SOIL AND SOILLESS CULTIVATION INFLUENCE ON NUTRIENTS AND HEAVY METALS AVAILABILITY IN SOIL AND PLANT UPTAKE

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Abstract

Nowadays, most countries especially in arid and dry climate zones had experienced the water scarcity problems. In the agricultural sector, freshwater play a major role to supply water for the plant grows. Thus, the reuse of wastewater as alternative water resources in agricultural is highly recommended. However, wastewater is always contaminated despite after secondary treatment. Along beneficial factors, wastewater contributes to the presence of harmful heavy metals to the plant and soil which may toxicity to the people to direct or indirect contact. This paper discusses the effect of soil and soilless culture to the availability of heavy metals in soil and plant uptake with secondary treated wastewater irrigation. The study involves the assessment of heavy metal including Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn by using soil and soilless cultivation. The accumulation of heavy metals in soilless cultivation was relatively higher than soil cultivation due the facts that soilless media were directly uptake by plants without absorption by soil. The study also found that soil can act as a filter to reduce uptake of heavy metals by the plant. Besides, different growing media conditions had contributed to the divergent influences of the heavy metal availability in plant and soil. If adequate amounts of macronutrients concentrations such as nitrogen, phosphorus and potassium availability in wastewater, successful growing plants will be achieved either in soil or soilless cultivation. The used of secondary treated wastewater were believed to improved soil properties and thus increased plant growth and productivity. The comparison between heavy metal accumulations in both growing media will contribute information and technique to be used with minimal risk.

Keywords: Secondary Treated Wastewater, Heavy Metal, Soil, Soilless, Plant Uptake

1 Introduction

The population growth and climate change have led to water scarcity problems worldwide. Therefore, the reuse of wastewater for agricultural irrigation is highly recommended as an alternative solution of freshwater decreases. The wastewater irrigation provides the beneficial aspects by adding valuable plant nutrients and organic matter to soil besides provides a convenient method of waste product disposal (Horswell *et al*., 2003). Previously, numerous studies found that wastewater rich with valuable sources such as organic matter, macronutrient and micronutrient that required by the plant for fertility and productivity of soil (Kiziloglu *et al*., 2008). Other researchers found wastewater used for irrigation supply nitrogen N, phosphorus P and potassium K with heavy metal to plants and soil, thus increasing yields and quality (Mohammad Rusan *et al*., 2007; Emongor *et al*., 2004).

However, along with beneficial to horticultural crops, wastewater and sewage effluents contain a significant amount of heavy metals and other substances that may be harmed and toxic to people (Sanderson, 1986). Pedrero *et al*.,(2009) found that sewage wastewater may contain high concentrations of heavy metals, salts, bacteria, viruses depending upon its sources and treatment applied. Trace elements and heavy metals such as Zn,Cd,Pb, Fe, Mn and Mo found in wastewater and sewage effluents may be phytotoxic and if accumulated in the crops and fruit will impose a health risk to humans (Omran *et al*., 1988; Yadav *et al*., 2002; Banin *et al*., 1981).

The effects of wastewater irrigation on soils have been widely documented, especially on heavy metal concentrations (Dominguez-Mariana *et al*., 2004; Yang, 2002) and toxicity. With continous wastewater applications, heavy metals can accumulate in the soil thus toxicity the plant growth (Chang *et al*., 1992). Besides, human are subjected to direct impact on health by contamination of soils due the facts that soils are easily contacted and transferred to them (De Miguel *et al*., 1998; Mielke *et al*., 1999; Madrid *et al*., 2002). Soils act as toxic chemical filters may absorb and retain heavy metals from wastewater. However, due to continous loading of pollutants and changes in pH, the capacity of soils to retain toxic metals being reduced thus soil may release heavy metals into groundwater or available for plant uptake (Mapanda *et al*., 2005). Accumulation of metals in crop tissues are different by species (Datta *et al*., 2000) and metals absorption efficiency by different crops is judged either by plant metal uptake or by metals transfer factor from soil to plant (Rattan *et al*., 2005).

Emongor *et al*., (2004) found that heavy metals took up by vegetables grown with wastewater tend to remain in roots. Only a fraction of heavy metals are translocated to the shoots, and even a small fraction reaches the fruit (Berry *et al*., 1980). However, Khan *et al*., (2008) found that vegetables cultivated on the wastewater-contaminated soils may take up polycyclic aromatic hydrocarbons and heavy metals in sufficient quantities to cause health problems for the consumers.

