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Evaluation of Soil Fertility Improvement Potential of Water and Methanolic Neem (*Azadirachta indica* A. Juss) Leaf Extract on the Growth and Yield of Tomato (*Solanum lycopersicon* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author OOC designed the study, performed the statistical analysis. Author AOS wrote the protocol and the first draft of the manuscript. Author OOI managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted during the period from May 2015 and August 2015 at Screenhouse of a faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria to evaluate the fertility content of different extracts of neem on growth and yield of tomato. The experiment consisted of methanolic extract of neem in sterilized soil with tomato plant, methanolic extract of neem in unsterilized soil with tomato plant, water extract of neem in sterilized soil with tomato plant, water extract of neem in unsterilized soil with tomato plant and the two controls which are sterilized soil with tomato plant and unsterilized soil with tomato plant. Treatments were in triplicate and arranged in a randomised complete block design (RCBD). Regarding yield, treatment with methanolic neem in sterilised soil had 8 fruits during the 4 weeks of harvest while the least number of fruit was in treatment with water extract of neem in the unsterilised soil which had 1 fruits all through. The

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highest value for the weight of fruit was also recorded in treatment with methanolic neem in sterilised soil with the mean of 0.8 gram while the treatment with methanolic neem extract in unsterilised soil had the least value of 0.2 gram which was lower than the two controls. The diameter of fruit showed that the treatment with methanolic neem extract in sterilised soil had the highest value with the mean of 25.43 cm while the minimum value for diameter was recorded in treatment with methanolic neem extract in unsterilized soil with mean of 6.54 cm. Regarding growth, results at Nine weeks after planting showed that someof leaves, leaf area and vine length was significantly higher in treatment with neem methanolic extract in the sterilised soil, while girth size and a number of branches were higher in the control treatment with decontaminated soil. It is recommended that methanolic neem extract should be used by farmers to increase tomato production.

Keywords: Soil fertility; neem extract; sterilized soil; unsterilized soil; water extract and methanolic extract.

1. INTRODUCTION

Tomato (*Solanum lycopersicon*) is a herbaceous plant in the Solanaceae family. Tomato is the second largest vegetable food crop after potato and pepper and it is widely consumed around the globe [1]. It is one of the significant condiments for food all around the world. Nigeria is the second largest producer in Africa and leads in West Africa sub-region with an estimated output of 1.10 metric tonnes and an average yield of 10 t ha-1 [2]. Low soil fertility and non-availability of disease-tolerant cultivar had been the significant constraints to its production. The dependency on the use of inorganic fertilizer as a source of plant nutrient have a negative implication in terms of soil degradation and environmental pollution.

Azadirachta indica known as Neem tree is one of the two species in the genus of *Azadirachta* [3]. It is a tropical evergreen with wide adaptability. Native to India and Burma, it has been transplanted to Africa, Middle East, South America and Australia [4]. Water extract of *Azadirachta indica* leaf has 3.56% Nitrogen, 0.83% phosphorus, 1.67% Potassium, 0.77% calcium and 0.75% Magnesium [5].

Tomato has high economic and nutritional values, but its production had always been affected as a result of low soil fertility. Efforts aimed at improving the soil fertility using inorganic fertilisers are limited by the high cost of purchase and destruction of soil properties on continuous use.

Research effort aimed at improving soil fertility in an environmentally friendly way has to lead to the use of extracts from leaves of neem (*Azadirachta indica*) because of its relative availability.

The objectives of this research are as follows:

1. To determine the effect of different extracts of neem leaf on the growth and yield of tomato.
2. To assess the effect of different extracts of neem on the physicochemical properties of the soil.

2. MATERIALS AND METHODS

This research was carried at the screenhouse of Faculty of Agriculture, Obafemi Awolowo University, southwestern Nigeria.

2.1 Preparation of Neem (*Azadirachta indica*) Extract

Neem leaves (*Azadirachta indica*) were collected beside the Central Science Laboratory (Latitude: 7º31´61´´N and Longitude: 4º32´61´´E) which is a site of abundance at Obafemi Awolowo University. The leaves were carefully removed from the branches, washed with water and air-dried to remove dust and stone particles from them. The air drying took four days to reduce the water content of the leaves which were blended into pellets using an electric blender to facilitate the extraction. The extraction was done by measuring 30 ml of methanol into a conical flask which contained 70 ml of distilled water. One gram of ground Neem (*Azadirachta indica*) was measured into the conical flask containing the mixture of water and methanol. The mixture was left to soak for 48 hours after which it is filtered with Whatman filter paper.

