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Original Research Article

EFFECT OF *PSEUDOMONAS AERUGINOSA* AND *TRICHODERMA HARZIANUM* IN THE YIELD RESPONSE OF *SOLANUM LYCOPERSICUM* IN HEAVY METAL CONTAMINATED SOIL

ABSTRACT

This study determined the yield of *Solanum lycopersicum* in heavy metal contaminated. Experimental pots containing 3000 g of sterilized soil was used for this experiment whereby 60 sample pots were used with various treatments in this study. *Solanum lycopersicum* seeds were raised in the nursery for a period of 3 weeks and treatments applied just before transplanting into the experimental pots. The plants were left for a week so as to be established properly and overcome transplanting shock before watering with the contaminated stream water. Heavy metal analysis using Atomic Absorption Spectroscopy (AAS) method was carried out on the contaminated stream water to determine the amount of heavy metal in the stream water before the commencement of the experiment. The contaminated stream water was applied to the pots in measured quantities; 0, 5 and 10%. Yield data from the experiment were obtained and recorded. The results showed that heavy metals were present in high concentration in the stream water sample. The values of the heavy metals in the stream water sample used for watering were Iron – 138.15 mg/L, Zinc – 68.4 mg/L, Lead – 7.89 mg/L and Copper – 8.98 mg/L. The effect of *P. aeruginosa* were found to be more pronounced among all the treatments as it enhanced the yield of the plants when compared with other treatments. Highest fruit yield was produced in tomato plants treated with *P. aeruginosa* at 5% and 10% level of contaminated stream water sample concentration. The study concluded that the use of contaminated stream water for irrigation could be a potential source of heavy metals in tomato. However, inoculation of microorganisms for the treatment of the heavy metal contaminated sites was effective for increased health, growth and yield of tomato fruits.

KEYWORDS: *Solanum lycopersicum, Pseudomonas aeruginosa, Trichoderma harzianum*

INTRODUCTION

Heavy or toxic metals are trace metals which are detrimental to human health and they have density that is at least five times that of water. Once released into the environment through the air, drinking water, food, or countless varieties of man-made chemicals and products, heavy metals are taken into the body via inhalation, ingestion and skin absorption (Suruchi and Khanna , 2011). Wastewaters contain toxic heavy metals that are introduced into the soil and aquatic system through various processes, prominent among them is irrigation (Khan *et al*., 2008). Heavy metal pollution in the air increases through human activities (Khan *et al*., 2008). Heavy metal contamination may occur due to factors which could include irrigation with contaminated water, addition of fertilizers and metal based pesticides, industrial emissions, and transportation (Radwan and Salama, 2006; Tuzen and Soylak, 2007; Duran *et al*., 2007). Heavy metal pollution does not only affect the production and quality of crops, it also influences the quality of the atmosphere and water bodies. This threatens the health and life of animals as well as human beings by the way of food chain and most phenomenal is that, this kind of pollution is covert, long term and non-reversible (Zhang, 1999). Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals because these metals are absorbed in their leaves. Tomato (*Solanum lycopersicum*) is one of the most important vegetable and one of the most widely cultivated crops wordwide (Seleim *et al*., 2011). This is due to its acclimatization to a wide variety of environment as well as its nutritive value. They contribute to a healthy, well balanced diet and are rich in minerals, vitamins essential amino acids, sugars and dietary fibres (Ensminger *et al*., 1995). *Trichoderma harzianum* has potential in stimulating phytoremediation directly and indirectly and therefore, inoculation of plants with this fungus could be a feasible approach to enhance the degradation of hydrocarbons in polluted soil. *T. harzianum* also have the ability to solubilize metal ions and produce siderophores to chelate iron, making metal ions required for

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plant growth more available to the plant (Harman *et al*., 2004). The fungus is thought to colonize roots of annual plants for their entire lifetime by penetrating the outer layers of the roots (Harman *et al*., 2004). This makes the plants release more root exudates to the surrounding soil, thus, stimulating microbial degradation of pollutants. *Trichoderma harzianum* has been shown to induce the production of larger and deeper root systems, and plants inoculated with *Trichoderma harzianum* also produce greater plant biomass. Such plants are more resistant to abiotic stress and take up nutrients more effectively (Harman *et al*., 2004). Edward *et al*., (2006) noted that various bacteria such as *Pseudomonas aeruginosa* produce surfactants that aid in the biodegradation. A recent study has found a *P. aeruginosa* strain that actually supports plant growth. This characteristic, along with the fact that *P. aeruginosa* can degrade polycyclic aromatic hydrocarbons, suggests the future uses of *P. aeruginosa* for environmental detoxification of synthetic chemicals and pesticides and for industrial purposes (Botzenhardt and Doring, 1993).

