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Impact of lime and lemon peel extracts on synergistic correlation between soil microbial load and growth parameters of soybean

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Abstract
This study investigated the impact of lime and lemon peel extracts on synergistic correlation between soil microbial load and growth parameters of soybean at the department of Plant of Plant Science and Biotechnology, Rivers State University. Completely randomized design was adopted. Treatments were lime peel extract, lemon peel extract, and a combination of both at $5mgl^{-1}$, $10mgl^{-1}$ and $15mgl^{-1}$ concentration levels in triplicates plus the control. Colony forming unit was used to determine the soil microbial load 7 Days After Planting (7DAP) and growth parameters such as plant height, leaf area, number of nodes, and number of leaves were examined at 7 days interval. Data were depicted as mean values and standard deviation of triplicate experiments. The data collected were analyzed for significant difference at 5% level of probability ($p<0.05$) using a sample T-Test analysis. Results showed that lime and lemon peel extracts influenced amount of soil microbial load and growth parameters of soybean when compared to the control. The microbial load generally decreased as the concentration of lemon and lime peel extracts increased which however, reflected on the growth parameters of soybean. This proved that there was synergistic relationship between the amounts of fungal pathogens in the soil and health status of soybean. Extracts from lime and lemon peels can be used for sustainable and eco-friendly agricultural practices.

Keywords: Lime peel, lemon peel, microbial load, growth parameters, synergistic and correlation

Introduction

Soybean plant (*Glycine max*) is a leguminous crop that belongs to Fabaceae family and widely cultivated for its edible seeds that are highly proteinous and full of oil (Singh *et al*., 2007) [17]. Although native to East Asia but have become one of the most populous and important agricultural commodities worldwide due to the fact that they used as food for humans, animal feed, and industrial products (Hymowitz, 1990) [10]. The soybean plant is characterized by its erect, bushy structure with heights ranging from 20 to 100 cm and the leaves are trifoliate, meaning each leaf consists of three leaflets, and they display a variety of shapes from oval to lanceolate, depending on the cultivar (Singh *et al*., 2010) [18].

Reports have shown that soybean thrives in a variety of soil types and climates but requires well-drained soils and adequate moisture for optimal growth which is enhanced by its nitrogen-fixing ability that is essential for enriching soil fertility and promoting sustainable agricultural practices (Specht *et al*., 1999) [20].

Several agricultural practices such as crop rotation, soil fertility management, pest and disease control, and proper irrigation involved in soybean cultivation to ensure high yield and quality (Hartman *et al*., 2011) [9]. Crop rotation with cereals like maize helps in breaking the cycle of pests and diseases while enhancing soil fertility through nitrogen fixation by the soybean roots (Haque *et al.*, 2016) [8]. Fertilization practices often include the application of phosphorus and potassium, as well as inoculation with rhizobium bacteria to enhance nitrogen fixation (Nakatani *et al*., 2014) [11]. Effective pest and disease management strategies are crucial, as soybeans are susceptible to a variety of pests and diseases that can significantly reduce yields (Wrather and Koenning, 2009) [25].

In addition to the cultural practices in the cultivation of soybean is the application of plant based biological methods to improve health status of plants and have been proven to be more sustainable and eco-friendlier as they are easily biodegraded. Extracts from citrus plants do not only control diseases, but the synergistic application of lemon and lime extracts has been shown to enhance the growth parameters, higher yields and better-quality produce of soybean plants, making it a promising strategy for sustainable agriculture (Hamza *et al*., 2020) [7].

Lime and lemon peel extracts have been shown to content bioactive compounds and essential oils, flavonoids, and phenolic compounds that are not just known for their antimicrobial and antioxidant properties but also for their potential effects on plant growth and development, which when applied to plants, can influence several physiological processes, including seed germination, root growth, and overall plant vigor (Tuang *et al*., 2007). The presence of citric acid and other organic acids in the extracts can improve the availability of essential nutrients, promoting faster and more uniform germination (Huang *et al*., 2007). Additionally, these extracts can reduce the incidence of fungal infections in seeds, further aiding germination, positively affect root and early seedling development (Oyebanji and Oyeleke, 2019) [14].

