International Journal of
Life Sciences
International Peer Reviewed Open Access Refereed Journal

Int. J. of Life Sciences, 2018; 6 (1):18-28
ISSN:2320-7817(p) | 2320-964X(o)
UGC Approved Journal No 48951

Original Article Open Access

# Heavy Metal Accumulation and Mycorrhizal Association of the Common Agroforestry Crops in the Ultramafic Soils of Dinagat Islands, Philippines

**Aribal** Lowell G, **Mancile** Danilo S, **Marin** Rico A, **Bruno** Angela Grace T

Central Mindanao University, Musuan, Maramag, Bukidnon,
Email: ariballowell@gmail.com

**Manuscript details:**

Received : 09.11.2017
Accepted : 05.02.2018
Published : 24.02.2018

**Editor: Dr. Arvind Chavhan**

**Cite this article as:**
Aribal Lowell G, Mancile Danilo S, Marin Rico A, Bruno Angela Grace T (2018) Heavy Metal Accumulation and Mycorrhizal Association of the Common Agroforestry Crops in the Ultramafic Soils of Dinagat Islands, Philippines, *Int. J. of Life Sciences*, Volume 6(1): 18-28



Available online on http://www.ijlsci.in
ISSN: 2320-964X (Online)
ISSN: 2320-7817 (Print)

**ABSTRACT**

Common Agroforestry crops in the ultramafic soils of Santo Niño, Cagdianao, Dinagat Islands were studied to determine their heavy metal accumulation and mycorrhizal association. Three Agroforestry farms were sampled for the crops such as coconut, sweet potato, and banana. On each farm, plant parts were collected separating the edible and the non-edible parts such as shoots and roots and were tested for accumulation of nickel and chromium via atomic absorption spectrophotometry. Soil samples within the rhizosphere of the crops were also collected for mycorrhizal studies. Results showed that all Agroforestry crops accumulated nickel and chromium on roots and shoots above the normal range at 0.05-10 mg/kg, however, only banana has nickel concentration exceeding the normal range of 5-25 mg/kg. For the edible parts, all Agroforestry crops have nickel and chromium concentration above the safety limits of 0.0028 and 0.3 mg/kg body weight per day for nickel and chromium, respectively. Only sweet potato has shoot/root quotient or translocation factor greater than one for both nickel and chromium which was 12.73 and 11.09, respectively, thus considered as hyperaccumulator species. Six genera of mycorrhiza were identified in all crops with Glomus as the most abundant followed by Acaulospora, Scutellospora, Entrophospora, Sclerocystis, and Gigaspora.

**Keywords:** Heavy metal, Agroforestry crops, ultramafic soil, mycorrhiza

## INTRODUCTION

In the Philippines, ultramafic soil accounts for about 5% of the total land area (Baker *et al.*, 1992). Ultramafic soils also known as serpentine soils are known to be naturally poor in terms of fertility and low in water holding capacity (Alban *et al.*, 2004) due to high concentration of heavy metals such as iron, cobalt, magnesium, chromium, and nickel and low concentrations of phosphorus, potassium, and calcium (Fernando *et al.*, 2008) hence, pose extreme limitations to agriculture otherwise not apt for cultivation at all.

For plant species to survive and adapt in ultramafic soil amidst extreme conditions has to form symbioses with mycorrhizal fungi (Turk *et al.*, 2006). This may represent an important survival strategy and also minimize if not restrained the accumulation of heavy metals. Mycorrhizal fungi help protect the plants by storing toxic metalloids in a sheath or mantle around the roots (Turk *et al.*, 2006). It also helps in increasing nutrients and water uptake and in return, the fungi benefit from the carbon compounds provided by the plants (Ianson and Smeenk, 2014).

In an agricultural country like the Philippines, farmers intend to raise crops on any parcel of land despite prevailing adverse soil conditions. In Dinagat Province, an ultramafic island, Agroforestry crops like coconut, sweet potato, and banana are widely cultivated and consumed by the locals. If these crops have developed an association with arbuscular mycorrhizal fungi (AMF) and thrive well, the possibility of metal accumulation in tissues and edible parts of the crops is still inevitable because not all heavy metals could be contained by the mycorrhiza. The risks of consuming agroforestry crops planted in ultramafic soils still remain because continued consumption, even in small amounts for a prolonged period may have serious implication to human health. Heavy metal-contaminated food can reduce some essential body nutrients causing brain retardation, gastrointestinal cancer, malnutrition, and other diseases (Dioka *et al.*, 2004). Thus, this study was conducted to investigate the heavy metal uptake of the agroforestry crops such as coconut, sweet potato, and banana in the area.

## MATERIALS AND METHODS

### *Location of the Study*

The study was carried out at Barangay Sto. Niño, Municipality of Cagdianao situated in the southern portion of the province of Dinagat Islands with geographic coordinates 09°54' N and 125°38' E (Fig. 1). The climate in the province is a Type II characterized by no dry season, but with a very pronounced maximum

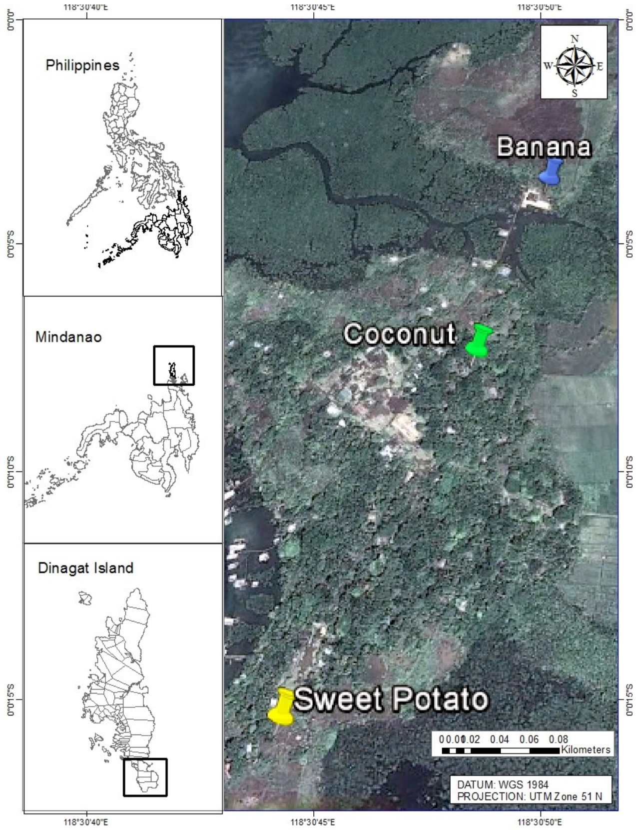


**Figure 1.** Map of the Study Area

rainy period from November to February (Alban *et al.*, 2004). The whole of Dinagat Island soil type is ultramafic hence classified as mineral land based on DENR's land classification. Despite the adverse soil conditions various portions are still cultivated and planted with agroforestry crops such as coconuts, sweet potato, and banana.