In recent years, a number of researchers have addressed the effects of wastewater irrigation on soils, crops and groundwater. However, information regarding on the effects of wastewater irrigation under different types of planting media is still under study. This study highlights on the effects of treated wastewater on crop growth under different planting media. The potential risks caused by the heavy metal contamination may be very severe. This study was conducted in order to evaluate the effect of treated wastewater on the crop growth (with a present of N, P and K), to compare the crop growth and plant uptake of heavy metals by two different planting media, and to assess the ability of soil to act as a filter for heavy metal removal. In order to achieve the objectives, *Brassica Juncea Sp.* as leafy vegetable was growth under soil and soilless (hydroponic) cultivation.

2 Materials and Methods

2.1 Experimental Conditions

The experiment was conducted in two different locations at Universiti Teknologi MARA, Shah Alam. For soil cultivation, experimental plot under the Faculty of Plantation and Agrotechnology was selected while Mawar Wastewater Treatment Plant was selected for soilless cultivation. All wastewater was collected from Mawar Wastewater Treatment Plant effluent after secondary treatment.

2.2 Growing Vegetable Plants

Seeds of green mustard (*Brassica Juncea Sp.*) obtained directly from local market were germinated in soilless (hydroponic) and soil cultivation as growing media as shown in Figure 1. In soilless culture, plants were grown with secondary treated wastewater effluent as sources of nutrients. In soil culture, plants are frequently watered daily with secondary treated wastewater effluent. All plants were grown directly under sunlight. The mature plants were harvested after 6-8 weeks growths. The roots and leaves were separated and then thoroughly washed. Soil samples beneath each plant were collected after harvesting the plant. The Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn assessment were carried out on plant and soil samples.


Figure 1: Soil (Left) and Soilless (Right) Cultivation as Planting Media

2.3 Wastewater Analysis

Wastewater samples were collected two times in order to characterize the wastewater quality for irrigation purposes. The concentration of nutrients (NO_3^-, NO_2^-, PO_4^{3-}, and K) and heavy metals (Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn) were determined by Atomic Absorption Spectrometer (AAS). Besides, physicochemical parameter (pH, turbidity and conductivity) was determined.

2.4 Soil Analysis

Soil samples from 0 to 10 cm depths were collected before and after irrigation with secondary treated wastewater. Then, after oven-dried at 70^{o}C for 48 has shown in Figure 2, 0.25-0.5g of each soil sample was accurately weighted into a 100-mL digesdahl digestion flask . Then, 6mL of concentrated sulphuric acid (spec. gravity 1.84), H_2SO_4 were added to the digestion flask. The sample was then heated and boiled at 440^{o}C (825^{o}F) for 4 minutes.

Then, 10mL-20mL of 50% hydrogen peroxide (H_2O_2) was added to the flask via the funnel. The sample was then continued heated for one more minute. Then, the digested sample was diluted with approximately 70mL with deionized water. After cooling, the sample was filtered through a Whatman No.41 filter paper into a 100 mL volumetric flask. Finally, the concentration of nutrients (NO_3^-, NO_2^-, PO_4^{3-}, and K) and heavy metals (Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn) were determined by Atomic Absorption Spectrometer (AAS).

2.5 Plant Analysis

Plant samples were collected after irrigation in both soils and soilless cultivation. The roots and leaves were separated and then thoroughly washed. The same procedure was applied to plants-igestion. After oven-dried at 70^{o}C for 48 has shown in Figure 2, 0.25-0.5g of each plants sample was accurately weighted into a 100-mL digesdahl digestion flask. Then, 4mL of concentrated sulphuric acid (spec. gravity 1.84), H_2SO_4 were added to the digestion flask. The sample was then heated and boiled at 440^{o}C (825^{o}F) for 4 minutes. Then, 10mL of 50% hydrogen peroxide (H_2O_2) was added to the flask via the funnel. The sample was then continued heated for one more minute. Then, the digested sample was diluted with approximately 70mL with deionized water. After cooling, the sample was filtered through a Whatman No.41 filter paper into a 100 mL volumetric flask. Finally, the concentration of nutrients (NO_3^-, NO_2^-, PO_4^{3-}, and K) and heavy metals (Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn) were determined by Atomic Absorption Spectrometer (AAS).