Literatures have shown that bioactive compounds in the extracts can stimulate root growth, leading to a more extensive root system that enhances water and nutrient uptake and this increased root development can improve the plant's overall growth and resilience, especially in challenging environmental conditions (Oyebanji and Oyeleke, 2019) [14]. Reports have shown that the combination of plant extracts promote better seed germination rates due to their ability to improve nutrient availability and reduce pathogen loads in the soil and consequently ensures that seedlings emerge more robustly and uniformly, providing a strong foundation and overall plant vigor for subsequent growth and developmental stages

(Saleem *et al*., 2018; Ahmed *et al*., 2019; Hamza *et al*., 2020) [1, 7, 16]. This improved root architecture not only supported better growth during normal conditions but also increased the plant's resilience to environmental stresses such as drought or poor soil fertility (Zhang *et al*., 2017) [27].

Researchers have it that the combined use of lemon and lime extracts also positively impacts the above-ground growth parameters of soybean plants by enhancing photosynthetic activity, increasing biomass accumulation, and improving pod development in soybean plants by protecting it from various pathogens (Singh *et al*., 2013; El-Mohamedy *et al*., 2018) [5, 19]. Reducing the load of harmful microbes (bacteria, fungi, and viruses) that commonly affect soybean, plant extracts would help maintain plant health, promote robust growth and productivity (Chutia *et al*., 2009; Singh *et al*., 2013) [3, 19].

Researchers indicated that lime and lemon peel extracts can effectively combat bacterial pathogens in soybeans, such as *Pseudomonas syringae* and *Xanthomonas campestris*. The bioactive compounds in the extracts disrupt the bacterial cell membrane, leading to cell lysis and death (Dandekar and Jayaprakasha, 2012) [4].

Subsequently, fungal pathogens, such as *Phytophthora sojae* and *Fusarium* spp., have also been shown to be susceptible to the antimicrobial effects of lime and lemon peel extracts (Singh *et al.*, 2013) [19]. The phenolic compounds present in these extracts have been reported to interfere with fungal cell wall synthesis and function, inhibiting fungal growth and spore germination (Tripathi and Dubey, 2004) [21]. Fungal infections have been mitigated via the extracts that resulted in the reduction in the occurrence of root rot and damping-off diseases in soybeans, thereby enhancing plant survival and yield (Nguefack *et al*., 2012) [12]. Therefore, the study was designed to examine the effect of lime and lemon on the microbial load and the impact on growth parameters and overall health of soybean in order to provide biological alternative to chemical pesticides that will support sustainable agricultural practices.

Materials and Methods

Study Area and Materials Used

The research was carried out in the Plant Science and Biotechnology demonstration plot beside the Screen house at Faculty of Science, Rivers State University, Port Harcourt, Nigeria, which lies within latitudes 4°43'0743'07" and 4°54'3254'32"N and longitudes 6°56'0456'04" and 7°03'2003'20"E with a mean of annual rainfall of over 2000mm and mean temperature of 29°C (Tubonimi and Udonna, 2015). And the materials used are thus; Hoe and cutlass, Spade, Polythene bag, soybean seeds, Meter rule, weigh balance, lemon and lime. Others are sample collection polythene bags, hand gloves, test tubes, 90 ml disposable sterile petri dish, inoculating needle, spirit lamp, wire loop, auto clave, Aluminum foil, paper tape, ethanol, amoxicillin (antibiotics), beakers (200ml), potato dextrose agar (PDA), salt, micro pipette, pipette tip, cotton wool, weigh balance, measuring cylinder, conical flask, distilled water, forceps.