Three agroforestry farms were sampled since not all crops were found on a single agroforestry farm. All farms sampled were less than one (1) hectare. Farm one (1), two (2) and three (3) were dominated by banana, coconut, and sweet potato, respectively. These agroforestry crops were mainly cultivated for subsistence. Excess crops for consumption, especially coconut were being sold to the community and to the nearest city which is Surigao. Table 1 shows the geographic coordinates and elevation of the three agroforestry farms.

**Table 1. Geographic coordinates and elevation of the Agroforestry farms**

| Agroforestry farms | Coordinates | | Elevation (masl) |
|---|---|---|---|
| | Latitude | Longitude | |
| Banana (Farm 1) | 9°54’59.51”N | 125°38’53.17” E | 9 |
| Coconut (Farm 2) | 9°54’52.25”N | 125°38’51.25” E | 19 |
| Sweet potato (Farm 3) | 9°54’39.79”N | 125°38’46.58” E | 12 |

### Sampling
In each farm plant parts were collected separating the edible and the non-edible parts such as shoots, roots, and stem. These samples were washed using distilled water and placed in containers and were properly labeled.

### Oven-drying
Prior to oven-drying, the samples were thinly chopped and were placed in blotters. These were then oven-dried at 60°C temperature for 3 weeks. From the oven-dried samples, a 300-gram was obtained for laboratory analyses.

### Soil sampling
The soil samples were collected within the rhizosphere of the different crop parts. Soil samples obtained from the plot were thoroughly mixed and a composite sample of approximately 2 kg plot was collected for laboratory analyses and for mycorrhizal studies.

### Separating Mycorrhizal Spores from Soil
a. Soil sieving and centrifugation (after Daniels and Skipper, 1982 and Tommerup, 1992).
The collected soils per plot were weighed to obtain 100 grams sample preparations at 10 proportions per plot. A substantial volume of distilled water was added to each 100-gram samples and undergone decantation process through a series of sieves after allowing heavy soil particles to settle for a few seconds. The washing and decanting process was repeated until the water is clear. A 150μm, 180μm, and 250μm core screen fractions were used to ensure soil aggregates were broken apart to free spores.

The sievings that settle at 150μm, 180μm, and 250μm core screens after decantation were collected and placed into the centrifuge tube. Centrifugation follows within 5 minutes at 2000 rpm to remove substantial amounts of floating organic debris. After centrifugation, the supernatant and floating debris were discarded. The pellet was then suspended in 50% sucrose solution and was shaken vigorously. This was followed by another centrifugation for 1 minute at 2000 rpm to separate the spores.

### Spore Count
The supernatant from the three finest screens (*i.e.* 150μm, 180μm, and 250μm) was collected and carefully transferred to Petri-dishes. Spores were then counted via the stereoscopic microscope.

### Spore Identification
Spores suspended in the supernatant were collected using a syringe. This was then placed on the glass slide and was covered with a cover-slip and was identified under a compound microscope. Photographs of spores were taken and were compared using Brundrett *et al*., (1996), Morton and Benny (1990), and Elmore (2006) for identification.

### Shoot/Root Quotient or Translocation Factor
To evaluate the ability of the plant to accumulate or translocates heavy metal in their tissues, shoot/root quotient (SRQ) or translocation factor (TF) was used. The species that has SQR or TF greater than one (1) is considered as hyperaccumulator otherwise, characterized as heavy metal excluders (<1) (Rotkittikhun *et al*., 2006).

$$SRQ \text{ or } TF = \frac{\text{Heavy metal concentration in the shoot}}{\text{Heavy metal concentration in the root}}$$

## RESULTS AND DISCUSSIONS

### Heavy Metal Accumulation
The results of heavy metal accumulation in roots and shoots of the three agroforestry crops were shown in Figure 2. Based on the result, among the three crops, banana obtained the highest concentration of nickel both in shoots and roots. Sweet potato has the lowest concentration in the roots while coconut obtained the lowest accumulation of nickel in the shoots. Bhalerao *et al*. (2015) reported that majority of plant species contain nickel at very low concentration for only 0.05-10 mg/kg dry weight and for normal functioning plants accumulation of nickel should not exceed 10 mg/kg for their metabolic needs (Lasat, 2000). Above that range, plants would show nickel toxicity symptoms like inhibition of growth, photosynthesis, seed germination, sugar transport and induction of chlorosis, necrosis, and wilt (Bhalerao *et al.*, 2015). But in plants growing in metalliferous soils, the normal range of this metal in the shoots is 5-25 mg/kg (Reeves and Baker, 2000) due to high concentration of nickel in ultramafic soils (Brooks, 1987) that can be readily accumulated since it is often mobile in plants (Welch and Cary, 1975). In this case, only banana has above the normal range for plants growing in metalliferous soils.

For Cr accumulation, the sweet potato has the highest concentrations in shoots but has the lowest in rats.

