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# Compost impact on heavy metals uptake of two crops; *Hordeum vulgare* L. and *Vicia faba* L.

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## Highlights

- **This study was conducted in order to investigate the ability of plants to accumulate heavy metals, also determine the influence of compost on the mobilization of heavy metals, and thus reduce their ecological and environmental risks.**
- **The data obtained clearly illustrate that the compost used has increased some metals in the soil and plant especially Fe.**
- **The levels of heavy metals found in Barley (*Hordeum vulgare* L.) and Broad bean (*Vicia faba* L.), were generally low and still below the permissible levels recommended by the Food Agriculture Organization (FAO) and World Health Organization (WHO).**
- **Application of compost in the soil had increased the growth of both Barley and Broad bean.**

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ABSTRACT

Compost is a low-cost technology, environmentally friendly process used to treat organic waste. It has been shown to have several positive impacts when applied to soil on plant growth and some improvements on the physical and chemical properties of soil. It also controls the movements and uptake of metals by plants and animals. The plant species *Hordeum vulgare* L. (Barley) and *Vicia faba* L. (Broad bean) were used in this study. The organic fertilizer used was obtained from the local market. The results obtained showed that the application of compost in the soil had increased the growth of both Barley and Broad bean. The data obtained clearly illustrated that the compost used increased the concentration of some metals in the soil and plant especially Fe. But; the levels of heavy metals found in Barley and Broad bean were generally low and still below the permissible levels recommended by the Food Agriculture Organization (FAO) and the World Health Organization (WHO). Variations of the metals in the plants and soils were in the order of Fe>Zn>Ni. The Transfer Ratio (TR) of the metals from the soil to plants the values obtained found the following trend Fe>Ni>Zn.

## 1. Introduction

Composting refers to the process of humification and stabilization of organic wastes e.g., green manure, rural wastes, crop residues, and biofertilizers (Kant *et al.*, 2018; Kumar *et al.*, 2018a). Under the action of microorganisms and enzymes, organic wastes are degraded and transformed into $CO_2$, $H_2O$, mineral ions, and humic substances through different phases (mesophilic, thermophilic, and maturation stages) (Lu *et al.*, 2014; Bialobrzewski *et al.*, 2015). Mineral ions, humic substances, and microbes in compost considerably influence the mobilization of heavy metals and reduction of the ecological and environmental risks of heavy metals in agricultural soils (De la Fuente *et al.*, 2011; Udovic and McBride, 2012). Heavy metal immobilization can involve one or a combination of the following reactions: adsorption, complexation, precipitation, and redox reactions (Vaca-Paulin *et al.*, 2006; Huang *et al.*, 2010; Lagomarsino *et al.*, 2011; Park *et al.*, 2011), Generally, reducing the risk of crop failure and economic losses, and decreasing human health risks from heavy metals may be achieved by using compost.

Compost is regarded as a great alternative for waste management. After undergoing the composting process, the volume and weight of organic wastes are reduced, the phytotoxicity of heavy metals and organic pollutants is released, and most pathogens and parasites are removed from the wastes (Chefetz *et al.*, 1996; Kapanen *et al.*, 2013; Kulikowska and Gusiatin, 2015). Additionally, compost can be regarded as a way of closing the loop of the waste cycle by using it as organic fertilizer in order to replace chemical fertilizers in agriculture. The application of organic fertilizer, will improve soil properties, enhance the microbial activity, increase crop biomass, and promote crop growth (Perez-de-Mora *et al.*, 2006; Fagnano *et al.*, 2011; Calleja-Cervantes *et al.*, 2015; Proietti *et al.*, 2015 and Tian *et al.*, 2015). Therefore, composting is a low-cost, highly practical, and environmentally friendly approach to repair heavy metal-contaminated agricultural soil. Considering these merits, compost has received widespread attention for its use as a soil amendment procedure. From the perspective of heavy metal remediation, most previous studies found that compost is a promising strategy to control heavy metals in soils. As well as to control the uptake of metals by organisms and especially by plants through changing the physicochemical property of soils (Bolan *et al.*, 2014 and Liu *et al.*, 2009). However, the extensive use of compost may introduce an additional problem to the soils and increase the risk of heavy metal pollution Such as Cd, As, Hg, Pb, Zn, and Cu (Gonzalez *et al.*, 2012; Sharifi and Renella, 2015). Thus, the risk and security of using compost in agriculture cannot be ignored. The objectives of this study were to investigate the impact of mixing agricultural soil with compost on the growth of barley(*Hordeum vulgare* L.) and broad bean (*Vicia faba* L.) as well as, to evaluate the effects of heavy metal-containing compost on soil, plants, and human health through the food chain.