Sample Size

A total of 30 stands of soybean which comprised of 3 replicates of each of the treatment at three ($5mgl^{-1}$, $10mgl^{-1}$ and $15mgl^{-1}$) different concentration levels and Soil only which served as the control. The three replicates at each level were considered as one treatment. Therefore, a total of three (lime, lemon, lemon and lime) different treatment at three different levels were treated plus overall control (Soil Only - SO), all monitored and measured at 7 days interval for 8 weeks (Worlu *et al.*, 2026) [24]

Collection of Soil Sample

Soybean seeds were obtained from the market 16th July 2024. The soil samples were collected from ten different points ($18\times18cm^2$) with the aid of farm spade which was used to dig a V-shaped hole to sample depth (3-6"). The soil cores were homogenized in a clean plate and placed in some 17 × 17cm perforated polythene bags which weighed 4kg then, exposed to heat from sunlight between 27-35°C for five days. The collected samples were loamy soil. This is because it is the only soil that generally supports plant growth. However, the soil samples were collected from the Botanical Garden, Rivers State University, Port Harcourt and transferred to the Plant Science and Biotechnology demonstration plot beside the Screen house at Faculty of Science, Rivers State University, Port Harcourt where the research was carried out.

Planting Operation and Experimental Design

A completely randomized design was adopted. Soybean seeds were planted in polythene bags of about 17cm in height and 17cm in width with 4kg of soil in each bag. Each bag had 3 soybean seeds but one week after germination (1WAG), 2 seedlings of soybean were removed from each bag such that only one would be continually treated with the lemon and lime extracts. This was to reduce nutrient competition between the plants. There were nine bags per treatment at different concentrations ($5mgl^{-1}$, $10mgl^{-1}$ and $15mgl^{-1}$) giving a total of 30 bags including the control experiment ((Nmom *et al.*, 2023; Worlu *et al*., 2026) [13, 24].

Preparation and Application of Lemon and Lime Dried Peel Extract

Citrus peels powder was obtained by grinding dried citrus peels using the air-drying method allowing air to circulate, and stirred occasionally for 2 weeks.

The powder was weighed and tied into transparent polythene bags. The prepared powder was measured into $5mgl^{-1}$, $10mgl^{-1}$ and $15mgl^{-1}$ and poured into bags containing 4kg of soil at the interval of 7 days for 8 weeks (Nmom *et al.* 2023) [13]

Determination of Microbial Load of Soil Samples

Preparation of Medium

Treated and untreated soil samples were collected and transferred to the Plant Science and Biotechnology demonstration plot, Rivers State University, Port Harcourt, Nigeria. 25.5g of PDA was measured into a 1000ml of sterile conical flask. Thereafter 600ml of distilled water was added and shaken for 10 minutes. This was autoclaved for 15 minutes at 121°C, ($1.02kgcm^{-3}$). The flask was later taken out of the autoclave and the temperature of the medium was allowed to cool down at 45°C before adding 250g of amoxicillin for the inhibition of bacteria growth. The PDA was then poured into disposable sterile petri dishes and swerved gently and was allowed to cool down to solidify before inoculation.

Isolation and Identification of Fungal Pathogens

A stock solution of 900ml of water and 8.5g of NaCl was prepared. 9ml of the stock solution was pipetted into 40 test

tubes and was corked with a cotton wool. The test tube alongside micro pipette tips were sterilized for 15 minutes at 121°C, (1.02kgcm–3) for 15 minutes. The sterilized test tubes were allowed to cool down at 40°C. Test tubes where arranged in three per rack and were labeled (10^{-1}, 10^{-2} & 10^{-3}). A pair of forceps was used to collect the soil sample and was placed into the first tube (10^{-1}, and was shaken vigorously to mix with the saline solution. 1ml was transferred via a pipette from the first test tube (10^{-1}) to another test tube on the similar rack (10^{-2}) and mixed with the pipette. 1ml was pipetted from it and poured into the third test tube (10^{-3}) and was properly mixed with the pipette making it a threefold dilution. 1 ml of each concentration were inoculated into the plates (three replicates for each concentration). The plates were incubated at room temperature between 3 days to allow fungal growth. The fungi were identified at the pathology laboratory, Department of Plant science and Biotechnology Rivers state university Port Harcourt, Nigeria (Worlu *et al*., 2026) [24].