MATERIALS AND METHOD

Collection of Contaminated water, seeds and microorganisms

Heavy metals contaminated stream water was obtained from a flowing stream. It is situated at 7°30' Northern latitude and 4°28' Eastern longitude. The sampling point was located at the back of the Ife Iron and Steel Nigeria Limited along Ife-Ibadan expressway. Surface water samples was collected at downstream into clean plastic kegs. The water samples were collected during the month of April, 2015. Seeds of *Solanum lycopersicum* cultivar (ROMA VF) were obtained from Institute of Agricultural Research and Training, Moor Plantation, Ibadan.

Culturing of Organisms

A culture of *Pseudomonas aeruginosa* was obtained from the Department of Microbiology, Obafemi Awolowo University (OAU), Ile-Ife. A culture of *Trichoderma harzianum* was also obtained from the Mycology unit of the Department of Crop Production and Protection, OAU, Ile-Ife. A single colony of *P. aeruginosa* was subcultured by using nutrient agar in Petri dishes and kept in the incubator for 48 hours at 37°C to a medium after which it was harvested by flooding with sterile distilled water. The bacterium inoculum was prepared by streaking a single colony of *P. aeruginosa* earlier isolated on plated nutrient agar plate and incubated at 37°C for 48 hours. Cells of *P. aeruginosa* were harvested from agar plates by flooding with sterile distilled water and standardized using a colorimeter to 10^8 CFU/ml. Spores of *Trichoderma harzianum* was subcultured by using potato dextrose agar in Petri dishes and kept in the incubator for 7 days at 37°C to a medium after which it was harvested by flooding with sterile distilled water. The fungal spore solution was prepared by picking spores of *T. harzianum* earlier isolated on potato dextrose agar plate and incubated at 37°C for 7 days. Spores of *T. harzianum* were harvested from agar plates by flooding with sterile distilled water and standardized using a colorimeter to 10^7spores/ml.

Preparation of Sterilized Soil for Field work

Top soil and river sand were mixed together and sieved before it was sterilized using an autoclave by heating for 5 hours at 131°C and left to cool for four (4) days.

Planting of seeds and contamination of experimental pots

Seedlings of *S. lycopersicum* were raised on nursery beds for a period of three weeks. Sixty pots, each containing three kilograms of soil from sterilized soil was used for this study. *Pseudomonas aeruginosa* inoculum solution (30 ml) was poured into a hole that was made in the middle of a set of 15 experimental pots containing sterized soil before *S. lycopersicum* seedlings are transplanted to it. *Trichoderma harzianum* spore solution (30 ml) was also poured into a hole that was made in the middle of another set of 15 experimental pots before *S. lycopersicum* seedlings are transplanted to them. The third set of 15 pots received dual inoculation of *Trichoderma harzianum* spore solution (15 ml) and *P. aeruginosa* innoculum before *S. lycopersicum* seedlings were transplanted into it; with the final set of 15 pots acting as control at various levels. Thereafter, pot preparation was arranged in a completely randomized design in the screenhouse.

Seedlings were left for a week to establish and overcome transplanting shock before wetting with the contaminated stream water at various concentrations of 0%, 5% and 10% v/v. Contaminated stream water was quantified using the formula: percentage soil contamination = (Volume of polluted stream water applied / Volume of soil) x 100. Each

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treatment of the experiment was replicated three times. Twenty four pots were watered with the contaminated stream water once during the experiment and another 24 pots watered daily with the contaminated stream water. The remaining 12 pots which served as the control experiment were watered daily with distilled water. Pots containing *S. lycopersicum* was watered regularly to ensure adequate moisture.

Data on yield parameters such as number of fruits, weight of fruit and diameter of fruit was recorded at every harvest from 13 weeks after planting till the experiment was terminated at 15 weeks after planting. Data obtained was subjected to statistical analysis using descriptive and inferential methods.

