DOI: https://doi.org/10.67042/njss.2022.cnkae10v

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

Biofortification of Agricultural Effluents on Translocation and Accumulation of Micronutrients Content in Cucumber (*Cucumis sativus*) Plants Grown in a Coastal plain Sand Soil South-South Ecological Zone, Nigeria.

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ARTICLE INFO

Article history:
Received September 3, 2023
Received in revised form September 14, 2023
Accepted October 17, 2023
Available online December 12, 2023

Keywords:
Cucumber
Micronutrients
Biofortification
Coastal plain sand
Agricultural effluents

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ISSN– Online **2736-1411**
Print **2736-142X**

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ABSTRACT

The study was conducted to evaluate the effects of agricultural effluents on Cu, Fe, Mn and Zn, partitioned in cucumber plants. Eight treatments, cassava mill effluent (CME), palm oil mill effluent (POME), poultry waste effluent PWE and their combinations were biofortified on cucumber plants. Samples were collected from the amended soils and plant parts (roots, shoots and fruits) and analyzed for Cu, Fe, Mn, and Zn. The Bioaccumulation Factor (BAF), Translocation Factor (TF) as well as the Enrichment Factor (EF) of the micronutrients in the cucumber plant parts were determined. The results shows that, the micronutrients budgeted by the effluents had their highest values from CME+PWE, POME+PWE, CME+POME+PWE, and POME. The abundance of the micronutrients budgeted in soils was in the order of $Fe^{3+} > Zn^{2+} > Mn^{2+} \geq Cu^{2+}$. The micronutrients in cucumber plants follows the order of Shoots >Fruits ≥ Roots for Cu, Shoots > Root > Fruits for Fe, Root > Shoots > Fruits for Mn, and Fruits > Shoots > Root, for Zn. Zinc was shown to be more accumulated in cucumber plants than the other micronutrients, as indicated by the BAF's order of (Zn > Mn ≥ Cu > Fe). Zn (Shoots to Fruits) was found to be the micronutrient which was more translocated (TF >3) than the others. Cu, Fe, Mn, and Zn had EF values were greater than 1. The order in which the effluents' capacity to transmit micronutrients to cucumber shoots and fruits are Zn>Fe>Mn>Cu.

1.0 INTRODUCTION

Cucumis sativus (cucumber), is a member of the Cucubitaceae family (Eifediyi and Remison, 2010; Saeed and Waheed, 2018). Because of its high nutritional value, Nigerians cultivate and consume it in large quantities (Chinatu, 2017; Prudent *et al*., 2014). Low soil fertility has been found to significantly hinder the production of cucumbers in farmers' fields, leading to low yields despite the growing significance of a nutritious diet (Ikeh *et al.*, 2012). However, soils with moderate to high nutrient levels are reported to produce cucumbers with high yields (Ikeh *et al*., 2012). Cucumbers are grown in healthy soil; poor soils produce bitter, malformed fruits frequently rejected by consumers (Eifediyi et al, 2012). It is increasingly essential to use outside inputs, such as organic manures and agricultural wastes, to meet the crop's nutritional needs for human consumption (Enujeke, 2013).

Micronutrients such as zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu) are essential for the growth of both plants and animals. The transfer of these nutrients from the soil to the plant is the main mechanism by which humans are exposed to this mineral nutrition found in plants and fruits (Jolly *et al*., 2013). The Transfer Factor (TF), an in-

dicator that can be used to study the transfer of micronutrients from soil to plant tissues, is based on the ratio of a mineral nutrient's concentration in plant tissue to that of the mineral nutrient in the soil (Rangnekar *et al.*, 2013; Tasrina *et al*., 2015).

In contrast, lower values suggest that plants do not respond well to metal absorption and that the plant is suitable for human consumption (Smical *et al*., 2008; Rangnekar *et al.*, 2013). According to Jolly *et al*. (2013), the concentrations of micronutrients in plants vary depending on the portion of the plant. The roots and leaves are thought to contain the highest concentrations, while the fruits and seeds have the lowest quantities. Assessing the impact of soil nutrient budget on plant-metal uptake requires an understanding of plant micronutrient mobility (Lokeshappa *et al.*, 2012). Accordingly a study of the roots can also provide insight on the degree of soil availability, the amount of nutrient transport and building in the surrounding soil, and even some indications of the amount of atmospheric availability (Smical *et al*., 2008).