Number of Colony Forming Units (NCFU) and Microbial Load of Microflora

Number of colonies forming units (per unit volume) is a measure of viable micro-toxic fungal cells in a sample. It is also used to calculate the number of CFU per volume (CFU/ml) of the original culture.

$$\text{NCFU} = \frac{Number\ of\ Colomes \times Dilution\ Factor}{Volume\ of\ Culture\ Plated}$$

Where;

Number of colonies = number of colonies counted on the plate

Dilution factor= dilution factor used to prepare the plated culture (e.g., 10^{-5}, $10^{-5)}$

Volume of culture plated = volume of culture actually plated (e.g., 0.1g, 1g)

This formula takes into account the dilution factor and the volume of the original sample to calculate the microbial load. It also provides a more accurate calculation of microbial load considering the dilution factor and the sample volume.

Determination of Growth Parameters

The leaf length, plant height, leaf width and leaf area were determined using meter rule whereas, the number of leaves and number of nodes were counted at 7 days intervals.

Statistical Analysis

Results were depicted as mean values and standard deviation of triplicate experiments. The data collected were analyzed for significant difference at 5% level of probability ($p<0.05$) using a sample T- Test with Statistical Package for Social Science (SPSS) version 20.0.

Results

Number of Colony Forming Units (NCFU)/Microbial Load of Microflora of Lemon Peel Extracts

Tables 1, 2 and 3 present the microbial load of soil treated with lemon peel extracts, lime peel extracts and combination of lemon and lime peels extracts respectively. The microbial load assay of the soil, generally decreased as the concentration of lemon and lime peel extracts increased from $5mgl^{-1}$ to $15mgl^{-1}$ whereas, the microbial load in the control samples was generally higher than in the lemon peel extract treated samples indicating an overall inhibitory effect of the extract on microbial growth.

Table 1: Effects of Lemon Peels Extracts on Microbial Load of Soybean Soil

Isolate/Conc.	5(CFU/ml)	10 (CFU/ml)	15 (CFU/ml)	Control
Candida sp.	4.0×10^{-3}	4.0×10^{-3}	1.0×10^{-3}	5.0×10^{-3}
Mucor sp.	4.0×10^{-3}	3.0×10^{-3}	2.0×10^{-3}	6.0×10^{-3}
P. notatum	3.0×10^{-3}	3.0×10^{-3}	1.0×10^{-3}	5.0×10^{-3}
Rhizopus sp.	3.0×10^{-3}	2.0×10^{-3}	1.8×10^{-3}	4.1×10^{-3}
A. niger	6.0×10^{-3}	3.0×10^{-3}	2.0×10^{-3}	7.0×10^{-3}
Fusarium sp.	5.0×10^{-3}	4.0×10^{-3}	1.3×10^{-3}	6.0×10^{-3}

Table 2: Effects of Lime Peels Extracts on Microbial Load of Soybean Soil

Isolate/Conc.	5(CFU/ml)	10 (CFU/ml)	15 (CFU/ml)	Control
Candida sp	3.0×10^{-3}	Nil	Nil	5.0×10^{-3}
Mucor sp	4.0×10^{-3}	Nil	Nil	6.0×10^{-3}
P. notatum	2.0×10^{-3}	1.0×10^{-3}	3.0×10^{-3}	5.0×10^{-3}
Rhizopus sp.	1.0×10^{-3}	Nil	Nil	4.1×10^{-3}
A. niger	3.0×10^{-3}	2.9×10^{-3}	1.0×10^{-3}	7.0×10^{-3}
Fusarium sp	5.0×10^{-3}	3.0×10^{-3}	Nil	6.0×10^{-3}

Table 3: Interactive Effects of Combined Citrus Extracts (Lime+Lemon) Peels on Microbial Load of the Soybean Soil

