Research Journal of Agriculture
Volume 16, Number 6; June-2025;
ISSN: 2836-6050 | Impact Factor: 8.70
https://zapjournals.com/Journals/index.php/rja/index
Published By: Zendo Academic Publishing

EFFECT OF LEAD - CONTAMINATED SOIL ON THE YIELD AND LYCOPENE CONTENT IN TOMATO GENOTYPES, LYCOPERSICON *ESCULENTUM (MILL.)*

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Article Info
Keywords: Lead Contaminated Soil, Yield, Lycopene, Tomato Genotypes
DOI
10.5281/zenodo.15754401

Abstract
This study was conducted on the "Effect of lead - contaminated soil on lycopene content and yield of tomato, Lycopersicon esculentum (Mill) genotypes". This study aimed to determine the effect of lead - contaminated soil on the lycopene content and yield of tomato genotypes. Twelve tomato genotypes utilized for this study were obtained from the tomato germplasm collection of the National Center for Genetic Resources and Biotechnology (NACGRAB), Department of Plant Genetic Resources Ibadan, Oyo-State, Nigeria. The experiment was carried out at the Teaching and Research Farm, Obakekere, Federal University of Technology, Akure, Ondo-State. The lead - contaminated soil samples were obtained from the piggery unit at the Teaching and Research Farm of the Federal University of Technology, Akure, Ondo-State. The experiment was a potted experiment with each pot filled with 5kg of lead - contaminated soil, while the control pots were filled with 5kg of normal topsoil. NGB00708, NGB00713, NGB00724, NGB00735, and NGB00737 recorded the shortest number of days to flowering (32.20 days and 32.40 days) on lead - contaminated soil and (29.20 days and 29.40 days) on uncontaminated soil, respectively. This implies that these varieties can be improved upon in future tomato breeding programs and released as early maturing varieties. NGB00752, NGB00737, and NGB00724 were found outstanding in terms of the number of fruits, individual fruit weight, and total yield per plant both on lead - contaminated and uncontaminated soil. These varieties can be improved upon and regenerated through hybridization for the production of tomato hybrids. NGB00713, NGB00725, and NGB00729 recorded high lycopene contents in lead - contaminated soil. It can be concluded from this study that lead contaminated soil retarded the growth and reduced the yield and lycopene content of tomato varieties.

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INTRODUCTION

Tomato, *Lycopersicon esculentum* (Mill.) is a member of the Solanaceae family (Kumar *et al.*, 2020). In Africa, Egypt is the largest producer of tomato (6,245 million metric tons per annum), followed by Nigeria (3,575 million metric tons per annum) (Ogunsola and Ogunsola, 2021). Tomato is one of the most important vegetable crops in the world and is valued for its flavor and nutritional qualities. Tomatoes are rich rich in vitamins A and C, as well as minerals such as calcium, potassium, and phosphorus (Irina *et al.,* 2023). The presence of lycopene in tomatoes has served as a preventive measure against prostate cancer, thyroid cancer and some other cardiovascular diseases (Ibrahim *et al.,* 2023). Lycopene is a naturally occurring pigment that gives fruits and vegetables a red color (Ranveer, 2018). It is a type of carotenoid, which are organic pigments that are essential nutrients for humans (Maoka, 2020). Lycopene has been researched extensively for its potential health benefits, including its anti-oxidative and anticancer properties (Khalaf and Awad, 2023). Lead contamination is one of the major problems facing tomato farmers today, especially when it is planted on soils where soil analysis test is not carried out (Amati, 2018). Lead is a toxic heavy metal that can have adverse effects on human health and the environment (Raj and Das, 2023). It can result in a range of negative effects on plants such as; stunted growth, reduced fruit production, discoloration of leaves, and reduced photosynthetic activity (Zulfiqar *et al.,* 2019). Additionally, lead buildup in the soil can affect the nutrient uptake of tomatoes (Doostikhah *et al.*, 2020). Research has shown that ingesting tomatoes grown in soil with high levels of lead can pose health risks to humans, so it is important to take measures to avoid lead - contaminated soil for tomato production (Watson and Margenot, 2022). The lycopene content of tomato varies with variety and increases with fruit ripening (Ayuso - Yuste *et al.,* 2022). This research was carried out to determine: (i) the effect of lead - contaminated soil on the growth performance of the tomato genotypes (ii) the effect of lead - contaminated soil on the yield of the tomato genotypes (iii) the effect of lead - contaminated soil on the lycopene content of the tomato genotypes.