Experiment (Treatment Layout)

Sterilized soils were polluted with contaminated stream water at a calculated percentage using the formula; Percentage soil contamination = (Volume of Contaminated stream water/Volume of soil) x 100.

The layout of the experiment is as follows;

Treatment 1- sterilized soil + *S. lycopersicum*
Treatment1d- sterilized soil + *S. lycopersicum* (2)
Treatment 2- sterilized soil + *Trichoderma harzianum* + *S. lycopersicum*
Treatment 2d- sterilized soil + *Trichoderma harzianum* + *S. lycopersicum* (2)
Treatment 3- sterilized soil + *Pseudomonas aeruginosa* + *S. lycopersicum*
Treatment 3d- sterilized soil + *Pseudomonas aeruginosa* + *S. lycopersicum* (2)
Treatment 4- sterilized soil + *T. harzianum* + *P. aeruginosa* + *S. lycopersicum*
Treatment 4d- sterilized soil + *T. harzianum* + *P. aeruginosa* + *S. lycopersicum* (2)
Note: (2) and d means daily wetting of pots with contaminated water

Each of the layouts contaminated at 0, 5, and 10% (v/w) contaminated stream water concentration was replicated thrice. The experimental pots were watered regularly to ensure adequate moisture for proper growth of the test plant.

RESULTS

The heavy metals analysis of the stream water showed that heavy metals (Iron, Zinc, Copper and Lead) were present in high concentration in the water. Iron (Fe) had the highest concentration of 138.15 mg/L followed by zinc (Zn) which had a concentration of 68.4 mg/L. The order of concentration was Fe>Zn>Cu>Pb.

YIELD DATA

The yield data of *S. lycopersicum* was taken from 13WAP to 15WAP across all the treatments at different levels of contamination with contaminated stream water which showed yield results. The yield data parameters include:

Number of Fruits Produced under different Treatments

For 0% level of contaminated stream water concentration, treatment 3(with innoculation of *P.aeruginosa*) produced the highest number of fruits with nine (9) *S.lycopersicum* fruits while treatment 2(with inoculation of *T. harzianum*) and treatment 4(with dual inoculation of *T. harzianum* and *P.aeruginosa*) produced three (3) *S.lycopersicum* fruits having the same number of fruits. At 13WAP, treatment 3 produced the highest number of fruits while treatment 1 (with no inoculation of micro-organism) produced the lowest number of fruits with 4 *S.lycopersicum* fruits (Table 1).

For 5% level of contaminated stream water concentration, at 13WAP, treatment 1d(with no inoculation of micro-organism) and treatment 2(with inoculation *T. harzianum*) produced two (2) fruits having same number of fruits (Table 2). Similarly, treatment 1(with no inoculation of micro-organism) and treatment 3(with inoculation of *P. aeruginosa*) produced the highest number of fruits producing 7 fruits . Treatment 3 and treatment 3d produced the same number of fruits, also treatment 2 , treatment 2d and treatment 4 also produced the same number of fruits at

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14WAP. Treatments 1, 1d and 4d also produced the same number of fruits at 14WAP. Treatment 1 did not produced any fruit at 15WAP but treatment 3d produced the highest number of fruits at 15WAP.

Table 1: Total Number of Fruits produced and Mean Number of Fruits under Different Treatment with 0% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total number	**Mean**	**Total number**	**Mean**	**Total number**	**Mean**
1-SS + TP	6	2	3	1	4	1.3
2-SS + TH + TP	3	1	3	1	2	0.6
3-SS + PA + TP	9	3	4	1.3	3	1
4-SS+TH+PA+TP	3	1	2	0.6	2	0.6

Legend
SS: Sterilised soil
TP: Test plant
TH: *Trichoderma harzianum*
PA: *Pseudomonas aeruginosa*
Treatment 1 – Sterilised soil + *Solanum lycopersicum*
Treatment 2 – Sterilised soil + *T. harzianum* + *Solanum lycopersicum*
Treatment 3 – Sterilised soil + *P.aeruginosa* +*Solanum lycopersicum*
Treatment 4 – Sterilised soil + *T. harzianum*+ *P. aeruginosa* + *Solanum lycopersicum*