Microorganism	5g CFU/mol	10g CFU/mol	15(g) CFU/mol	Control
Candida sp.	Nil	4.0×10^{-3}	Nil	5.0×10^{-3}
Mucor sp.	Nil	Nil	Nil	6.0×10^{-3}
P. notatum	1.0×10^{-3}	Nil	Nil	5.0×10^{-3}
Rhizopus sp.	2.0×10^{-3}	Nil	5.0×10^{-3}	4.1×10^{-3}
A. flavus	Nil	Nil	1.0×10^{-3}	7.0×10^{-3}
Fusarium sp.	Nil	Nil	1.0×10^{-3}	6.0×10^{-3}

Table 4 shows the comparative effects of lemon and lime peels on the physical growth parameters of soybean at 2WAP. From the result, there were significant differences in the plant height, leaf area and number of leaves, except in the number of nodes between lemon and lime peels at 5gml^{-1} and 10gml^{-1}. There were also significant differences in the plant height and leaf area between lemon and lime peels at 15gml^{-1} but there was no significant different in leaf length, leaf width, number of node and number of leaves between lemon and lime peels at 15gml^{-1}. Conversely, there was no significant difference in the leaf length, leaf width, plant height, leaf area, number of nodes and number of leaves between the treatments at 5gml^{-1}, 10gml^{-1} & 15gml^{-1} of lemon but there were significant differences in the leaf length, leaf width, plant height, leaf area, and number of leaves in the lime at 5gml^{-1}, 10gml^{-1}, & 15gml^{-1}. However, there were significant differences in the growth parameters of soybean between the treatments (lemon and lime peels) at the various concentrations (5 gml^{-1}, 10 gml^{-1} & 15 gml^{-1}) when compared to the control at 2WAP.

Table 4: Comparative Effect of Lemon and Lime Peels on Physical Parameters of Soybean at 2 WAP

Week/gram (g)	Leaf length (cm)		Leaf width (cm)		Plant height (cm)		Leaf Area (cm^2)		No. of node (n)		No. of leaves (n)	
	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime
5	2.57±1.16^a	3.40±0.85^b	2.07±1.30^a	2.57±0.67^b	6.67±3.18^a	8.83±1.40^b	5.29±5.59^a	7.10±3.16^b	0.10±1.15^a	0.00±0.00^a	5.33±2.31^a	4.00±0.00^b
10	2.90±0.40^a	3.60±1.21^b	2.43±0.40^a	2.73±0.64^a	9.30±2.25^a	8.77±1.57^b	5.59±1.44^a	8.09±3.95^b	0.00±0.00^a	1.00±1.00^a	4.00±0.00^a	6.67±2.52^b
15	2.83±0.30^a	2.40±0.53^a	2.07±0.40^a	2.00±0.26^a	8.00±1.32^a	6.17±0.29^a	4.64±1.28^a	3.83±1.37^b	0.00±0.00^a	0.00±0.00^a	4.00±0.00^a	4.00±0.00^a
Control	6.27 ± 0.92^c		4.70 ± 0.53^c		17.50 ± 0.87^c		23.37 ± 6.12^c		12.33 ± 16.17^c		12.00 ± 1.00^c	

Means with different letters down the column within a growth parameter are significantly different at (P< 0.05)

Table 5 shows the combined effects of lemon + lime peels on the growth parameters of soybeans at 2WAP. The result revealed that there was no significant difference in leaf length, leaf width, plant height, number of nodes and number of leaves of soya bean between 5gml^{-1} and 10gml^{-1} but there were significant differences in all the growth parameters within treatments 5 gml^{-1}, 10gml^{-1}and 15gml^{-1}. However, there were significant differences in all the growth parameters in the treatments when compared to the control.

