

Growth behaviour and metal accumulation of two varieties of maize *Zea mays* L. sown on a soil obtained from a mining site

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Abstract. A screen house study was conducted to evaluate the effect of gemstone mining on the growth behaviour of maize *Zea mays* L. A completely randomized design involving two samples of soil (FUTA (control) and Ijero (mined soil)), two varieties of the maize (TMZ234 and Sammarz 39) was used. The seeds were sown into experimental pots containing the soils and the whole set up was left for eight weeks. Growth parameters (plant height, leaf area and stem girth) were taken at a weekly basis up till the eighth week. Eight heavy metal (Cd, Cu, Cr, Fe, Ar, Zn, Pb and Ni) concentration in the soils, roots and shoots of the plants was determined at the end of the experiment using atomic absorption spectrophotometer. Baseline data indicates that the mined soil is acidic (pH 4.12), with low organic carbon (0.92), low organic matter (1.59) and low total nitrogen (0.76). Results obtained from this study show that all growth parameters were negatively affected by the mined soil. Plant height was significantly higher in the control varieties (82.28 and 40.46, respectively) when compared with the mined soil varieties (30.5 and 29, respectively) at 8 weeks after planting (WAP). Leaf area also followed the same pattern with varieties grown on control soil having significantly higher leaf area (48.22 and 25.22, respectively) than varieties grown on mined soil (19.08 and 19, respectively). Stem girth of variety TMZ234 in control soil was also significantly higher than the rest (2.24 as against 1.68, 1.5 and 1.74). Heavy metals concentration in the soil, shoot and root of the plants grown in mined soils were all higher than in those grown on control soils. In the soil, Cr, Ni and Pb were 0.24, 0.15, 0.10 and 0.20, 0.13, 0.10, respectively, in both varieties grown on mined soils as against 0.03, 0.01, 0.00 and 0.03, 0.08, 0.00 for Cr, Ni and Pb, respectively, for both varieties grown on control soils. Bioaccumulation and translocation factors for the metals were less than 1 in all the soils except for Ni which had BCF of 2.80 and 6.90 for both varieties grown in the control soils.

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The results from this study has shown the negative effect of gemstone mining activities on the growth of two varieties of *Zea mays*.

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Introduction

According to Oxford Advanced Learner's Dictionary, mining is the activity of removing solid valuables from the earth. Mining is an important economic activity and it has the potential of contributing positively to the economic development of any nation (Yeboah, 2008).

According to the World Mining Data (Reichl et al., 2015), about 17 million metric tonnes of minerals excluding construction minerals was produced in 2012. In Africa, about 1 million tonnes of minerals was produced in the year 2013 with the exception of construction minerals (Reichl et al., 2015). It was also estimated that Nigeria produces an estimated 4 metric tonnes of precious metals (which includes gold) was in Nigeria in 2013 alone. To underscore the economic importance of the mining industry, it was estimated that 5,433,759 billion dollar worth of minerals was mined in the year 2013 (diamonds was excluded) in the world with Nigeria accounting for about 193,660 million dollars of that (Reichl et al., 2015).

According to Oladipo et al. (2014), mining operations completely alter a site's ecosystem by disrupting the ecological balance, natural landscapes, agricultural lands, forests, plantations and vegetation as well as the economic food and tree crops. A review of literature show other impacts of mining to include: air, soil and water pollution, alteration of the soil structure, instability of soil and rock masses, loss and overturning of the fertile top soil, destruction of flora and fauna and noise pollution, causing mass exodus of species of animals (Ojo and Adeyemi 2003; Aigbedion and Iyayi, 2007; Adegboye 2012). It has been observed that soil degradation resulting from mine wastes generated during exploitation activities result in low pH, depleted organic matter, nutrients, solubility of heavy metals, poor physical structure, texture, drainage and porosity, reduced biological activities (Akciil and Koldas 2006; Oelofse et al., 2008; Awotoye et al., 2009; Adegboye 2012; Oladipo et al., 2013).

In Nigeria, the mining sector is yet to be well organised and managed. This is evident in the fact that most companies duly issued with mining licences are hardly carrying out mining activities thereby creating a huge lacuna. This lacuna has been filled by illegal miners since nature abhors vacuum. The problem with this is that people who lack the proper equipment and knowledge of safe mining are those currently doing so thereby compounding the problem of the environment and host communities.