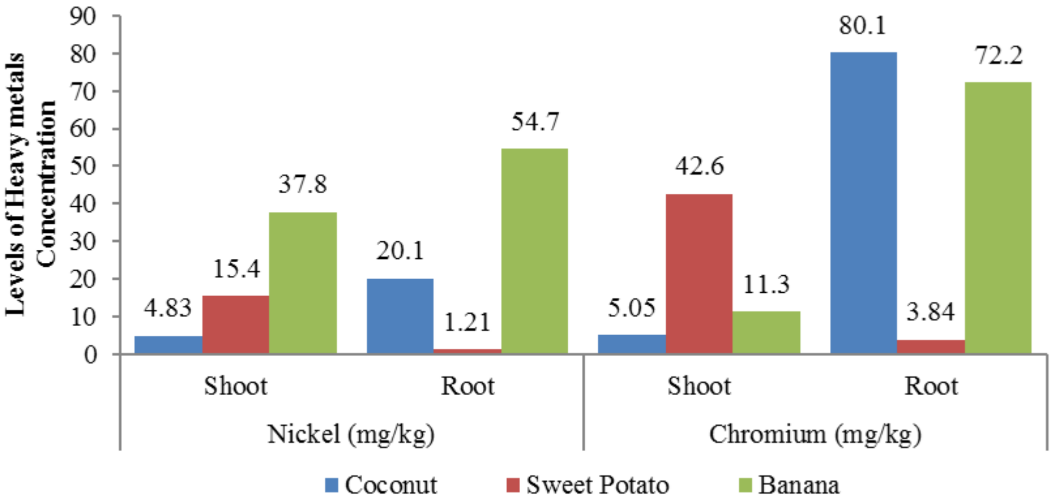


**Figure 2.** Quantified nickel and chromium in plant tissues

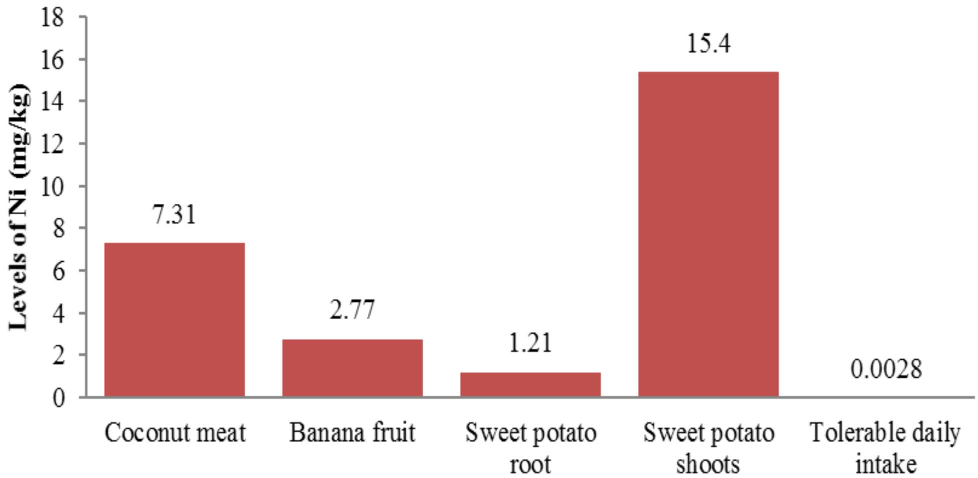


**Figure 3.** Nickel concentrations (mg/kg) in the edible part of Agroforestry crops

Banana ranked second both in roots and shoots. Coconut has the lowest Cr accumulation shoots but has the highest Cr in roots (Fig. 2). Chromium is often less than 1 mg/kg and rarely exceeds 5 mg/kg in normal soils and the concentration of more than 50 mg/kg are so uncommon on serpentine soils that this may be used as an indicator of soil contamination (Reeves, 2015). In vegetative organs, most of the plant's chromium toxicity starts from 10-15 mg/kg (Verbruggen *et al*., 2009). In this study, all of the Agroforestry crops exceed the normal range of plants growing in serpentine soils. Coconut and banana even have chromium above 50 mg/kg.

***Edible parts***

Results through AAS showed that the shoots of sweet potato obtained the highest concentration of nickel in the edible parts, followed by coconut meat and the lowest was sweet potato roots (Fig. 3). In general, all the agroforestry crops evaluated have accumulated higher nickel concentration above the general range of edible parts which normally ranges from 0.1 to 0.5 mg/kg (Clarkson, 1988; Andersen *et al.*, 1990; Aitio *et al.*, 2012; Fawell *et al.*, 2007; Leblanc *et al*., 2005; Cempel and Nikel, 2006; DudaChodak and Blaszczyk, 2008; Rose *et al*., 2010; Becker and Kumpulainen, 2011; Noël *et al*., 2012).

A tolerable daily intake of nickel is 0.0028 mg/kg body weight per day (Benford *et al*., 2015) and recommended a daily intake of 0.4 mg (Iyengar, 1985) suggest that frequent consumption of sweet potato roots, banana fruits, coconut meat, and especially sweet potato shoots will pose health problems. Aitio *et al.* (2012) classified nickel and nickel compounds as human carcinogens causing cancers of the lung, nasal cavity and paranasal sinuses after inhalation. Chronic oral exposures to nickel also cause reproductive and developmental toxicity.

In terms of chromium concentration in the edible parts, sweet potato shoots obtained the highest followed by sweet potato roots. The lowest was obtained in coconut meat (Fig. 4). All of the crops have chromium concentration above the safety limits. The most type of chromium present in a variety of food was Cr (III) and exposure to it was mainly via diet/food rather than inhalation (Benford *et al.*, 2015). Adequate intake of chromium ranging from 0.0002-0.0055 mg/day for infants to 0.035 mg/day for males between 19 and 50 years old; 0.029-0.030 mg/day during pregnancy; and 0.044-0.045 mg/during lactation were determined by Rusell *et al.* (2001). Havel *et al.* (1989) also established a range of 0.05-0.2 mg/day as safe and adequate daily intake for adults and adolescents. And Benford *et al*. (2014) derived a tolerable daily intake of 0.3 mg/kg body weight per day.

There was no clear evidence of genotoxic and carcinogenic effects of Cr (III) even at higher dose levels than the suggested dietary intakes (Santonen, 2009a). And an intake ranging between 1-2 mg/day shows no adverse effect (COMA, 1991). Still, frequent consumption of sweet potato shoots, sweet potato roots, banana fruits, and coconut meat could cause health risks since it is above the safety limits. Gastrointestinal effects, epigastric pain, irritation, and ulceration are the reported effects of inhalation and ingestion of high doses of chromium (Wilbur *et al*., 2012).

***Mycorrhizal association***

Soil samples from the rhizospheres of banana, sweet potato and coconut showed different types of spores. The spores examined consisted of six genera, namely: *Glomus* (Glomaceae), *Acaulospora* (Acaulosporaceae), *Gigaspora* (Gigasporaceae), *Entrophospora* (Acaulosporaceae), *Scutellospora* (Gigasporaceae), and *Sclerocystis* (Glomaceae) (Fig. 5).