Table 2: Total Number of Fruits produced and Mean Number of Fruits under Different Treatment with 5% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total number	**Mean**	**Total number**	**Mean**	**Total number**	**Mean**
1-SS + TP	4	1.3	1	0.3	-	-
1d-SS + TP	2	0.6	1	0.3	1	0.3
2-SS + TH + TP	2	0.6	2	0.6	4	1.3
2d-SS+TH +TP	3	1	2	0.6	3	1
3- SS + PA + TP	4	1.3	4	1.3	5	1.6
3d-SS + PA + TP	7	2.3	4	1.3	7	2
4-SS+TH+PA+TP	3	1	2	0.6	3	1
4d-SS+TH+PA+TP	5	1.6	1	0.3	5	1.6

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For contaminated stream water concentration at 10%, treatment 1 and treatment 1d produced the same number of fruits ,also treatments 4 and 4d produced the same number of fruits, both producing three (3) fruits at 13WAP (Table 3) . Treatment 3d had the highest number of fruits producing 6 fruits. From 14WAP to 15WAP, treatment 1 and treatment 1d did not produce any number of fruit. At 15WAP treatment 3 and treatment 4 produced the highest number of fruits both producing the same number of fruits.

Table 3: Total Number of Fruits produced and Mean Number of Fruits under Different Treatment with 10% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total number	**Mean**	**Total number**	**Mean**	**Total number**	**Mean**
1-SS + TP	1	0.3	-	-	-	-
1d-SS + TP	1	0.3	-	-	-	-
2-SS + TH + TP	4	1.3	3	1	2	0.6
2d-SS+TH +TP	2	0.6	3	1	3	1
3- SS + PA + TP	4	1.3	3	1	4	1.3
3d-SS + PA + TP	6	2	3	1	3	1
4-SS+TH+PA+TP	3	1	2	0.6	4	1.3
4d-SS+TH+PA+TP	3	1	1	0.3	2	0.6

Weight of Fruits Produced under different Treatments

For 0% level of contaminated stream water concentration, treatment 3(with inoculation of *P. aeruginosa*) had the highest value of weight of fruit with 23.0g followed by treatment 1(with no inoculation of micro-organism) with 12.4g weight of fruit while treatment 4 (with dual inoculation of *T. harzianum* and *P. aeruginosa*) having the lowest weight of fruit with 5.7g at 13WAP. There was an increase in the weight of fruit in treatment 1 and treatment 4 while treatment 2 and treatment 3 showed a decrease in weight of fruit from 14WAP to 15WAP. At 15WAP, treatment 1 had the highest value of weight of fruit while treatment 2 had the lowest value in weight of fruit (Table 4)

For contaminated stream water concentration at 5%, treatment 3d (with inoculation of *P. aeruginosa*) had the highest value of weight of fruit with 45.5g followed by treatment 4d (with dual inoculation of *T. harzianum* and *P. aeruginosa*) with 35.2g weight of fruit while treatment 2 (with inoculation of *T. harzianum*) had the lowest weight of fruit with 16.1g at 13WAP. From 14WAP to 15WAP there was an increase in the weight of fruit in all the treatments except treatment1. At 15WAP, treatment 3d had the highest weight of fruit (Table 5).

For 10% level of contaminated stream concentration, treatment 3d had the highest value in weight of fruit with 39.3g while treatment 1d has the lowest weight of fruit with 5.3g. Treatment 1 and treatment 1d had no weight of fruit from 14WAP to 15WAP since they produced no fruit from 14WAP to 15WAP (Table 6). There was an

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increase in weight of fruit in treatment 2, treatment 2d, treatment 3, treatment 4 and treatment 4d from 14WAP to 15WAP. At 15WAP, treatment 3 had the highest value in weight of fruit followed by treatment 4.

Table 4: Total Weight of Fruit produced (g) and Mean Weight of Fruit (g) under Different Treatment with 0% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Weight	**Mean**	**Total Weight**	**Mean**	**Total Weight**	**Mean**
1-SS + TP	37.1	12.4	16.3	5.4	19.9	6.6
2-SS + TH + TP	22.5	7.5	19.2	6.4	13.5	4.5
3-SS + PA + TP	69.1	23	27.2	9.1	18.6	6.2
4-SS+TH+PA+TP	17.1	5.7	13.5	4.5	13.7	4.6