2.2 Preparation of Unsterilized Soil for Field Work

Top soil was collected at the back of Spider Building at Obafemi Awolowo University in Ile-Ife at the depth of 0-10 cm. The top soil was air dried for 3 days and sieved.

2.3 Preparation of Sterilized Soil for Field work

Top soil and river sand were mixed together at ratio 20:1 and sieved before they were sterilized using an autoclave by heating for 5 hours at 131^0C and left to cool for four (4) days.

2.4 Preparation of Pots for the Experiment

Sterilized and unsterilized soils were used for this research. There were eighteen (18) experimental pots, six pots contained 3 kg of sterilized soil while the other six pots contained 3 kg of unsterilized soil. The test plant used for this study was *Solanum lycopersicon*. Seed variety "UC-82" was obtained from National Horticultural Research Institute, Ibadan. Tomato seedlings for this experiment were raised at the Screenhouse. An average sized bowls were filled with sterilized soil and the seeds of UC-82 tomato cultivar were carefully sown in it. The seedlings were allowed to grow in the nursery for a period of three weeks.

2.5 Methodology

One hundred (100) ml of methanolic neem extract was added to three (3) experimental pots containing sterilized soil and another set of three (3) experimental pots containing unsterilized soil before *Solanum lycopersicon* seedlings were transplanted into them. There were six (6) controls, three (3) for sterilized soil and (3) for unsterilized soil. There were no extracts added to them before *Solanum lycopersicon* seedlings were transplanted. Pots were arranged in a completely randomized design in the screenhouse. Seedlings were left for a week to become established and overcome transplanting shock. Each treatment of the experiment was replicated three times. Pots containing *Solanum lycopersicon* were watered regularly to ensure adequate moisture.

Growth data on number of leaves, girth size, vine length, leaf area and number of branches was collected weekly between three weeks after planting to nine weeks after planting. Number of fruit, weight of fruit and diameter of fruit was collected for yield data between thirteen week to sixteen week after planting.

2.6 Statistical Analysis

The data were analyzed using SAS 9.2 statistical package by subjecting the data to descriptive statistics and Least Significant Difference (LSD).

3. RESULTS

3.1 Physico-chemical Properties of the Soil before Planting

The growth result showed that extract of neem was able to increase the vegetative growth of tomato. Number of leaves increased across the treatments and the controls as the week progressed. Maximum number of leaves was recorded in neem water extract in sterilized soil with value of 92.33 while the minimum was recorded in neem water extract with value of 29.33 (Table 2). However, girth size had the maximum value in the control treatment with sterilized soil with the value of 2.06 cm while the minimum was in treatment with water extract of neem in unsterilized soil which had a value of 0.67 cm (Table 3). Vine length had the maximum value in treatment with methanolic neem extract in sterilized soil with values of 36.67 cm (Table 4), while the minimum value was in treatment with water extract of neem in unsterilized soil which had the value of 5.57 cm (Table 4). Area of leaf had the maximum value in treatment with methanolic extract of neem in sterilized soil with mean of 78.87 cm^2 while the minimum value was recorded in treatment with water extract of neem in unsterilized soil with mean of 5.57 cm^2 (Table 5). Maximum value for number of branches was recorded in treatment with water extract in sterilized soil with mean of 15.67 while the minimum was in treatment with water extract of neem in unsterilized soil which had a mean of 6.67 (Table 6). In general, treatment with water extract of neem in unsterilized soil had a relatively poor vegetative growth (Table 2-6).

The yield results which were recorded between 13 WAP to 16 WAP showed that the treatment with methanolic neem extract in sterilized soil had a total of Eight (8) fruits which is the highest number of fruits and it was significantly higher than all other treatments (Fig. 1). The least number of fruit was in treatment with water extract of neem in the unsterilized soil with a total of 1 fruit (Fig. 1). The weight of fruit also had the

highest value in treatment with methanolic extract of neem in sterilized soil with mean weight of 0.81 gram while the least was in treatment with methanolic extract of neem in the unsterilized soil with mean of 0.066 gram which was significantly lower than the two controls (Fig. 2). The result of the research also showed that diameter of fruit which is one of the parameters of yield had its highest value in the treatment with the methanolic neem extract with value of 25.4 cm.