The result showed that 39 species belonging to the genus *Glomus* were recorded and considered the highest. It was followed by *Acaulospora* with 14 species and *Scutellospora* with only 4 species. Only one species were found in the genera of *Gigaspora, Entrophospora*, and *Sclerocystis*, respectively. This finding conforms to that of Aribal *et al.* (2017) in ultramafic soils of Mt. Kiamo where the genus *Glomus* was the most abundant and widely distributed. The dominance of *Glomus* in ultramafic soils was due to its higher metal tolerance (Martina and Vosatka, 2005; Schwartz *et al*., 2006; Chen *et al*., 2007; Zaefarian *et al*., 2010; Carrasco *et al*., 2011). Morton (1988) also considered *Glomus* species as the common species all over the world comprising more than 75 percent of the total isolates followed by *Acaulospora*. Bouamri *et al*. (2006) also mentioned that many studies revealed that different species of AM fungi were obtained depending on plant species and geographic location, but amongst AM fungal species, *Glomus* species were consistently observed while others species belonging to the genera *Acaulospora*, *Gigaspora* and *Scutellospora* were either absent or found in fewer numbers showing the same result of this study.

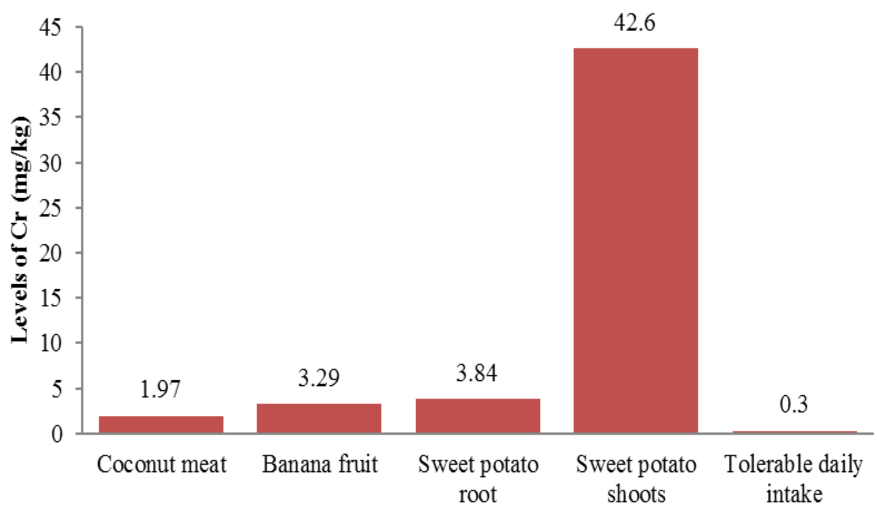


**Figure 4.** Chromium concentrations (mg/kg) in the edible part of Agroforestry crops

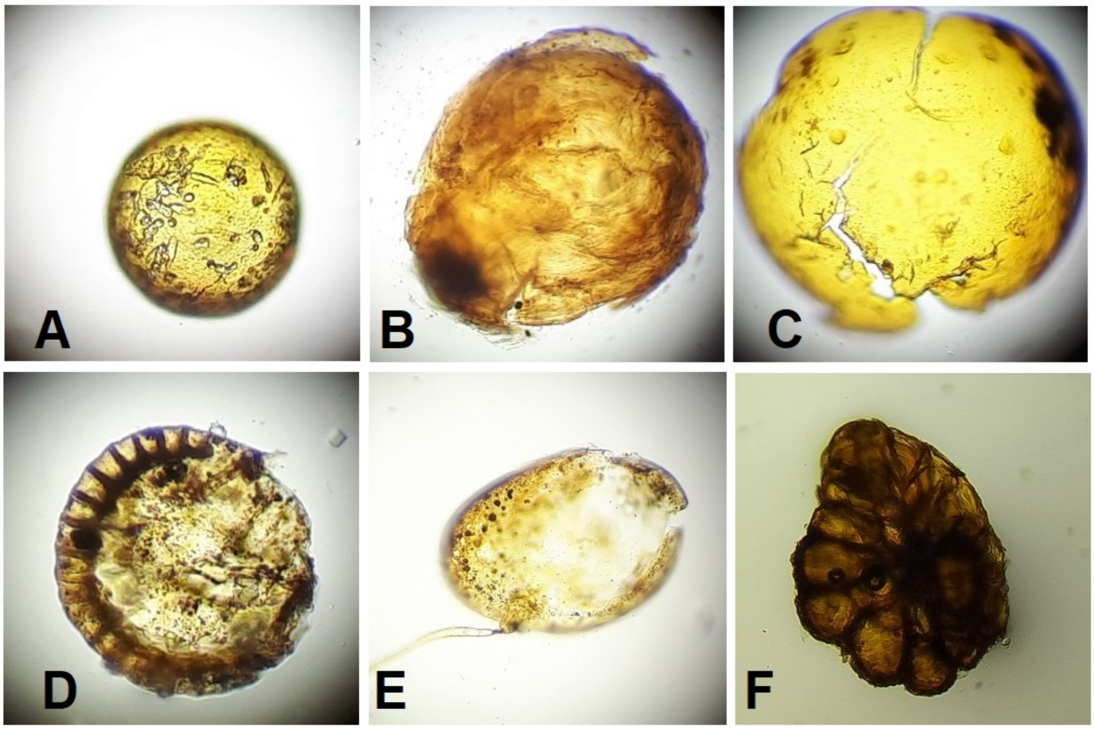


**Figure 5. A,** *Glomus sp. 6*; **B**, *Acaulospora sp.1*; **C**, *Gigaspora sp.*; **D**, *Entrophopora sp.*; **E**, *Scutellospora sp.1*; and **F**, *Sclerocystis sinuasa*