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## 2. Materials and Methods

### 2.1. Soil Sampling

Soil samples were collected at a depth of (0-20 cm) from a farm that is located at Bodrisa village, about 40 Km south of Benghazi city (longitude 20° 04' 39.23"Elatitude31° 52' 41.79"N). The soil was air-dried and sieved using mechanical sieves with different size mesh and soil texture were identified using soil texture triangle test (USDA, 2011). Compost used in this study was obtained from a local market in Benghazi (Oritici Firma, Ciftciler TorfNak. Bes) and mixed with the soil by hand at a 50:50 ratio (in dry weight). Soil samples and compost were taken to the Botany Department, Ecology Laboratories at Benghazi University in order to determine the physical and chemical properties of the samples.

### 2.2-Plant Growth

Twenty-three pots were filled with soil in all treatments. The seeds of tested plant species (*Hordeum vulgare* L. *and Vicia faba* L.) were selected to be similar in shape and size. Seeds were planted and irrigated daily with tap water. After four weeks, plant length (cm), shoot and root length (cm), fresh weight of plant (shoots and roots) (g) were measured using an analytical balance. Shoots and roots were separated and placed in the oven at 70°C for 72 hours (Lu, 2008), and their dry weights were determined (g).

### 2.3. Heavy Metal Analysis

#### 2.3.1. Plant Digestion Procedure

After four weeks, all plants were harvested. They were washed with tap and distilled water and then were separated into shoots and roots and dried in an oven at 65°C for 48 hours. The digestion method applied was described by Antonious *et al.* (2011). One gram of each dried plant sample was weighed using a fine analytical balance and transferred into a prepared digestion tube. Ten ml of concentrated nitric acid ($HNO_3$) was added and the mixture was allowed to stand overnight, and then heated for 4 hours at 125°C on a hot plate. After cooling, samples were filtered through filter paper (Wattman No. 1) into a 50 ml volumetric flask and made up to the mark with distilled water. The metals Zn, Fe, Ni, and Cu in the samples were determined by Atomic Absorption Spectrophotometer (AAS), Analytic Jena NOVAA 300 at the laboratories of Ras Lanuf petrochemicals Company. The data were subjected to different statistical analysis programs of (SPSS) version 11.0 including the analysis of variance (one-way ANOVA).

#### 2.3.2- Soil Digestion Procedure

The collected soil samples were oven-dried at 105°Cand sieved to a size of 2 mm. One gram of dried and homogenized soil was weighed into a beaker and 10 ml of concentrated nitric acid ($HNO_3$) was added and the mixture was allowed to stand overnight, and then heated and digested for 4 hours at 125°C on a hot plate in a similar way that was used for the plant. Zn, Fe, Ni, and Cu in this solution were also determined by atomic absorption spectrophotometer (Analytic Jena NOVAA 300).

### 2.4.Transfer Factors (TFs) of Heavy Metals from Soil to Plants

One approach to assess the mobility of metal by plants is to calculate the transfer factor (TF), as defined in the following equation (Sauerbeck, 1991; Gray *et al.,* 1999; Cui *et al.,* 2004; Chojnacka *et al.*, 2005):

$$TF = \frac{C\ total\ in\ the\ plant}{C\ total\ in\ the\ \ soil}$$

TF is the ratio of metals transfer from soil to the plant, where *C is the total* concentration of an element in the shoot and root of each plant (dry weight basis) and *C total is the total* concentration of an element in the soil (dry weight basis) where the plant was grown.