In Nigeria, the cultivation of oil palm, cassava, and chicken is a significant agricultural industry that supports several families. *Osakwe* (2012), Ondo *et al*. (2013); Igbinosa and Igiehon (2015), and other reports have indicated that the agro -waste from the processing mills, such as cassava milled effluent (CME), palm oil milled effluent (POME), and poultry waste effluent (PWE from battery cage waste), has contributed to high levels of pollution and this according to Obueh and Odesiri-Eruteyan (2016) has produced an unpleasant and offensive odor that has disturbed many people living in the surrounding environs.

If the wastes are managed appropriately, they might be effectively used as biofortification to improve soil fertility and facilitate cucumber farming. Nonetheless, research conducted by Osemwota *et al*. (2010), Akpan *et al*. (2011), Abhanzioya (2018), Chinyere *et al*. (2018), Nsoanya (2018), and Akinwole *et al*. (2019) has demonstrated that biofortifying CME, POME, and PWE into soils may improve the release of certain micronutrients (Cu, Fe, Mn, and Zn) in the soils as well as their translocation to the edible part of cucumbers (Jolly *et al.*, 2013; Tasrina *et al.*, 2015).

It is well known that a balanced diet is essential in maintaining good health. Hence, the nutritional value of foods is an important aspect that should be considered especially with respect to metal intake such as copper, iron, manganese and zinc. The transfer of these micronutrients from soil to roots and from roots to cucumber plants has received little to no research in south-south Nigeria. This being the case, the study aimed to ascertain the budgets of Cu, Fe, Mn, and Zn in soils, as well as in cucumber roots, leaves, and fruit samples that were treated with different agricultural waste effluents. It also sought to ascertain the possibility of bioaccumulation and transfer, along with the health advantages of Cucumis sativus, and offer suggestions to both farmers and customers concerning cucumber cultivation.

2.0 MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted at Uyo Peri-urban, Nigeria (Latitude $5^0 17^I$ and $5^0 27^I$N, Longitude $7^0 27^I$ and $7^0 58^I$E, and at 38.1m above sea level). Uyo town is in the tropical rainforest zone which receives about 2500mm rainfall annually. The rainfall pattern is bimodal, with long (March - July) and short (September – November) rainy seasons separated by a short dry spell of uncertain length usually during August. The mean relative humidity is 78% and the atmospheric temperature is 30^0C. The mean sunshine hours is 12 as reported by Ikeh *et al*., (2012). The soils are mainly formed from coastal plain sands and alluvial deposits. The soil has been classified as Grossarenic Plinthic Kandiudalf (Ogban *et al*., 2011; Ibia, 2012).

3.1.1 Sources of experimental materials and experimental design used for the study

The cucumber seeds used were the Thia 999 variety. The agricultural wastes used for the study were poultry waste effluent (PWE) obtained from the battery cage poultry farm, while the agricultural wastes; cassava mill effluent (CME) and palm oil mill effluent (POME) were collected from the respective agro-processing mills in Uyo peri-urban areas.

The experiment was laid out in a completely randomized design (CRD) replicated three times. The experimental treatments had eight (8) levels of agricultural waste products. A total of 24 experimental treatment combinations and 24 experimental plots (*i.e.* 8 agro-waste treatments x 3 replicates) were used for the study.

The 8 levels of agricultural waste products consist of:

Control
= C
Poultry waste
= PM
Cassava mill effluent
= CME
Palm oil mill effluent
= POME
Poultry waste + Cassava mill effluent
= PW + CME
Poultry waste + Palm oil mill effluent
= PM + POME
Cassava mill effluent + Palm oil mill effluent
= CME + POME
Poultry waste + Cassava mill effluent + Palm oil mill effluent
= PM + CME + POME

2.2 Sample Collection and Treatment

After six weeks of planting, Cucumis sativus whole plants—roots, shoots, and fruits—were removed and analyzed from the soils treated with agricultural effluent. Using a hand trowel, equal portions of soil (150g) were taken from the root zone of each plant at a depth of 15 cm, and the samples were thoroughly mixed. While the plant samples—fruits, shoots, and roots—were washed individually and dried in an oven, the soil samples were allowed to air dry for a full 72 hours at room temperature. Using an agate mortar, the plant samples were ground into fine particles and sieved. Ten milliliters of aqua regia were used to digest one gram of soil and one gram of plant sample each, and the mixture was then heated for ten minutes. Distilled water was added to avoid drying up the sample digest and then filtered through Whatman number 1 filter paper into a 50cm3 standard volumetric flask and made up to mark.

The micronutrients, Copper, Iron, Manganese, and Zinc were

analyzed in the soil and parts of the plant samples using an Atomic absorption spectrophotometer (Buck 200A model). The micronutrient determination was done in triplicates. All reagents used for the analysis were of analytical grade. Glass wares and plastics were soaked in 20% HNO_3 washed with detergent and copiously rinsed with distilled water.

