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EFFECTS OF LEAD ON THE GROWTH OF TOMATO (*Lycopersicon esculentum* Miller.)

***[1]Grace E. Obi-Iyeke and [2]Evieva F. Ogbara**

[1]Department of Botany, Delta State University, Abraka, Nigeria.
[2]Department of Biological Sciences, University of Africa, Toru-Orua, Bayelsa State, Nigeria

*Corresponding authors' email: **ekyobiiyeke@gmail.com**

ABSTRACT

The research aimed at investigating the effects of Lead as Pb^{2+} ion on growth of tomato (*Lycopersicon esculentum* M.). The study comprised two phases, *in vitro* and field experiment. The concentration of lead treatment applied to *in vitro*, and field base experiment were 0ppm, 50ppm, 100ppm, 150ppm, 200ppm, 250ppm, 300ppm, 350ppm, and 400ppm with four replications each. The parameters investigated include percentage germination, radicle length, plumule length, plant height, fresh weight, dry weight, and number of leaves. The results showed action of Pb^{2+} ion increase percentage germination while radicle and plumule length, fresh weight, dry weight and number of leaves significantly decreased at high concentration of Pb^{2+} ion compared to controls. Moreover, plants height revealed stunted growth. Furthermore, the results showed no significant variation ($p > 0.05$) in the studied parameters with respect to the different Pb concentrations used for the treatment. Conclusively, actions of Pb^{2+} ion at high concentration revealed decreased in plant activities associated with tomato growth.

Keywords: Tomato, Lead, Growth, *Lycopersicon esculentum* Miller

INTRODUCTION

The effects of lead exposure are worldwide (Payne, 2008). Lead exposure accounts for about 0.2% of all deaths and 0.6% of all disability adjusted life years globally (WHO, 2016). Urban areas in general have received higher depositions of lead than have rural areas because of lingering lead in soil which contributes to lead exposure in these urban areas (Guidotti and Ragain, 2007). Lead pollution can be from various sources, such as broken-down lead paint, residues from lead-containing gasoline, used engine oil, or pesticides used in the past (Deni, 2014).Waste disposal is also a factor, Contaminated landfills, or nearby industries such as foundries or smelters (Woolf *et al.*, 2007). Lead contamination remains prevalent, raising concerns about the safety of urban agriculture (Murphy, 2009). Eating food grown in contaminated soil can present a lead hazard referred to as lead poisoning (WHO, 2021).

Lead remains one of the most widely used element in many industrial processes and is found in all environmental compartments (soils, water, the atmosphere, and living organisms). The prominence of environmental lead contamination results both from its persistence and from its present and past sources (Punamiya *et al.* 2010). Occurrence of lead in the soil results in deleterious effects both on the plant morphology, growth and photosynthetic processes while causing inhibition of enzyme activities, water imbalance, alterations in membrane permeability and disturb mineral nutrition (Singh *et al.*, 2010). Sharma and Dubey (2005) also reported Seed germination inhibitions by heavy metals.

There have been reports on lead-induced inhibition of seed germination (Islam *et al.*, 2007; Sengar *et al*., 2009). At higher concentrations, lead may speed up germination and simultaneously induce adverse effects on the length of radical and hypocotyls (Islam *et al.*, 2007). Inhibition of germination may be caused by lead interfering with amylase and protease enzymes (Sengar *et al.*, 2009). Plants exposure to lead exposure to lead strongly limits the sprouting of and development seedlings (Dey *et al.*, 2007; Gichner *et al.*, 2008; Gopal and Rizvi, 2008).

The toxicity of lead vary between soils closest to highways busy streets and near old buildings where lead-based paint has washed off. Lead exposure in plants has significant detrimental effect in the plant development. It limits the growth and sprouting of seedlings as well as inhibiting seed germination. The major concern is on the rate of accumulation of lead inside the plant body as the greatest challenge is on direct consumption via the soil or dust route. Thus the objectives of this study are to evaluate the effect of lead contaminated soil on germination of tomato and to determine the effects of lead on the growth characteristics (plant height and number of leaves).

