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DYNAMICS OF HEAVY METALS IN MAIZE CAN BE DETERMINED BY ECTOMYCORRHIZA *PISOLITHUS ARHIZUS*

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Abstract – The Effects of ectomycorrhiza *Pisolithus arhizus* on absorption, accumulation, and translocation dynamics of heavy metals in maize seedling were investigated in this study. The result revealed that effects of the mycorrhiza on the concentration of the heavy metals and other nutrient elements in maize seedlings depend on particular heavy metal, plant's part (root or shoot) and the soil type in which the plant was cultivated. The mycorrhiza greatly increased ($\alpha = 0.05$) root absorption of Fe, Ni, Mn, Cd, and Cr by maize seedlings but also suppressed absorption of Cu, Pb, and Zn by the root. The result of the Bioconcentration Factor indicated that maize is a hyperaccumulator of Fe (119.8%), Cu (137.0%), Mn (122.5%) and Cd (260%). It is a moderate accumulator of Zn (10.5%%) and Pb (12.8); and low accumulator of Mg (5.0%) and Ni (3.3%). The mycorrhiza increased the hyperaccumulation ability of the maize seedlings for Fe from 119.8% to 722.6%; Mn from 122.5% to 208.8%; and that of Cd from 260% to 430%. Cu accumulation was decreased by the mycorrhiza from hyperaccumulator (137.0%) to moderate accumulator (32.1%). Zn and Pb were decreased from moderate accumulator (10.5% and 12.8%, respectively) to low accumulator (3.6% and 8%, respectively). Ni was also increased from low accumulator (3.3) to moderate accumulator (42.7); while Mg remained low accumulator (from 5.0% to 4.9%). Bioaccumulation of Zn, Mg, and Ni was suppressed by soil amended even in the presence of the mycorrhiza. The mycorrhiza increased the Transfer Factors of Mg, K, Cu, Zn, Pb, Cd, and Cr. While the mycorrhiza decreased the TFs of Fe, N, Ni, and Mn. Also, the amendment of the background soil greatly suppressed the TFs of all the metals except Zn.

INTRODUCTION

The vast majority of people particularly in sub-Saharan Africa depend on rain-fed agriculture for their livelihoods (Bekele *et al.*, 2014). Paradoxically, food insecurity and malnutrition are the norm in this region, with millions of poor people often being afflicted (Schmidhuber and Tubiello, 2007; Otaha, 2013; Bekele *et al.*, 2014). This problem is further complicated with the concomitant rapid population increase in this region that demands intensification of crop production. Unfortunately, many environmental issues pose a lot of constraints to agricultural production which perpetuates the food crisis among the populace. Soil erosion, soil nutrient deficiency and high cost of fertilizer are among the mainlimiting factors to the agricultural output (Hrynkiewicz and Baum, 2011; Sasson, 2012). Since chemical fertilizers are beyond the reach of most poor farmers as a result of the economic crisis in the developing countries, soil from refuge dumpsites are being used for crop cultivation or a source of manure for agricultural soil amendment in many places. The wastes dump soils are being added to agricultural land to improve soil fertility and serve as an important nutrient for plants, thus becoming a cheaper alternative source of nutrients for the farmers (Pasquini and Harris, 2005; Azeez *et al.*, 2011; Mashi *et al.*, 2014). Waste dump soils improve both soil physicochemical properties and nutrient status for better crop production. Such soils have increased total porosity; reduced bulk density; and high organic matter, which enrich the soil nitrogen content; cation exchange capacity and improve pH (Azeez *et al.*, 2011; Amos-tautua *et al.*, 2014). However, the wastes dump soils for crop cultivation can lead to increased levels of potentially harmful heavy metals in the soil and the crops that are consumed by humans or their animals (Mashi *et al.,* 2014).

Several heavy metals in minute quantities are essential for the normal growth of living organisms, although excessive amounts of these essential elements can become harmful. These include cobalt, copper, iron, manganese, molybdenum, and zinc. The rest (cadmium, chromium, lead, silver, thallium, uranium and mercury) are always toxic. Some metalloids are generally referred to as heavy metals because they are non-beneficial to organisms and very harmful to both plants and animals (Bothe, 2011; Nanda and Abraham, 2013; Chibuike and Obiora 2014). The ecotoxicological risks of soil contamination by heavy metals are the potential harm to plants, animals, humans, and microorganisms. Soil pollution by heavy metals can suppress or kill sensitive tissues of plant and soil microbial communities, resulting in a shift in their functional diversity and structure. Even a little concentration of heavy metals can accumulate in the food chain and greatly buildup in the higher tropic levels. This process is termed biomagnification (Chibuike and Obiora, 2014; Bandurska *et al.,* 2016). Although heavy metals are part of the constituents of our natural environment, indiscriminate anthropogenic activities have altered their normal geochemical cycles and biochemical balance, which result in excess accumulation of these heavy metals (such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) into soil (Dixit *et al.,* 2015). Currently, there is an increasing concern over heavy metal accumulation in agricultural soils because of the potential of risk of their uptake by crops and subsequent transfer into the food chain. The heavy metals are potentially toxic and have cumulative properties and are hazardous not only on crop plants but also on human health. When crops are planted in soils polluted by heavy metals, the heavy metals will be extracted by the crops, causing growth retardation and loss of vigor. When these crops are consumed by animals and humans, the heavy metals are directly or indirectly ingested, hence greatly threatens human health as well as the safety of the ecosystem in general. (Chopra *et al.,* 2009; Azeez *et al.,* 2011; Ali *et al.,* 2014; Hong *et al.,* 2014). Many of these heavy metals are toxic even at very low concentrations as they are naturally carcinogenic and mutagenic (Chopra *et al.,* 2009; Salano, 2013; Girma, 2015; EL Ghachtouli *et al.,* 2017; Fan *et al.,* 2017). Different methods are already in use for remediation or amelioration of heavy metals from soils. These include chemical and thermal methods; excavation and subsequent disposal and soil washing. However, these methods are cost-effective.