## 3. Results and Discussion

### 3.1. Effect of Compost on soil properties

Table 1 shows the result of pre-planting soil and compost analysis carried out. In general, the results obtained from this study showed that the addition of compost to plant potting media had caused significant changes in almost all the physical and chemical properties of the selected soil parameters such as pH, moisture contents, and organic matter contents. The percentage (%) of moisture content in soil mixed with compost increased by almost (44.6%), while the organic matter content increased by more than 4-fold from the actual level after planting for the broad bean. In barley, an approximately similar result was obtained in organic matter (%), but the percentage increase was (40.4%) for moisture content. The levels obtained in this study were in agreement with the finding of other studies such as (Celik, 2004; Helmi, 2018 and Kumar *et al.*, 2017, 2018b). However, it was found not to agree with the finding reported by Abedel-Rahman (2009) who found no significant difference in soil organic matter between treated and non-treated soil with compost, but there were an increase in soil Cation Exchange Capacity (CEC) as well as an increase in soil pH. Similar results were obtained by Abou-Hassien (2019).

**Table 1**

Pre –planting soil and compost analysis.

| Parameter | Treatment | |
|---|---|---|
| | Soil (Control) | Soil+Compost |
| Soil texture | L.Clay | - |
| pH | 8.12 | 8.83 |
| OM (%) | 4.38 | 42.3 |
| Zn(mg/kg) | 39.66 | 50.22 |
| Ni(mg/kg) | 19.15 | 30.55 |
| Fe(mg/kg) | 490.00 | 880.42 |
| Cu(mg/kg) | ND | 0.01 |

ND=Not detected

### 4.2. Heavy Metal Concentration in the Soil

The highest concentration of Fe was found in soil mixed with compost while the concentration for Cu was found to be well below the detection limits. The percentage of increase for Fe was around (94%) for the soil mixed with compost and (24.7 and 76%), for Zn and Ni respectively. The uptake of metals from the soil depends on different factors such as their solubility, soil pH, plant growth stages types of species, fertilizer and soil has been indicated by (Ismail *et al.,* 2005, Sharma *et al.,* 2006). It can be seen that there were significant differences ($P<0.01$) in the concentration of Zn between the soil (control) and mixed sample with compost, as well as for Ni concentration ($P<0.001$). Significant differences were also observed for Fe concentration between soil (control) and soil mixed with compost ($P<0.001$), (Table 2).

**Table 2**

The concentration of total Zn, Ni, Fe, and Cu (mg/kg) in the soil (control) and soil mixed with compost (ND = Not detected).

| Concentration mg/kg | Treatment | |
|---|---|---|
| | Soil (Control) | Soil+Compost |
| Zn | 39.66 | 49.47 |
| Ni | 19.15 | 33.71 |
| Fe | 490.00 | 950.66 |
| Cu | ND | ND |

The results obtained (Table 3) indicated that there were also significant differences ($P< 0.05$) in shoot and root concentration of

Fe in both *H. vulgare* L. *and V. faba* L. for Fe were found between soil (control) and soil mixed with compost, however, there were no significant differences in Zn and Ni concentration for both shoot and root for both plants between soil (control) and soil mixed with compost. While the concentration of Cu in all samples was found to be well below the detection limit.

**Table 3**

The concentration of Zn, Ni, Fe, and Cu (mg/kg) in the shoots and roots of (*H. vulgare* L. *and V. faba* L.) grown in soil (control) and soil mixed with compost. (ND = Not detected).

