step 3	90	10	15	3	Off	Off	Off
Step 4	120	15	10	3	Off	Off	Off
Step 5	800	10	5	3	Off	Off	Off
Step 6	800	0	1	Off	Off	Off	On
Step 7	2100	0.7	1.2	Off	Off	On	On
Step 8	2100	1	2	3	Off	Off	Off