Bioremediation is an environmentally friendly, inexpensive but effective method that is used to extract, remove or ameliorates heavy metals from contaminated soils. In this technology, microorganisms are used for biotransformation of the heavy metals into nontoxic forms (Tangahu *et al.,* 2011; Dixit *et al.,* 2015). Microorganisms can greatly limit the translocation of heavy metals by binding heavy metal ions to their cell wall components (such as cellulose, chitin, lignin, and melanins) and limit their penetration into soil matrix and plant systems (Chopra *et al.,* 2009). Attention is increasingly paid to certain fungi as important natural factors that may be used for reducing the impact of heavy metals on plants and significantly enhances their tolerance to the toxic heavy metals. Some of these fungi are ectomycorrhiz as that form a mutualistic symbiosis with plants and produce ectomycorrhizal roots. Mutualistic ectomycorrhizal symbiosis has a diverse and highly beneficial effect on the host plant. These include increased growth as a result of more efficient extraction and transport of water and nutrient from the soil to the plant root; amelioration of the effects of heavy metal toxicity; increased resistance to pathogenic organisms and other environmental stresses like organic pollution, salinity, and acidity. They also contribute toward carbon and nutrients sequestration belowground andmitigating depressive allelopathic effects (Duèiæ *et al.,* 2008; Sanon *et al.,* 2010; Bandurska *et al.,* 2016). The ectomycorrhiza act by filtering soil water solutions and mineral salts and a considerable amount of heavy metals in their internal mycelium, on its surface or in root tissue. It was well documented that plants with proper ectomycorrhiza grow better in salty, sterile or heavy metals contaminated soils (Jha and Kumar, 2011; Bandurska *et al.,* 2016). The host plant in turn helps in providing carbohydrates to the fungus (Duèiæ *et al.,* 2008). Assessment of heavy metal accumulation in soils and plants and their remedy is a priority in many environmental monitoring (Salano, 2013). However, to fully understand the potentials of ectomycorrhizal fungi in heavy metals ameliorations, several issues need to be explored (Abler, 2004). For example, the impact of ectomycorrhizal on plant growth and ameliorations of heavy metal uptake cannot be generalized. Also, different plant responses vary with different fungal species or isolates as a result of differences in fungal characteristics such as degree of tolerance to different types of heavy metal and functional compatibility. Therefore, there is an urgent need for comprehensive research works on ameliorations of different heavy metals in refuge dump soils by different ectomycorrhizal fungi and different crop responses, hence the necessity for this study.

The general aim of this study is to investigate the effects of ectomycorrhizal fungus *Pisolithusarhizus* on absorption, accumulation, and translocation of heavy metals in maize seedlings. Specifically, determine the impacts of soil type on the effect of the ectomycorrhiza on the heavy metals' dynamics in maize seedlings.

METHODOLOGY

The Study Area

This study was conducted in Bauchi state which is located in the North-East of Nigeria at 300 to 900 m above sea level (Abdul Kadir *et al.,* 2013). It has a seasonal climate with alternate wet and dry seasons. Temperature is highest in April/ May and lowest in December/January. The amount of annual rainfall ranges from 600 to 900 mm,mostly between May and September (Yusuf and Yusuf, 2008; Concha *et al.,* 2013).

Soil Sampling

The soil used in this study was collected from solid waste dumpsites in Yelwa area of Bauchi town. The wastes were from domestic sources. Farmers in this area frequently used the soil from these dumpsites as an alternative to fertilizer. Background soil (0-20 cm) was also collected from cultivated fields with poor nutrient status as observed from the crop yield. The soils were sieved with a 2 mm diameter mesh to remove larger debris and gravel. All the soil samples were sterilized by autoclave (Abler, 2004; Azeez *et al.,* 2011; Mashi *et al.,* 2014).

Soil Analysis

Soils used in this experiment were analyzed for their physicochemical properties (Table 1). Sub-samples of all the soils collected were oven-dried at 80 °C to a constant weight. A small portion (0.5g) of the soil samples was measured and transferred into a 250 mL beaker and then digested in a binary mixture of HNO_3 - HCl in 2:1. After digestion, the digested samples were subsequently analyzed for pH, N, P, C, Mg, K, Cu, Zn, Mn, Cr, Cd, Ni and Pb using standard techniques: 1) total nitrogen was determined by Kjeldahl distillation method; 2) Available phosphorus was estimated using Bray P No.2 method; 3) the soil pH was determined in a 1:1 soil/solution ratio using a pH meter and a combination electrode; 4) K and amounts of the heavy metals in the digests obtained were estimated using Atomic absorption spectrophotometer (AAS). The organic matter content of the soils was quantitatively determined using Walkey-Black chromic acid titration method (Abler, 2004; Pasquini and Harris, 2005; Azeez *et al.,* 2011; Salano, 2013; Mashi *et al.,* 2014; Onweremadu, 2014; Fan *et al.,* 2017). The pH, organic carbon content and a textural class of the soils were analyzed in the soil laboratory of Abubakar Tafawa Balewa University, Bauchi. Heavy metals analyses were carried out in Energy Center in the same institution.