MATERIALS AND METHODS

Area of study

The *in vitro* investigation was done in the laboratory, while the field experiment was conducted at the research, garden located in the Botany Department, Faculty of Science, Delta State University, Abraka, Delta State, Nigeria.

Plant material

Seeds of *Solanum lycopersicum*, Variety is UC82B produced by Starke Ayres, South Africa, were utilised for this study and purchased from shoprite mall, Warri, Delta State, Nigeria.

Collection of topsoil

Soil sample (0-12 cm depth) was collected from a farm site at campus 1, Delta state University, Abraka.

Soil and Pb solution Preparation

Preparation of deionized water: Deionized water was prepared at the laboratory using a deionizer. Tap water from the Botany laboratory was collected and deionized in Botany laboratory, Delta State University, Abraka.

Preparation of Pb^{2+} Solutions: Analytical grade of Lead nitrate ($PbNO_3$ of 99% purity) was purchased. One gram (1g) of the heavy metal was weighed using a sensitive balance and put in a 1-litre measuring cylinder and 10ml of deionized water was used to dissolve it and then made up to the 1L mark to obtain a concentration of 1g/1L of the Pb solution. Different volumes (50, 100, 150, 200, 250, 300, 350 and 400ml) were pipetted from the prepared Pb^{2+} solution and put in the different measuring cylinders and each made up to the 1litre mark to obtain different treatments of 50, 100, 150, 200, 250, 300, 350 and 400ppm (Parts Per Million) Pb^{2+} solutions.

Preparation of Soil Sample: Thirty-six (36) polybags were used for the experiment and 3kg of soil was weighed using a weighing balance, packed into each polybag, and labelled according to different treatments. Each treatment was replicated four times.

Application of Pb treatments to soil
The experiment was setup with nine treatments including control. The control was wet with deionized water. Then the different Pb treatments (50ppm, 100ppm, 150ppm, and 200ppm etc.) were also used to wet the soil and left to stand for 24 hours before planting. Subsequently, 200ml of each treatment of each solution was used to wet the soil every four (4) days for the next five weeks.

Sowing of Seeds
The seeds were soaked for 3 hours before planting. Five (5) seeds were sown into each polybag.

Experimental Setup
`The site was cleared and the polybags containing the soil with different treatment arranged as a completely randomized design. Each treatment of each was replicated four (4) times and arranged randomly on the site.

Germination Measurement or Radicle
The protrusion of the plumule or radicle was recorded as the germination. The germination record was taken for eight (8) days in the in vitro study, and fourteen days in the field. The number of germinated seeds were counted and recorded. The germination records were used to calculate germination percentage.

$$Percentage\ germination\ = \frac{number\ of\ seeds\ that\ germinated}{Number\ of\ seed\ sown} \times\ 100$$

Plant Height
The height of the tallest plant was in each experimental pot and marked for subsequent measurement. Measurement was carried out using metre rule and this was done once a week for four weeks.

Number of Leaves
The number of leaves was counted for the selected plant from each polybag.

Fresh Weight of Plant
The fresh weights of plants were obtained after harvesting and then weighed using sensitive weighing balance.

Dry Weight of Plant
Dry weight measurement was carried out after oven-drying the plant samples at 70^0C for five days until a constant weight was obtained.

Statistical Analysis
Data collected were used to calculate mean ± standard deviation of the parameters of interest. Analysis of variance was used to determine if there was significant variation in the parameters of interest with respect to the different Pb concentrations used for treatment with a p-value less than 0.05 ($p < 0.05$) consider statistically significant. All data analysis were done using Microsoft Excel package.

RESULTS

In-vitro study

The results obtained for the in vitro study carried out are showed in below in Table 1-3.