Figure 2: Oven- Dried Plant Samples (Left), Soil Samples (Middle) with Plant and Soil Powder (Right)

3 Results and Discussion

3.1 Secondary Treated Wastewater Characteristics

The characteristics of wastewater used for irrigation of plants are described in Table 1. The secondary treated wastewater used contains macronutrients such as nitrite, phosphorus and potassium which are considered essential for improving plant growth, soil fertility and productivity of plants. In contrast, the amount of heavy metals and micronutrients is relatively low and meet the standards for reuse of wastewater for irrigation of plants. However, with continuing wastewater irrigation accumulated heavy metals in soil and plants. Thus, monitoring and assessments of heavy metals are required. This wastewater is also alkaline with 7.3 pH values, had 325 µs/cm of conductivity and 9.66 NTU of turbidity.

Table 1: Physicochemical analysis of secondary treated wastewater effluent used

Nutrients (mg/L)	Nitrate (NO3-N)	0.000
	Nitrite (NO2-N)	0.003
	Phosphorus (P)	27.000
	Potassium (K)	7.000
Heavy Metals (mg/L)	Cadmium (Cd)	0.350
	Chromium (Cr)	0.057
	Cobalt (Co)	0.110
	Copper (Cu)	0.020
	Iron (Fe)	0.016
	Lead (Pb)	0.800
	Manganese (Mn)	0.021
	Nickel (Ni)	0.025
	Zinc (Zn)	0.060
Physicochemical Parameters	pH	7.300
	EC (µs/cm)	325.000
	Turbidity (NTU)	9.660

3.2 Soil Characteristics

The soil characteristics considered with high potassium content but poor with nitrate, nitrite and phosphorus content. After irrigated with secondary treated wastewater effluent, the contents of nitrate, nitrite and phosphorus increased as shown in Table 2. However, the potassium value decreased from the original contents which are considered to be used by the plant for growth purposes. The soil micronutrients and heavy metals (Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn) were found to decrease from the original contents. It shows that, the heavy metals had accumulated in plants with continues wastewater irrigation.

Table 2: Physicochemical analysis of the soil before and after secondary treated wastewater effluent irrigation

		Before	**After**
Nutrients (mg/L)	Nitrate (NO3-N)	0.010	0.060
	Nitrite (NO2-N)	0.011	0.060
	Phosphorus (P)	0.000	0.020
	Potassium (K)	37.900	9.700
Heavy Metals (mg/L)	Cadmium (Cd)	0.243	0.144
	Chromium (Cr)	0.138	0.059
	Cobalt (Co)	0.045	0.034
	Copper (Cu)	1.100	1.080
	Iron (Fe)	1.449	1.362
	Lead (Pb)	0.311	0.282
	Manganese (Mn)	0.398	0.330
	Nickel (Ni)	0.048	0.125
	Zinc (Zn)	0.000	0.000

3.3 Plant Growth and Development

The average of the leaf numbers of the plants in soil cultivation was relatively higher compared to the average of leaf numbers of the plants in soilless cultivation as shown in Figure 3. Temporal variation in plant height for under soilless and soil cultivation conditions are shown in Figure 4. At the beginning of the experiment, the plant heights in soilless cultivation were relatively high compared to those in soil media. However, after 4 weeks irrigation the plant height in soil cultivation were relatively higher than in soilless cultivation. This explained that the plants in soilless cultivation received earlier sources of nutrients compared to the plants in soilless cultivation through direct uptake. Those grown in soilless media the plants reached only 8 cm while the 15 cm in soilless media. Besides, the average diameters of the leaf of the plants in soil cultivation were relatively high compared to in soilless cultivation as shown in Figure 5. The final weights of the plants harvested were relatively higher in soil cultivation than in soilless cultivation as shown in Figure 6 which is 3.513 kg and 2.311 kg respectively.