With the current drive of the Nigerian government to diversify the economy, it is expected that mining and agriculture will be in the forefront of this drive. Therefore, there will be noticeable increase in mining activities all over the country. Most mines found in South Western Nigeria are located deep in the forests and farms; places not readily accessible by regulatory agencies so impunity reigns.

This study aims to determine the growth performance and heavy metal accumulation in two varieties of maize *Zea mays* L. sown on a soil obtained from a gemstone mining site.

Materials and method

The study was conducted in a screen house and the two varieties of maize seed used were obtained from the genetic resource centre of the International Institute of Tropical Agriculture, Ibadan. Soil used was collected from a gemstone mining site in Ijero-Ekiti, Ekiti State. The soil samples were collected from the site using a shovel and was bagged and taken to the screen house to be used for planting. The sample was also labelled before taking it to the laboratory for to check for Heavy Metals present and also the soil physiochemical properties.

A completely randomized design was used in this experiment. 10 kg of Ijero soil was weighed using a measuring scale and put into already perforated buckets, the same procedure was repeated for the FUTA soil which served as the Control. A total of 20 buckets was used, 10 buckets for control (5 buckets each for both varieties) 10 buckets for Ijero soil (5 buckets each for both varieties). Five seeds were planted in each bucket.

Plant growth parameters were accessed on a weekly basis. These include plant height, number of leaves, leaf length and breadth (leaf area) and stem girth. Plant height was measured from the top of the soil to the longest apex. The stem girth was measured by putting a thread round the stem and placing it on a measuring tape. The breadth of leaf was determined by measuring the widest area of the leaf. The leaf area was determined by the addition of the length and breadth (L*B) of the leaf, multiplied with the correction factor of maize which is 0.75.

Soil pH was determined using pH meter (pH-2 Hanna). Total Nitrogen was estimated using N-Kjeldahl procedure (Bremner and Keeney, 1966). Bray method was used for determination of available phosphorus (Bray and Kurtz, 1945). Organic matter of the soil was estimated following Walkley-Black Method (Walkley and Black, 1934) while the cation exchange capacity (CEC) was determined using the procedure explained by Jackson (1969). Soil particle size was determined using the hydrometer method (Bouyoucos, 1962). Heavy metals (Cd, Cu, Cr, Fe, As, Zn, Pb and Ni) content of the soil were determined using Bulk Atomic Adsorption Spectrophotometer (AAS) following Ayten (2004). Bioaccumulation and translocation factors was determined using the formulas of Radulescu et al. (2013), and Barman et al. (2000), respectively:

$$BCF = \frac{\text{Mean metal in the plant}}{\text{Mean metal in the soil}}$$

$$TCF = \frac{\text{Mean metal in outer leaf or other part of leaf}}{\text{Mean metal concentration in root}}$$

All data obtained from this study was subjected to one-way analysis of variance (One-Way ANOVA) and means were separated with Duncan's test using SPSS ver. 16.0 statistical package.

Results

The baseline physico-chemical properties of the mined soil and the control soil is presented in Table 1 below. Using a textural triangle, the soil from the control site is sandy loam while that of Ijero mine soil is clay. pH of the control soil was 5.29 while that of Ijero was 4.12. Cation exchange capacity was also significantly higher in the Ijero mine soil (6.78) when compared to the control soil (4.14).

Table 1. Baseline soil physico-chemical properties.

Soil parameter	IJERO (Mined soil)	FUTA (Control soil)	P value	Remarks
pH (1:2)	4.2	5.39	0.00	S
OC (%)	0.92	1.12	0.29	NS
OM (%)	1.59	1.93	0.54	NS
TN (%)	0.76	0.64	0.67	NS
AP (mg/kg)	14.99	4.96	0.03	S
K (cmol/kg)	0.20	0.45	0.39	NS
CEC (cmol/kg)	6.78	4.14	0.02	S
EC (μ S 76 °F)	97.00	48.00	0.92	NS
Sand (%)	18.00	70.00	0.02	S
Silt (%)	20.00	15.00	0.61	NS
Clay (%)	62.00	15.00	0.01	S

P value < 0.05 indicates significance. N = significant; NS = Not significant.

The result of the baseline heavy metal content both in the mined soil and the control are presented in Table 2. The results of the baseline heavy metal concentration shows that all heavy metals tested were significantly higher at the Ijero mine soil when compared with the control soil with the exception of Copper which was not significantly different from that of the control.

Table 2. Heavy metals present in the soil before planting.