MATERIALS AND METHODS

The experimental materials for this research consist of twelve varieties of tomato, *Lycopersicon esculentum* (Mill.). The tomato genotypes were obtained from the tomato germplasm collection of the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Oyo state, Nigeria. The names of the tomato genotypes are: NGB00695, NGB00696, NGB00708, NGB00713, NGB00721, NGB00724, NGB00725, NGB00726, NGB00729, NGB00735, NGB00737 and NGB00752.The project was carried out in two phases. The first phase is the nursery preparation, while the second phase is the field evaluation of the tomato seedlings.

NURSERY PREPARATION

The tomato varieties were planted in nursery trays filled with sterilized topsoil. Each of the trays consisted of 120 holes, and a seed of each tomato genotype was planted in each hole.After emergence, the seeds were adequately cared for and 4weeks after emergence, the seedlings were transplanted into the field for field evaluation.

FIELD EVALUATION

The experiment was a potted experiment in which polythene bags were filled with 5kg top soil consisting of topsoil and another sets of poly pots filled with lead contaminated soil.8 pots were allotted to each of the tomato varieties which were planted at one seedling per pot. 96 pots were allotted to poly pots containing lead - contaminated soil and 96 pots to the uncontaminated soil to serve as the control in three replicates. The polythene pots were arranged at a spacing of 60cm by 45cm between and within rows to enhance easy passage during data collection. Staking was performed 4weeks after transplantation, shortly before flowering. DD force was applied as an insecticide to combat the problem of insect pests at 25mls per 10 liters of water on a fortnight basis from 2 weeks after transplanting. NPK 15:15:15 fertilizer was applied on a fortnight basis at 2 weeks after transplanting.

DATA COLLECTION:

Data were collected on 5 plants on the following agronomic traits:-

Plant height at flowering (PHTF), Number of leaves per plant at flowering(NLPF), Number of branches per plant (NBP), Number of fruits per plant (NFP), Number of clusters per plant (NCP), Days to flowering (DTF), Days to maturity (DTM), Plant height at maturity (PHTM), Plant height at Harvesting (FPHT), Individual fruit weight (IFWt), Yield per plant (Yd/P), and Yield per Hectare (Yd/Ha)

LEAD DETERMINATION AND ANALYSIS IN RESISTENCE TO VARIOUS SOIL SAMPLES

Four samples were obtained from different locations with potential contamination with lead for lead analysis. The four soil samples analyzed for lead contamination were obtained from a mechanic workshop which was labeled sample A, an electronic workshop which was labeled sample B, piggery unit at the Teaching and Research farm Federal University of Technology, Akure which was labeled sample C, and Cropping areas beside the Vice - Chancellor's lodge Federal University of Technology, Akure which was labeled Sample D.

Materials and Reagents

Nylons, latex gloves, beaker, sieve, tray, 0.1M HCl, Whatman filter paper, AAS (Atomic absorption spectrophotometry) buck scientific 210 VGP and lamotte 2000.

Procedure

The obtained soil samples were first air dried for 5 - 7days. Using a 2-mm sieve, the samples were properly sieved, after which 5g soil was soaked into 50ml of 0.1M HCl overnight. The mixture was then filtered using Whatman filter paper. The filtrate was then introduced into a separate beaker. Using an AAS (Atomic absorption spectroscopy) buck scientific 210 VGP and lamotte 2000, the lead concentration in the filtrate was determined. Sample C (3.014ng/µL) recorded the highest lead concentration, followed by Sample D (2.840ng/µL) followed by Sample a (2.310ng/µL) while Sample B (2.160ng/µL) recorded the lowest lead concentration. Samples C and D were selected for cultivation because they both had high lead concentrations.