The Bioaccumulation Factor (BAF), Translocation Factor (TF), and Enrichment Factor (EF) of the micronutrients were computed from the relations (Obasi *et al*., 2013; Setpathy *et al.*, 2014; Zakka *et al*., 2014).

Bioaccumulation Factor (BAF): The capacity of plants to accumulate metals present in soils is defined as the ratio of the metal concentrations measured in plant tissues to the one measured in soils, on a dry weight basis (Brzostowski *et al*., 2011).

$$BAF = \frac{\text{Concentration of metals in the plant}}{\text{Concentration of metals in soil}} \quad (1)$$

Translocation Factor (TF): It is well established that transpiration is a major driver of heavy metal. The transfer capacity of metal elements between the roots and aerial parts of a plant can be defined by the ratio of their concentrations and called the Translocation Factor (TF) (Deng et al., 2004).

$$TF\ (\text{Shoot to Fruit}) = \frac{\text{Concentration of metals in fruit}}{\text{The concentration of metals in the shoot}}$$

$$TF\ (\text{Root to Shoot}) = \frac{\text{Concentration of metals in the shoot}}{\text{The concentration of metals in root}}$$

$$TF\ (\text{Soil to Root}) = \frac{\text{Concentration of metals in the root}}{\text{Concentration of metals in soil}}$$

Enrichment Coefficient (EC) of Micronutrients

EC for the vegetable/soil system was also calculated to assess the accumulating capability of heavy metals from soil to vegetable following Antoniadis and Alloway (2001). Enrichment coefficient (EC) was calculated using the following equation:

$$EC = \frac{[\text{Metal in plant/metal soil (sample)}]}{[\text{Metal in plant/metal soil (control)}]} \quad \mathbf{(5)}$$

2.3 DATA ANALYSIS

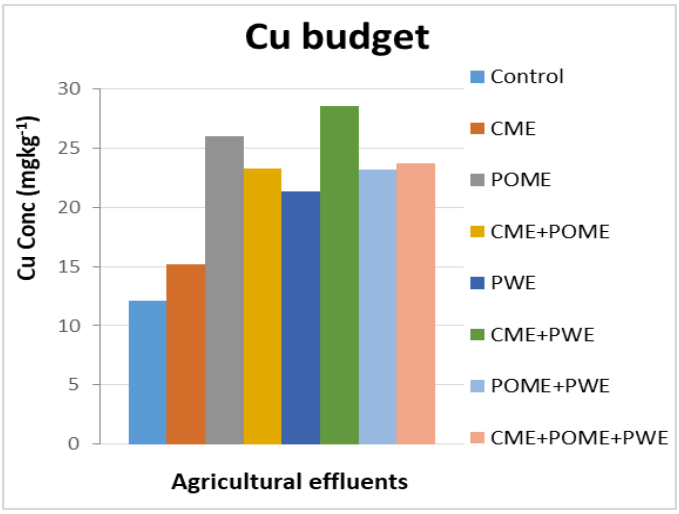
The data collected from the field study were subjected to analysis of variance (ANOVA) procedure, using general linear model of GenStat and PASW Statistics 18 for Window 7.0. Significant means were separated using Fisher's Least Significant Different where appropriate at $P<0.05$.