Table 5: Combined Effects of Lemon + Lime Peels on Physical Growth Parameters of Soybean at 2 WAP

Week/gram(g)	Leaf length(cm)	Leaf width (cm	Height (cm)	Leaf area (cm^2)	No. of nodes (n)	No. of leaves (n)
5	2.57 ± 0.40^a	1.93 ± 0.35^a	8.20 ± 1.85^a	3.94 ± 1.28^a	0.00 ± 0.00^a	4.00 ± 0.00^a
10	2.33 ± 0.29^a	1.80 ± 0.26^a	8.00 ± 1.00^a	3.34 ± 0.85^a	0.00 ± 0.00^a	4.00 ± 0.00^a
15	3.47 ± 0.50^b	2.73 ± 0.50^b	9.73 ± 0.40^b	7.55 ± 2.41^b	1.33 ± 1.15^b	7.07 ± 3.21^b
Control	6.27 ± 0.92^d	4.70 ± 0.53^d	17.50 ± 0.87^c	23.37± 6.12^c	12.33 ± 16.17^c	12.00 ± 1.00^c

Means with same letters down the column are not significant at (P< 0.05)

Table 6 shows the comparative effects of lemon and lime peels on growth parameter of Soybean at 6WAP. From the result, there was no significant difference in the leaf length and leaf width but there were significant differences in plant height, leaf area, number of nodes, number of leaves Soybean between lemon and lime peels at 5 gml^{-1}, 10gml^{-1}and 15gml^{-1} but there were significant differences in all the growth parameters when comparing the treatments 5 gml^{-1}, 10gml^{-1}and 15gml^{-1} to the control.

Table 6: Comparative Effects of Lemon and Lime Peels on Physical Growth Parameter of Soybean at 6 WAPS

Week/gram (g)	Leaf length (cm)		Leaf width (cm)		Plant height (cm)		Leaf Area (cm^2)		No. of node (n)		No. of leaves (n)	
	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime	Lemon	Lime
5	5.17±0.76^a	5.96±0.50^a	4.33±0.58^a	4.70±0.30^a	16.00±4.58^a	15.03±2.47^b	17.23±2.71^a	22.13±3.40^b	3.67±1.53^a	3.33±05^b	13.67±1.53^a	14.33±2.08^b
10	6.40±0.69^a	6.60±1.65^a	5.03±0.40^a	4.93±0.97^b	18.0±3.16^a	16.83±0.76^b	25.50±4.90^a	26.33±11.93^b	3.00±0.00^a	4.33±1.15^b	11.67±1.15^a	17.00±4.00^b
15	6.23±0.64^a	6.00±0.10^a	4.87±0.81^a	4.17±0.70^a	17.50±0.86^a	12.83±0.29^a	24.00±6.02^a	19.53±2.24^b	3.67±0.58^a	3.00±0.00^a	13.00±2.64^a	13.33±1.53^a
Control	6.27 ± 0.92^b		4.71 ± 0.53^a		17.50 ± 0.87^a		23.37 ± 6.12^c		12.33 ± 16.17^c		12.00 ± 1.00^c	

Means with different letters down the column within a growth parameter are significantly different at (P< 0.05)

Table 7 shows the effects of the combined treatment (lemon + lime peels) at 6WAP. There were significant differences in all the growth parameters between the treatments 5 gml^{-1}, 10gml^{-1}and 15gml^{-1} when compared to the control.

Table 7: Combined Effect of Lemon + Lime Peels on Growth Parameters of Soybean at 6WAP

Week/Gram	Leaf Length (cm)	Leaf width (cm)	Height (cm)	Leaf area (cm^2)	No. of node (n)	No. of leaves (n)
5	5.83±0.29[a]	4.43±0.38[a]	16.17±1.26[a]	20.20±1.71[a]	3.07±0.50[a]	13.67±0.57[a]
10	5.90±0.53[a]	4.83±0.58	13.67±1.53[a]	22.53±4.83[b]	3.00±0.00[b]	11.66±1.15[b]
15	7.60±1.65[b]	6.37±0.75[b]	18.90±0.79[b]	39.60±12.99[c]	4.33±1.15[c]	16.00±4.58[c]
Control	6.27±0.92[c]	4.70±0.53[c]	17.50±0.87[b]	23.37±6.12[d]	12.32±16.17[d]	12.00±1.00[d]

