Mercury effect on seed germination

Science, Chemistry

MERCURY EFFECT ON GERMINATION AND GROWTH OF Capsicum annuum SEEDS NURSHAHIDA BINTI OSMAN BACHELOR OFSCIENCE(Hons.)TECHNOLOGYAND PLANTATION MANAGEMENT FACULTY OF PLANTATION AND AGROTECHNOLOGY UNIVERSITI TEKNOLOGI MARA JULY 2012 MERCURY EFFECT ON GERMINATION AND GROWTH OF Capsicum annuum SEEDS NURSHAHIDA BINTI OSMAN Final Year Project Report Submitted In Partial Fulfillment of the Requirements for the Degree of Bachelor of Science (Hons.) Technology and Plantation Management In the Faculty of Plantation and Agrotechnology

Universiti Teknologi MARA JULY 2012 DECLARATION This Final Year Project is a partial fulfilment of the requirements for a degree of Bachelor of Science (Hons.) Technology and Plantation Management, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA. It is entirely my own work and has not been submitted to any other University or highereducationinstitution, or for any otheracademicaward in this University. Where use has been made of the work of other people it has been fully acknowledged and fully referenced.

I hereby assign all and every rights in the copyright to this Work to the Universiti Teknologi MARA (“ UiTM”), which henceforth shall be the owner of copyright in this Work and that, any reproduction or use in any form or by any means whatsoever is prohibited without a written consent of UiTM. Candidate’s signature: .... Date: .... NURSHAHIDA BINTI OSMAN Name: ....

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Science (Hons.) Technology and Plantation Management, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA. Signature: …………………………………………….. DR. TSAN FUI YING Name of Supervisor: ……………………………… SENIOR LECTURER Position: ………………………………………………. Date: ……………………………………………………. ii ACKNOWLEDGEMENTS Alhamdulliah and praise be to Allah for the guidance and blessing, I was able to complete this final year project.

First of all, I would like to express my gratitude to my supervisor, Dr Tsan Fui Ying, for her guidance, advice, encouragement, good criticisms and also for he r patience in guiding me throughout final year project. My special thanks from the bottom of my heart go to my parent s and my siblings for their understanding and support during my study in UiTM. Lastly, I would also like to express my special thanks to all my friends who were directly or indirectly involved in giving their ideas, advice, criticism, and moral support throughout the project. Thank you very much. NURSHAHIDA BINTI OSMAN ii TABLE OF CONTENTS

 LIST OF ABBREVIATIONS UiTM Universiti Teknologi MARA Hg Mercury HgCl2 Mercury chloride mg/l milligram per liter cm Centimeter vii ABSTRACT Mercury Effect on Germination and Growth of Capsicum annuum Seeds A study was carried out to determine the germination and growth of Capsicum annuum after application of mercury chloride (HgCl2) at various concentrations. This study was conducted at Laboratory A603, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Shah Alam.

A total of 600 C. annuum seeds were used in this study. A total of 5 different concentration s of HgCl2 (0 (control), 25, 50, 75 and 100 mg/l) were applied in this study. The treatments were carried out by means of applying the chemical to the seeds on paper towel in Petri dishes. The application volume was 2 ml per Petri dish at alternate days unless the paper towel was still

moist with the previous application of solution. The data in terms of seed germination and growth, included length of radical and plumule, were recorded.

This study was based on Complete Randominized Design (CRD) with 5 replicates for each treatment. All the data were subjected to Analysis of Variance (ANOVA) and treatment means were compared using Tukey's Simultaneous Test. The germination and growth of C. annuum was significantly affected by the concentration of the heavy metal under study, especially with concentration ? 50 mg/l. Radical growth was found more sensitive to the presence and concentration of HgCl 2 as compared to plumule with this fruit vegetable species. viii ABSTRAK Kesan Merkuri terhadap Percambahan dan Pertumbuhan

Biji Benih Capsicum annuum Satu kajian telah dijalankan untuk menentukan percambahan dan pertumbuhan biji benih Capsicum annuum selepas aplikasi merkuri klorida (HgCl2) pada kepekatan yang berbeza. Kajian ini telah dijalankan di Makmal A603, Fakulti Perladangan dan Agroteknologi, Universiti Teknologi MARA, Shah Alam. Sebayak 600 biji benih telah digunakan dalam kajian ini. Sebanyak 5 kepekatan HgCl2 (0 (kawalan), 25, 50, 75 and 100 mg/l) telah digunakan dalam kajian ini. Rawatan ke atas biji benih adalah dengan menggunakan bahan kimia pada biji benih yang diletakkan di atas tuala kertas dalam piring Petri.