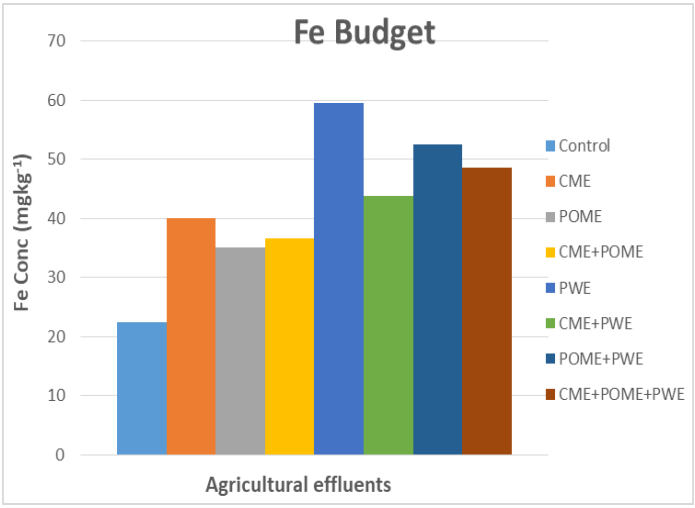
3.0 RESULTS AND DISCUSSION

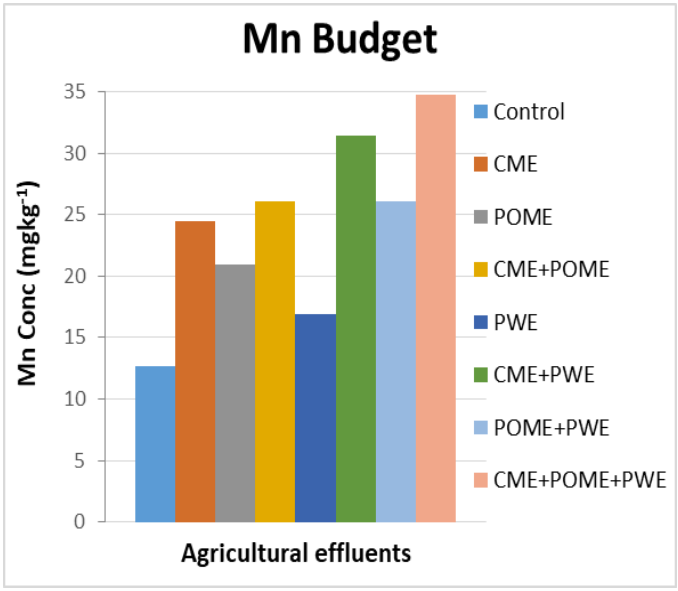
3.1 Micronutrients (Cu, Fe, Mn, and Zn) budget in soils as amended by agricultural effluents

The concentration of the micronutrients in cucumber plants depends upon the relative level of exposure of roots to the available nutrients released by the agricultural effluents into the soil. According to the results presented in Figure 1, Fe was the most dominant micronutrient in the agricultural effluent amended soil with a mean value of 42.33 $mgkg^{-1}$. The next predominant micronutrient was Zn with a mean value of 38.07 mg/kg^{-1}. Manganese and copper were 25.47 and 21.91 mg/kg^{-1} respectively (Fig. 1). Generally, the abundance of the micronutrients budgeted in soils by the agricultural effluents was in the order of $Fe^{3+} > Zn^{2+} > Mn^{2+} \geq Cu^{2+}$. The effluent amended soil's heavy metal Concentrations were higher than the control soils. The micronutrient concentration of the control non-amended soil follows in the order of Zn > Fe> Mn = Cu.

Comparing the sources of the effluents, Cu budgeted in the soil had a higher value of 28.61 $mgkg^{-1}$ which was determined from the combined effects of CME+PWE. Also, Fe, Mn, and Zn had their highest values of 52.58, 34.75, and 48.88 $mgkg^{-1}$ which were obtained from the combined effects of POME+PWE, CME+POME+PWE, and POME, respectively. Cucumber is considered as nutrient-exhaustive crop, hence any omission of the micronutrients in the fertilizer schedule will reduce growth and yield attributes of the crop (Chitdeshwari, 2019). Application of the agricultural waste effluents which may have released the micronutrients and this have attributed to the increase in growth and fruit yield. Similar results were reported by Kamal and Yousuf (2012), Rajeev *et al*. (2013), and Anuradha *et al.* (2018)







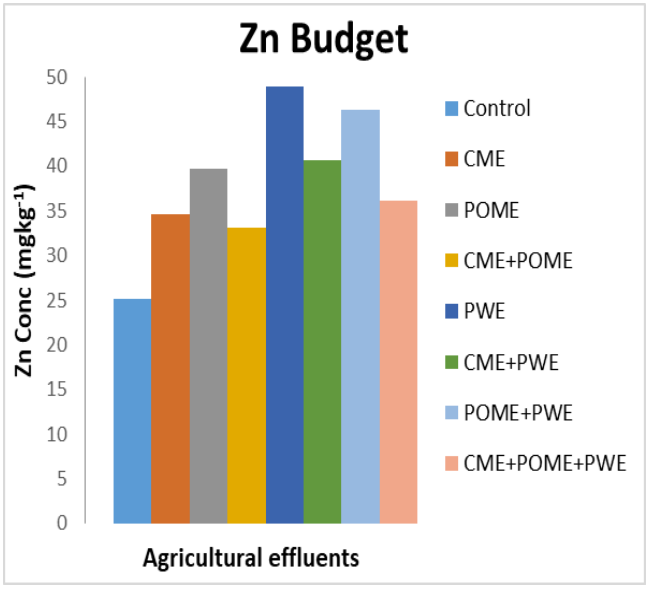
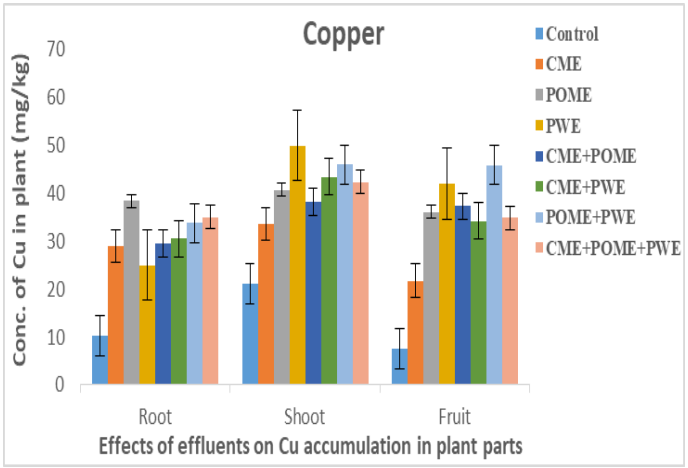