Post soil analysis after planting showed that there was a significant increase in the pH of the post planting soil when compared with its pre-planting status (Fig. 4). There was a reduction in the calcium content of the post-planting soil in the control treatments. However, there was as increase in calcium content in treatment with methanolic neem extract in sterilized soil (Fig.5). All through the treatments; there was a significant reduction in the potassium content of the post-planting soil (Fig. 6). Nitrogen content of the post-planting soil was significantly reduced in the control treatments but was higher in the treatment with methanolic neem extracts both in sterilized soil and unsterilized soil (Fig. 7). Content of magnesium and phosphorus was reduced across all the treatments in post planting soil (Fig. 8-9).There was a slight reduction in hydrogen ion content of the post-planting soil of the control treatments.

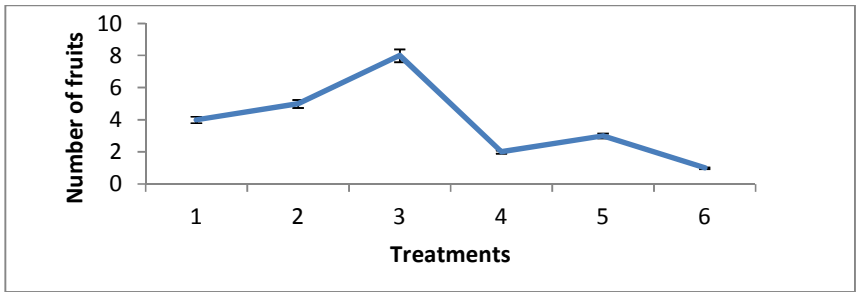

Fig. 1. Number of fruit of *Solanum lycopersicon*

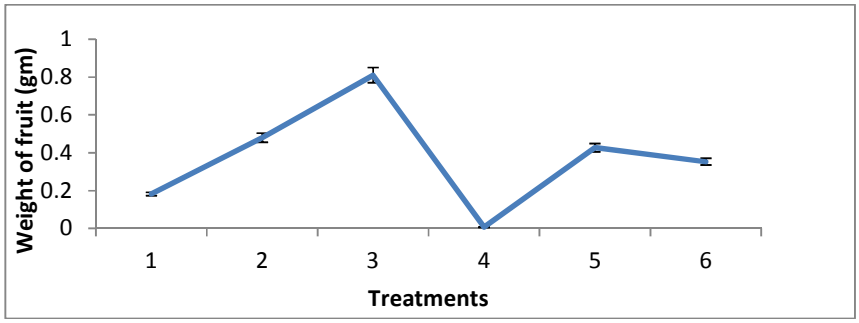

Fig. 2. Weight of fruit of *Solanum lycopersicon* (gm)

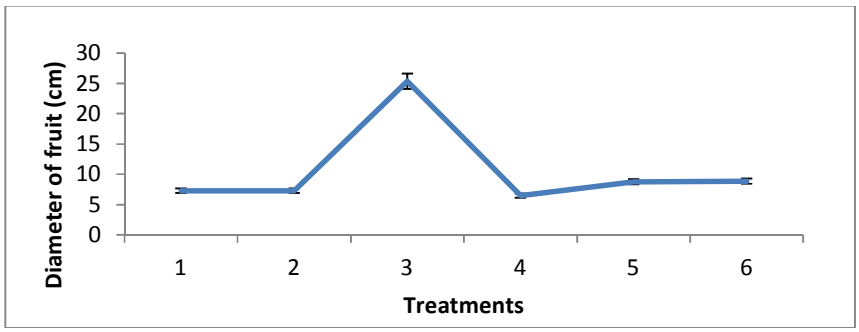

Fig. 3. Diameter of *Solanum lycopersicon* (cm) fruit

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5 - NM+H2O+CD+SS+TP; 6 - SF+H2O+CD+US+TP