Isipadu aplikasi ialah 2 ml bagi setiap piring Petri dan rawatan diulang pada selang 2 hari kecuali tuala kertas masih lembap dengan larutan sebelumnya. Data mengenai percambahan biji benih dan pertumbuhan, termasuk panjang akar dan pucuk, dicatatkan. Kajian ini dijalankan berdasarkan Rekabentuk

Rambang Lengkap (CRD) dengan 5 kali pengulangan bagi setiap rawatan. Semua data dianalisis dengan menggunakan Analysis of Variance (ANOVA) dan purata rawatan dibandingkan dengan menggunakan Tukey's Simultaneous Test. Percambahan dan pertumbuhan C. annuum dipengaruhi dengan ketaranya oleh kepekatan logam berat yang dikaji, terutamanya pada kepekatan ? 0 mg/l. Pertumbuhan akar didapati lebih sensitif kepada kehadiran dan kepekatan HgCl2 berbanding dengan pucuk untuk spesis sayuran buah ini. ix CHAPTER 1 INTRODUCTION 1. 1 Background of Capsicum Capsicum annuum is a member of thefamilySolanaceae and a class of Dicotyledons. It is commonly known as Chili. Capsicum contains high amount of nutritive value such as vitamin C (ascorbic acid), A, B-complex and E along with minerals like molybdenum, manganese, folate, potassium and thiamine. Capsicum contains seven times more vitamin C than orange (Simone et al. , 1997).

Capsicum terminology is quite confusing, the terminology is synonymously used for " chilli pepper" plants called such as pepper, chili, chile, chilli, aji, paprika and Capsicum. There are thought to be 25-30 Capsicum species with five different names, such as C. annuum L. , C. frustescens Mill. , C. baccatum L. , C. chinense and C. pubescens Ruiz and Pavon, which have been domesticated and currently cultivated (Csillery, 2006). Capsicum is the most widespread and widely cultivated species in subtropics and temperate countries (Belletti et al. , 1998). The scientific classification of C. nnuum is as below: 1 Kingdom : Plantae – Plants Class : Magnoliopsida – Dicotyledons Subclass : Asteridae Order : Solanales Family : Solanaceae – Potato family Genus : Capsicum L. – Pepper Species : Capsicum annuum L. – cayenne pepper Although the species name annuum means “ annual” (from Latin annus “ year”), the plant is not an annual and in the absence of winter frosts, it can survive several seasons and grow into large perennial shrub. The si ngle flowers are of off-white (sometimes purplish) color while the stem is densely branched and the plant can grow up to 60 centimeter tall.

The fruit is berry which may be green, yellow and red when ripe. While the species can tolerate most climates, C. annuum is especially productive in warm and dry climates (Anonymous, 2012b). 1. 2 Value of capsicum Capsicums have their own benefits and values to human beings. As we know, capsicums are used in cooking and also as medicines. Capsicum is an indispensable spice used as basic ingredient in a great variety of cuisine all over the world. It is also used as flavoring, colorant and adds tang and taste to the otherwise insipidfood. Moreover, Capsicum species are employed whole 2 r ground and alone or in combination with other flavorings agents, primarily in the pickles, stewed or barbeques (Ravishankar et al. , 2003). Table 1. 1: Raw chili peppers (C. annum), nutrient value per 100 g Principle Nutrient Value Percentage of RDA Energy 40 Kcal 2% Carbohydrates 8. 81 g 7% Protein 1. 87 g 3% Total Fat 0. 44 g 2% Cholesterol 0 mg 0% Dietary Fiber 1. 5 g 3% Vitamins Folates 23 mcg 6% Niacin 1. 244 mg 8% Pantothenic acid 0. 201 mg 4% Pyridoxine 0. 506 mg 39% Riboflavin 0. 086 mg 6. 5% Thiamin 0. 72 mg 6% Vitamin A 952 IU 32% Vitamin C 143. 7 mg 240% Vitamin E 0. 69 mg 4. % Vitamin K 14 mcg 11. 5% Electrolytes Sodium 9 mg 0. 5% Potassium 322 mg 7% Minerals Calcium 14 mg 1. 5 % Copper 0. 129 mg 14% Iron 1. 03 mg 13% Magnesium 23 mg 6% Manganese 0. 187 mg 8% Phosphorus 43 mg 6% Selenium 0. 5 mcg 1% Zinc 0. 26 mg 2% Phytonutrients Carotene-? 534 mcg -Carotene-? 36 mcg -Cryptoxanthin-? 40 mcg -Lutein-zeaxanthin 709 mcg -Source: USDA National Nutrient data base (Anonymous, 2012a) 3 1. 3 Background of heavy metal According to Thomine et al. (2000), metals such as iron (Fe), manganese (Mn), and copper (Cu) are necessary as co-factors for many enzymatic reactions.