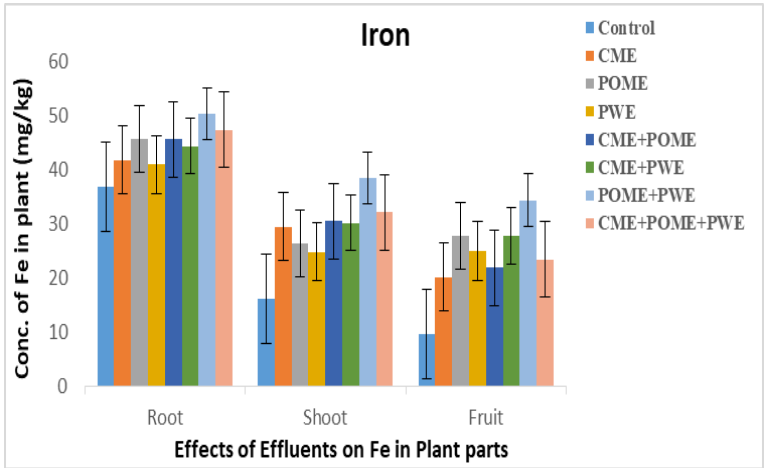
Fig. 1: Effects of agricultural effluents on soil Cu, Fe, Mn, and Zn budget for cucumber production

3.2 Micronutrients (Cu, Fe, Mn, and Zn) accumulation in cucumber plant compartments as influenced by agricultural effluents

The agricultural effluents were found to have a significant ($P<0.05$) impact on the micronutrient concentrations in the roots, leaves, and fruits (Fig. 2). Depending on soil transfer and plant conditions, the contents of the micronutrients partitioned in plants varied substantially (Kabata-Pendias, 2011). Zinc concentration in cucumber plants was more accumulated in the fruits than in the roots and the leaves and follows the order of Fruits > Shoots > Root. The order of Fe accumulation was Root > Shoots > Fruits, with higher concentrations found in the roots than in the leaves and fruits. Copper and Mn were more accumulated in the leaves than in the roots and the fruits and, this followed the order of Shoots >Fruits ≥ Roots for Cu and, Shoots > Root > Fruits for Mn. Satpathy *et al.* (2014) reported higher concentrations of these metals in the root than in the shoot, while Zakka *et al*. (2014) reported higher concentrations of the metals in the shoot than in the root. In general, the concentration of micronutrients is as follows: Zn> Cu> Mn >Zn = Fe in the fruitss, Cu = Mn >Zn> Fe in the shoots, and Fe>Mn>Cu> Zn in the root. Cu and Mn concentrations in Cucumis sativus root, shoots, and fruit were highest in POME+PWE. The amendment of combined impacts of CME, POME, and PWE resulted in a higher concentration of Mn in the fruit, leaves, and root of Cucumis sativus, while PWE gave the highest concentration of Zn in the same fruit, leaves, and root.

P lant Zn had a distinct mobility feature whereby the shoots functioned as a main, temporal source of Zn. Phytic acid, a strong inhibitor of zinc absorption, is found in high concentrations in plants. Additionally, in many developing nations where zinc shortage is common, high quantities of Fe in the roots and Zn in the fruits may be helpful as supplements (Olivares *et al*., 2004). In regions where reports of iron insufficiency have been made, nutritional zinc deficiency is also prevalent. According to Kabata-Pendias (2011), one of the main factors influencing the transfer of metals to the above-ground portions of roots is their immobilization due to a variety of mechanisms. 2011).