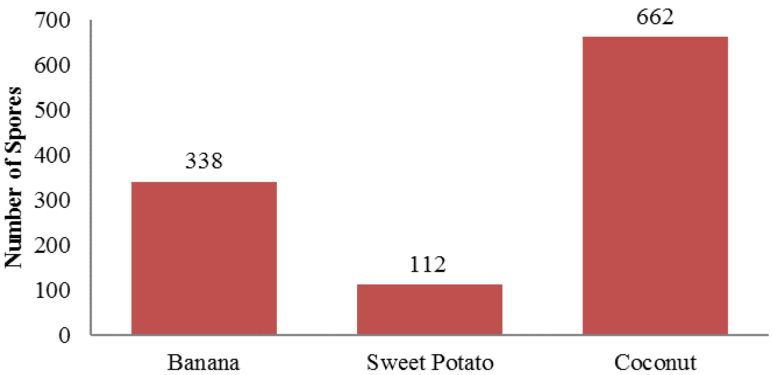


**Figure 6.** Total number of spores of the Agroforestry crop

On the other hand, the number of spores within the rhizospheres of the 3 agroforestry crops varied with a total of 1,112 spores counted (Fig. 6). The highest spore count was observed in the rhizospheres of coconut with 662 spores followed by banana with 338 spores while the lowest spore number was in sweet potato with 112 spores. Spore production by mycorrhizal fungi is influenced by many factors, including the host plant (Brundrett and Kendrick, 1988) through the difference in the effects on the hyphal growth and sporulation (Eom *et al.,* 2000).

*Glomus sp. 5* obtained the highest total spore count with 295 spores in all, obtained mycorrhizal spores and was followed by *Glomus sp. 6* with 278 spores (Table 2). *Glomus intraradices* was also observed which, according to Regvar *et al*. (2003) this type of mycorrhiza was common and has adapted to heavy metal contaminated sites. In general, spore numbers were dominated by *Glomus* species followed by *Acaulospora, Scutellospora, Entrophospora, Sclerocystis and Gigaspora* species as having the lowest spore count. A small number of Gigasporaceae (*Gigaspora* and *Scutellospora*) was due to its large size, which requires long periods of their development than smaller-sized spore species (Hepper, 1984) and since they were usually found in sandy dunes (Lee and Koske, 1994).

**Table 2.** Mycorrhiza spore count per Agroforestry crop

| Mycorrhizal Species | Agroforestry Crop | | | Total |
|---|---|---|---|---|
| | Banana | Sweet Potato | Coconut | |
| *Glomus sp. 5* | 11 | 36 | 248 | 295 |
| *Glomus sp. 6* | 236 | 6 | 36 | 278 |
| *Glomus sp. 3* | 9 | 23 | 111 | 143 |
| *Glomus intraradices* | - | - | 90 | 90 |
| *Glomus sp. 1* | 15 | 23 | 4 | 42 |
| *Glomus sp. 24* | - | - | 42 | 42 |
| *Glomus sp. 10* | 36 | - | 4 | 40 |
| *Glomus sp. 8* | 1 | 3 | 24 | 28 |
| *Glomus sp. 34* | - | - | 14 | 14 |
| *Acaulospora sp. 1* | 5 | 4 | 5 | 14 |
| *Glomus fasciculatum* | - | - | 11 | 11 |
| *Glomus sp. 33* | - | - | 8 | 8 |
| *Entrophospora sp.* | 6 | - | 1 | 7 |
| *Glomus sp. 7* | 1 | 2 | 3 | 6 |
| *Glomus sp. 9* | 3 | - | 3 | 6 |
| *Glomus macrocarpum* | - | - | 6 | 6 |
| *Acaulospora sp. 2* | 1 | 1 | 3 | 5 |
| *Glomus sp. 2* | 4 | - | - | 4 |
| *Glomus sp. 15* | 1 | - | 3 | 4 |
| *Glomus sp. 12* | 1 | - | 2 | 3 |
| *Glomus sp. 14* | 2 | - | 1 | 3 |
| *Glomus sp. 25* | - | - | 3 | 3 |
| *Glomus sp. 27* | - | - | 3 | 3 |
| *Sclerocystis sp.* | - | - | 3 | 3 |
| *Glomus sp. 4* | 2 | - | - | 2 |
| *Glomus sp. 13* | 1 | - | 1 | 2 |
| *Glomus sp. 17* | - | 1 | 1 | 2 |
| *Glomus sp. 22* | - | 2 | - | 2 |
| *Glomus sp. 23* | - | - | 2 | 2 |
| *Glomus sp. 35* | - | - | 2 | 2 |
| *Acaulospora sp. 5* | - | 2 | - | 2 |
| *Acaulospora sp. 9* | - | - | 2 | 2 |
| *Scutellospora sp. 2* | - | - | 2 | 2 |
| *Scutellospora sp. 3* | - | - | 2 | 2 |
| *Glomus sp. 11* | 1 | - | - | 1 |
| *Glomus sp. 16* | - | 1 | - | 1 |
| *Glomus sp. 18* | - | 1 | - | 1 |
| *Glomus sp. 19* | - | 1 | - | 1 |
| *Glomus sp. 20* | - | 1 | - | 1 |
| *Glomus sp. 21* | - | 1 | - | 1 |
| *Glomus sp. 26* | - | - | 1 | 1 |
| *Glomus sp. 28* | - | - | 1 | 1 |
| *Glomus sp. 29* | - | - | 1 | 1 |

**Table 2. Continued….**

| Mycorrhizal Species | Agroforestry Crop | | | Total |
|---|---|---|---|---|
| | Banana | Sweet Potato | Coconut | |
| *Glomus sp. 30* | - | - | 1 | 1 |
| *Glomus sp. 31* | - | - | 1 | 1 |
| *Glomus sp. 32* | - | - | 1 | 1 |
| *Acaulospora sp. 3* | 1 | - | - | 1 |
| *Acaulospora sp. 4* | 1 | - | - | 1 |
| *Acaulospora sp. 6* | - | 1 | - | 1 |
| *Acaulospora sp. 7* | - | 1 | - | 1 |
| *Acaulospora sp. 8* | - | - | 1 | 1 |
| *Acaulospora sp. 10* | - | - | 1 | 1 |
| *Acaulospora sp. 11* | - | - | 1 | 1 |
| *Acaulospora sp. 12* | - | - | 1 | 1 |
| *Acaulospora sp. 13* | - | - | 1 | 1 |
| *Acaulospora sp. 14* | - | - | 1 | 1 |
| *Gigaspora sp.* | - | 1 | - | 1 |
| *Scutellospora sp. 1* | - | 1 | - | 1 |
| *Scutellospora sp. 4* | - | - | 1 | 1 |
| **TOTAL** | **338** | **112** | **662** | **1,112** |

*Glomus* and *Acaulospora* species were observed in all crops. *Gigaspora species* were obtained only in sweet potato. *Sclerocystis sp.* was observed only in coconut. And *Scutellospora sp.* was noticed in coconut and sweet potato. Presence of *Glomus* in every Agroforestry crop can lead to assumptions that *Glomus* might have developed a good adaptive symbiotic with different host plants (Heijden *et al*., 1998). Symbioses with mycorrhizal fungi help in increasing nutrients and water uptake of plants (Ianson and Smeenk, 2014).