DETERMINATION OF LYCOPENE CONCENTRATION IN TOMATO GENOTYPES.

2 sets of the 12 tomato genotypes from three replicates each were selected for the determination of lycopene concentration and control.

Materials and Reagents

Test-tubes, mortar, pestle, analytical weighing balance, 5ml of Petroleum ether, 5ml of Sodium sulfate, $1cm^3$ quartz cuvette, UV/Visible spectrometer.

Procedure

Mortar and pestles were used to blend tomato samples to homogeneity. An analytical weighing balance was used to measure 2.5g of blended tomato samples and then transferred carefully into test-tubes. 5ml of petroleum ether was introduced into the samples inside the test-tubes, then 5ml of sodium sulfate was also introduced and was shaken to allow for even dissolution. The solution was allowed to stand for 5mins to allow for phase separation; thereafter, the upper layer was collected into a $1cm^3$ quartz cuvette and the absorbance was measured at 543nm using a UV/Visible spectrophotometer. This was done for the two sets of the 12 tomato genotypes. The first set represent the ones planted on lead - contaminated soil, while, the other set serves as the control. The lycopene content of each genotype was recorded.

RESULTS AND DISCUSSION

The estimates of the mean growth performance of the agronomic characters under study in tomato genotypes in lead - contaminated soil are presented in Table 1. Plant height at flowering ranged from 16.00 to 32.80cm, with genotype 9 being the tallest plant at flowering with the maximum value of 32.80cm, while the shortest plants were observed in genotype 11 (16.00cm). The highest number of branches per plant was observed in genotype 9 (9.20), whereas the lowest values were observed in genotypes 5 and 15 (7.00). The tallest plant at maturity was genotype 9 (107.80cm), whereas the shortest plant at maturity was genotype 11 (91.00cm). The tallest plant at harvesting was genotype 9 (145.80cm), whereas the shortest plants at harvesting were observed in genotype 11(129.00cm).

Table 1: Mean Performance of Agronomic Growth Characters of the Tomato Genotypes on Lead- Contaminated Soils

GEN NO.		CONTROL						CONTAMINATED SOIL						
	PHTF (cm)	**NLPF**	**NBPF**	**DTF (days)**	**DTM (days)**	**PHTM (cm)**	**PHTH (cm)**	**PHTF (cm)**	**NLPF**	**NBPF**	**DTF (days)**	**DTM (days)**	**PHTM (cm)**	**PHTH (cm)**
G1	37.40a	24.20ab	8.80ab	31.60b	73.60ab	157.40a	182.40ab	25.40b	23.60ab	8.20ab	34.60ab	88.60a	100.40ab	138.40a
G2	3b3.80b	19.20bc	8.80ab	31.20b	73.20ab	153.80ab	178.80ab	21.80bc	19.80b	7.40b	34.20ab	88.20a	96.80ab	134.80ab
G3	35.00ab	20.80b	7.80c	29.20b	67.20b	155.00ab	180.00ab	23.00b	19.20bc	7.2b0	32.20b	79.20ab	98.00ab	136.00ab
G5	32.00b	22.00b	8.00b	29.40b	67.40b	152.00b	177.00ab	22.60bc	18.60bc	7.00bc	32.40bb	79.40ab	95.00b	133.00ab
G8	35.40ab	20.60b	8.00b	33.60a	78.60a	155.40ab	180.40ab	23.40b	20.00b	7.40b	36.60a	90.60a	98.40ab	136.40ab
G9	44.80a	28.60a	9.40a	29.40b	67.40b	164.80a	189.80a	32.80a	28.20a	9.20a	32.40b	79.40ab	107.80a	145.80a
G10	38.40a	18.80bc	8.20b	33.60a	78.60a	158.40a	183.40ab	26.40ab	18.60bc	7.20b	36.60a	90.60a	101.40ab	139.40a
G11	28.00bc	23.60ab	8.00b	33.60a	78.60a	148.00	173.00b	16.00c	20.80b	7.60ab	36.60a	90.60a	91.00b	129.00b
G13	44.00a	26.60ab	8.80ab	34.60a	79.60a	164.00a	189.00a	32.00a	23.80ab	8.80ab	37.60a	91.60a	107.00a	145.00a
G15	38.20a	22.60b	8.00b	29.40b	67.40b	158.20a	183.20ab	26.20ab	20.20b	7.00bc	32.40b	79.40ab	101.20ab	139.20a
G16	39.00a	27.60a	9.60a	29.40b	67.40b	157.00a	182.00ab	26.60ab	25.20a	9.00a	32.40b	79.40ab	100.0ab	138.00a
G19	34.40ab	28.40a	9.60a	33.60a	78.60a	154.40ab	179.40ab	23.60b	27.20a	9.00a	36.60a	90.60a	97.40ab	135.40ab