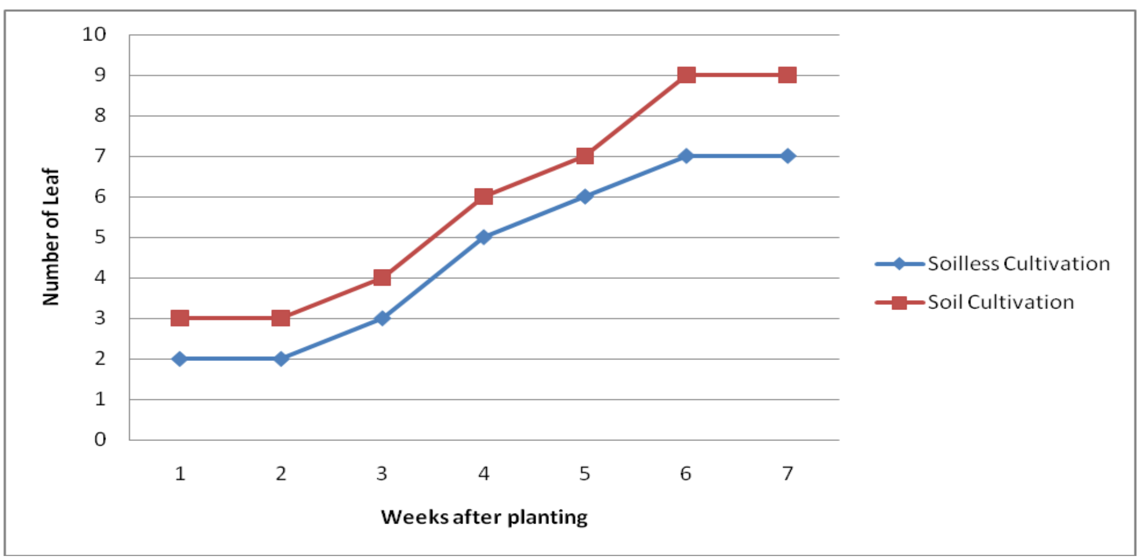

Figure 3: The average of the leaf numbers of the plants in the different planting media.

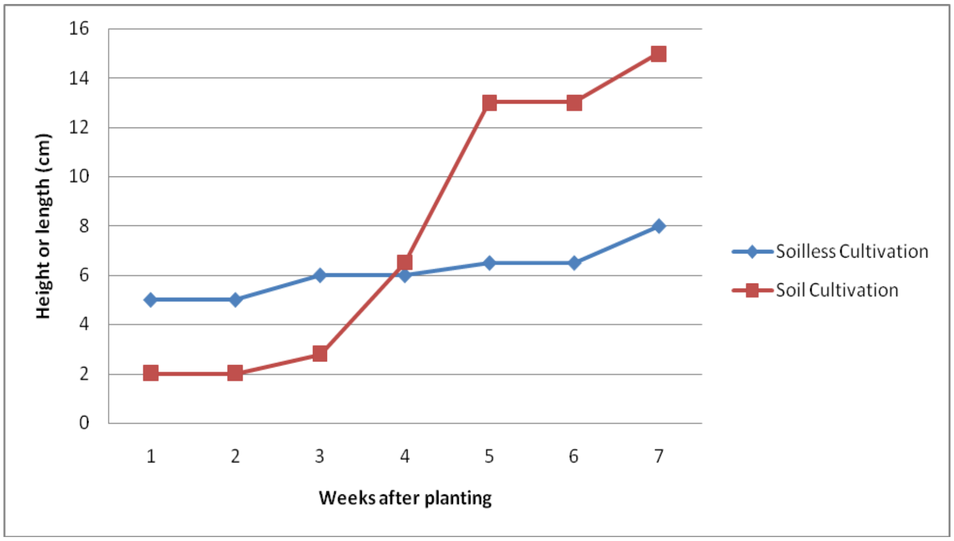

Figure 4: The average height of the plants in the different planting media.

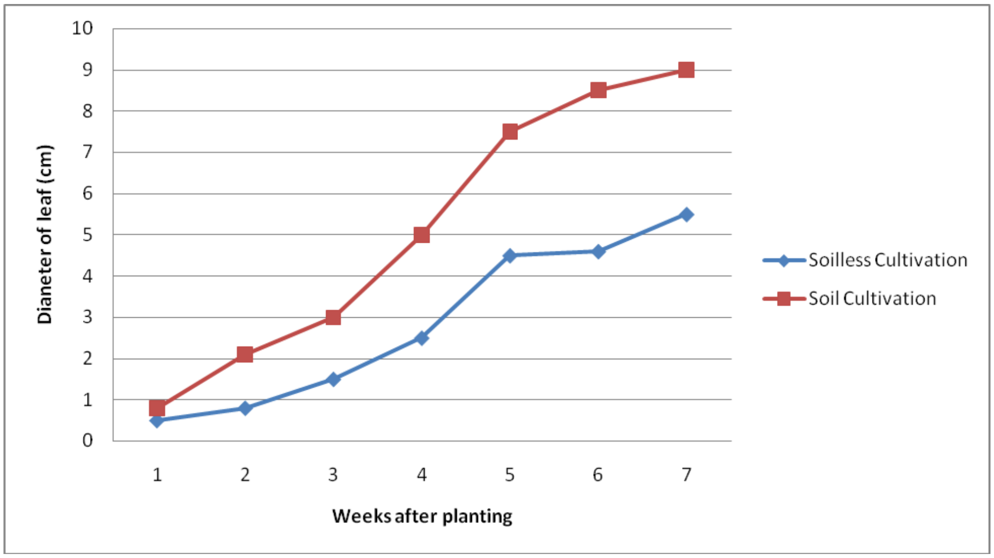

Figure 5: The average leaf diameters of the plants in the different planting media.