Soil heavy metals	IJERO (Mined soil)	FUTA (Control soil)	P value	Remarks
Cadmium	1.530	BDL	0.006	S
Copper	2.710	0.970	0.148	NS
Chromium	0.810	0.070	0.005	S
Iron	54.700	15.500	0.003	S
Arsenic	0.010	BDL	0.004	S
Zinc	4.950	0.110	0.001	S
Lead	0.100	BDL	0.004	S
Nickel	0.170	0.010	0.005	S

Pvalue < 0.05 indicates significance. N = significant; NS = Not significant; BDL = Below Detection Limit.

The result of the heavy metal contents in the soil after eight weeks of planting (8 WAP) are represented in Table 3. From the table, cadmium, iron, zinc and nickel in the control soil sown with both variety of maize were significantly higher than the Ijero soils. Arsenic and Lead were both below the detection limit in their control soils as against the Ijero soils which were detected.

The results of the heavy metal contents in the shoot after eight weeks of planting are presented in Table 4. From the table, Copper was significantly lower in the shoots of both varieties of maize sown in the control soil as against those sown in the Ijero soil. Iron shows no significant difference in both varieties planted in control soil, but shows that there is a significant difference between the mined soil in both varieties. Arsenic and chromium were below the detection limit in all the shoots.

Table 3. Heavy metals content of the soil eight weeks after planting.

Heavy metals	Control soil (V1)	Control soil (V2)	Ijero (V1)	Ijero (V2)
	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E
Cadmium	0.12 ^b \pm 0.00	0.10 ^a \pm 0.02	1.26 ^d \pm 0.03	1.22 ^c \pm 0.01
Copper	0.54 ^c \pm 0.02	0.42 ^a \pm 0.01	0.57 ^d \pm 0.16	0.53 ^b \pm 0.10
Chromium	0.03 ^a \pm 0.00	0.03 ^b \pm 0.00	0.24 ^d \pm 0.09	0.20 ^c \pm 0.02
Iron	7.96 ^a \pm 0.02	8.42 ^b \pm 0.02	16.75 ^c \pm 1.20	17.32 ^d \pm 1.30
Arsenic	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.02 ^b \pm 0.01	0.02 ^b \pm 0.01
Zinc	2.05 ^a \pm 0.01	2.09 ^b \pm 0.02	4.98 ^d \pm 0.10	4.46 ^c \pm 0.12
Lead	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.10 ^b \pm 0.16	0.10 ^b \pm 0.15
Nickel	0.01 ^a \pm 0.00	0.08 ^b \pm 0.04	0.15 ^c \pm 0.14	0.13 ^{bc} \pm 0.1

Each value is the mean of 3 replicates. Mean followed by the same letters are not significantly different ($p < 0.05$) from each other using Duncan's test. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

Table 4. Heavy metal contents in the shoot.

Heavy metal	Control soil (V1)	Control soil (V2)	Ijero (V1)	Ijero (V2)
	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E
Cadmium	0.04 ^a \pm 0.00	0.01 ^a \pm 0.00	0.02 ^a \pm 0.02	0.22 ^a \pm 0.10
Copper	0.01 ^a \pm 0.00	0.01 ^a \pm 0.01	0.03 ^b \pm 0.07	0.53 ^c \pm 0.02
Chromium	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00
Iron	0.80 ^b \pm 0.01	1.01 ^c \pm 0.02	1.38 ^d \pm 0.12	0.57 ^a \pm 0.07
Arsenic	0.00 ^b \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00
Zinc	0.02 ^a \pm 0.00	0.20 ^c \pm 0.01	0.17 ^b \pm 0.10	0.02 ^a \pm 0.01
Lead	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.08 ^a \pm 0.06
Nickel	0.04 ^a \pm 0.00	0.07 ^c \pm 0.01	0.07 ^c \pm 0.20	0.05 ^b \pm 0.02

Each value is the mean of 3 replicates. Mean followed by the same letters are not significantly different ($p < 0.05$) from each other using Duncan's test. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

The results of the heavy metal contents in the shoot after eight weeks of planting are presented in Table 5.

Table 5. Heavy metal contents in the root.