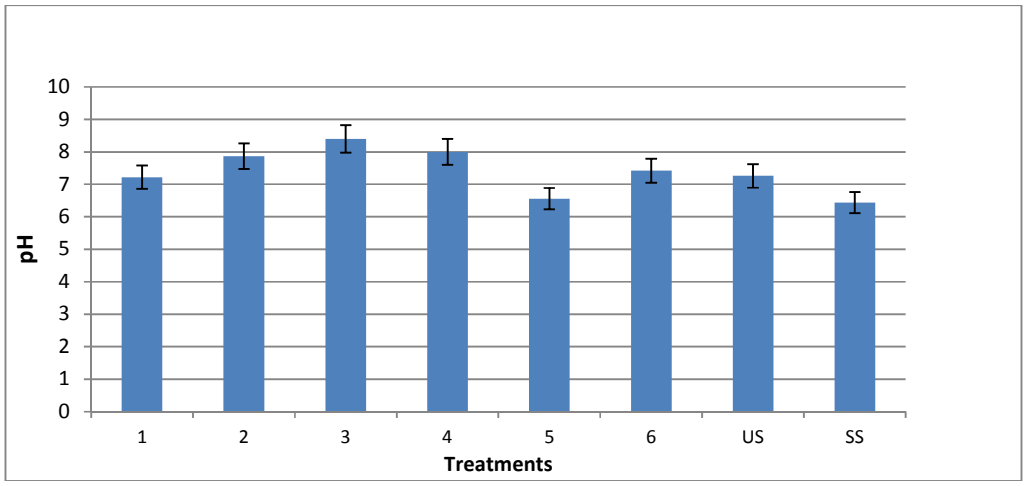

Fig. 4. pH of Pre planting and post planting soil samples

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5 - NM+H2O+CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

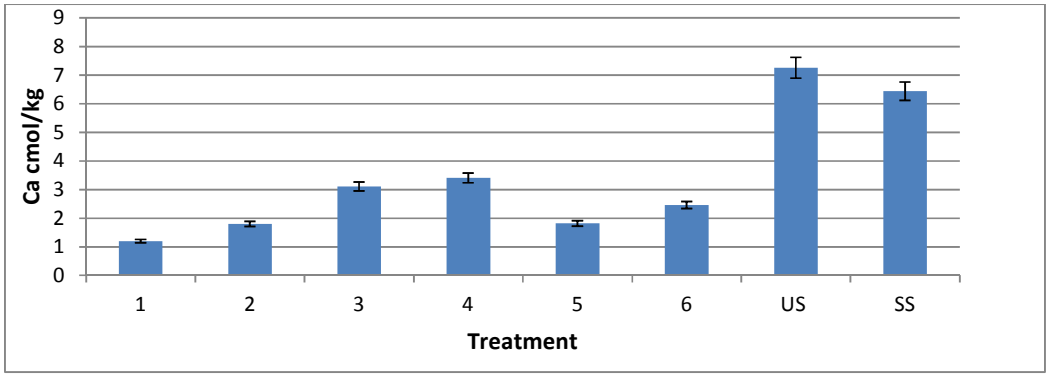

Fig. 5. Calcium content of pre planting and post planting soil samples

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5 - NM+H2O+CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