Experimental Design and treatments

Seeds of local white maize was purchased from a local vendor. The seeds were surface-sterilized in 30% H_2O_2 (hydrogen peroxide) for 15 min and then ringed in plenty of distilled water. Uniform-size seeds were selected for use (Brundrett *et al.,* 1996).

The experiment was carried out in three different soils: the background soil (S_1), which was poor in nutrient, organic matter and most of the heavy metals; waste dump soil (S_2), which was richer in nutrient, organic matter and most of the heavy metals; and the third was a mixture of the waste dump and the background soil in a ratio of 3:1 (background soil/waste dump soil). About one kilogram of each of these soil types was placed in a one-liter plastic cup (Brundrett *et al.,* 1996). One kilogram of dried fruiting body (sporocarps) of ectomycorrhiza *Pisolithus arhizus* were gently crushed in four liters of sterile water. The mixture obtained was used to inoculate the soils. Four tablespoonsful of the mycorrhizal inoculum were placed at 2 cm depth in each pot. The control was waste dump soil (i.e., S_2) that were not inoculated with the mycorrhiza. Two seeds of uniform sizes were planted directly on the mycorrhizal inoculum in the soil inside the pots. The pots were then arranged in a randomized complete block design (RCBD), each with eight replicates. All the plants were watered regularly and uniformly twice a week with ½ L of tap water. This amount of water was just enough to saturate the soil with minimal leaking at the bottom of the perforated pots (Ingrid, 2011). The plants were allowed to grow for six weeks before harvesting. The experiment took place in a screen house of the Abubakar Tafawa Balewa University.

Analysis for Heavy Metals Content

The plants were harvested after six weeks. They were carefully washed with running tap water properly and then separated into shoots and roots. The plants were then tag according to the experimental setup and dried in a hot air oven at 80 ^{o}C for 72 hours. The dried plant materials were then grounded and sieved through a 0.2 mm (100 mesh) nylon sieve. Each sample was separately digested with concentrated nitric acid and hydrogen peroxide. The concentrations of different heavy metals in each treatment and the control were analyzed in triplicate using atomic absorption spectroscopy (Krpata *et al.,* 2009; Ingrid, 2011; Salano, 2013; Mashi *et al*., 2014; EL Ghachtouli *et al*., 2017; Fan *et al.,* 2017).

Data Analyses

Metal bioconcentration factor (BCF)

The concentrations of heavy metal in soils and that of the plant parts were calculated based on dry weight. The bioaccumulation factor of the metal, which is a ratio of plant/soil metal concentration, was calculated as follows:

BCF = *C* plant/*C* soil X100

where *C* plant and *C* soil represent the heavy metal concentrations in the plant part and that soil, respectively (Zhuang *et al.,* 2013). BCF value of 1 to 10 indicates hyperaccumulator plant, BCF values of >0.1 to 1 indicates moderate accumulator plant, BCF value of 0.01 to 0.1 indicates low accumulator plant, and BCF value of <0.01 indicates non-accumulator plant (Syam *et al*., 2016; Sulaiman and Hamzah, 2018).

Translocation factor (Tf) is considered as the ability of a plant to translocate the metals from the root the to shoot. This was determined by calculating the ratio of metal concentration in the shoot to that of the root using the formula (Magaji *et al*., 2018):

$$\text{Translocation factor} = \frac{\text{Metal concentration in shoot}}{\text{Metal concentration root}} \times 100$$

TF values were expressed in percentages (Syam *et al*., 2016).

Statistical analysis

Statistical analysis of the data was done using analysis of variance (ANOVA) followed by Tukey Multiple Comparison of means; the means were considered significantly different at $P \leq 0.05$ level of significance (Kaur, 2018).

RESULTS

In this study effects of ectomycorrhiza *Pisolithus arhizus* on absorption, accumulation and translocation dynamics of heavy metals in maize were investigated.

The absorption pattern of heavy metals in roots of maize seedlings

The result showed that themycorrhiza had affected the concentration of the heavy metals and other nutrient elements in maize seedlings, which depend on particular heavy metal, plant's part (root or shoot) and the soil type in which the plant was cultivated (Table 2). The mycorrhiza increased the concentration (mg/kg) of iron (Fe) in the root of

Table 1a. Physicochemical properties of soils used in this study (mg/kg)

Soil type	Mn	Cd	Ni	Zn	Cu	Pd	Cr	Mg	K	Fe	N
Background soil (1)	1.32	0.00	0.08	2.00	0.28	0.21	0.01	46.2	60	124	0.354
3:1 T/WD (3)	1.52	0.00	0.11	5.35	0.58	0.22	0.00	193.33	160	120	1.035
Waste dump soil (2)	0.80	0.01	0.15	6.05	1.27	0.25	0.00	353	280	11.1	8.451

Table 1b. Physicochemical properties of soils used in this study (mg/kg)

Soil type	OM (%)	pH	Soil Class
Background soil (1)	0.36	5.48	Loamy sand
3:1 T/WD (3)	0.54	5.74	Sandy Loam
Waste dump soil (2)	1.09	6.13	Sandy Loam

plants cultivated on the waste dump soil, which was 80.21 compared to 13.30 in the same soil but without the mycorrhiza. The Fe concentration was also higher in the root of the amended background soil than the non-amended background soil.