Table 1 shows effect of Pb^{2+} ion on percentage germination of tomato in the *in vitro* study. Result showed that germination was observed in all Pb^{2+} ion treatments. Tomato seeds treated with Pb^{2+} ion concentrations of 50 and 150 ppm and 100 ppm have the highest and lowest mean percentage germination respectively after 2 days of treatment while tomato seeds treated with 50 ppm and 250 ppm of Pb^{2+} ion have the highest and lowest mean percentage germination respectively after 4 days of treatment. After 6 days of treatment, tomato seeds treated with 150 ppm and 300 ppm of Pb^{2+} ion have the highest and lowest mean percentage germination respectively. However, tomato seeds treated with 150 ppm and 400 ppm of Pb^{2+} ion have the highest and lowest mean percentage germination respectively after 8 days of treatment. Analysis of Variance (ANOVA) showed that there was no significant variation ($p > 0.05$) in the mean percentage germination of tomato seed treated with different concentrations of Pb^{2+} ion *in vitro* study after 2, 4, 6 and 8 days treatment.

Table 1: Percentage germination (Mean ± S.D) of tomato seeds treated with different concentration of Pb^{2+} ion *in vitro* study

Treatment	Number of days after treatment			
(ppm)	2	4	6	8
0	42.50±9.57	70.00±21.60	80.00±11.55	82.50±9.57
50	25.00±12.91	77.50±9.57	85.00±5.77	87.50±5.00
100	12.50±9.57	65.00±17.32	77.50±9.57	80.00±8.17

150	25.00±19.15	70.00±14.14	87.50±5.00	90.00±8.17
200	20.00±11.55	67.50±5.00	75.00±5.77	80.00±8.17
250	17.50±5.00	62.50±9.57	77.50±9.57	80.00±11.55
300	20.00±8.16	72.50±15.00	65.00±37.86	87.50±12.58
350	20.00±8.17	67.50±9.57	82.50±5.00	82.50±5.00
400	17.50±5.00	67.50±9.57	72.50±5.00	75.00±5.77
P - value	0.883277	0.664339	0.659017	0.422143

Table 2 showed radicle length of seeds germinating under Pb^{2+} ions treatments during *in vitro* study. Result revealed decreased radicle of all treatment groups compared to control. Tomato seeds treated with Pb^{2+} ion concentrations of 250 ppm and 200 ppm have the highest and lowest mean radicle length respectively after 2 days of treatment while tomato seeds treated with 250 ppm and 400 ppm of Pb^{2+} ion have the highest and lowest mean radicle length respectively after 4 days of treatment. However after 6 and 8 days of treatment, tomato seeds treated with 150 ppm and 400 ppm of Pb^{2+} ion have the highest and lowest mean radicle length respectively. ANOVA showed that there was no significant variation (p-value > 0.05) in the mean radicle length of tomato seed treated with different concentrations of Pb^{2+} ion *in vitro* study after 2, 4, 6 and 8 days treatment.

Table 2: Radicle length (Mean ± S.D in mm) of tomato seeds treated with different concentration of Pb^{2+} ion *in vitro* study

Treatment	**Number of days after treatment**			
(ppm)	**2**	**4**	**6**	**8**
0	2.50±1.00	7.75±0.96	10.25±1.71	10.25±1.71
50	1.00±0.00	5.00±0.82	8.50±1.29	8.50±1.29
100	1.00±0.00	4.75±0.50	7.50±1.29	7.50±1.29
150	1.00±0.00	5.5±0.58	9.50±2.52	10.00±3.46
200	0.75±0.50	4.00±0.82	7.25±1.71	7.25±1.71
250	1.75±0.50	5.75±1.71	8.50±1.73	8.00±1.15
300	1.00±0.00	4.00±1.41	5.75±0.96	7.50±1.73
350	1.25±0.50	4.00±0.82	5.75±0.50	6.00±0.82
400	1.00±0.00	3.00±0.82	5.25±0.50	5.50±0.58
P-value	0.052627	0.069815	0.284471	0.116586