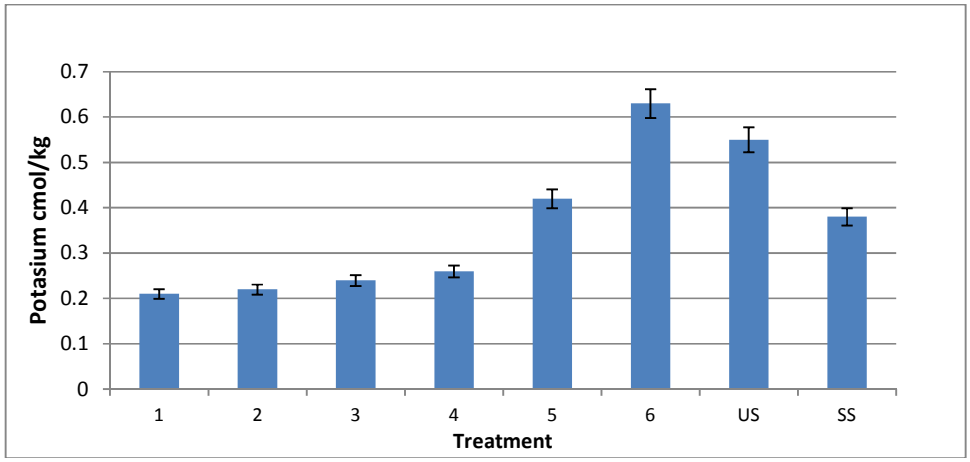

Fig. 6. Potassium content of pre planting and post planting soil samples

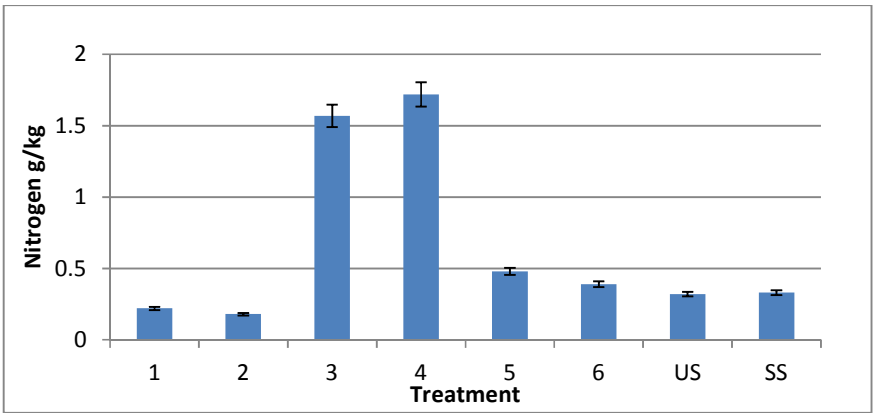

Fig. 7. Nitrogen content of pre planting and post planting soil samples

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5 - NM+H2O+CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

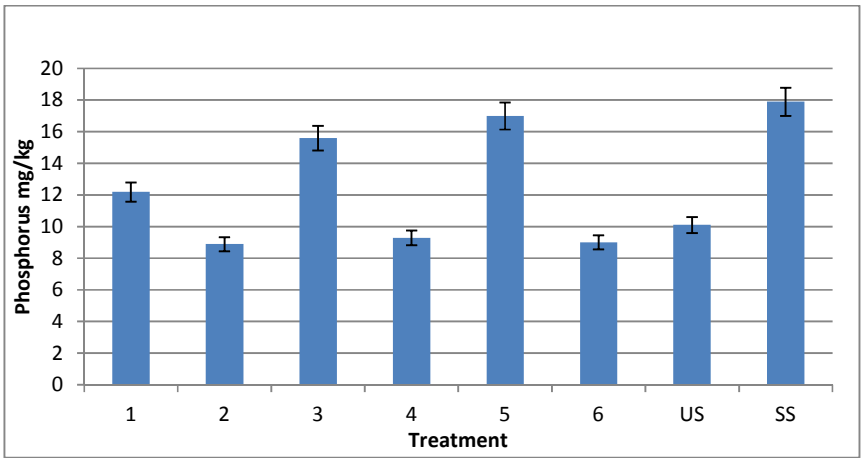

Fig. 8. Phosphorus content of pre planting and post planting soil samples

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5- NM+H2O+CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

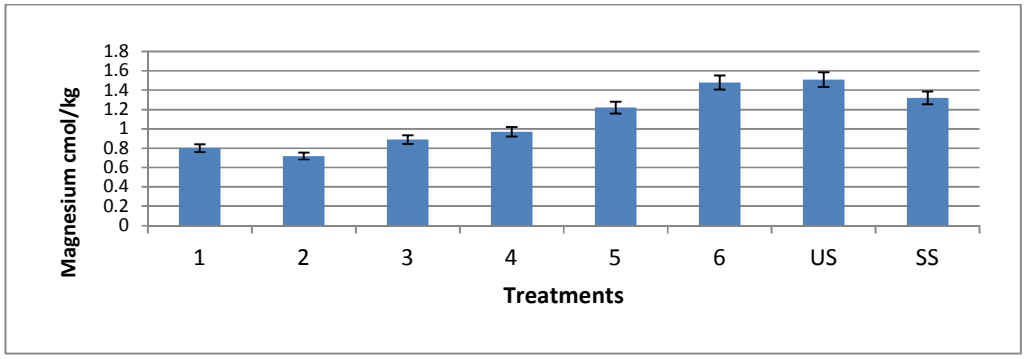

Fig. 9. Magnessium content of pre planting and post planting soil samples

Legend: 1 - SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5 - NM+H2O+CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