Heavy metal	Control soil (V1)	Control soil (V2)	Ijero (V1)	Ijero (V2)
	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E	Mean \pm S.E
Cadmium	0.02 ^b \pm 0.00	0.01 ^a \pm 0.00	0.63 ^d \pm 0.01	0.05 ^c \pm 0.01
Copper	0.08 ^c \pm 0.01	0.04 ^b \pm 0.00	0.18 ^d \pm 0.10	0.02 ^a \pm 0.01
Chromium	0.00 ^a \pm 0.00	0.04 ^d \pm 0.00	0.02 ^c \pm 0.01	0.01 ^b \pm 0.00
Iron	1.99 ^a \pm 0.01	2.64 ^c \pm 0.10	4.15 ^d \pm 0.09	2.16 ^b \pm 0.12
Arsenic	0.02 ^b \pm 0.01	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00
Zinc	0.64 ^a \pm 0.12	0.83 ^c \pm 0.07	1.01 ^d \pm 0.01	0.83 ^b \pm 0.06
Lead	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.00 ^a \pm 0.00	0.03 ^b \pm 0.01
Nickel	0.08 ^c \pm 0.02	0.07 ^b \pm 0.01	0.09 ^d \pm 0.01	0.06 ^a \pm 0.02

Each value is the mean of 3 replicates. Mean followed by the same letters are not significantly different ($p < 0.05$) from each other using Duncan's test. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

From the table, Cadmium was significantly lower in the roots of both varieties of maize sown in the control soil as against those sown in the Ijero soil. Lead was below the detection limit in all the roots except in the variety 2 of Ijero soil.

The results of the bioaccumulation and translocation factors are presented in Table 6.

Table 6. Bioaccumulation factor (BCF) and translocation factor (TCF) in the plants.

Heavy metal	BCF				TCF			
	Control (V1)	Control (V2)	Ijero (V1)	Ijero (V2)	Control (V1)	Control (V2)	Ijero (V1)	Ijero (V2)
Cd	0.03	0.50	0.02	0.00	0.20	0.50	0.03	0.00
Cu	0.02	0.02	0.06	0.05	0.11	0.18	0.19	1.20
Cr	0.00	0.10	0.02	0.00	0.00	0.10	0.20	0.00
Fe	0.01	0.12	0.08	0.03	0.40	0.40	0.33	0.00
As	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Zn	0.08	0.10	0.03	0.04	0.25	0.23	0.17	0.67
Pb	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.67
Ni	3.80	6.90	0.47	0.39	0.50	0.10	0.78	0.85

Bioaccumulation and translocation factor were found to all be below 1 except in Nickel and Copper where the bioaccumulation factors in control and translocation factor in variety 2 of Ijero soil, respectively, were higher than 1.

The results of the plant growth parameters (plant height, leaf area and stem girth) are represented in Figures 1, 2, and 3, respectively. Plant height of control plants was consistently higher than those sown in mine soil across all weeks of the study. At 8 WAP, the highest plant height was recorded by control variety 2 with an average height of 82cm. The lowest was Ijero variety 2 with average height of 29 cm. Like plant height, leaf area was also consistently higher in the control plants. At the end of the experiment (8 WAP), control variety 1 had the highest leaf area while the least was obtained by Ijero variety 2. Stem girth in control variety 1 was higher than the rest in all the weeks data was collected. At 8 WAP, stem girth was 3.24 cm in control variety 1 while the lowest was 1.5 cm attained by Ijero variety 1.

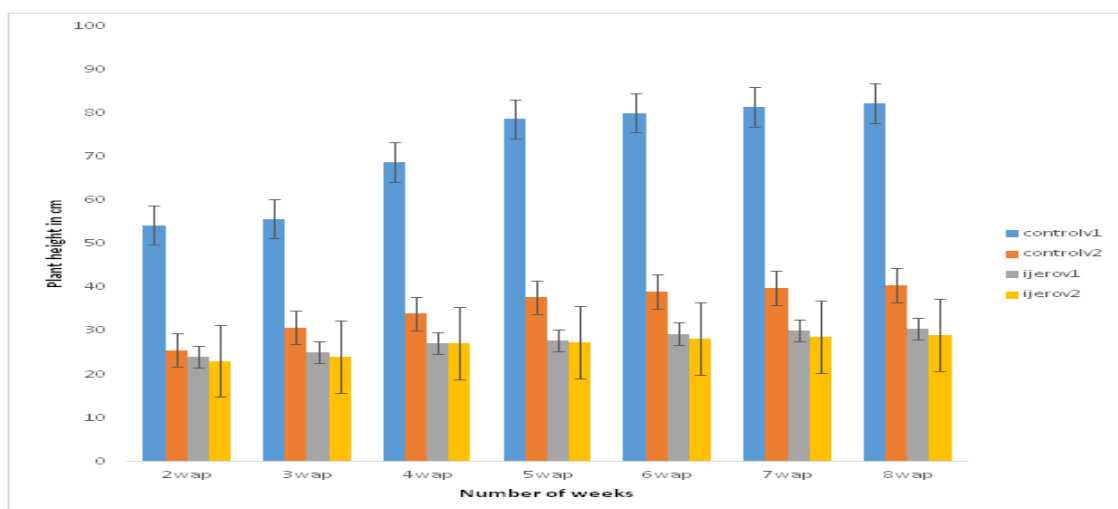


Figure 1. Effect of mined soil on the plant height (cm) of maize *Zea mays* L. seedlings. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