Table 3 showed plumule length of seeds germinating under Pb^{2+} ion treatments during *in vitro* study. Result showed decrease in plumule length of all test groups compared to control. After 4 and 6 days of treatment, tomato seeds treated with 150 ppm and 100 ppm of Pb^{2+} ion have the highest and lowest mean plumule length respectively while tomato seeds treated with Pb^{2+} ion concentrations of 50 ppm and 400 ppm have the highest and lowest mean plumule length respectively after 8 days of treatment. No plumule was observed at day 2. ANOVA showed that there was no significant variation (p-value > 0.05) in the mean plumule length of tomato seed treated with different concentrations of Pb^{2+} ion *in vitro* study after 4, 6 and 8 days treatment.

Table 3: Plumule length (Mean ± S.D in mm) of tomato seeds treated with different concentration of Pb^{2+} ion *in vitro* study

Treatment (ppm)	Number of days after treatment			
	2	4	6	8
0	0.00±0.00	4.00±2.71	13.00±4.76	21.00±4.2
50	0.00±0.00	1.50±0.58	9.25±1.50	15.75±2.87
100	0.00±0.00	0.50±1.00	3.75±3.59	7.50±5.07
150	0.00±0.00	2.25±0.50	9.50±1.00	14.75±3.59
200	0.00±0.00	0.75±0.96	5.25±3.78	7.75±5.32
250	0.00±0.00	2.00±0.82	7.5±2.08	10.25±2.22
300	0.00±0.00	1.50±0.58	7.25±2.50	9.00±2.58
350	0.00±0.00	0.75±0.96	5.25±3.20	9.25±4.65
400	0.00±0.00	1.75±0.50	5.25±2.36	6.50±3.70
P-value	-	0.100510	0.149075	0.082857

Field Experiment

The result obtained from the field on the effect of Pb^{2+} ion on germination and growth of tomato are shown in Tables 4 to 6 and Figures 1 to 3.

Table 4 shows effect of Pb^{2+} ion on percentage germination of tomato in field study. Result revealed increase germination percentage for all treatment groups compared to the control. For day 4 after treatment, soil treated with Pb^{2+} ion concentrations of 200 ppm and 250 has the highest mean percentage germination of tomato while soil treated with 50 ppm of Pb^{2+} ion has the lowest mean percentage germination of tomato. For day 6 after treatment, soil treated with 300 ppm of Pb^{2+} ion has the highest mean percentage germination of tomato while soil treated with 50 ppm, 100 ppm and 400 ppm of Pb^{2+} ion has lowest mean percentage germination of tomato. However, for day 8 after treatment, soil treated with 300 ppm and 350 ppm of Pb^{2+} ion has the highest mean percentage germination of tomato while soil treated with 100 ppm and 400 ppm of Pb^{2+} ion has lowest mean percentage germination of tomato. ANOVA showed that there was no significant variation ($p > 0.05$) in the mean percentage germination of tomato in Pb^{2+} ion treated soil after 4, 6 and 8 days of planting.

Table 4: Percentage germination (Mean ± S.D) of tomato in Pb^{2+} ion treated soil

Treatment (ppm)	Number of days after planting		
	4	6	8
0	10.00±11.55	50.00±11.55	67.50±15.00
50	0.00±0.00	45.00±19.15	60.00±16.33
100	15.00±10.00	45.00±25.17	45.00±25.167
150	10.00±11.55	55.00±25.17	55.00±25.17
200	20.00±0.00	55.00±25.17	70.00±34.64
250	20.00±16.33	50.00±25.82	75.00±30.00
300	10.00±11.55	60.00±28.28	80.00±28.28
350	15.00±10.00	55.00±30.00	80.00±28.28
400	5.00±10.00	45.00±10.00	45.00±10.00