Values with the same letters along the same column are not significantly different.

GENOTYPE NUMBER: G1 = NGB00695; G2 =NGB00696 ; G3 = NGB00708; G5 = NGB00713; G8 = NGB00721; G9 = NGB00724; G10 = NGB00725; G11 = NGB 00726; G13 = NGB00729; G15 = NGB00735; G16 = NGB00737; G19 = NGB00752.PHTF = Plant height at flowering(cm); DTF = Days to flowering(days); NLPF = Number of leaves per plant at flowering; NBP = Number of branches per plant at flowering, DTM = Days to maturity(days); PHTM = Plant height at maturity(cm); PHTH = Plant height at harvesting(cm)

Estimates of the mean yield and its related traits for tomato genotypes in lead - contaminated soil are presented in Table 2. The highest number of clusters was recorded in genotype 9 (6.20), whereas the lowest value was recorded in genotype 5 (4.00). The number of fruits ranged between 23.40 and 42.00 being maximum in genotype 19 (42.00), followed by genotype 9 (38.80), and finally genotype 16 (36.60). The lowest value of number of fruits was recorded for genotype 8 (23.40). The biggest fruits were observed in genotype 19 (6.24g) , whereas the smallest fruits were recorded in genotype 1 (3.75g). The highest yield was recorded in genotype 19 (262.08g),

followed by genotype 9 (235.90g), followed by genotype 16 (217.77g), whereas the lowest yield was recorded in genotype 2 (95.20g).

TABLE 2: MEAN OF YIELD AND ITS RELATED CHARACTERS OF THE TOMATO GENOTYPES ON LEAD - CONTAMINATED SOILS

	CONTROL SOIL					CONTAMINATED SOIL				
GEN.. NO	NFP	NCP	IFWt(g)	Yd/P(g)	Yield/ha (ton)	NFP	NCP	IFWt (g)	Yd/P(g)	Yield/ha (ton)
G1	44.00ab	7.00a	4.10b	180.15ab	6.67b	29.20ab	5.60ab	3.75c	109.50bc	4.04bc
G2	33.80b	5.60ab	4.03b	134.07bc	4.96c	25.80b	4.60ab	3.69c	95.20c	3.51c
G3	40.20ab	6.40a	4.99ab	200.45ab	7.42ab	31.00a	5.60ab	4.85ab	150.35ab	5.55ab
G5	34.00b	5.40ab	5.25ab	177.30b	6.56b	25.60b	4.00b	4.85ab	124.16b	4.58b
G8	29.20bc	5.40ab	5.30ab	154.20b	5.71bc	23.40bc	4.40b	5.25ab	122.85b	4.53b
G9	51.20a	7.00a	6.93a	355.19a	13.15a	38.80a	6.20a	6.08a	235.90a	8.73a
G10	33.60b	5.40ab	6.05a	203.15ab	7.52ab	27.00ab	5.00ab	5.77a	155.79ab	5.76ab
G11	34.20b	5.60ab	5.51ab	187.61ab	6.94ab	27.00ab	5.00ab	4.83ab	130.41b	4.84b
G13	47.60a	6.40a	6.82a	323.21a	11.97a	28.20ab	5.00ab	5.63a	158.77ab	5.89ab
G15	28.20bc	5.20ab	4.84b	136.32bc	5.04c	23.80bc	4.20b	4.67b	111.15bc	4.09bc
G16	52.80a	6.80a	7.10a	375.00a	13.88a	36.60a	6.00a	5.95a	217.77a	8.10a
G19	56.40a	6.80a	6.90a	386.10a	14.29a	42.00a	6.00a	6.24a	262.08a	9.72a