Some metals, such as zinc (Zn), play important structural roles in proteins. Furthermore, metal cations have recently been shown to be involved in signaling in animals and plants. According to Ghavri and Singh (2010) in terms of stabilizing contaminated sites, a lower metal concentration in stem is preferred in order to prevent metal from entering into ecosystem. However, plants also need to control against excessive accumulation of essential cations and toxic heavy metals, such as cadmium (Cd2+), lead, mercury, and arsenic.

When taken up in excessive quantities, these elements are transferred in the food chain where they may have adverse effects on thehealthof humans and animals. Heavy metals can enter the food chain via plant uptake (Chayed, 2009). According to Mami (2011) from Guilan University, Rasht, Islamic Republic of Iran, heavy metals have recently received the attention of researchers all over the world, mainly due to also their harmful effect on plant. 1. 4 Seed germination and growth According to the seed physiologists, germination is defined as the emergence of the radical through the seed coat.

Basic requirements for germination include water, gases, temperature and moisture availability. 4 According to Vera et al. (2010), exposure to heat and to low pH promotes germination and reduces time to germinate, which indicates that germination is related to passage of fire and to soil pH. Germination is also correlated with wet and cold conditions and dormancy can be classified as being the physiological type. In addition, it well known that temperature, light conditions, nitrates or hormonal treatment may also affect germination. In an experiment conducted by Koger et al. 2004), Caperonia palustris seeds from naturally dehisced with predominant dark gray color were exposed to pre chilling in attempts to break any dormancy mechanism imposed on seed kept at room temperature. Results showed that pre chilling did not release dormancy. Seed germinated with fluctuating 12-h light/dark and constant dark conditions. Seed germination test using buffer solutions of pH 4 to 10 recorded germination of 31 to 62% over a pH range from 4 to 10. Heavy metals may also affect seed germination, mainly believed to be attributed to toxicity effects. They can be hazardous because they cannot be estroyed or despoiled but they are bioaccumulated. 1. 5 Problem statement Capsicum annuum is a kind of fruit vegetable most commonly consumed and its production is of concerned. Like other crops, Capsicum needs to control against excessive accumulation of essential cations and toxic heavy metals for seed development and production. The heavy metals may cause a negative effect to the seed germination and growth. 5 1. 6 Objective of study The experiment was conducted by considering the objectives of study as below: 1. To determine the mercury effect on germination of C. nnuum seeds. 2. To identify the mercury effect on subsequent initial seedling growth of C. annuum after seed germination. 1. 7 Significance of study This study is important to observe and determine the mercury effect on germination and growth of C. annuum seeds. The result from this study is hoped to provide information on germination and growth of C. annuum seeds as affected by mercury concentration in soil, e. g. ex-mining soils. 1. 8 Scope of Study The experiment conducted to identify the concentration of mercury that may affect germination and growth of C. nnuum seeds involved the seed extraction from fruits, seed treatment with mercury chloride (HgCl2), seed germination recording, measurement of length of radical and plumule, data analysis and report writing. 6 CHAPTER 2 LITERATURE REVIEW 2. 1 Source of heavy metal There are many sources of heavy metals in soil including natural sources e. g. soil parent material, volcanic eruptions, marine aerosols, and forest fires; agricultural sources e. g. fertilizers, sewage sludge, pesticides and irrigation water; energy and fuel production sources e. g. emissions from power stations; mining and smelting e. . tailing, smelting, refining and transportation (Reichman, 2002). It is generally accepted that heavy metal contamination can not only result in adverse effects on various parameters relating to plant quality and yield, but also cause changes in the size, composition and activity of the soil microbial community (Giller et al. , 1998). Heavy metals might accumulate in the food chains, with risks for the health of animals and humans, which are less sensitive to metal toxicity than plants, but they are capable of concentrating heavy metal in certain tissues and organs (Peralta et al. 2001). The influence of metals on development and reproduction of plants can be firstly quantified by determining the germination traits of seeds and growth performance of seedling. In the presence of high concentrations of some heavy metals, most plant species performe the reduction of seed germination and seedling growth (Patra and Sharma, 2000). 7 The high metal contents suggest the potential for heavy metal accumulation and phytotoxicity for crops grown in soils receiving the metal enriched sewage sludge.