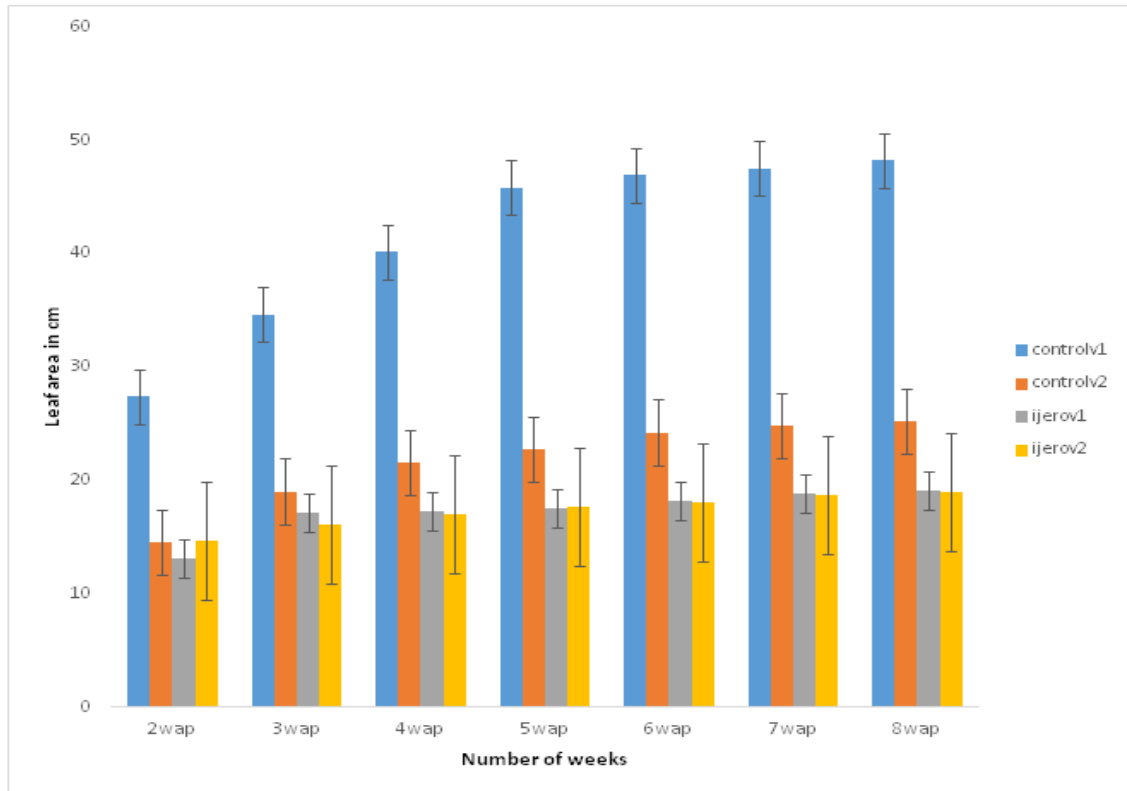


Figure 2. Effect of mined soil on the leaf area (cm) of maize *Zea mays* L. seedlings. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