Values with the same letters along the same column are not significantly different.

GENOTYPE NUMBER: G1 = NGB00695; G2 =NGB00696; G3 = NGB00708; G5 = NGB00713; G8 = NGB00721; G9 = NGB00724; G10 = NGB00725; G11 = NGB 00726; G13 = NGB00729; G15 = NGB00735; G16 = NGB00737; G19 = NGB00752.NFP = Number of fruits per plant; NCP = Number of clusters per plant; IFWt = Individual fruit weight (g); Yd/P = Yield per plant (g); Yd/Ha = Yield per hectare(ton).

The effects of lead contaminated soil on lycopene content of the tomato genotypes are presented in Table 3. The highest concentration of lycopene content is recorded in genotype 5 (11.85%), followed by genotype 13 (8.42%), followed by genotypes 1 and 10 (7.80%), while the lowest concentration of lycopene was recorded in genotype 9 (0.62%).

TABLE 3: EFFECT OF LEAD CONTAMINATED SOIL ON LYCOPENE CONTENT IN TOMATO GENOTYPES.

GENOTYPES.	LEAD -CONTAMINATED SOIL (%)	UNCONTAMINATED SOIL (%)
G1	7.80ab	16.22b
G2	1.87c	17.16b
G3	3.12bc	14.04b
G5	11.85a	13.73bc
G8	2.80bc	24.02ab
G9	0.62cd	2.49d
G10	7.80ab	14.35b
G11	2.18bc	14.04b
G13	8.42ab	12.48bc
G15	3.74bc	31.20a
G16	0.93cd	14.97b
G19	6.55b	10.92bc

Values with the same letters along the same column are not significantly different.

GENOTYPE NUMBER: G1 = NGB00695; G2 =NGB00696; G3 = NGB00708; G5 = NGB00713; G8 = NGB 00721; G9 = NGB00724; G10 = NGB00725; G11 = NGB00726; G13 = NGB00729; G15 = NGB00735; G16 = NGB00737; G19 = NGB00752.

The effect of lead - contaminated soil on total yield per plant for tomato genotypes is presented in Figure 1. The maximum value was observed for genotype 19 (262.08g) and the minimum value was observed for genotype 2 (95.20g).