Hence, it will limit its application on land, because of the stringent regulations for land application of heavy metals i n the form of sewage (Wong et al. , 2001). The high heavy metal contents might pose a toxic effect to plants and cause heavy metal accumulation in plant tissues (Wong et al. , 2001). Many of those who performed short-term laboratory studies also discuss ed their results in relation to existing regulations for heavy metals in soils, or the possible effect of the agricultural use of metal-contaminated products such as sewage sludge, animal manures and fungicides (Giller et al. 1998). The distribution of heavy metals in the organs of plants is not homogenous; it depends on the species and the element (Kozanecka et al. , 2002). The application of cow dung in wasteland soil not only provided nutrients for plant growth, but also stabilized the metal in the soil and reduced metal toxicity to the plant (Ghavri and Singh, 2010). According to Longman (2006), mercury is a heavy silver white poisonous metal that is liquid at ordinary temperature and it is a chemical element symbol is Hg. It is a pervasive pollutant that accumulates in organisms and is highly toxic.

Elemental mercury is efficiently transported as a gas around the 8 globe, and even remote areas show evidence of mercurypollutionoriginating from industrial sources such as power plants (Morel et al. , 1998). Mercury is a toxic heavy metal that is of significant concern as an environmental pollutant since mercury is not very phototoxic in normally occurring concentrations. In polluted regions, mercury is a non -degradable toxic heavy metal pollutant when it is accumulated by plants. The information is scare about its uptake mechanism and growth inhibition. There are a wide range of sources that emit mercury to the atmosphere.

Approximately half of the atmospheric budget of vapor-phase mercury is attributed to anthropogenic sources and half to natural source (Nriagu, 1989) The accumulation of mercury in terrestrial plants increases with increasing soil mercury concentration. Soil type has considerable influence on this process, i. e. high organic matter content will decrease uptake. Generally, the highest concentrations of mercury are found at the roots, but translocation to other organs occurs. In contrast to higher plants, mosses are known to take up mercury via atmospheric deposition (Boening, 2000).

The characterization of mercury uptake showed that mercury binding is dependent on initial pH, agitation speed, amount of dosage and also the interaction between pH and contact time (Ling, 2010). 2. 2 Inhibition of seed germination According to Longman (2006), seed is a small, hard object produced by plants, from which a new plant of the same kind grows. Poor quality seeds suffer from following problems of low germination percentage, poor 9 emergence, poor survival, and poor adaptability to site, susceptible to disease and pests, poor growth, and low productivity (Anonymous, 2011a).

The characteristics of good seeds are well ripened, healthy and true to type, pure and free from inert materials and weed seeds, viable and have good germination capacity, uniform in its texture, structure and appearance, and free from damage and should not be broken and inflected by pests and diseases (Anonymous, 2011a). Seed germination is defined as the emergence and development from seed embryo of those essential structures, which are indicative of the ability of seed to produce a normal plant under favorable conditions (Anonymous, 2011a).

Seeds need to be handled carefully to avoid damage to the embryo. Rough handling at threshing time can result in a lower percentage of germination. Actual tests are made at intervals to insure a good percentage of germination. Many seeds will germinate in a week or two or three weeks, but some seeds may take weeks or even years until barriers to germination are removed (Butterfield, 1967). Although seeds are rather similar in structure and in the same taxonomic family, their germination patterns are quite different (McDonald, 2011).

Seeds exist in a state of dormancy, absorbing oxygen, giving off carbon dioxide, and slowly using up their stored food reserves during germination (Rindels, 1996). Every viable seed has the potential to become a plant. For this to happen, the seed must germinate, and for germination to occur, a seed 10 essentially needs water (during absorption and subsequent stages of growth), oxygen (for respiration) and temperature adequate for metabolism and growth. Some seeds also require light and therefore must be on the soil surface in order to germinate, and not buried beneath the soil surface (McDonald, 2011).

A general statement was made that percent of germination or p ercent of viable seeds of Rumex scutatus drop over time as a result of exposure to environmental conditions (Yilmaz and Aksoy, 2007). Some seeds have certain chemicals inside them to which prevent their germination, while some seeds may not have well developed embryo and require storage for a few weeks before germination can take place (Anonymous, 2011a). Some seeds present deep physiological dormancy with a very low germination percentage and they need a long time to start germination (Vera et al. , 2010).