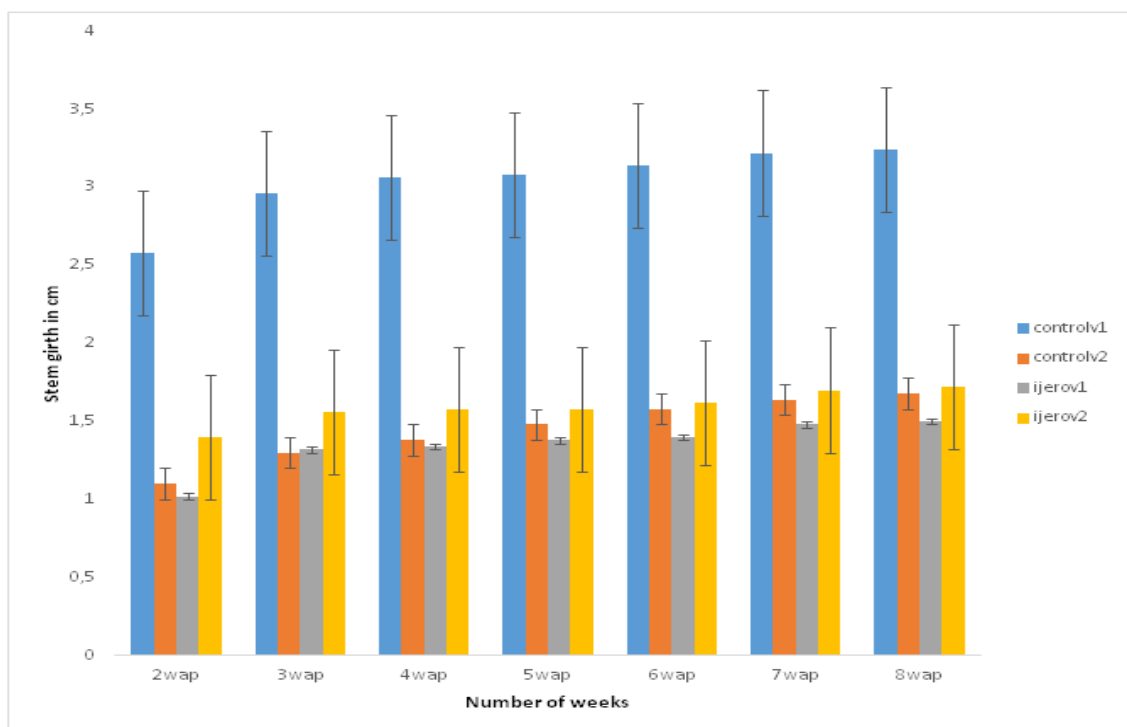


Figure 3. Effect of mined soil on the stem girth (cm) of maize *Zea mays* L. seedlings. V1 = Variety 1 (TMZ234), V2 = Variety 2 (Sammarz 39).

Discussion

The results of the baseline physico-chemical properties of the mined and control soil are in agreement with studies of Eludoyin et al. (2017) and Oladipo et al. (2014). pH of the mined soil was observed to be more acidic than that of the control. This increase in acidity can be attributed to acid mine drainage which occurs in mining areas (Adekoya, 2003). As was with Eludoyin et al. (2017) and Oladipo et al. (2014) organic carbon and potassium was also lower in mined soil than in the control soils. The higher level of electrical conductivity in the mine soil can be attributed to the release of ions which ordinarily should be bound to rocks but are inadvertently released as a result of the breaking and washing of rocks during the mining process. This conforms to results by Abiya et al., 2018 in gold mining sites. Heavy metals in mined soil was consistently higher in mined soil than in the control soil. This is in conformity with earlier studies by Abiya et al. (2018), Eludoyin et al. (2017), Oladipo et al. (2014) and Olatunji and Osibanjo (2012). According to Oelofse et al. (2008), when a mining site is continuously exploited, it leads to increased soil degradation, higher acidity levels of the soil and eventual increase in solubility of heavy metals in the soil.

The growth parameters were observed to have been negatively affected by the mined soil when compared with the control. Plant height, leaf area and stem girth were consistently lower in maize varieties sown in mine soil across all weeks measurements were taken. This is in agreement with studies by (Sahu and Pradhan, 2004).

BCF values in the maize varieties sown on mined soil were all below 1. This is in agreement with studies conducted by Ashraff et al. (2011) on plants growing in ex-tin mining sites. Ekwue et al. (2012), reported a bioconcentration factor of < 1 for Cd, Cu, Pb, Zn, Cr and Co in plants growing in a secondary goldmine.

At the end of planting, heavy metals in the soil, roots and shoots of the plants was observed to be higher in the mined soil than the control. Results found in plants indicated that Iron was in most cases significantly higher. Although Iron is abundant and an essential constituent for all plants and animals, at high concentration it causes tissue damage and some other diseases in human (WHO, 1996). The metals accumulated in the shoots were found to be below WHO guidelines for metals in plants, this could be as a result of reduced transfer of metals from the root to the shoot.

Conflict of Interest

The authors declare that they have no conflict of interest in this publication.

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