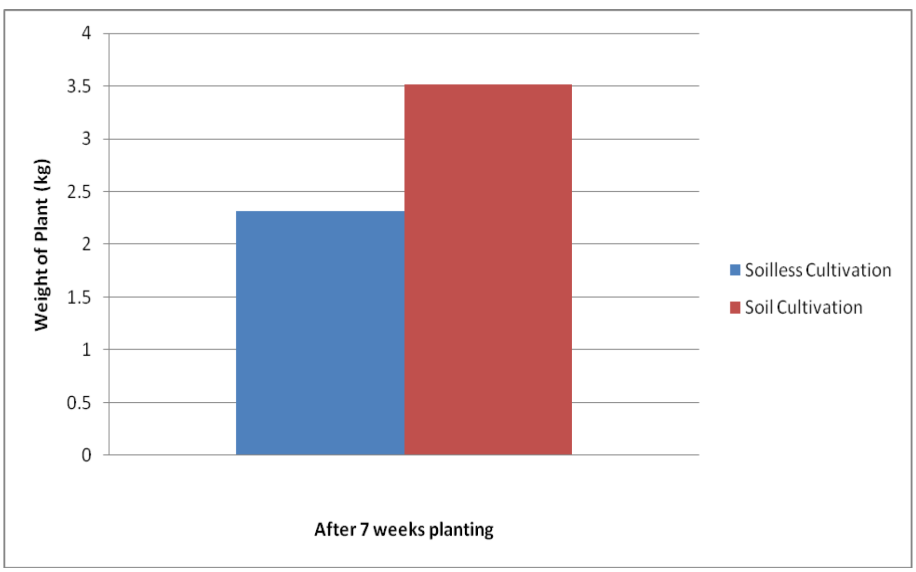

Figure 6: The average of plant weights of the different planting media.

3.4 Plant Characteristics Under Soilless and Soil Cultivation

Heavy metals (Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn) concentrations in plants are shown in Table 3 for soil and soilless cultivation. Different growing media conditions contributed to the divergent influences of the heavy metal availability in the plant. The metal concentrations in plants for soilless cultivation were relatively high compared to metals concentrations in plants for soil media. This is affected by the soil media which acts as a filter to the metals availability to be uptake by plants. For heavy metals availability in plant for soilless cultivation, directly uptake by the plant without absorption by soil contributed to higher heavy metals accumulated in plants.

Table 3**:** Physicochemical analysis of plant after secondary treated wastewater effluent irrigation under the soilless (hydroponic) and soil cultivation.

		Soilless Cultivation	Soil Cultivation
Nutrients (mg/L)	Nitrate (NO3-N)	0.020	0.030
	Nitrite (NO2-N)	0.014	0.014
	Phosphorus (P)	0.010	0.010
	Potassium (K)	52.200	59.600
Heavy Metals (mg/L)	Cadmium (Cd)	0.185	0.163
	Chromium (Cr)	0.508	0.351
	Cobalt (Co)	0.081	0.075
	Copper (Cu)	2.040	2.090
	Iron (Fe)	1.534	1.438
	Lead (Pb)	0.064	0.131
	Manganese (Mn)	0.011	0.015
	Nickel (Ni)	0.146	0.125
	Zinc (Zn)	0.000	0.000

4 Conclusion

The accumulation of heavy metals in soilless cultivation was relatively higher than soil cultivation due the facts that soilless media were directly uptake by plants without absorption by soil. The study also found that soil can act as a filter to reduce uptake of heavy metals by the plant. Besides, different growing media conditions had contributed to the divergent influences of the heavy metal availability in plant and soil. If adequate amounts of macronutrients concentrations such as nitrogen, phosphorus and potassium availability in wastewater, successful growing plants will be achieved either in soil or soilless cultivation. The used of secondary treated wastewater were believed to improved soil properties and thus increased plant growth and productivity.

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