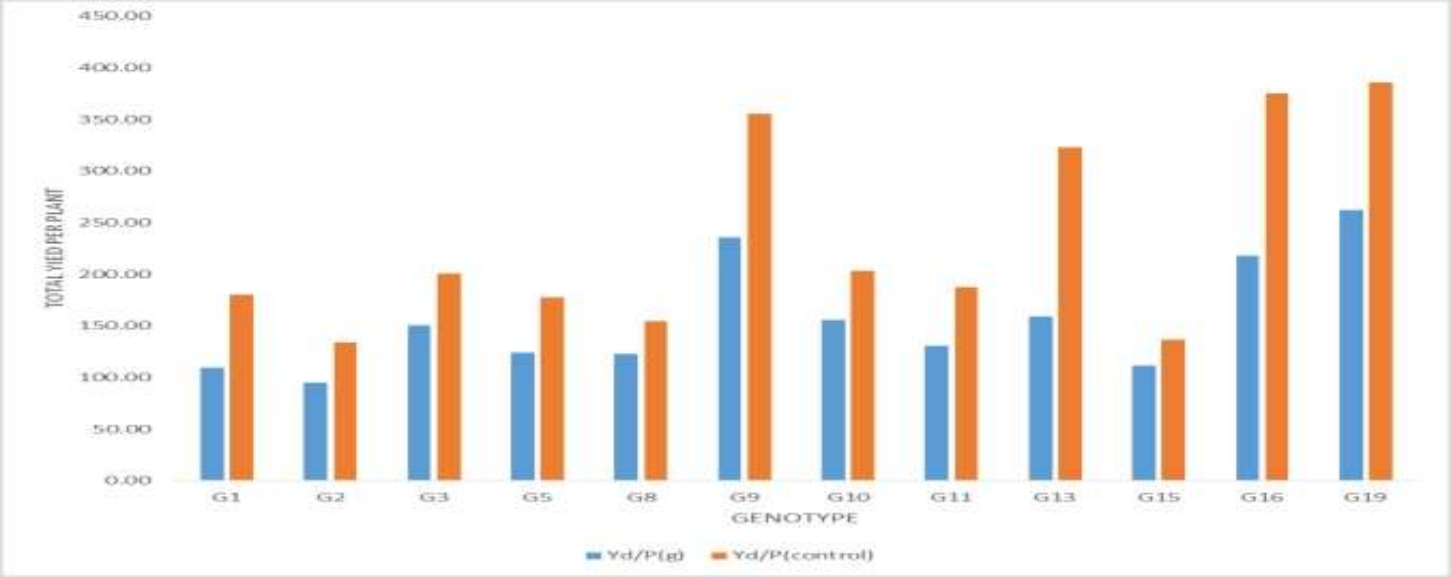

Figure 1: Effects of lead contaminated soil on Yield per plant In tomato genotypes

GENOTYPE NUMBER: G1 = NGB00695; G2 =NGB00696; G3 = NGB00708; G5 = NGB00713; G8 = NGB 00721; G9 = NGB00724; G10 = NGB00725; G11 = NGB00726; G13 = NGB00729; G15 = NGB00735; G16 = NGB00737; G19 = NGB00752.

The effects of lead - contaminated soil on lycopene content (%) in tomato genotypes are presented in Figure 2. The maximum value was observed in genotype 5 (11.85%), whereas the minimum value was observed in genotype 9 (0.62%).