Pvalue	0.185379	0.987511	0.493326

Table 5 shows the plant height recorded for tomato plant grown in Pb^{2+} ion treated soils. Result showed decreased plant height (stunted growth) of all treatment groups compared to control. After 2 weeks of planting, soil treated with 300 ppm and 150 ppm of Pb^{2+} ion have the highest and lowest mean heights respectively of tomato plants grown. Whereas, after 3 weeks of planting, soil treated with 50 ppm of Pb^{2+} ion has the highest mean height of tomato plant grown while soil treated with 350 ppm and 400 ppm of Pb^{2+} ion has the lowest mean height of tomato plants grown. After 4 weeks of planting, soil treated with 300 ppm and 350 ppm of Pb^{2+} ion have the highest and lowest mean heights respectively of tomato plants grown while soil treated with 50 ppm and 350 ppm of Pb^{2+} ion have the highest and lowest mean height respectively of tomato plants grown after 5 weeks of planting. ANOVA showed that there was no significant variation ($p > 0.05$) in the mean height of tomato plants grown in Pb^{2+} ion treated soil after 2, 3, 4 and 5 weeks of planting.

Table 5: Height (Mean ± S.D in cm) of tomato plants grown inPb^{2+} ion treated soil 5 weeks after planting.

Treatment	**Number of weeks after planting**			
(ppm)	**2**	**3**	**4**	**5**
0	5.00±1.41	6.38±1.80	7.63±2.50	8.75±3.10
50	4.38±1.25	6.00±.82	6.50±1.00	8.00±0.82
100	4.00±0.82	5.50±1.29	6.50±1.29	7.50±1.29
150	3.00±0.00	5.75±1.19	6.63±1.38	7.75±0.96
200	3.75±0.96	5.25±0.65	6.00±0.82	7.00±0.00
250	4.25±0.50	5.88±0.85	6.38±1.25	7.25±0.96
300	4.50±0.58	5.75±0.50	7.00±1.16	7.25±0.96
350	3.75±0.65	4.88±0.85	5.75±0.96	6.50±1.30
400	3.75±0.50	4.88±1.31	6.13±1.65	7.00±1.16
P-value	0.332221	0.732896	0.936670	0.848316

Table 6 shows the mean number of leaves recorded for tomato plant grown in Pb^{2+} ion treated soils. Result showed decreased number of leaves of all treatment groups compared to control. After 2 weeks of planting, soil treated with 250 ppm of Pb^{2+} ion has the highest mean number of leaves of tomato plants grown while soil treated with 50 ppm and 200 ppm of Pb^{2+} ion has the lowest mean number of leaves of tomato plants grown. After 3 weeks of planting, soil treated with 300 ppm and 200 ppm of Pb^{2+} ion have the highest and lowest mean number of leaves respectively of tomato plants grown while After 4 weeks of planting, soil treated with 400 ppm and 200 ppm of Pb^{2+} ion have the highest and lowest mean number of leaves respectively of tomato plants grown. However, soil treated with 150 ppm and 250 ppm of Pb^{2+} ion has the highest mean number of leaves of tomato plants grown while soil treated with 200 ppm of Pb^{2+} ion has the lowest mean number of leaves of tomato plants grown after 5 weeks of planting. ANOVA showed that there was no significant variation ($p > 0.05$) in the mean number of leaves of tomato plants grown in Pb^{2+} ion treated soil after 2, 3, 4 and 5 weeks of planting.

Table 6: Number of leaves (Mean ± S.D) of tomato grown in Pb^{2+} ion treated soil 5 weeks after planting

Treatment (ppm)	**Number of weeks after treatment**			
	2	**3**	**4**	**5**
0	7.00±0.82	12.00±4.10	13.25±4.50	15.00±4.69
50	6.00±1.41	8.25±0.50	11.50±3.11	12.00±2.71

100	7.25±1.50	9.50±1.00	11.75±1.26	12.00±1.63
150	6.75±1.26	8.75±2.50	11.50±2.52	12.25±1.71
200	6.00±0.82	7.00±0.00	8.50±2.38	9.00±2.16
250	7.25±0.50	8.75±1.71	11.25±2.87	12.25±2.99
300	7.00±0.82	10.25±2.06	11.75±2.63	11.75±2.63
350	6.25±0.96	8.00±1.83	9.50±3.70	9.50±3.70
400	7.00±0.00	9.50±1.73	12.00±3.37	12.00±3.37
P-value	0.592353	0.365544	0.748769	0.669950