The mycorrhiza had slightly suppressed absorption of magnesium (Mg) by the roots in waste dump soils, with the value of 17.15 and 17.79 in the mycorrhizal and non-mycorrhizal soils respectively. The concentration in the root was higher in the waste dump soils and the amended background soil than the non-amended background soil.

The mycorrhiza also increased absorption of nitrogen as revealed in all the soil types, i.e., the concentration was least in the non-mycorrhizal waste dump soil (0.010); but highest in the mycorrhizal waste dump soil (0.019). Absorption of potassium (K) by the maize seedlings was greatly suppressed by the mycorrhiza as indicated in the waste dump soil. The concentration in the root was higher in the non-mycorrhizal (20.00) than mycorrhizal (12.33) waste dump soil. The concentration was even higher in the amended background soil than the waste dump soil. The least was the background soil. Absorption of nickel (Ni) by the roots of maize seedlings was increased by the mycorrhiza. The concentration of the Ni in the root of the plant in the mycorrhizal and the non-mycorrhizal waste dump soil was 0.064 and 0.005, respectively. Higher concentrations were found in the root of plants in the background soil and the amended background soil (0.095 and 0.092, respectively). The mycorrhiza also suppressed copper (Cu) absorption by the root. The concentration of the Cu in the root of maize in the mycorrhizal and the non-mycorrhizal waste dump soil were 0.408 and 1.740, respectively. The roots accumulate more Cu in the waste dump soil than the background soil (0.170) and the amended background soil (0.167). The absorption of zinc (Zn) was suppressed by the mycorrhiza. The concentration values in the root of plants in the mycorrhizal and the non-mycorrhizal waste dump soil were 0.220 and 0.636, respectively. Roots of plants cultivated in the waste dump soil accumulated more Zn than their counterparts in the background soil (0.165) and the amended background soil (0.163).

The mycorrhiza increased the absorption of manganese (Mn) by the roots in the waste dump soil. The concentration values in the mycorrhizal and the non-mycorrhizal waste dump soil were 1.67 and 0.98, respectively. The values for the background soil and the amended background soil were 1.100 and 0.900, respectively. The concentration of lead (Pb) in the roots was slightly decreased by the mycorrhiza in the waste dump soil. Concentration values were just 0.004 in the background soil compared to 0.02 in both the waste dump soil and the amended background soil. There

Table 2. Analyses of Variance (ANOVA) of concentration (mg/kg) of different metals in root and shoot of maize seedlings planted in different soil types ($\alpha = 0.05$).

	†Root S_2M_+	Root S_2M_0	Root S_1M_+	Root S_3M_+	Shoot S_2M_+	Shoot S_2M_0	Shoot S_1M_+	Shoot S_3M_+	Pooled StDev	P-Value
Fe	80.21^{a}	13.30^{c}	13.90^{b}	10.20^{e}	13.10^{d}	2.28^{g}	2.41^{f}	0.91^{h}	0.0361	0.001
Ca	151.62^{a}	138.20^{e}	142.47^{c}	111.07^{g}	140.10^{d}	144.53^{b}	113.47^{f}	106.17^{h}	0.0764	0.001
Mg	17.15^{e}	17.79^{a}	16.04^{g}	17.66^{c}	17.41^{d}	17.74^{b}	17.15^{e}	16.99^{f}	0.0046	0.001
N	0.019b	0.010g	0.015e	0.016d	0.021a	0.019b	0.018c	0.012f	0.0000	0.001
K	12.33de	20.00a	10.33	15.33bc	17.33b	17.33b	10.67e	13.67cd	0.8165	0.001
Ni	0.064c	0.005f	0.095a	0.092b	0.028d	0.003g	0.019e	0.002g	0.0006	0.001
Cu	0.408b	1.740a	0.170c	0.167d	0.156e	0.095g	0.151f	0.064h	0.0005	0.001
Zn	0.220b	0.636a	0.165c	0.163c	0.042e	0.040e	0.122d	0.220b	0.0007	0.001
Mn	1.670b	0.980e	1.100d	0.900f	0.591g	2.481a	1.510c	0.491h	0.0005	0.001
Pb	0.020b	0.032a	0.004c	0.020b	0.003d	0.002e	0.001f	0.001f	0.0002	0.001
Cd	0.043a	0.026d	0.032c	0.012f	0.038b	0.019e	0.032c	0.006g	0.0000	0.001
Cr	0.079b	0.019f	0.067c	0.020e	0.080a	0.009g	0.056d	0.008^{h}	0.0002	0.001

Means that do not share a letter are significantly different.
†S_1M_+Background soil inoculated with mycorrhiza
S_2M_+Waste dump soil inoculated with mycorrhiza
S_2M_0 Waste dump soil without mycorrhiza
S_3M_+Amended Background soil (Background soil +Waste dump soil (3:1) inoculated with mycorrhiza