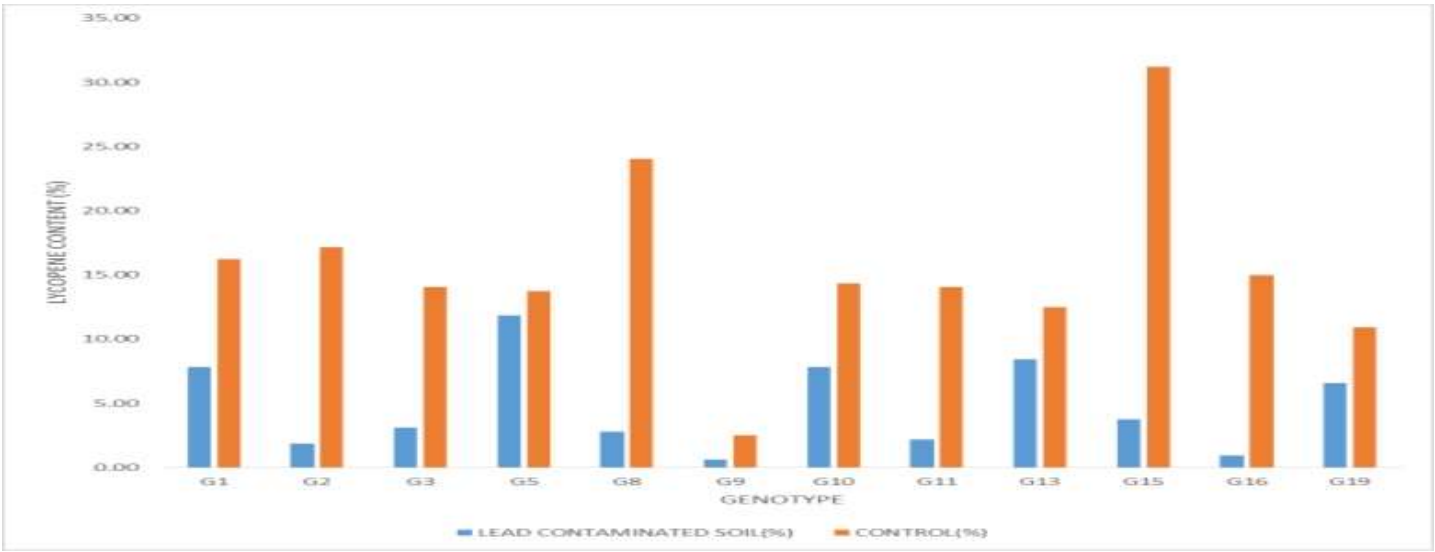

Figure 2: Effect of Lead - contaminated soil on Lycopene content (%) tomato genotypes

GENOTYPE NUMBER: G1 = NGB00695; G2 =NGB00696; G3 = NGB00708; G5 = NGB00713; G8 = NGB 00721; G9 = NGB00724; G10 = NGB00725; G11 = NGB00726; G13 = NGB00729; G15 = NGB00735; G16 = NGB00737; G19 = NGB00752.

DISCUSSIONS

The results show a decreased mean value in plant height in tomato genotypes cultivated on lead contaminated soil in comparison with the control. This implies that lead contaminated soil tends to result in retarded growth and development in tomato plants (Collin *et al.,* 2022). This finding is also in consonance with earlier studies showing that the presence of lead in the soil significantly results in stunted growth in tomato plants (Taghipour and jalali, 2020). It can be observed from the study that tomatoes cultivated on lead - contaminated soil exhibit a reduction in fruits yield production. These findings corroborate the findings of Rashid *et al*., (2023). Hence, there is a need to take into consideration the type of soil to be chosen for tomato production. The results of the lycopene content analysis suggest that lead - contaminated soil has an adverse effect on the lycopene content of tomato genotypes. These findings corroborate the findings of Hedayati *et al*., (2019). They reported a significant reduction in the concentration of lycopene content of tomato plants cultivated on lead - contaminated soil. The presence of lead in soil has an adverse effect on the lycopene content because of impaired nutrient uptake and interference with the enzymatic pathway (Kaur and Garg, 2014).

CONCLUSION

It can be concluded from the study that lead - contaminated soil resulted in stunted growth rate and reduced yield in terms of number of fruits and total yield in the tomato varieties. NGB00724, NGB00752, and NGB00737 were outstanding in terms of number of fruits, individual fruit weight, and total fruit yield per plant. NGB00737, NGB00724, NGB00713, and NGB00708 recorded shorter number of days to flowering. This implies that these varieties can be bred for earliness in tomato breeding program to be released as early maturing tomato varieties to farmers. The tomato varieties with outstanding fruit yield can also be improved and released as tomato hybrids. The study also revealed that lead - contaminated soil had an adverse effect on the lycopene content of the tomato varieties. NGB00729, NGB00713, and NGB00725 recorded high lycopene contents despite being planted on lead - contaminated soil;hence, these genotypes can be improved upon in future tomato breeding programs for their high lycopene contents.

ACKNOWLEDGEMENTS

The author acknowledges the Head, tomato germplasm center of the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan, Oyo State, Nigeria; for the supply of the tomato genotypes used for the research. The contributions of Mrs. C.O. Adeniran, Department of Animal Production and Health, Federal University of Technology, Akure, Ondo State, Nigeria for the lycopene content analysis was also acknowledged.

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