***Shoot/Root Quotient or Translocation Factor***

To assess the potential of coconut, sweet potato and banana as nickel or chromium hyperaccumulator, the shoot/root quotient (SRQ) or translocation factor (TF) was determined (Table 5). SRQ or TF was used to evaluate the ability of the plant to accumulate or translocates heavy metal in their tissues. The species that SQR or TF greater than one (1) is considered as hyperaccumulator or has the ability to translocate heavy metals effectively from roots to shoots and can effectively remediate heavy metal contaminated sites, otherwise characterized as heavy metal excluders or has the ability to tolerate high amounts of heavy metals. (Rotkittikhun *et al*., 2006; Baker and Brooks, 1989).

The result showed that only sweet potato hash an SRQ or TF greater than one, both in nickel and chromium, thus, considered as hyperaccumulator species and could be used to remediate nickel and chromium contaminated sites (Table 3). Coconut and banana only contain an SQR or TF of less than one both in nickel and chromium thus, classified as an excluder. Excluder species accumulate metals mostly in their roots than in shoots and show inhibited root growth than shoots (Seregin and Ivanov, 2001; Samantaray *et al*., 1997).

Moreover, it was observed that most of the heavy metals were absorbed greater by the roots than in shoots. According to Shanker *et al*. (2005), accumulating more heavy metals in roots is a natural reaction of plants to reduce the toxic effect of it.

**Table 3.** Shoot/root quotient or translocation factor of Agroforestry crops

| Agroforestry crop | Nickel SRQ/TF | Chromium SRQ/TF | Classification |
|---|---|---|---|
| Coconut | 0.24 | 0.06 | Ni and Cr excluder |
| Sweet Potato | 12.73 | 11.09 | Ni and Cr hyperaccumulator |
| Banana | 0.69 | 0.16 | Ni and Cr excluder |

**Table 4.** Levels of total nitrogen, extractable phosphorus, and exchangeable potassium

| Agroforestry crops | Total Nitrogen (%) | Extractable Phosphorus (ppm) | Exchangeable Potassium (ppm) |
|---|---|---|---|
| Banana | 0.1474 | 0.245 | 42 |
| Coconut | 0.1985 | 0.389 | 39 |
| Sweet Potato | 0.0422 | 0.751 | 18 |

***Soil Properties***

All of the soils collected from the rhizosphere of three agroforestry crops have lower levels of total nitrogen, extractable phosphorus, and exchangeable potassium (Table 4). The usual range of results has been observed since, it has been known that these micronutrients were normally at lower concentrations in ultramafic soils (Brooks, 1987). Total nitrogen concentration ranges from 0.0422 to 0.1985% were classified as very low (< 0.1%) to low (0.1-0.2%) for optimum plant growth. The moderate concentration of nitrogen ranges from 0.2-0.5% and may reach more than 1 percent (Allan, 2009). Low levels of nitrogen would result in stunted growth, and chlorosis; in severe cases, flowering and yield are greatly reduced (Silva and Uchida, 2000). Concentration of extractable phosphorus was also very low (< 5ppm) which ranges from 0.245 to 0.751ppm. The medium range was normally 13–25ppm (Ward, 1993). The lower concentration of phosphorus may cause delayed maturity and poor seed and fruit development (Silva and Uchida, 2000). Exchangeable potassium ranging from 18 to 42 ppm was classified as very low (< 40ppm) and low (41-80ppm) (Ward, 1993). A deficiency of potassium would result to chlorosis, slow and stunted growth, weak stems, and low quantity of seeds and fruits (Silva and Uchida, 2000). Generally, the all the soils collected were nutrient deficient making it infertile for plant growth. Plants that have survived have adapted to the adverse soil condition through evolution and have ultramafic soil tolerance (Proctor, 1999).

## CONCLUSION

Based on the results of the study the following conclusions are drawn:

1. All of the agroforestry crops accumulated chromium above the normal range for plants growing in metalliferous soils while only the bananas accumulated nickel. But all crops exceed the range of chromium and nickel concentration for normal soils.

2. Nickel and chromium concentration in edible parts exceed the safe limits and may pose health risks.

3. The agroforestry crops have an association with mycorrhizal fungi with the genus *Glomus* as the most abundant.

4. The sweet potato was both nickel and chromium hyperaccumulator while banana and coconut were metal excluders.

**Conflicts of interest:** The authors stated that no conflicts of interest.

## REFERENCES

Aitio A, Attfield M, Cantor K, Demers P, Fowler B., Fubini B, Gérin M, Goldberg M, Grandjean P, Hartwig A, Heinrich U, Henderson R, Ikeda M, Infante P, Kane A, Kauppinen T, Landrigan P, Lunn R, Merletti F, Muhle H, Rossman T, Samet J, Siemiatycki J, Stayner L, Waalkes M, Ward E and Ward, J (2012) Nickel and nickel compounds. IARC monographs 100 c. World Health Organization, Lyon.

Alban JD, Altamirano RA, Batangan E, Gonzales M, Hilario MV, Narvades V and Gaerlan F (2004) Mts. Kambinliw & Redondo Loreto, Dinagat Island, Surigao del Norte: Integrating Forest Conservation With Local Governance. Quezon City, Philippines: Haribon Foundation, 20 & 72.

Allan R (2009) Soil tests & interpretation. Hill laboratories. www.hill-laboratories.com. Date Accessed: June 15, 2017.