| Plant type | Concentration mg/kg | | Treatment | |
|---|---|---|---|---|
| | | | Soil (Control) | Soil+Compost |
| Broad bean | Zn | Shoot | 1.85 | 2.22 |
| | | Root | 1.47 | 1.83 |
| | Ni | Shoot | 1.69 | 2.06 |
| | | Root | 1.45 | 1.66 |
| | Fe | Shoot | 5.98 | 8.77 |
| | | Root | 2.88 | 4.82 |
| | Cu | Shoot<br>Root | ND | ND |
| Barley | Zn | Shoot | 1.38 | 1.68 |
| | | Root | 2.67 | 3.64I |
| | Ni | Shoot | 1.09 | 1.22 |
| | | Root | 0.97 | 1.07 |
| | Fe | Shoot | 5.12 | 7.04 |
| | | Root | 3.50 | 4.65 |
| | Cu | Shoot<br>Root | ND | ND |

The results showed that the increment in the percentage of these metals in soil mixed with compost was found to be 20% and 24.4% in shoot and root of *V. faba* L. respectively for Zn, 46.6% and 67.3% for Fe, while 21.8% and 14.4% for Ni. While the percentage increase of these metals in soil mixed with compost was found to be 21.7% and 36.3% in shoot and root of *H. vulgare* L. respectively for Zn, 37.5% and 32.8% for Fe, while 11.9% and 10.3% for Ni. The low concentration levels of Ni recorded in this study could be attributed to the fact that metal being not important for plant growth and metabolism (Brown *et al.,* 1987). The role of Ni in the plant is not very clear but, it is required in small quantities (Hopkins, 1999). Interestingly, a high concentration of Fe was found in both treatments when compared with the concentration of other metals moreover Fe may be is important for some enzyme activities is a constituent in chlorophyll, and is involved in electron transport in the photosystem (Hopkins, 1999).

In addition, the importance of Fe in plant growth and abundance of the metal in the earth crust (Harrison and Chirgawi, 1989). The variation in the concentrations of heavy metals in plants may be ascribed to the heavy metals concentration of soil. In addition, this study showed that the concentration of Cu in the soil was found to be well below the detection limits compared to that in other metals. Thus, the absence of Cu in the plants is attributed to the unavailability of Cu in the soil. Generally, the trend in the variations of the heavy metals in plants and soils obtained in this study was Fe > Zn > Ni.

### 4.4-Transfer Factors (TFs) of Heavy Metals from Soil to Plants

The results (Table 4) for the total transfer factors (TF) values for both shoot and root system of broad bean for Zn, Fe, and Ni ranged from 0.07, 5.88, and 0.15 respectively for the soil (control) and 0.07, 14.29, and 0.1 respectively for soil mixed with compost. While total transfer factors (TF) values for both shoot and root system of *H. vulgare* L. for Zn, Fe, and Ni ranged from 0.09, 7.15, and 0.1 respectively for the soil (control) and 0.1, 12.29 and 0.06 respectively for soil mixed with compost (Table 5). Transfer factors were computed for the heavy metals to quantify the relative differences in bioavailability of metals to plants or to identify the efficiency of a plant species to accumulate a given heavy metal. These factors were based on the root uptake of the metals and discount the foliar absorption of atmospheric metal deposits (Lokeshwari and Chandrappa, 2006). The results indicate that the TF values for Fe were generally higher (the more mobile/availably) when soil mixed with compost than those for Zn and Ni in both *H. vulgare* L. *and V. faba* L. The order of the transfer factor was Fe > Ni> Zn. However, the levels of the metals in the plants in this study were below the permissible levels recommended by the Codex Alimentarius Commission (FAO/WHO, 2001). Therefore, the consumption of these plants as food may not pose health hazards to humans at the time of the study. Some of the results recorded in this study were in agreement with those of related studies by various researchers, such as the study reported by Hatam and Ronaghi *et al.* (2012) who found that application of compost in clay loam soil and sandy soil increased shoot and root concentrations of Nitrogen (N), Iron (Fe), and Zinc (Zn). Khairiah *et al.* (2009) reported similar results.