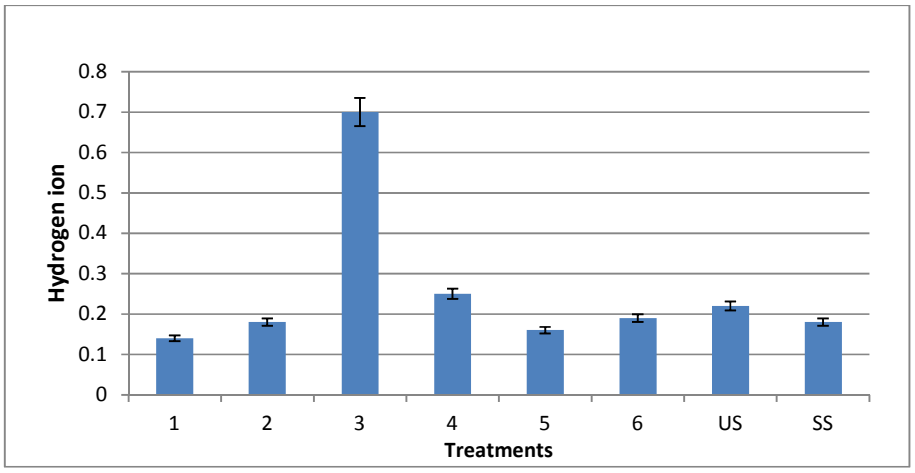

Fig. 10. Hydrogen ion content of pre planting and post planting soil samples

Legend: 1- SS+TP; 2 - US+TP; 3 - NM+METH CD+SS+TP; 4 - NM+METH CD+US+TP; 5-NM+H2O+ CD+SS+TP; 6 - NM+H2O+CD+US+TP; US=Pre-planting unsterilized soil; SS=Pre-planting sterilized soil

Table 1. Physicochemical properties of sterilized and unsterilized soil before planting

Parameters	Sterilized	Unsterilized
pH	6.44	7.26
Ca (cmol/kg)	1.75	2.38
Mg (cmol/kg)	1.32	1.51
K (cmol/kg)	0.38	0.55
Nitrogen g/kg	0.33	0.32
P (mg/kg	17.9	10.12
H^+	0.18	0.22
Al^{3+}	0.10	0.13
Organic matter %	6.7	5.30
Clay %	12.6	14.6
Silt %	15.4	7.40
Sand %	72.0	77.0

4. DISCUSSION

There were differences in response of Tomato to the different extract of *Azadirachta indica* leaf that was added to the soil. The initial fertility status of the control treatments was low and this was shown in the poor vegetative growth of the tomato planted in them.

The improved vegetative growth in terms of girth size and vine length recorded in the control treatment with sterilized soil shows us that inherent fertility in soil was optimized through sterilization as it was seen that many of the growth parameters in the control treatment with sterilized soil were significantly higher than those with extracts with water and methanolic extract of neem with unsterilized soil. The improved growth in the sterilized soil agreed with [6] who opined that soil sterilization removes deleterious microbes and also increased nutrient availability for improved growth and yield.

Both water and methanolic extracts of neem in sterilized soil had a robust vegetative growth when compared to the same extracts in unsterilized soil. This agreed with [7] who confirmed the significant contributions of organic fertilizers in improving vegetative growth and marketable yield of vegetables. Moreover, the poor growth in the control treatment with unsterilized soil agreed with [8] who reported poor growth and yield in soil that was poorly fertilized.

The poor growth in the unsterilized control could be as a result of the competition on the little available nutrients by the weeds and other micro-organisms growing within the soil during the planting period [9]. Soil pH is one of the determinants of growth response of plants also established in this study. The better growth performance of tomato in the sterilized soil agreed with [10] who opined that tomato grows well within the soil pH range of 5.5 to 6.8, with optimum being between 6.0 and 6.5.