Figure 1 showed decrease in fresh weight of tomato plant in all the treatment groups compared to the control. The highest mean fresh weight (1.61 g) of tomato plant grown was observed in soil treated with 300 ppm of Pb^{2+} ion while the lowest mean fresh weight (0.42 g) of tomato plant grown was observed in soil treated with 50 ppm of Pb^{2+} ion. ANOVA showed that there was no significant variation ($p > 0.05$) in the mean fresh weight of tomato plants grown in soil treated with different concentrations of Pb^{2+} ion.

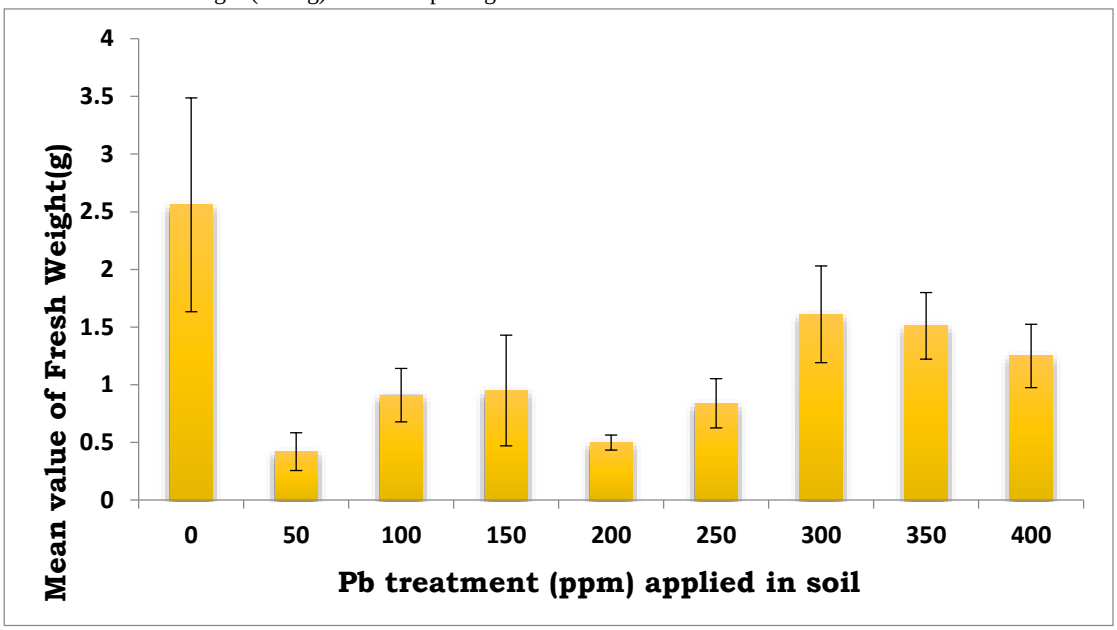

Figure 1: Fresh weight of tomato grown in Pb^{2+} ion treated soil 5 weeks after planting

Figure 2 showed decrease in dry weight of tomato plant in all the treatment groups compared to the control. The highest mean fresh weight (0.46 g) of tomato plant grown was observed in soil treated with 300 ppm of Pb^{2+} ion while the lowest mean dry weight (0.18 g) of tomato plant grown was observed in soil treated with 50 ppm of Pb^{2+} ion. ANOVA showed that there was no significant variation ($p > 0.05$) in the mean dry weight of tomato plants grown in soil treated with different concentrations of Pb^{2+} ion.