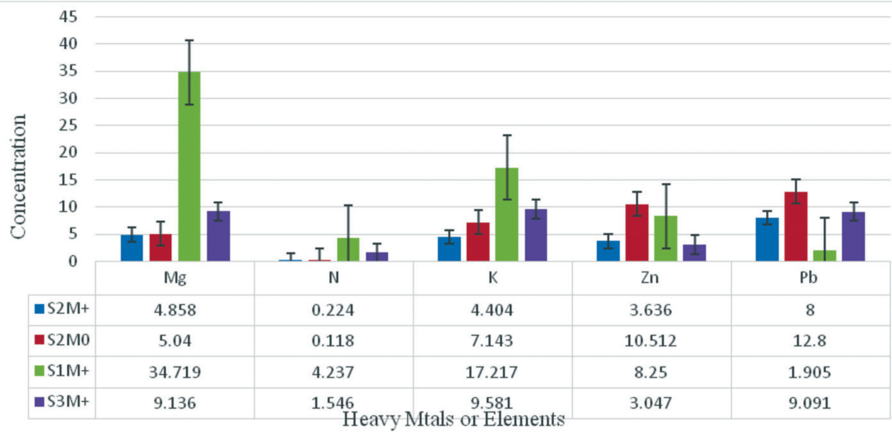
was a higher concentration of cadmium (Cd) in the roots of plants in the mycorrhizal waste dump soil (0.043) than those in the same soil but without the mycorrhiza (0.026). The values were also higher in the roots of plants in the background soil than the amended background soil. Absorption of chromium (Cr) by the roots of plants in the waste dump soil was greatly increased by the mycorrhiza. The concentration values were 0.079 and 0.019 for the mycorrhizal and the non-mycorrhizal soil, respectively. In the mycorrhizal background soil and the amended background soil, the concentration of the Cr in the plants' roots was0.067 and 0.020, respectively.

Bioconcentration Factor (BCF) of heavy metals in the Root of maize seedlings

The result of bioconcentration factor (BCF) of the maize seedlings' root (which indicates the degree of ability of the plant's root to accumulator heavy metals relative to the concentration of the heavy metal in the soil) showed that maize is a hyperaccumulator, moderate accumulator or low accumulator of some heavy metals. The value ranged between >100% (hyperaccumulator); ≤ 100% (moderate accumulator); ≤ 10% (low accumulator) and ≤1% indicated non-accumulator.

The BCF values in the root of plants cultivated in the non-mycorrhizal waste dump soil indicated that maize is a hyperaccumulator of Fe (119.8%), Cu (137.0%), Mn (122.5%) and Cd (260%) (Figure 2). It is a moderate accumulator of Zn (10.5) and Pb (12.8); and low accumulator of Mg (5.0) and Ni (3.3). The BCF values in the root of plants cultivated in the mycorrhizal waste dump soil was different from that of the non-mycorrhizal waste dump soil, which indicated that the ectomycorrhiza had affected the absorption of the heavy metals by the maize seedlings. Hyper accumulation ability of the maize seedlings was increased for Fe from 119.8% to 722.6%; Mn from 122.5% to 208.8%; and that of Cd from 260% to 430%. Cu accumulation was decreased from hyperaccumulator (137.0%) to moderate accumulator (32.1%). Zn and Pb were decreased from moderate accumulator (10.5% and 12.8%, respectively) to low accumulator (3.6% and 8%, respectively). Ni was also increased from low accumulator (3.3) to moderate accumulator (42.7); while Mg remained low accumulator (from 5.0% to 4.9%).

The BCF values of some of the plants' roots cultivated in the mycorrhizal background soil were lower than their counterparts in the mycorrhizal waste dump soil. These include Fe (11.2%), Mn (83.3%) and Pb (1.9%), i.e., the plant was reduced from hyperaccumulator to moderate accumulator for Fe and Mn. However, the plants' BCF roots that were cultivated in the mycorrhizal background soil were increased for Mg (34.7%), Ni (118.8%), Cu (60.7%) and Zn (8.3%) than their counterparts in the mycorrhizal waste dump soil. This means the plants' BCF increased from a moderate accumulator to a hyperaccumulator for Ni; and from the low accumulator to moderate accumulator for Mg. Also, the BCF values of plants' roots cultivated in the mycorrhizal background soil were greater than their



	Mg	N	K	Zn	Pb
🟦 S2M+	4.858	0.224	4.404	3.636	8
🟥 S2M0	5.04	0.118	7.143	10.512	12.8
🟩 S1M+	34.719	4.237	17.217	8.25	1.905
🟪 S3M+	9.136	1.546	9.581	3.047	9.091

Fig. 2A. BCF with error bars of roots of maize seedling cultivated on different soil types
†S_1M_+ Background soil inoculated with mycorrhiza
S_2M_+Waste dump soil inoculated with mycorrhiza
S_2M_0 Waste dump soil without mycorrhiza
S_3M_+ Amended Background soil (Background soil +Waste dump soil (3:1) inoculated with mycorrhiza

counterparts in the amended background soil except for Pb. The BCF values for Cr indicated that the plant is a hyperaccumulator of Cr in background soil, but for other soils, the BCF values could not be estimated as the presence of the metal was failed to be detected. This was also the case for Cd in the background soil and the amended background soil.

Translocation Factor

Translocation Factor (TF), which measures the ability of plants to transport a particular metal from the roots to the shoot, was described as a percentage of that metal in plant shoot relative to its value in the plant root (Figure 3). Metals whose TFs were positively amplified by the mycorrhiza include Mg, K, Cu, Zn, Pb, Cd, and Cr. The TF values of these metals in plants cultivated in the mycorrhizal and non-mycorrhizal waste dump soil, respectively, were 101.5 and 99.7 for Mg; 140.6 and 86.7 for K. Others were 38.2 and 5.6 for Cu; 19.1 and 6.3 for Zn;