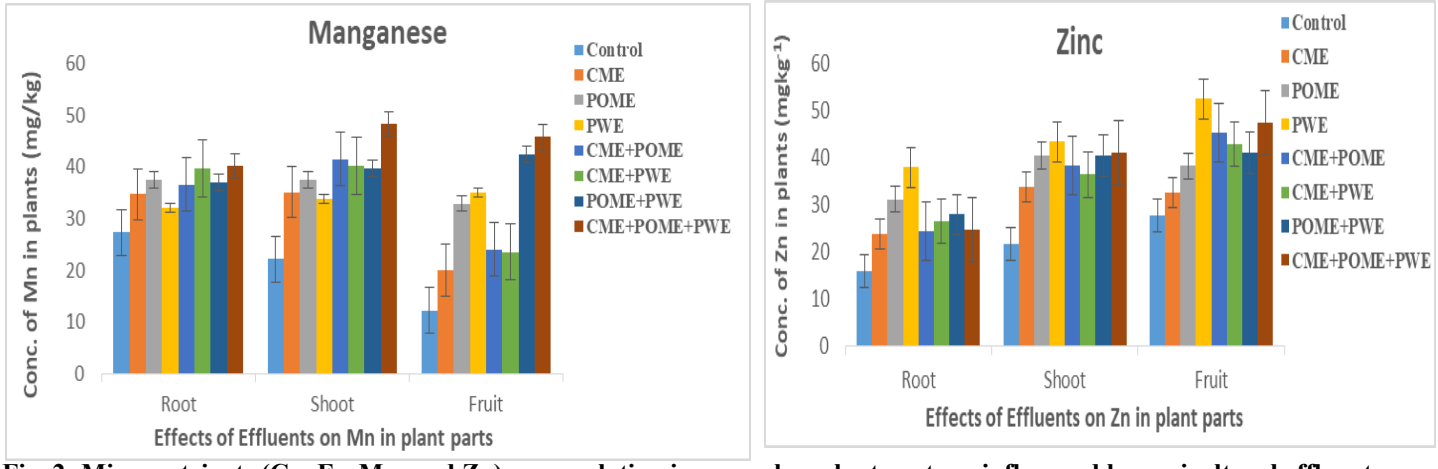


Fig. 2: Micronutrients (Cu, Fe, Mn, and Zn) accumulation in cucumber plant parts as influenced by agricultural effluents

3.3 Bioaccumulation factor (BAF) of micronutrients in cucumber shoots

Using the bioaccumulation factor (BAF), which is the dry weight ratio of the metal concentrations recorded in plant tissues to the metal concentrations measured in soils, the ability of plants to absorb metals present in soils was evaluated (Brzostowski *et al*., 2011). Table 1 displays the impact of agricultural effluents on the bioaccumulation factor (BAF) for copper, iron, manganese, and zinc, respectively. According to the results presented, the mean BAF for Cu, Fe, Mn, and Zn in the cucumber plant were 0.89, 0.73, 1.04, and 1.27, respectively. The applications of CME+PWE yielded the greatest BAF values for Fe and Zn, PWE recorded higher BAF for Cu while, CME+POME+PWE had higher BAF for Mn, and the control treatments yielded the lowest BAF values for Cu, Fe, Mn, and Zn, respectively.

When compared to other micronutrients, the edible portions of cucumbers with high BCF values for zinc indicate that the fruit absorbs and accumulates large amounts of Zn, and in cases where, Zn shortage occurs, this fruit may be suggested as a food source for Zn supplementation. Zinc was shown to be more accumulated in cucumber plants than the other micronutrients, as indicated by the BAF's order of (Zn > Mn ≥ Cu > Fe). According to Cui et al. (2004), the bioaccumulation factor (BAF) is a measure of the concentration of micronutrients in the plant shoot which is used to compare the amount of micronutrients in the plant parts to the corresponding amount of soil. Tiwari et al. (2011) refer to the bioaccumulation factor (BAF) as the metal uptake factor from soil to plant. The assessment of micronutrient uptake from soil and their subsequent bioaccumulation in the vegetative portion of the plant could be conducted using this method.

The Bioaccumulation factor for the cucumber plant as influenced by the effluents follows in the order of Zn > Mn > Cu>Fe (Table 3). BAF values less than or equal to 1 imply that the plant only absorbs the micronutrients but, no accumulation of the nutrients while, BAF values greater than 1 indicate that the micronutrients are accumulated (Satpathy *et al.*, 2014). The BAF values for the Cu, Fe in cucumber plants were all less than 1 except for Mn (1.04) and Zn (1.27) which, were greater than 1. This indicates that Cucumber is a good bioaccumulator for Mn and Zn.