The higher number of fruits as well as the fruit weight in the treatment with methanolic neem extract in sterilized soil agreed with [11] who reported in his work that higher yield was obtained in treatments with calcium calbide in *Mangifera indica* and [12] who reported an increase in weight of mango in treatment with 30 and 20 g of calcium.

Growth Result of Tomato

Table 2. Number of leaves of *Solanum lycopersicon* at different ages

	Week after planting							
Treatments	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**LSD**
1 - SS+TP	NINE POINT ZERO ZERO	12.00	16.67	17.33	32.33	38.67	SIXTY EIGHT POINT THREE THREE	27.73
2 - US+TP	SIX POINT SIX SEVEN	7.00	10.33	12.33	17.67	19.67	THIRTY NINE POINT THREE THREE	13.37
3-NM+METH CD+SS+TP	SEVEN POINT EIGHT FIVE	14.33	22.00	26.33	33.00	59.00	SIXTY SEVEN POINT ZERO ZERO	21.66
4 - NM+METH CD+US+TP	EIGHT POINT THREE SIX	6.33	11.67	9.00	11.33	24.00	SIXTY SEVEN SIX SEVEN	10.00
5- NM+H_2O CD+SS+TP	EIGHT POINT TWO THREE	16.67	18.33	21.33	42.67	87.33	NINETY POINT THREE THREE	43.30
6- NM+H_2O CD+US+TP	TEN POINT SIX SEVEN	5.00	8.33	9.00	20.33	26.33	TWENTY NINE POINT THREE THREE	10.09

Legend: SS: Sterilized soil; US: Unsterilized soil; NM: Neem; METH: Methanol; CD: Cold; TP: Test plant

Table 3. Girth size of solanum lycopersicon (cm) at different ages

	Week after planting							
Treatments	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**LSD**
1 - SS+TP	ZERO POINT SIX ZER	1.20	1.30	1.51	1.60	1.80	TWO POINT ZERO SIX	0.19
2 - US+TP	ZERO POINT FIVE THREE	0.80	1.06	1.50	1.56	1.73	THREE POINT ZERO ZERO	0.14
3-NM+METH CD+SS+TP	ZERO POINT FIVE SIX	0.66	0.93	1.16	1.36	1.66	SIXTY SEVEN POINT ZERO ZERO	0.19
4 - NM+METH CD+US+TP	ZERO POINT FIVE SIX	0.80	1.06	1.30	1.40	1.43	ONE POINT SEVEN ZERO	0.62
5- NM+H_2O CD+SS+TP	ONE POINT ZERO ZERO	1.33	0.90	1.60	0.80	1.40	ONE POINT SIX ZERO	0.58
6- NM+H_2O CD+US+TP	ONE POINT ZERO THREE	1.33	1.00	0.36	0.40	0.47	ZERO POINT SIX SEVEN	0.14

Legend: SS: Sterilized soil; US: Unsterilized soil; NM: Neem; METH: Methanol; CD: Cold; TP: Test plant

Table 4. Vine length of *Solanum lycopersicon* (cm) at different ages

	Week after planting							
Treatments	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**LSD**
1 - SS+TP	NINE POINT EIGHT THREE	10.67	15.33	17.23	21.00	27.33	THIRTY FIVE POINT FIVE ZERO	10.43
2 - US+TP	SEVEN POINT THREE THREE	8.23	9.47	11.93	12.67	13.50	FIFTEEN POINT ZERO ZERO	3.37
3-NM+METH CD+SS+TP	ELEVEN POINT SIX ZERO	13.6	17.3	18.0	20.00	27.33	THIRTEEN POINT ZERO ZERO	3.17
4 - NM+METH CD+US+TP	NINE POINT THREE THREE	10.16	12.50	14.83	17.00	26.67	TWENTY NINE POINT THREE THREE	3.20
5- NM+H_2O CD+SS+TP	TWO POINT EIGHT NINE	6.85	6.55	11.40	20.77	13.54	FOURTEEN POINT NINE FOUR	12.15
6- NM+H_2O CD+US+TP	TWO POINT THREE SEVEN	4.19	4.10	3.33	2.37	4.59	FIVE POINT FIVE SEVEN	1.96