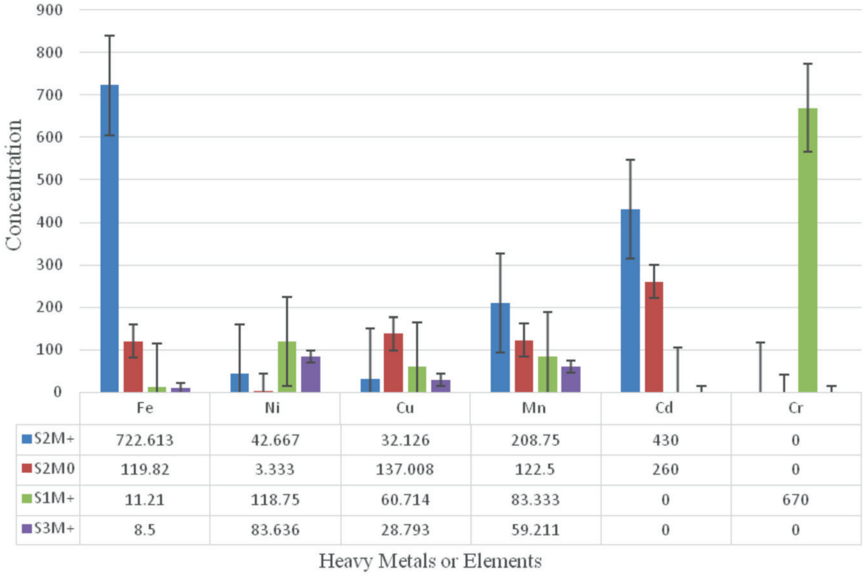


Fig. 2b. BCF with error bars of roots of maize seedling cultivated on different soil types
†S_1M_+ Background soil inoculated with mycorrhiza
S_2M_+Waste dump soil inoculated with mycorrhiza
S_2M_0 Waste dump soil without mycorrhiza
S_3M_+ Amended Background soil (Background soil +Waste dump soil (3:1) inoculated with mycorrhiza

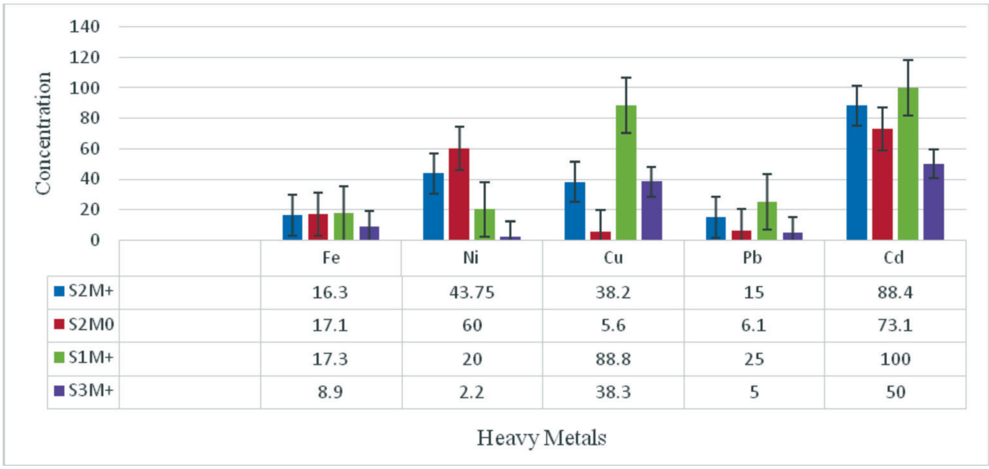
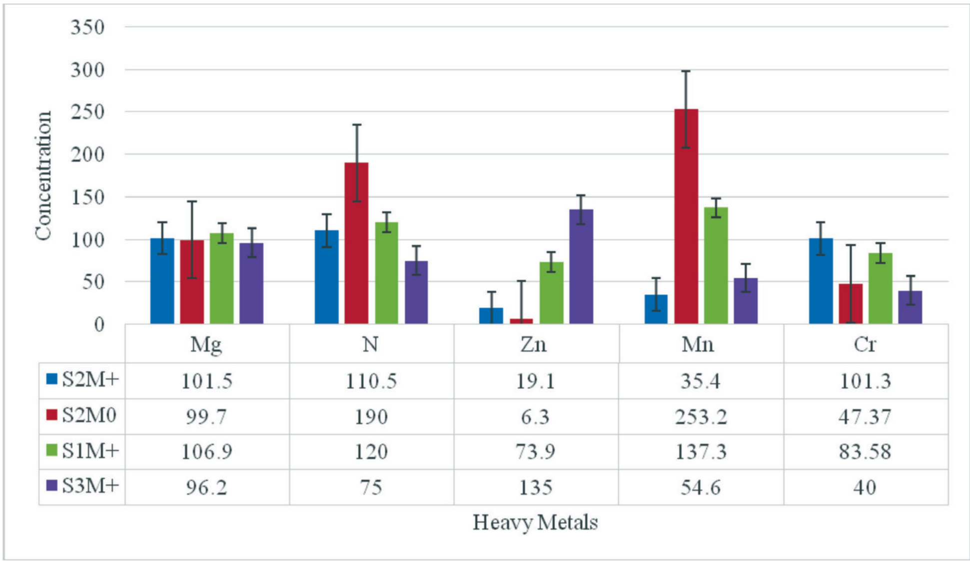


Figure 3a: Translocation Factor (TF) with error bars of maize seedling cultivated on different soil types
†S_1M_+ Background soil inoculated with mycorrhiza
S_2M_+Waste dump soil inoculated with mycorrhiza
S_2M_0 Waste dump soil without mycorrhiza
S_3M_+ Amended Background soil (Background soil +Waste dump soil (3:1) inoculated with mycorrhiza