Table 1: Effects of Agricultural effluents on micronutrients bioaccumulation factor in cucumber plant

Treatments	Micronutrients transfer factor (BAF) in the plant parts			
	Cu	Fe	Mn	Zn
Control	0.29	0.47	0.35	0.77
CME	1.21	0.57	0.46	1.16
POME	0.44	0.21	1.09	1.45
CME+POME	1.15	0.49	0.71	1.03
PWE	2.19	1.12	1.22	1.11
CME+PWE	0.28	1.33	1.56	2.03
POME+PWE	0.27	1.09	1.14	1.27
CME+POME+PWE	1.26	0.55	1.82	1.35
Mean	0.89	0.73	1.04	1.27

3.4 Translocation of micronutrients in cucumber plants

Table 3 displays the translocation factors, which are TF (soil to root), TF (root to shoot), and TF (shoot to fruit). Human exposure to mineral nutrients through the food chain is largely influenced by the transfer factor (Satpathy *et al*., 2014). The micronutrient translocation factor for the cucumber plants as displayed in Table 2 follows the order: Zn>Cu>Mn>Fe for TF (shoot to fruit), Fe>Mn=Zn>Cu>Fe for TF (root to root), and Mn>Zn>Cu>Fe for TF (root to shoot). Cu and Fe had higher TF (soil to root) values from POME (0.37) and PWE (4.73), whereas Mn and Zn had higher TF values from CME+PWE (0.92 and 0.86). For Cu, Fe, Mn, and Zn, respectively, the effluents CME+POME,

POME+PWE, PWE, and POME had the highest TF (root to shoot) coefficients of 2.17, 0.71, 5.25, and 3.42, and TF (shoot to fruit) coefficients of 1.25, 0.57, 0.84, and 5.78.

The TF (soil to root) for Cu, Fe, Mn, and Zn, were 0.22, 3.45, 0.61, and 0.60, relative to each other. The Translocation Factor (soil to root) for Fe was greater at >1, indicating that while, it was difficult for these plants to transfer these micronutrients from the soil to the roots, this was easy with Fe. Furthermore, the average TF (root to shoot) values for Cu, Fe, Mn, and Zn were 1.35, 0.49, 2.92, and 1.59, respectively. Cu and Zn have mean values greater than one for their TFs (root to shoot). This suggests that these plants are capable of easily translocating the metals to the shoot (Obasi et al., 2013).

For Cu, Fe, Mn, and Zn, the TF (shoot to fruit) values were 0.75, 0.28, 0.59, and 3.46, correspondingly. TF (shoot to fruit) mean values less than 1, indicating that it was not possible for these micronutrients to be translocated by these shoots to the fruit. Whereas, Zn had a mean value of >1, indicating that the metals were easily translocated to the fruits. According to Sakka et al. (2014) and Zhao et al. (2001), the translocation factor (TF) is a crucial indication that makes it possible to evaluate the mobility of heavy metals in plants. The greater the TF values, the more readily available or mobile the metals are (Satpathy, 2014). To find out how metals are distributed across various plant tissues, it requires the use of the metal transfer mechanism (Xiong, 1998).

The individual element follows the orders of Cu ($TF_{Roots-Leaves} > TF_{Leaves-Fruits} > TF_{Soil-Roots}$), Fe ($TF_{Soil-Root} > TF_{Roots-Leaves} > TF_{Leaves-Fruit}$), Mn ($TF_{Roots-Leaves} > TF_{Soil-Root} > TF_{Leaves-Fruit}$), and Zn ($TF_{Leaves-Fruit} > TF_{Root-Leaves} > TF_{Leaves-Fruit}$) respectively. The plant may move metals from the root to the shoot with a high degree of efficiency when the concentration of metals aboveground is larger than that belowground. With the exception of Fe, where TFroot was higher than TFshoot for Cucumber, TFshoot was often found to be above TFroot for Cu, Mn, and Zn. This suggests that cucumber treated with the effluents absorbed a large amount of Cu, Mn, and Zn. A large percentage of soil-plant transfer coefficients implies that micronutrient mobility from soil to plant roots, from soil to cucumber leaves, and finally to the cucumber fruit, must be greater.