Table 5: Total Weight of Fruit (g) produced and Mean Weight of Fruit (g) under Different Treatment with 5% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Weight	**Mean**	**Total Weight**	**Mean**	**Total Weight**	**Mean**
1-SS + TP	25	8.3	6.5	2.1	-	-
1d-SS + TP	19.7	6.5	5.3	1.7	6.5	2.1
2-SS + TH + TP	16.1	5.4	14.0	4.7	26.5	8.8
2d-SS+TH +TP	18	6.0	13.3	4.4	22.3	7.4
3- SS + PA + TP	28.6	9.5	27.6	9.2	36.5	12.2
3d-SS + PA + TP	45.5	15.2	28.3	9.4	50.1	16.7
4-SS+TH+PA+TP	19.6	6.5	13.8	4.6	19.6	6.5
4d-SS+TH+PA+TP	35.2	11.7	5.3	1.7	33.3	11.1

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Table 6: Total Weight of Fruit (g) produced and Mean Weight of Fruit (g) under Different Treatment with 10% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Weight	**Mean**	**Total Weight**	**Mean**	**Total Weight**	**Mean**
1-SS + TP	6.1	2.0	-	-	-	-
1d-SS + TP	5.3	1.7	-	-	-	-
2-SS + TH + TP	28.4	9.5	16.3	4.4	11.6	3.9
2d-SS+TH +TP	14.2	4.7	18.3	6.1	19.1	6.4
3- SS + PA + TP	25.5	8.5	19.0	6.3	31.0	10.3
3d-SS + PA + TP	39.3	13.1	20.5	6.8	18.9	6.3
4-SS+TH+PA+TP	16.0	5.3	9.3	3.1	23.1	7.7
4d-SS+TH+PA+TP	13.2	4.4	5.8	1.9	12.6	4.2

Diameter of Fruits Produced under different Treatments

For 0% level of contaminated stream water concentration, treatment 2 and treatment 3 had the same value in diameter of fruit at 13WAP. There was a decrease in fruit diameter in all the treatments from 13WAP to 14WAP. At 15WAP, treatment 1 had the highest diameter of fruit with 20.2cm followed by treatment 4 with 15.5cm while treatment 2 had the lowest diameter of fruit with 14.0cm (Table 7).

For 5% level of contaminated stream water concentration, at 13WAP, treatment 3 had the highest diameter of fruit with 26.0cm while treatment 1d had the lowest diameter of fruit with 14.0cm. There was an increase in diameter of fruit in treatments 2, 2d, 3, 3d, 4 and 4d from 14WAP to 15WAP. Treatment 1 had no diameter of fruit at 15WAP but treatment 3 had the highest diameter of fruit with 26.7cm (Table 8).
For contaminated stream water concentration at 10%, at 13WAP treatment 3 had the highest diameter of fruit with 27.3cm while treatment 1d had the lowest diameter of fruit with 7.5cm. Treatments 1 and 1d had no diameter of fruit from 14WAP to 15WAP since they produce no fruit. There was a decrease in diameter of fruit in treatments 2 and 3d from 14WAP to 15WAP. At 15WAP, treatment 3 had the highest diameter of fruit followed by treatment 3d (Table 9).

Table 7: Total Diameter of Fruit produced (cm) and Mean Diameter of Fruit (cm) under Different Treatment with 0% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Diameter	**Mean**	**Total Diameter**	**Mean**	**Total Diameter**	**Mean**
1-SS + TP	22.0	7.3	20.0	6.7	20.2	6.7
2-SS + TH + TP	22.5	7.5	15.2	5.1	14.4	4.8
3-SS + PA + TP	27.5	9.1	23.0	7.7	14.0	4.7

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4-SS+TH+PA+TP	22.5	7.5	14.5	4.8	15.5	5.2

Table 8: Total Diameter of Fruit (cm) produced and Mean Diameter of Fruit (cm) under Different Treatment with 5% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Diameter	**Mean**	**Total Diameter**	**Mean**	**Total Diameter**	**Mean**
1-SS + TP	17.6	5.8	15.0	3.0	-	-
1d-SS + TP	14.0	4.7	7.2	2.4	7.0	2.1
2-SS + TH + TP	17.0	5.7	15.7	5.2	17.0	5.7
2d-SS+TH +TP	14.5	4.8	13.0	4.3	15.7	5.2
3- SS + PA + TP	26.0	8.7	17.0	5.7	26.1	8.7
3d-SS + PA + TP	25.5	8.5	22.7	7.6	26.7	8.9
4-SS+TH+PA+TP	22.7	7.6	14.5	4.8	18.6	6.2
4d-SS+TH+PA+TP	24.4	8.1	8.0	2.6	19.5	6.5