Heavy metals of Zn and ZnO particles were observed to have significant inhibition on seed germination and root growth (El-Temsah and Joner, 2010). The decrease in the value of germination percentage and germination index of the seed caused by the increased amount of metallic compound indicates that at a lower concentration, the contaminant posed little or no harm on the seed viability but in higher level, germination is retarded (Jaja and Odoemena, 2004). In the presence of heavy metals at certain concentrations, the radical of Arabidopsis thaliana protruded from testa, but the embryo growth was arrested beyond the point (Li et al. 2005). Although the seed coat provides some protection from metalstressprior to germination, it will eventually 11 crack or become more permeable upon germination. The current literature suggests that seed germination is affected by metals in two ways. Firstly, by their general toxicity, and secondly are by their inhibition of water uptake (Kranner and Colville, 2011). The seed injury caused by organic mercurials to cereals was characterized by abnormal germination. The primary effect of mercury could possibly be on the embryo itself, and effects on the endosperm were of secondary importance (Patra and Sharma, 2000). . 3 Environmental effect Salinity reduced germination percentage and also delayed the germination rate as the salt level was increased. The germination rate, germination index and coefficient of velocity of germination of forage sorghums decreased under salinity treatments. The germination percentage was a maximum in distilled water, but decreased with increasing salinity (Siti Aishah et al. , 2010). The pH of soil plays a great role in the speciation and bio-availability of heavy metals thus; the maximum allowable con centrations in soil vary with soil (Luo et al. , 2011).

The percentage germination was low at acidic as well as alkaline conditions in both the sets of scarified and unscarified Solanum nigrum seeds. It was observed that neutral pH plays in an important role in increasing germination (Suthar et al. , 2009). 12 Erica australis had increased seed germination in response to factors related to passage of fire and low pH (Vera et al. , 2010). Caperonia palustris seed germination was less than 32% at pH 4 and 10. High seed germination over a broad pH range indicated that pH may not be a limiting factor for germination in most soils (Koger et al. , 2004).

The addition of lime caused a significant increase in soil pH providing an alkaline buffering capacity against heavy metal availability for the acid loamy soil while without liming the acidic soil may cause a lowering of the alkalinity of sludge resulting in a higher availability of heavy metals (Wong et al. , 2001). 13 CHAPTER 3 METHODOLOGY 3. 1 Location of the study This study was conducted at Laboratory A603, Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Shah Alam, Selangor. 3. 2 Test material Capsicum annuum fully ripe fruits were purchased from local market and a total of 600 seeds were extracted from the fruits.

The seeds were cleaned with running tap water, pat dried with paper towel and air dried for two days prior to experimentation. 3. 3 Experiment procedure 3. 3. 1 Sterilization of seed Seeds were rinsed with 10% Chlorox followed by 3 times rinsing with distilled water. 3. 3. 2 Treatment Seeds were germinated in enclosed Petri dishes on paper towel containing HgCl2 solutions at 0, 25, 50, 75, 100 mg/l respectively. The paper towel was moistened with 2 ml of the respective HgCl 2 solution before the seeds were placed on the paper towel for germination test. The paper towel was applied with 2 ml of the 14 espective mercury solution at alternate days unless the paper towel was still found moist with the previous application of solution. 3. 4 Data collection The germination/emergence of the seedling (radical and plumule) was recorded for a period of 10 days. Then, the length of the radical (primary root) and plumule (primary shoot) was measured at two days after germination. The other abnormal morphology, growth and development of seedlings were also recorded. 3. 5 Experimental design The experiment was based on completely randomized design (CRD) as it is the most commonly used design for laboratory research.

This experiment was arranged in a CRD as a single factor experiment with 5 replicates. There were 20 seeds in each replicate. 3. 6 Statistical analysis Analysis of variance (ANOVA) was carried out and treatment means were compared using Tukey’s Simultaneous Test. Germination percentage was transformed to arc-sine value before ANOVA. 3. 7 Work schedule This study was conducted starting from January 2011 until July 2011 (Table 3. 1). It involved extraction and cleaning of seeds, air drying of seeds, sterilization procedure, and treatment with HgCl2, data collection and data 15 analysis.

At the end of this study, project report was presented orally and the written final report was submitted. Table 3. 1: Work schedule for the study on germination and growth of C. annuum after application of HgCl2 at various concentrations Weeks activities 2 Collection of material / / 8 10 / 12 14 / / /