Legend: SS: Sterilized soil; US: Unsterilized soil; NM: Neem; METH: Methanol; CD: Cold; TP: Test plant

Table 5. Leaf area of *Solanum lycopersicon* (cm^2) at different ages

	Week after planting							
Treatments	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**LSD**
1 - SS+TP	SEVEN POINT THREE ZERO	9.97	12.43	21.10	35.23	39.10	FORTY NINE POINT ZERO SIX	13.13
2 - US+TP	FOUR POINT FOUR THREE	6.16	7.06	8.67	9.87	16.00	TWENTY TWO POINT TWO THREE	10.65
3-NM+METH CD+SS+TP	FIVE POINT ONE ZERO	6.37	10.43	12.20	25.33	57.33	SEVENTY EIGHT POINT EIGHT	23.62
4 - NM+METH CD+US+TP	FIVE POINT FOUR ZERO	8.00	8.56	9.40	12.06	21.06	TWENTY SIX POINT ONE SEVEN	10.16
5- NM+H_2O CD+SS+TP	SIX POINT FIVE FIVE	6.89	6.55	11.40	20.77	13.54	FOURTEEN POINT NINE FOUR	12.14
6- NM+H_2O CD+US+TP	TWO POINT NINE FOUR	4.19	4.10	3.33	2.37	4.59	FIVE POINT FIVE SEVEN	1.96

Legend: SS: Sterilized soil; US: Unsterilized soil; NM: Neem; METH: Methanol; CD: Cold; TP: Test plant

Table 6. Number of branches of *Solanum lycopersicon* at different age

	Week after planting							
Treatments	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**LSD**
1 - SS+TP	TWO POINT THREE THREE	4.00	5.33	5.67	8.66	9.67	TWELVE POINT THREE THREE	3.50
2 - US+TP	TWO POINT ZERO ZERO	3.33	3.66	4.67	6.00	6.66	SEVEN POINT ZERO ZERO	1.91
3-NM+METH CD+SS+TP	TWO POINT SIX SEVEN	4.00	6.67	7.33	7.67	9.33	ELEVEN POINT ZERO ZERO	2.35
4 - NM+METH CD+US+TP	TWO POINT THREE THREE	2.33	3.33	2.67	4.00	7.33	EIGHT POINT ZERO ZERO	2.45
5- NM+H_2O CD+SS+TP	TWO POINT ZER ZERO	5.00	6.00	5.00	11.00	14.67	FIFTEEN POINT SIX SEVEN	9.66
6- NM+H_2O CD+US+TP	TWO POINT SIX SEVEN	2.33	3.00	3.00	5.33	6.33	SIX POINT SIX SEVEN	1.24

Legend: SS: Sterilized soil; US: Unsterilized soil; NM: Neem; METH: Methanol; CD: Cold; TP: Test plant

Magnesium was significantly reduced across all the treatments including the control treatments in the post planting soil analysis. This could be an indication that there was easy uptake of the mineral nutrient in the soil due to its liquid state which required no need for mineralization or decomposition from solid state to liquid state if the mineral was to come from a solid organic source. Nitrogen status of the soil after planting revealed that there was a reduction in the control treatments but the improved nitrogen content in the treatment with neem suggested a superior nitrogen content of the extract. The reduction of nitrogen in the control treatments agrees with [13] who reported that nitrogen is used by plant for growth and leaf expansion needed for photosynthesis. There was an increase in the pH of the soil after planting. This could be as a result of the extracts added into it. The increase in the pH agreed with [14] who said that extracts of botanicals can be extracted and applied to soil to raise the pH as well as improving soil fertility which will lead to higher farm produce. The absence of Aluminion ion and the reduction of hydrogen ion in the post planting soil could be as a result of the increase in the pH of the soil. This suggests, according to [15] that organic substances can be used to manage soil pH leading to substantial reduction in the Aluminium ion content of the soil.

5. CONCLUSION

The study concluded that methanolic extract of neem in sterilised soil was able to increase the growth and yield of tomato. This will enable farmers to produce more tomato which will resultantly stabilise food security without the use of inorganic fertiliser which is not environmental friendly.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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