Andersen A, Baker D, Beyersmann D, Costa M, De Flora S, Gilman JPW, Grandjean P, Gray CN, Kasprzak KS, Levy, LS, Møller Jensen O, Mottet NK, Norseth T, Peto J, Schaller K-H, Simonato L, Stern R, Sunderman EW, Swierenga S, and Tossavainen A (1990) IARC monographs on the evaluation of carcinogenic risks to humans. Chromium, nickel, and welding. World Health Organization, Lyon, 49, 257–445.

Aribal L, Marin RA, Paquit JC, and Zanoria J (2017) Abundance and distribution of arbuscular mycorrhiza in the ultramafic soils of Mt. Kiamo in Bukidnon, Philippines. *International Journal of Scientific Research in Environmental Sciences*, 5(2), 36-41.

Baker AJM, Proctor J, van Balgooy MMJ and Reeves RD (1992) Hyperaccumulation of Nickel by the Flora of the Ultramafics of Palawan, Republic of the Philippines. In: Baker AJM, J. Proctor and RD. Reeves (eds.), The

Vegetation of Ultramafic (Serpentine) Soils: Proceedings of the *First International Conference on Serpentine Ecology*. Pp 291-304.

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

Becker W, and Kumpulainen J (1991) Contents of essential and toxic mineral elements in Swedish market-basket diets in 1987. *British Journal of Nutrition,* 66, 151–160.

Benford D, Ceccatelli S, Cottrill B, DiNovi M, Dogliotti E, Edler L, Farmer P, Fürst P, Hoogenboom L, Knutsen HK, Lundebye A-K, Metzler, M, Mutti A, Nebbia CS, O'Keeffe M, Petersen A, Rietjens I, Schrenk D, Silano V, van Loveren H, Vleminckx C and Wester P (2014) Scientific opinion on the risks to public health related to the presence of chromium in food and drinking water. *EFSA Journal,* 12(3): 3595, 261. doi:10.2903/j.efsa.2014.3595

Benford D, Ceccatelli S, Cottrill B, DiNovi M, Dogliotti E, Edler L, Farmer P, Fürst P, Hoogenboom L, Knutsen HK, Lundebye A-K, Metzler M, Mutti A, Nebbia CS, O'Keeffe M, Petersen A, Rietjens, I, Schrenk D, Silano V, van Loveren H, Vleminckx C and Wester P (2015) Scientific opinion on the risks to public health related to the presence of nickel in food and drinking water. *EFSA Journal,* 13(2): 4002, 202. doi:10.2903/j.efsa.2015.4002

Bhalerao S, Sharma A and Poojari A (2015) Toxicity of nickel in plants. International *Journal of Pure Applied Biosciences,* 3(2), 345-355.

Bouamri R, Dalpé Y, Serrhini MN and Bennani A (2006) Arbuscular mycorrhizal fungi species associated with rhizosphere of *Phoenix dactylifera* L. in Morocco. *African Journal of Biotechnology.* 5(6), 510-516.

Brooks R (1987) Serpentine & its Vegetation. Portland, Oregon. Dioscorides Press.

Brundrett M, Bougher N, Dell B, Grove T and Malajczu KN (1996) 'Working with mycorrhizas in forestry and agriculture. Australian Centre for International Agricultural Research: Canberra. 179-181.

Brundrett MC and Kendrick B (1988) The mycorrhizal status, root anatomy, and phenology of plants in a sugar maple forest. *Canada Journal of Botany*, 66: 1153-1173.

Carrasco L, Azcon R, Kohler J, Roldán A and Caravaca F (2011) Comparative effects of native filamentous arbuscular mycorrhizal fungi in the establishment of an autochthonous, leguminous shrub growing in a metal-contaminated soil. *Science of the Total Environment*, 409 (6), 1205-1209.

Cempel M and Nickel G (2006) Nickel: A review of its sources and environmental toxicology. *Polish Journal of Environmental Studies,* 15, 375–382.

Chen BD, Zhu Y, Duan J, Xiao XY and Smith SE (2007) Effects of the arbuscular mycorrhizal fungus *Glomus mosseae* on growth and metal uptake by four plant species in copper mine tailings. *Environmental Pollution Journal* 147(2), 374-380.

Clarkson TW (1988) Biological monitoring of toxic metals. New York. Plenum Press. Pp 265-282.

Committee on Medical Aspects of Food Policy (COMA) (1991) Dietary references values for food energy and nutrients for the United Kingdom. Department of Health Report 41, HMSO, London. 181-182pp.

Daniels BA and Skipper HD (1982) Methods for the recovery and quantitative estimation of propagules from soil. In: Schenck, NC (edition). Methods and principles of mycorrhizal research. The American Phytopathological Society. St. Paul. 29-35.

Dioka CE, Oresakwe OE, Adeniyi FA, and Meludu SC (2004) Liver and renal function tests in artisans occupationally exposed to lead in mechanic village in Nnewi, Nigeria. *International Journal of Environmental Research and Public Health,* 1, 21–25.

Duda-Choda, K and Blaszczyk U (2008) The impact of nickel on human health. *Journal of Elementology,* 13, 685–696.

Elmore, WC (2006) Population and identification of mycorrhizal fungi in St. Augustine grass in Florida and their effect on soil-borne Pathogens. *Ph.D. Dissertation*. University of Florida.

Eom AH, Hartnett DC, and Wilson GWT (2000) Host plant effects on arbuscular mycorrhizal fungal communities in tall-grass prairie. *Oecologia*, 122, 435-444.

Fawell JK, Grawé K, Cotruvo J, Giddings M, Jackson P, Magara Y, Ohanian E, Bartram J, Vickers C, Bos R, Ward P and Sheffer M (2007) Nickel in Drinking Water. WHO/SDE/ WSH/07.08/55. Geneva. Available at: http://www.who.int/water_sanitation_health/dwq/chemicals/ Nickel110805.pdf

Fernando ES, MH Suh, J Lee, and DK Lee (2008) Forest Formations of the Philippines ASEAN-Korea Environmental Cooperation Unit (AKECU). GeoBook Publishing Company, 232pp.

Havel R, Calloway D, Gussow J, Mertz W and Nesheim M (1989) Recommended dietary allowances, 10th Edition. Washington, DC. National Academy Press.

Heijden VD, Klironomos MGA, Ursic JN, Moutoglis M, and Streitwolf-Engel P (1998) Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability, and productivity. *Nature*, 396, 69-72.