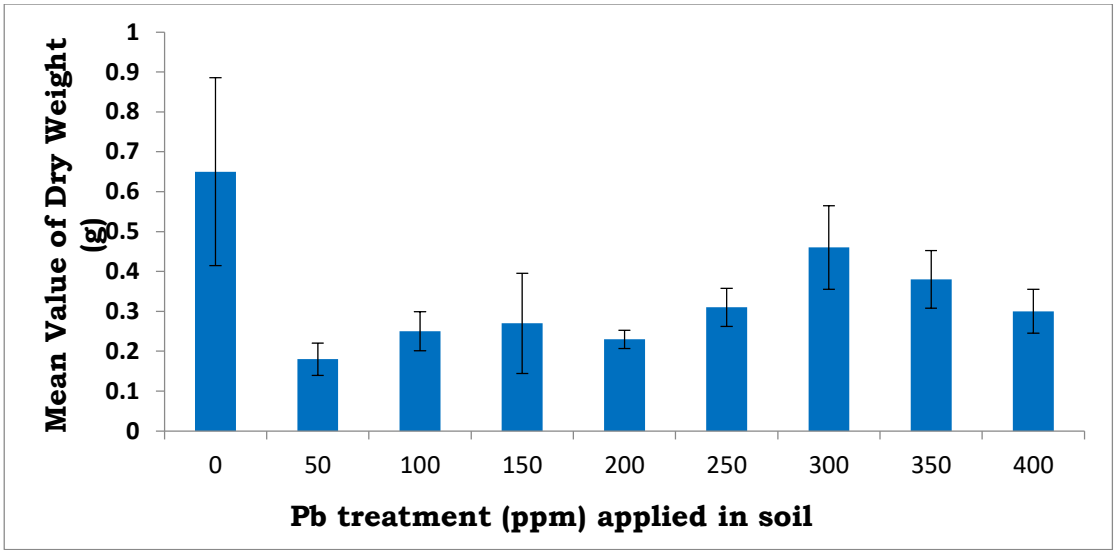

Figure 2: Dry weight of tomato grown in Pb^{2+} ion treated soil after 5 weeks after planting.

Plate 1: Tomato (*Lycopersicon esculentum*) seeds

Plate 2: $Pb(NO_3)_2$ salt

Plate 3: Seeds sown *in vitro* study

Plate 4: Soil treated with Pb^{2+} ion

Plate 5: Young tomato (*Lycopersicon esculentum*) seedling growing in lead treated soil after 4 weeks

Plate 6: Differences between control and 400ppm tomato (*Lycopersicon esculentum*) treatments.

DISCUSSION

Lead (Pb) is one of the most abundant and universally ubiquitously distributed toxic elements in soils. At elevated levels, lead is thought to alter membrane permeability and disturb mineral nutrition, inhibit enzyme activities and cause water imbalance (Sharma and Dubey, 2005). In this study, Pb affected the germination, radicle length and plumule length of tomato. These findings agree with Fargasova (2001) on effect of Pb $(NO_3)_2$, who reported action of Pb $(NO_3)_2$ at high concentration to decrease tomato plant radicle and plumule length. Pb also affected the number of leaves of tomato plants grown in Pb treated soils in this study. This finding is in consonance with earlier studies that report Pb to significantly reduced number of leaves in tomato plant (Stevens *et al.,* 2003; Opeolu, *et al*., 2010; Deni, 2014). For instance, Deni (2014) reported that Pb coat the surface of leaves and reduces amount of light reaching it, thereby causing stunted growth. Furthermore, Pb affected the fresh and dry weight of tomato grown on Pb treated soil. This was consistent with Stevens *et al.,* (2003) and Opeolu, *et al.* (2010) who reported decrease in fresh, dry weight and root length of tomato following activities Pb $(NO_3)_2$.

CONCLUSION

The evidence of this research showed that lead contamination has adverse effects on growth parameters of tomato. The effects were pronounced on number of leaves, fresh and dry weights, and radicle as well as plumule length and plant height. Therefore, actions of lead at high concentration revealed decrease in plant characteristics associated with tomato growth.

Recommendation

There is need to carry out similar field and *in vitro* experiments and a wider survey of impact of lead contamination on tomato and other vegetable crops.

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