Table 9: Total Diameter of Fruit (cm) produced and Mean Diameter of Fruit (cm) under Different Treatment with 10% Contaminated Stream Water Concentration

Age after planting

Treatment	13		14		15	
	Total Diameter	**Mean**	**Total Diameter**	**Mean**	**Total Diameter**	**Mean**
1-SS + TP	10	3.3	-	-	-	-
1d-SS + TP	7.5	2.5	-	-	-	-
2-SS + TH + TP	16.5	5.5	20.0	6.7	13.0	4.3
2d-SS+TH +TP	8.5	2.8	15.0	5.0	20.0	6.7
3- SS + PA + TP	27.3	9.1	19.0	6.3	21.4	7.1
3d-SS + PA + TP	23.8	7.9	23.0	7.7	19.4	6.5
4-SS+TH+PA+TP	14.5	4.8	14.5	4.8	18.0	6.0
4d-SS+TH+PA+TP	18.0	6.0	6.5	2.2	13.5	4.5

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DISCUSSION

Solanum lycopersicum grown in soil without contaminated stream water were found to grow better than those from contaminated soil. This shows that the contaminated stream water hinders the development and growth of the plant. Some of the direct toxic effects caused by high metal concentration include inhibition of cytoplasmic enzymes and damage to cell structures due to oxidative stress (Assche and Clijsters, 1990; Jadia and Fulekar, 2009). These toxic effects (both direct and indirect) could lead to a decline in plant growth which sometimes results in the death of plant (Taiz and Zeiger, 1991). It further denotes that soil polluted with contaminated stream water are low in fertility and nutrient hence, does not support adequate plant growth and development. The results obtained from this study indicates that the harvested fruits from soil samples with no inoculation of microorganisms contained higher levels of heavy metals (Iron, Zinc, Copper and Lead) in comparison with harvested fruit from soil samples with inoculation of one or two microorganisms. However soil samples inoculated with *P. aeruginosa* showed the lowest concentration of heavy metals in *S. lycopersicum* fruits. This study confirmed the reports by Liu *et al.* (2005), who found that tomatoes could accumulate high levels of heavy metals in the edible part. Heavy metal accumulation is known produce significant physiological and biochemical responses in vascular plants (Mangabiera *et al.,* 2001). The results obtained from this study showed that *S. lycopersicum* cultivated on soil samples with no inoculation of microorganisms at 5% and 10% concentration of contaminated stream water produced the lowest fruit yield (number of fruits, fruit diameter and weight of fruits). Treatments with *P. aeruginosa* inoculation were found to produce the highest fruit yield at 0%, 5% and 10% concentration of contaminated stream water. Treatments with a combination of *T. harzianum* and *P. aeruginosa* was also discovered to produce a higher number of fruits than treatments with single inoculation of *T. harzianum* The reduction of growth parameters in soil samples with no inoculation of microorganisms could be linked to the production of lower yield of fruits. Also the higher level of heavy metals uptake by the plants could be a determinant in the number of fruits produced. This is in agreement with report from Preeti and Tripathi, (2011) which noted that there is a direct relationship between heavy metals concentration and morphological and yield response of plants. The accumulation of heavy metals in plant tissues might cause reduction in biochemical response and physiological activities of plants resulting in lower biomass and yield (Scoccianti et al., 2008). Also the results in this study showed that *P. aeruginosa* used in this work did not only transform the heavy metals but also improved the growth and yield of *S. lycopersicum* fruits. There is also a positive relationship between *T. harzianum* and *P. aeruginosa* in enhancing the growth and yield of *S. lycopersicum*. Yield also has significant and negative relationship with concentrations of Cu, Pb, Zn, Fe, Cd and Cr in root and shoot of plants (Sutapa and Bhattacharyya, 2008). From the results obtained in this study, it was revealed that at higher concentration of contaminated stream water, the yield of the fruits was adversely affected.

CONCLUSION

This study was able to observe the morphological differences that took place under the different experimental treatments. It showed that use of *P. aeruginosa* and/or *T. harzianum* in the soil were able to tolerate physiological stress as a result of the heavy metal pollute environment. The presence of *P. aeruginosa* and *T. harzianum* were able to effectively transform the heavy metals in the soil and increase the yield of *S. lycopersicum*.

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