Data collection 6 / Treatment 4 Data analysis Oral presentation / Submission of report / 16 CHAPTER 4 RESULTS Figure 4. 1 indicates the germination of C. annuum seeds treated with varying concentrations of HgCl2. Capsicum annuum seed germination was significantly affected by treatment with HgCl2 up to 100 mg/l (Figures 4. and 4. 2; Table 4. 1; Appendices A and B). Seeds treated ? 50 mg/l HgCl 2 showed significantly lower germination percentage and germination index as compared to the control seeds treated with distilled water and those treated with lower HgCl 2 at 25 mg/l. This trend was visible from 4 days after germination onwards until end of the study period of 10 days. Figure 4. 1: Germination of C. annuum seeds after treatment with HgCl2 17 Figure 4. 2: Seed germination at the 10th day with HgCl2 treatment at 25mg/l Table 4. 1: Germination and growth of C. annuum after treatment withHgCl2 HgCl2 mg/l) Germination % Germination index Length of radical (cm) Length of plumule (cm) 0 100±0 a 5. 41±0. 84 a 1. 75±0. 11 a 0. 77±0. 07 a 25 95±6. 12 a 5. 38±0. 59 a 1. 23±0. 07 b 0. 70±0. 06 ab 50 56±9. 62 b 3. 08±0. 73 b 0. 95±0. 08 c 0. 58±0. 11 b 75 49±6. 52 b 3. 16±0. 66 b 0. 61±0. 02 d 0. 36±0. 01 c 100 28±9. 08 c 1. 90±0. 54 b 0. 47±0. 02 e 0. 33±0. 11 c Means with the same letter within the same column are not significantly different at 5% level of significance All HgCl2 treatments ranging from 25 – 100 mg/l as studied resulted in significant inhibition of radical growth (Table 4. ; Appendi ces B and C). Growth inhibition of 18 radical increased significantly and simultaneously with increasing HgCl 2 concentration indicating that radical was very sensitive to this heavy metal. Based on Table 4. 1, plumule growth of C. annuum seeds was also affected significantly by the HgCl2 treatment (Appendices B and D).

Plumule growth was less sensitive to this heavy metal; only those treated at higher rates of 75 and 100 mg/l showed significantly the greatest inhibition effects. Heavy metal of mercury was found to affect the germination and growth of C. nnuum seeds. Based on the results, mercury at 50 mg/l was found to retard seed germination in terms of germination percentage and germination index. This concentration of mercury also affected development of radical and plumule in terms of length of the organs. Toxicity caused by the under study heavy metal at concentration of 50 mg/l was presumed to result in obvious reduced seed germination and inhibition of growth of seedlings of C. annuum. 19 CHAPTER 5 CONCLUSION Seed germination and growth of C. annuum seedlings were affected with HgCl2 at 50 mg/l.

Reduced seed germination and inhibition of seedling growth were recorded with this treatment and higher concentration of HgCl2. The seeds of this fruit vegetable can be concluded to be sensitive to mercury contamination. 20 CITED REFERENCES Anonymous. (2012a). Chili peppers nutrition facts. Retrieved 20 May 2012, from http://www. nutrition-and-you. com/chili-peppers. html Anonymous. (2012b). PLANTS Profile Capsicum annuum L. var. annuum cayenne pepper Retrieved 20 May 2012, from http://plants. usda. gov/java/profile? symbol= CAAN4 Anonymous. (2011a). Seed technology.

Retrieved 21 September 2011, from http://ifs. nic. in/rt/main/courses/seed_tech. pdf Belletti, P. , Marzachi, C. & Lanteri, S. (1998). Flow cytometric measurement of nuclear DNA content in Capsicum (Solanaceae). Plant Systematic and Evolution 209: 85-91. Boening, D. W. (2000). Ecological effects, transport, and fate of mercury: a general review. Chemosphere 40: 1335-1351. Butterfield, H. M. , (1967). Seed germination.

California Horticultural Society Journal 28(2): 1-9. Retrived 20 May 2012 from http://www. calhortsociety. org/ Bulletins/journal-articles/seed-germination. html Chayed, N. F. (2009).

Determination of Heavy Metal Uptake by Acacia magnium Grown in Ex-mining Area in Kg Gajah, Perak. Universiti Teknologi MARA. Csillery G. (2006) Pepper taxonomy and the botanical description of the species, Acta Argon Hung. 5: 151-166. El-Temsah, Y. S. , & Joner, E. J. (2010). Impact of Fe and Ag nanoparticles on seed germination and differences in bioavailability during exposure in aqueous suspension and soil. Environmental Toxicology DOI 10. 1002/tox. Ghavri, S. V. , & Singh, R. P. (2010). Phytotranslocation of Fe by biodiesel plant Jatropha curcas L. grown on iron rich wasteland soil. Braz. J. Physiol. 22(4): 235243.

Giller, K. E. , Witter, E. , & McGrath, S. P. (1998). Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils: A review. Soil Biology and Biochemistry 30(10/11): 1389-1414. Jaja, T, E. , & Odoemena, C. S. I. (2004). Effect of Pb, Cu and Fe compounds on the germination and early seedling growth of tomato varieties. J. Appl. Sci. Environ. Mgt. 8(2): 51-53. 21 Koger, C. H. , Reddy, K. N. , & Poston, D. H. (2004). Factors affecting seed germination, seedling emergence, and survival of texasweed (Caperonia palustris). Weed Science 52: 989-995. Kozanecka, T. , Chojnicki, J. , & Kwasowski, W. (2002).