	Mg	N	Zn	Mn	Cr
■ S2M+	101.5	110.5	19.1	35.4	101.3
■ S2M0	99.7	190	6.3	253.2	47.37
■ S1M+	106.9	120	73.9	137.3	83.58
■ S3M+	96.2	75	135	54.6	40

Fig. 2b. Translocation Factor (TF) with error bars of maize seedling cultivated on different soil types
†S_1M_+ Background soil inoculated with mycorrhiza
S_2M_+Waste dump soil inoculated with mycorrhiza
S_2M_0 Waste dump soil without mycorrhiza
S_3M_+ Amended Background soil (Background soil +Waste dump soil (3:1) inoculated with mycorrhiza

15.0 and 6.1 for Pb. The remaining include 88.4 and 73.1 for Cd; and 101.3 and 47.4 for Cr. While the metals (or nutrient element) whose TFs were decreased by the mycorrhiza were: Fe, N, Ni, and Mn. Their TF values in plants cultivated in the mycorrhizal and non-mycorrhizal waste dump soil, respectively, were 16.3 and 17.1 for Fe; 110.5 and 190 for N; 43.75 and 60 for Ni; and 35.4 and 253.2 for Mn. The result also indicated that, by comparing the TFs of plants cultivated in the background soil and the amended background soil, soil amendment greatly suppressed the TFs of all the metals (including nutrient element) except Zn. The TF values of these metals in plants cultivated in the background soil and the amended background soil, respectively, were as follows: 17.3 and 8.9 for Fe; 106.9 and 96.2 for Mg; 120 and 75 for N; 103.3 and 89.2 for K; 20 and 2.2 for Ni; 88.8 and 38.3 for Cu; 73.9 and 135.0 Zn; 137.3 and 54.6 Mn; 25 and 5 for Pb; 100 and 50 for Cd; and 83.6 and 40 for Cr.

DISCUSSION

Effects of ectomycorrhiza *Pisolithus arhizus* absorption and translocation dynamics of heavy metals in maize were investigated in this study. The effects of mycorrhiza on concentration (mg/kg) of the heavy metals and other nutrient elements in maize seedlings depend on particular heavy metal, plant's part (root or shoot) and the soil type in which the plant was cultivated. Colpaert *et al.*, (2011) reported that *Pisolithus* sp. was frequently found to thrive on soils polluted with heavy metals. ªen *et al.*, (2012) further stated the fruiting body (mushroom) of *Pisolithus arhizus* in particular can absorb and accumulate heavy metals such as cadmium, chromium, copper, manganese, and zinc; which depend on the composition and concentration of the heavy metals on the growth substrates. The ectomycorrhizal fungi are known to tolerate and accumulate the heavy metals through extracellular mechanisms, which include chelation and cell-wall binding precipitation; and intracellular mechanisms such as binding to organic acids, peptides and other compounds (Aladesanmi *et al.*, 2019; Colpaert *et al.*, 2011). In this study, the mycorrhiza greatly increased root absorption of Fe, Ni, Mn, Cd, and Cr by maize seedlings in the waste dump soil compared to the same soil but without the mycorrhiza. However, the mycorrhiza greatly suppressed the absorption of Cu, Pb, and Zn by the root.

Concerning soil type, Fe and Mn, their absorption was found to be higher in the root of the amended background soil than the non-amended background soil; even though the later had more concentration of Fe than both the waste dump soil. This indicates that some constituents or factors of the waste dump soil most have enhanced the effect of the mycorrhiza in Fe and Mn absorption by the plant. Waste-dump soils are well known to be rich in nutrients (Opaluwa *et al.,* 2012). Some previous findings suggested that the phytoextraction of heavy metals depends on plants' growth vigor and the rate of biomass production (Cui *et al.,* 2004), hence plant growing on waste-dump soils should be expected to be growing faster with more biomass and subsequent heavy metals accumulation. Additionally, the mycorrhiza facilitates the acquisition of water and nutrients from the soil by the plants, giving the plants better growth, increasing root biomass, and hence greater ability to extract heavy metals from the soil (Singh *et al.,* 2019).

However, Absorption of Ni, Cd, and Cr were found to be higher concentrations were found in the root of plants in the background soil and the amended background soil than the waste dump soil, despite the presence of higher concentration of the Ni and Cd in the waste dump soil the both the background soil and the amended background soil. Absorption of some heavy metals from soil is believed to be affected by multiple factors which include soil organic matter content (Adekiya *et al.,* 2018; Aladesanmi *et al.,* 2019). The waste-dump soil contains a high amount of organic matter as shown by the result of this study; this, and possibly other factors in the waste-dump soil, might have also played role in suppression of absorption of these heavy metals by the maize seedlings.

The mycorrhiza had slightly suppressed root absorption of Zn, Pb, Cu, Mg, K, but the rate of absorption increases with increasing concentration of the metal in the soil. Many studies reported that the absorption of heavy metal by plants increases with increasing concentration in the soil, although a trade-off exists at higher concentrations due to the toxicity of the heavy metals, which reduces plant growth and subsequent absorption of the metals.

Bioconcentration Factor

In this study bioconcentration factor (BCF) of the maize seedlings' roots concerning the heavy metals was also determined. BCF indicates the degree of ability of the plant's root to accumulator heavy metals relative to the concentration of the heavy metal in the soil. The result showed that maize is a hyperaccumulator, moderate accumulator or low accumulator of some heavy metals. Generally, BCF values ranged between >100% (hyperaccumulator); ≤ 100% (moderate accumulator); ≤ 10% (low accumulator) and ≤ 1% indicated non-accumulator.