**Table 4**

Transfer factors (TFs) of Zn, Ni, and Fe from soil to *V. faba* L.

| Concentration mg/kg | | Treatment | |
|---|---|---|---|
| | | Soil (Control) | Soil+Compost |
| Zn | Shoot | 0.04 | 0.04 |
| | Root | 0.03 | 0.03 |
| | Total | 0.07 | 0.07 |
| Ni | Shoot | 0.08 | 0.06 |
| | Root | 0.07 | 0.04 |
| | Total | 0.15 | 0.1 |
| Fe | Shoot | 0.01 | 9.22 |
| | Root | 5.87 | 5.07 |
| | Total | 5.88 | 14.29 |

**Table 5**

Transfer factors (TFs) of Zn, Ni and Fe from soil to *H. vulgare* L.

| Concentration mg/kg | | Treatment | |
|---|---|---|---|
| | | Soil(Control) | Soil+Compost |
| Zn | Shoot | 0.03 | 0.03 |
| | Root | 0.06 | 0.07 |
| | Total | 0.09 | 0.1 |
| Ni | Shoot | 0.05 | 0.03 |
| | Root | 0.05 | 0.03 |
| | Total | 0.1 | 0.06 |
| Fe | Shoot | 0.01 | 7.40 |
| | Root | 7.14 | 4.89 |
| | Total | 7.15 | 12.29 |

### 4.5 Effect of Compost on Growth of *V. faba* L. and *H. vulgare* L.

After four weeks of planting, the *V. faba* L. samples grown in soil mixed with compost were significantly different ($p<0.01$) from than in the control in average length, fresh and dry weight. In addition, the *H. vulgare* L. samples grown in soil mixed with compost were significantly different ($p<0.01$) from that grown in the control in average length. However, the *H. vulgare* L. samples grown in soil mixed with compost were not significantly different from that grown in the control in average fresh and dry weight (Table 6). Thus, the application of compost to plants at the early stage of development results in a positive impact on biomass production by improving soil physical and chemical properties, similar result was observed by Sarwar *et al.,* (2007) investigated the effects of compost on crops (rice and wheat) in normal soil, who found that the grain yield and yield components (plant height and 1000 grain weight) of rice and wheat increased significantly with organic material application in the form of compost at both levels. Similar results were reported by Lazcano *et al.,* (2011) who found that the application of vermicompost had several positive impacts on plant growth and health. Also, Tejada and Gonzalez, (2003) showed that compost application in 2-continuous years increased the number of grains/spike, 1000 grain weight, and the number of spikes and grain wheat yield. This organic fertilizer is therefore increasingly considered in agriculture and horticulture as a promising alternative to inorganic fertilizers.

**Table 6**

Effect of compost on shoot length, Fresh weight and Dry weight of (*H. vulgare* L. *and V. faba* L.)

| Plant type | Parameter | Treatment | |
|---|---|---|---|
| | | Soil (Control) | Soil+Compost |
| Broad bean | Length(cm) | | |
| | Shoot | 20.69 | 20.00 |
| | Root | 12.67 | 16.56 |
| | Fresh weight(g) | | |
| | Shoot | 4.03 | 6.17 |
| | Root | 2.12 | 2.96 |
| | Dry weight(g) | | |
| | Shoot | 1.40 | 2.30 |
| | Root | 1.33 | 1.96 |
| Barley | Length(cm) | | |
| | Shoot | 15.91 | 20.82 |
| | Root | 14.40 | 15.43 |
| | Fresh weight(g) | | |
| | Shoot | 0.98 | 1.16 |
| | Root | 0.85 | 0.99 |
| | Dry weight(g) | | |
| | Shoot | 0.05 | 0.06 |
| | Root | 0.03 | 0.04 |

## 5. Conclusion

The levels of heavy metal in plants found in this study were generally low and still well below the permissible levels recommended by the World Health Organization (WHO) and the Food Agriculture Organization (FAO), and therefore doesn't poses any health effects. However, the values of the transfer factor may reflect on the need for future monitoring for both the uptake of metals by both plants tested. In addition, the use of compost has shown clear positive effects on soil fertility and have improved some Physico-chemical properties such as organic matter and moisture content and pH) reflecting on the possibility of being used as an effective alternative to the chemical fertilizer that is extensively used.

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