Content of heavy metals in plant from pollution-free regions. Polish Journal of Environmental Studies 11(4): 395-399. Kranner, I. , & Colville, L. (2011). Metals and seeds: Biochemical and molecular implications and their significance for seed germination. Environmental and Experinmental Botany.

72(1): 93-105 Li, W. , Khan, M. A. , Yamaguchi, S. & Kamiya, Y. (2005). Effect of heavy metal on seed germination and early seedling growth of Arabidopsis thaliana. Plant Growth Regulation 46: 45-50. Ling, T. , Fangke, Y. , & Jun, R. (2010). Effect of mercury to seed germination, coleoptile growth and root elongation of four vegetable.

Research Journal of Phytochemistry 4(4): 225-233. Longman (2006). Dictionary of Comtemporary English. Pearson Education Limited: 1950. Luo, C. , Liu, C. , Wang, Y. , Liu, X. , Li, F. , Zhang, G. , & Li, X. (2011). Heavy metal contamination in soils and vegetables near an e-waste processing site, south China. Journal of Hazardous Materials 186(1): 481-490. Mami, Y. , Ahmadi, G. , Shahmoradi, M. , & Gorbani, H. R. (2011). Influence of different concentration of heavy metals on the seed germination and growth of tomato. African Journal of EnvironmentalScience and Technology5(6): 420-426. McDonald, M. B. 2011). Physiology of Seed Germination. Retrieved 23 November 2011, from http://seedbiology. osu. edu/HCS631_files/4A%20Seed %20germination. pdf Morel, F. M. , Kraepiel, A. M. , & Amyot, M. , (1998). The chemical cycle and accumulation of mercury. Annual Review of Ecology and Systematics 29: 54-566. Nriagu, J. O. (1989). A global assessment of natural sources of atmospheric trace metals. Nature 338: 47-49. Patra, M. , & Sharma, A. (2000). Mercury toxicity in plant. The Botanical Review 66(3): 379-422. Peralta, J. R. , Gardea-Torresdey, J. L. , Tiemann, K. J. , Gomez, E. , Arteaga, S. , Rascon, E. & Parsons, J.

G. (2000). Study of the effect of heavy metal on seed germination and plant growth on alfalfa plant (Medicago sativa) grown in solid media. Proceeding of the 2000 Conference on Harzardous Waste Research: 135-140. 22

Ravishankar, G. A. , Suresh, B. , Giridhar, P. , Rao, S. R. and Johnson, T. S. (2003). Biotechnological studies on Capsicum for metabolite production and plant improvement. In: Amit Krishna, D. E. , (ed.). Capsicum: The genus Capsicum. Harwood Academic Publishers, UK,: 96-128. Reichman, S. M. (2002). The Responses of Plants to Metal Toxicity: A review focusing on Copper, Manganese and Zinc.

Australian Minerals & EnergyEnvironmentFoundation, Victoria, Australia: 1-54. Rindels, S. (1996). Successful seed germination. Horticulture and Home Pest News IC-475(2), Iowa State University. Retrived from http://www. ipm. iastate. edu/ipm/ hortnews/1996/2-9-1996/seed. html Simone, A. H. , Simone, E. H. , Eitenmiller, R. R. , Mills, N. R. , & Green, N. R. , (1997). Ascorbic acid and provitamin a contents in usually colored bell peppers (Capsicum annuum L.). Journal of Food Composition and Analysis 10(4): 299-311. Siti Aishah, H. , Saberi, A. R. , Halim, R. A. , & Zaharah, A. R. (2010). Salinity effects on germination of forage sorghums.

Journal of Agronomy 9(4): 169-174. Suthar, A. C. , Naik, V. R. , & Mulani, R. M. (2009). Seed and seed germination in Solanum nigrum Linn. American-Eurasian J. Agric. & Environ. Sci. 5(2): 179-183. Thomine, S. , Wang, R. , Ward, J. M. , Crawford, N. M. , & Schroeder, J. I. (2000). Cadmium and iron transport by members of a plant metal transporter family in Arabidopsis with homology to Nramp genes. PNAS 99(9): 4991-4996. Vera, D. T. , Martin, R. P. , & Oliva, S. R. (2010). Effect of chemical and physical treatment on seed germination of Erica australis. Ann. Bot. Fennici 47: 353-360. Wong, J. W. C. , Lai, K. M. D. , Su.