Hepper CM (1984) Isolation and culture of VA mycorrhizal (VAM) fungi. In: VA Mycorrhizae. (Eds. CL Powell, DJ Bagyaraj) CRC Press, Florida, USA, Pp 95-122.

Ianson D and Smeenk J (2014) Mycorrhizae in the Alaska landscape. Alaska: University of Alaska Fairbanks Cooperative Extension Service, Pp 1-2.

Lasat M (2000) The use of plants for the removal of toxic metals from contaminated soils, Unpublished Manuscript from the US EPA, American Association for Advancement of Sciences Fellowship Program, Pp 34.

Leblanc JC, Guerin T, Noel L, Calamassi-Tran G, Volatier JL and Verger P (2005) Dietary exposure estimates of 18 elements from the 1st French Total Diet Study. Food Additives and Contaminants, 22, 624–641.

Lee PJ and Koske RE (1994) *Gigaspora gigantia*: Seasonal, abundance, and aging of spores in a sand dune. *Mycological Research Journal,* 98, 453-457. doi.org/10.1016/S0953-7562(09)81203-3

Martina J and Vosatka M (2005) Response to cadmium of *Daucus carota* hairy roots dual cultures with *Glomus intraradices* or *Gigaspora margarita*. *Mycorrhiza* 15(3), 217-224.

Morton J (1988) Taxonomy of mycorrhizal fungi: classification, nomenclature, and identification. *Mycotaxon* (32), 267-324.

Morton JB and Benny GL (1990) Revised classification of arbuscular mycorrhizal fungi (Zygomycetes) a new order, Glomales: A sub-order Glomenieae and Gigasporanieae and two new families Acaulosporaceae and Gigasporaceae with an emendation of Glomaceae. *Mycorrhizal Taxonomy*, 37, 439-448.

Noël L, Chekri R, Millour S, Vastel C, Kadar A, Sirot V, Leblanc J and Guérin T (2012) Li, Cr, Mn, Co, Ni, Cu, Zn, Se and Mo levels in foodstuffs from the Second French TDS. Food Chemistry, 132, 1502–1513.

Proctor J (1999) Toxins, nutrient shortages & droughts: The serpentine challenge. *Trees*, 14, 334-335.

Reeves RD (2015) Hyperaccumulation of trace elements by plants. DOI:10.1007/1-4020-4688-X_2

Reeves RD and Baker AJM (2000) Phytoremediation of toxic metals: Using plants to clean up the environment. New York. John Wiley and Sons, Inc.

Regvar M, Vogel K, Irgel N, Wraber T, Hildebrandt U, Wilde P, and Bothe H (2003) Colonization of pennycresses *Thalspi sp*. of the Brassicaceae by arbuscular mycorrhizal fungi. *Journal of Plant Physiology,* 160, 615-626.

Rose M, Baxter M, Brereton N and Baskaran C (2010) Dietary exposure to metals and other elements in the 2006 UK Total Diet Study and some trends over the last 30 years. Food Additives and Contaminant Part A, 27, 1380–1404.

Rotkittikhun R, Kruatrachue M, Chaiyarat R, Ngernsansaruay P, Pokethitiyook C, Paijitprapaporn A, Baker AJM (2006) Uptake & accumulation of lead by plants from the Bo Ngamlead mine area in Thailand. *Environmental Pollution Journal,* 144, 681-688.

Rusell R, Beard J, Dunn J, Ferland G, Hambidge KM, Lynch S, Penland J, Ross AC, Stoeker B, Suttie J, Turnlund J, West K and Zlotkin S (2001) Chromium. In: Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Panel on Micronutrients, Subcommittees on Upper Reference Levels of Nutrients and of Interpretation and Use of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine (IOM). Washington, DC. National Academy Press (NAP), 197-223.

Samantaray S, Rout GR and Das P (1997) Tolerance of rice to nickel in nutrient solution. *Biologia Plantarum*, 40, 295–298.

Santonen T, Zitting A, Riihimäki V, and Howe P (2009a) Inorganic chromium (III) compounds. Concise International Chemical Assessment Document 76. Available online: http://www.inchem.org/documents/cicads/cicads/cicad76.pdf

Schwartz MW, Hoeksema JD, Gehring CA, Johnson NC, Klironomos, JN, Abbott LK and Pringle A (2006) The promise and the potential consequences of the global transport of mycorrhizal fungal inoculum. *Ecology Letters*, 9, 501-515.

Shanker AK, Cervantes C, Loza-Tavera H and Avudainayagam S (2005) Chromium toxicity in plants. *Environment International Journal,* 31, 739-753.

Silva JA and Uchida R (2000) Essential nutrients for plant growth: nutrient functions and deficiency symptoms. University of Hawaii, Manoa. College of Tropical Agriculture and Human Resources, 31-55.

Seregin IV and Ivanov VB (2001) Physiological aspects of cadmium and lead toxic effects on higher plants. *Russian Journal of Plant Physiology English Translation*, 523–544.

Tommerup IE (1988) The vesicular-arbuscular mycorrhizas. *Advances in Plant Pathology*, 6, 81-91.

Turk MA, Assaf TA, Hameed KM, and Al-Tawaha AM (2006) Significance of mycorrhizae. *World Journal of Agricultural Sciences*, 2(1), 16-20.

Verbruggen N, Hermans C and Schat H (2009) Molecular mechanisms of metal hyperaccumulation in plants. *New Phytologist*, 181, 759-776.

Ward R (1993) Soil and irrigation water interpretation manual. 2nd ed. U.S.A. Hach Company.

Welch RM and Cary EE (1975) Concentration of chromium, nickel, and vanadium in plant materials. *Journal of Agriculture and Food Chemistry*, 23, 479-482.

Wilbur S, Abadin H, Fay M, Yu D, Tencza B, Ingerman L, Klotzbach J, James S, Beyersmann D, Wise JP and Sedman R (2012) Toxicological profile of chromium. Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. Available online: http://www.atsdr.cdc.gov/ToxProfiles/tp7.pdf

Zaefarian F, Rezvani M, Rejali F, Ardakani MR and Noormohammadi G (2010) The ability of *Glomus mosseae*-Alfalfa (*Medicago sativa* L.) association for heavy metal phytoextraction from soil. *Environmental Science Journal,* 7(3), 77-90.


.