The BCF result showed that maize is a hyperaccumulator of Fe, Mn, Cd Cu, and Cr even in the absence of mycorrhizal; although the presence ofmycorrhiza greatly increased its hyperaccumulation of these metals to about 2-6 times, except Cu. However, comparison of BCF ability of maize cultivated in the amended background soil and the non-amended background soil (both inoculated with mycorrhiza) revealed that bioaccumulation of Fe and Mn was greatly facilitated by the amendment or the waste dump factors. This was even though the background soil had a greater concentration of these metals. These showed that there was a kind of synergy between the presence of the mycorrhiza and the waste dump soil or the amended soil maize that increased the bioaccumulation of Fe and Mn by the maize seedlings. Additionally, hyperaccumulation ability of Cd and Cr decreased by soil amendment or the waste dump factors; while the hyperaccumulation of Cu was greatly reduced by the presence of both the mycorrhiza and waste dump soil. Also, the rate of absorption of Cu appeared to be determined only by its level of concentration in the soil. Sharma *et al.,* (2018) maize is hyperaccumulators of Cu even in the grains. Therefore, there is a high indication that the application of the present mycorrhiza and soil amendment with organic matter can significantly solve the problem of Cu toxicity that comes through the consumption of maize. Maize was also reported to an accumulator of Cd (Aladesanmi *et al.,* 2019), but low accumulator or Pb (Adekiya *et al.,* 2018).

The result also showed that maize is a moderate accumulator of Zn and Pb; and low accumulator of Ni and Mg. This is contrary to the findings of Aladesanmi *et al.,* (2019) who found that maize accumulatesa high amount of Pb and Zn. Bioaccumulation of Zn, Pb, and Mg was further suppressed by the mycorrhiza, but increased with their increasing concentration in the soil. Bioaccumulation of Zn, Mg, and Ni was suppressed by soil amended even in the presence of the mycorrhiza. However, previous studies indicated that absorption and accumulation of heavy metals from soil to plants are extremely complex; this process is affected by numerous affected factors and mechanisms. Among them are plant species and variety in question, climatic conditions, chemical forms metals, soil pH, soil physicochemical parameters, organic matter content, etc., (Aladesanmi *et al.,* 2019; Shehu *et al.,* 2019).

Translocation Factor

The translocation factor (TF), which measures the ability of plants to remove a particular metal from the roots to the shoot was described as the percentage of that metal in plant shoot relative to that which was in plant root. In this study, metals whose TFs were positively amplified by the mycorrhiza include Mg, Cu, Zn, Pb, Cd, and Cr. While the metals (or nutrient element) whose TFs were decreased by the mycorrhiza were: Fe, Ni, and Mn. The result also indicated that, by comparing the TFs of plants cultivated in the background soil and the amended background soil, soil amendment greatly suppressed the TFs of all the metals except Zn. Conversely, Singh *et al.,* (2019) and Abdelmoneim *et al.,* (2014) reported that endomycorrhiza enhanced heavy metal (including Cd, Mn, and Zn) accumulation in roots tissue but restrict their translocation to the shoot portion. However, the species or the ectomycorrhizas used might be different from the one used in this study. Afolayan *et al.,* (2018) also stated maize translocate Fe from the root to the shoot efficiently, which was in line with the finding in this study. Many researchers who study accumulation of heavy metals by maize, but without mycorrhiza, reported that heavy metals (including Zn, Pb and Cd, Cu, Cr, and Ni) are mainly accumulated in the root (*Adewole et al.,* 2019; Aladesanmi *et al.,* 2019; Armienta *et al.,* 2019; Lu *et al.,* 2015; Oladejo *et al.,*2017). Singh *et al.,* (2019) also indicated plants treated with some species of endomycorrhiza accumulated heavy metals mainly in their roots, contrary to the finding of this study.

CONCLUSION

The effects of mycorrhiza on the concentration of the heavy metals and other nutrient elements in maize seedlings depend on particular heavy metal, plant's part (root or shoot) and the soil type in which the plant was cultivated. Mycorrhiza *Pisolithus arhizus* greatly increased root absorption of Fe, Ni, Mn, Cd, and Cr by maize seedlings but also suppressed absorption of Cu, Pb, and Zn by the root. The BCF result showed that maize is a hyper accumulator of Fe, Mn, Cd Cu, and Cr even in the absence of mycorrhizal. The presence of mycorrhiza greatly increased its hyperaccumulation of these metals except Cu. The result also showed that maize is a moderate accumulator of Zn and Pb; and low accumulator of Ni and Mg. Bioaccumulation of Zn, Pb, and Mg was further suppressed by the mycorrhiza, but increased with their increasing concentration in the soil. Bioaccumulation of Zn, Mg, and Ni was suppressed by soil amended even in the presence of the mycorrhiza. Transfer Factors of some of the heavy metals were positively amplified by the mycorrhiza, these include Mg, Cu, Zn, Pb, Cd, and Cr. While the metals whose TFs were decreased by the mycorrhiza were: Fe, Ni, and Mn. The result also indicated thatthe amendment of the background soil with the refuse dump soil greatly suppressed the TFs of all the metals except Zn. Hence, we recommend that the ectomycorrhiza *Pisolithus arhizus* and soil manipulations should be used in practice to enhance maize phytoremediation of/or protect the plant from heavy metals absorption, which depend on the heavy metal in question. However, more in-depth research is required in this aspect.

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