S. & Fang, M. (2001). Availability of heavy metals for Brassica chinensis grown in an acidic loamy soil amended with domestic and industrial sewage sludge. Water, Air and Soil Pollution 128: 339-353. Yilmaz, D. D. , & Aksoy, A. (2007). Physiological effects of different environmental conditions on the seed germination of Rumex scutatus L. (Polygonaceae). Erciyes Universitesi Fen Bilimleri Dergisi 23(1-2): 24-29. 23 APPENDIX A Germination of C. annuum seeds HgCl2 (mg/l) 0 25 50 75 100 Replicate 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 2 2 3 7 5 8 6 7 4 5 7 5 2 3 3 2 6 3 4 5 2 3 3 2 2 1 24 4 7 8 5 9 6 6 6 5 5 4 2 6 4 3 1 2 3 5 3 2 4 4 1 4 Period (days) 6 5 6 4 4 4 4 4 6 6 3 3 5 2 3 1 1 5 1 1 2 8 4 2 3 1 1 3 2 2 2 5 3 2 10 2 1 1 1 1 1 1 2 1 1 1 1 2 1 1 1 1 APPENDIX B ANOVA Sum of Squares df Mean Square germination Between Groups Within Groups G. I Length of radical Length of plumule Total Between Groups Within Groups Total Between Groups Within Groups Total Between Groups Within Groups Total 12408. 834 4 3102. 208 707. 247 20 F Sig. 35. 362 13116. 081 48. 100 9. 246 57. 346 5. 203 . 091 5. 294 . 758 . 130 . 888 25 24 4 20 24 4 20 24 4 20 24 12. 025 . 462 87. 726 . 000 26. 011 . 000 1. 301 286. 374 . 000 . 005 . 190 . 007 29. 159 . 00 Multiple Comparisons Tukey HSD Dependent Variable (I) treatment (J) treatment germination 0 25 50 75 100 25 0 50 75 100 50 0 25 75 100 75 0 25 50 100 100 0 25 50 75 95% Confidence Interval Mean Difference (I-J) Std. Error Sig. 9. 72566 3. 76098 . 111 Lower Bound Upper Bound -1. 5286 20. 9799 3. 76098 . 000 30. 2341 52. 7426 3. 76098 . 000 34. 3137 56. 8222 3. 76098 . 000 47. 0576 69. 5661 -9. 72566 3. 76098 . 111 -20. 9799 1. 5286 41. 48839 * 45. 56795 * 58. 31190 * 31. 76273 * 3. 76098 . 000 20. 5085 43. 0170 35. 84229 * 3. 76098 . 000 24. 5880 47. 0965 48. 58623 * 3. 76098 . 000 37.

3320 59. 8405 -41. 48839 * . 76098 . 000 -52. 7426 -30. 2341 -31. 76273 * 3. 76098 . 000 -43. 0170 -20. 5085 4. 07956 3. 76098 . 812 -7. 1747 15. 3338 16. 82351 * 3. 76098 . 002 5. 5693 28. 0778 -45. 56795 * 3. 76098 . 000 -56. 8222 -34. 3137 -35. 84229 * 3. 76098 . 000 -47. 0965 -24. 5880 -4. 07956 3. 76098 . 812 -15. 3338 7. 1747 12. 74395 * 3. 76098 . 022 1. 4897 23. 9982 -58. 31190 * 3. 76098 . 000 -69. 5661 -47. 0576 -48. 58623 * 3. 76098 . 000 -59. 8405 -37. 3320 -16. 82351 * 3. 76098 . 002 -28. 0778 -5. 5693 -12. 74395 * 3. 76098 . 022 -23. 9982 -1. 4897 26 Multiple Comparisons Tukey HSD 95% Confidence Interval Mean Difference (I-J)

Dependent Variable (I) treatment (J) treatment G. I 0 25 . 03500 . 43003 1. 000 -1. 2518 1. 3218 50 2. 33000 * . 43003 . 000 1. 0432 3. 6168 2. 25333 * . 43003 . 000 . 9665 3. 5401 3. 51167 * . 43003 . 000 2. 2249 4. 7985 0 -. 03500 . 43003 1. 000 -1. 3218 1. 2518 50 2. 29500* . 43003 . 000 1. 0082 3. 5818 75 2. 21833 * . 43003 . 000 . 9315 3. 5051 3. 47667 * . 43003 . 000 2. 1899 4. 7635 -2. 33000 * . 43003 . 000 -3. 6168 -1. 0432 -2. 29500 * . 43003 . 000 -3. 5818 -1. 0082 75 -. 07667 . 43003 1. 000 -1. 3635 1. 2101 100 1. 18167 . 43003 . 082 -. 1051 2. 4685 0 -2. 25333 * . 43003 . 000 -3. 5401 -. 9665 25 -2. 21833* . 43003 . 000