Discussion

The impact of lime and lemon peel extracts on synergistic relationship between soil microbial load and growth parameters of soybean was found to be effective as the result proved that the microbial load generally decreased as the concentration of lemon and lime peel extracts increased from $5mgl^{-1}$ to $15mgl^{-1}$ whereas, the microbial load in the control samples was generally higher than in the lemon peel extract treated samples. The decrease in microbial load as the concentration increased indicated an overall inhibitory effect of the extract on microbial growth which however, reflected on the growth parameters of soybean. This further shows that there is relationship between the amounts of fungal pathogens in the soil health status of a plant. This is in line with Oyebanji and Oyeleke, (2019) [14] and Hamza *et al*. (2020) [7] who reported that the bioactive compounds in the extracts can stimulate root growth, leading to a more extensive root system that enhances water and nutrient uptake and this increased root development can improve the plant's overall growth and resilience, especially in challenging environmental conditions. Similarly, the combination of plant extracts promotes better seed germination rates due to their ability to improve nutrient availability and reduce pathogen loads in the soil and consequently ensures that seedlings emerge more robustly and uniformly, providing a strong foundation and overall plant vigor for subsequent growth and developmental stages (Saleem *et al*., 2018; Ahmed *et al*., 2019; Hamza *et al*., 2020) [1, 7, 16].

The decrease in microbial load of the soil may have impacted positively on the root physiology to aid absorption which remarkably manifested on the growth parameters of soybean. This improved root architecture not only supported better growth during normal conditions but also increased the plant's resilience to environmental stresses such as drought or poor soil fertility (Zhang *et al*., 2017) [27].

The reduction in the microbial load in soybean soil was as a result of application of lime and lemon peel extracts. This was further verified with the control that had higher microbial loads than the various concentrations of lime and lemon peel extracts. And this resulted in the treatments enhancing the growth parameters better than the control. Researchers have indicated that bioactive compounds in the extracts lime and lemon peel can effectively combat bacterial pathogens such as *Pseudomonas syringae* and *Xanthomonas campestris* and fungal pathogens such as Mucor, Rhizopus, Fusarium, *A. niger, A. flavus* and *Phytophthora sojae* in soybeans by disrupting the bacterial cell membrane, leading to cell lysis and death (Wrather *et al*, 2001; Dandekar and Jayaprakasha, 2012; Singh *et al*., 2013) [4, 19, 26].

The growth parameters at 6WAP lemon and lime peel extracts showed notable differences in plant height, leaf length, leaf area, leaf width, number of nodes and number of leaves. However, extracts from lime peel had better performance than lemon peel extract. This suggested that lime favored and promoted growth and overall health status of soybean. This was justified by the reduction of microbial load in soybean soil which however truncated the manifestation of certain foliar diseases that would have impeded photosynthetic activities. The phenolic compounds present in these extracts have been reported to interfere with fungal cell wall synthesis and function, inhibiting fungal growth and spore germination (Tripathi and Dubey, 2004) [21]. Similarly, Nguefack *et al*. (2012) [12] reported that fungal infections have been mitigated via the extracts that resulted in the reduction in the occurrence of root rot and damping-off diseases in soybeans, thereby enhancing plant survival and yield.

On the other hand, there was significant difference in all the growth parameters at the various concentration levels. However, higher concentration of the combined extracts impacted positively on the vegetative development of soybean plant compared to the control. This suggested that the combined treatment produced best plant development at higher concentration which supports the vegetative growth of soybean. This aligns with the works of Galmaro and Glick *et al*. (2015) and El- Mahrouk *et al*. (2020) who reported that both treatments offer substantial benefits improving soil fertility but there phyto- constituents and grams cater for different aspects of growth, combining the treatment could show a more balanced approach to soil fertility and value of soybean.

Conclusion

Lime and lemon peel extracts influenced amount of soil microbial load and growth parameters of soybean when compared to the control. The microbial load generally decreased as the concentration of lemon and lime peel extracts increased which however, reflected on the growth parameters of soybean. This proved that there is synergistic relationship between the amounts of fungal pathogens in the soil and health status of soybean.

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