Table 2: Effects of agricultural waste products on Micronutrients translocation in the plant parts

Treatment	Micronutrients translocation factor (TF) in cucumber plant parts											
	Cu			Fe			Mn			Zn		
	$TF_{Soil-Root}$	$TF_{Root-Shoot}$	$TF_{Shoot-Fruit}$	$TF_{Soil-Root}$	$TF_{Root-Shoot}$	$TF_{Shoot-Fruit}$	$TF_{Soil-Root}$	$TF_{Root-Shoot}$	$TF_{Shoot-Fruit}$	$TF_{Soil-Root}$	$TF_{Root-Shoot}$	$TF_{Shoot-Fruit}$
Control	0.12	1.02	0.57	1.85	0.34	0.19	0.39	1.14	0.37	0.43	1.21	1.66
CME	0.31	1.31	0.75	2.7	0.45	0.25	0.51	3.22	0.67	0.55	1.32	2.09
POME	0.37	1.35	0.71	3.69	0.52	0.31	0.43	1.21	0.42	0.48	3.43	4.38
CME+POME	0.31	2.17	1.00	2.74	0.54	0.27	0.55	2.29	0.77	0.51	1.52	2.53
PWE	0.15	0.75	0.45	4.73	0.49	0.26	0.61	5.25	0.43	0.68	0.98	3.29
CME+PWE	0.27	1.45	0.76	3.66	0.44	0.21	0.92	2.27	0.65	0.86	1.81	3.19
POME+PWE	0.16	0.85	0.55	4.49	0.71	0.57	0.85	3.32	0.84	0.64	1.25	4.73
CME+POME+P	0.14	2.00	1.25	3.72	0.46	0.29	0.66	4.62	0.64	0.66	1.22	5.78
Mean	0.22	1.35	0.75	3.45	0.49	0.28	0.61	2.92	0.59	0.60	1.59	3.46

3.5 Enrichment factor of Micronutrients

Table 3 shows that the highest enrichment coefficients in this investigation were found in PWE for Cu (3.34), in CME+POME+PWE for Fe (5.69), in CME+POME Mn (5.04), and in PWE for Zn (9.62). In a similar vein, the highest EF was recorded by zinc (4.94), followed by iron (3.09), and the lowest by copper (2.43). Generally speaking, Zn>Fe>Mn>Cu is the order in which the effluents' capacity to transmit micronutrients to cucumber shoots occurs. Cu, Fe, Mn, and Zn all had EF values larger than 1, suggesting that they were widely distributed and easily obtainable in the soils treated with agricultural effluents (Satpathy *et al.*, 2014). This increased the accumulation of micronutrients in the cucumber plants grown on the agriculturally treated effluents. The physiology of plants as well as the physical, chemical, and biological processes of metals in the developing environment determine the pattern of metal accumulation in plants.

Table 3: Effects of agricultural effluents on enrichment factor of micronutrients in cucumber plant

Treatments	Enrichment factor of micronutrients in cucumber plant			
Table 3: Effects of agricultural effluents on enrichment factor of micronutrients in cucumber plant	Cu	Fe	Mn	Zn
CME	1.65	1.09	2.52	4.11
POME	2.39	4.42	3.23	2.96
CME+POME	2.17	2.37	5.04	5.16
PWE	3.34	2.54	2.57	9.62
CME+PWE	2.75	2.42	2.37	2.65
POME+PWE	2.28	3.15	2.66	6.72
CME+POME+PWE	2.42	5.69	2.32	3.35
Mean	2.43	3.09	2.96	4.94

4.0 CONCLUSION

The present study showed the effects of agricultural effluents on micronutrients (Cu, Fe, Mn and Zn) partitioned in cucumber plants. The bioaccumulation and translocation Factors as well as the Enrichment Factors of the micronutrients in the cucumber plant parts were determined. Cu, Fe, Mn, and Zn budgeted by the effluents had their highest values from CME+PWE, POME+PWE, CME+POME+PWE, and POME, respectively. The abundance of the micronutrients budgeted in soils was in the order of $Fe^{3+} > Zn^{2+} > Mn^{2+} \geq Cu^{2+}$. The concentrations of micronutrients in cucumber plants follows the order of Shoots >Fruits ≥ Roots for Cu, Shoots > Root > Fruits for Fe for Mn, Root > Shoots > Fruits and Fruits > Shoots > Root, for Zn. Zinc was shown to be more accumulated in cucumber plants than the other micronutrients, as indicated by the BAF's order of (Zn > Mn ≥ Cu > Fe). Zn (Shoots to Fruits) was found to be the micronutrient which was more translocated (TF >3) than the others, indicating easy translocation of the Zn nutrition to the cucumber fruits. Cu, Fe, Mn, and Zn all had EF values greater than 1, suggesting that they were widely distributed and easily obtainable in the soils treated with agricultural effluents. Zn>Fe>Mn>Cu is the order in which the effluents' capacity to transmit micronutrients to cucumber shoots occurs.

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