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Bioactive effect of lime and lemon peels extracts on soil microflora load and disease incidence on soybean

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Abstract
This study investigated the bioactive effects of lime and lemon peels extracts on microbial load and disease incidence of soybean plant. The research was carried out at the demonstration site 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 visual assessment method was used to describe and estimate the quantitative damage that manifested in plant leaves 8 Weeks After Planting (8WAP) for the various concentrations. Results showed that lime and lemon peels extracts exhibited bioactive effect on the soil-borne fungal pathogens associated with soybean by reducing Mucor sp, Rhizopus sp, *Aspergillus flavus, Penicillium notatum,* Fusarium sp, Candida sp. load in the soil thereby inhibiting disease incidences such as chlorosis, leaf spot, leaf blight, rust and curling to economic manageable level. Mucor sp was mostly inhibited. The disease symptoms were susceptible to lemon and lime peels extracts at lower concentrations but had more inhibitory impact at higher concentrations. The combination of lime and lemon peels extracts showed rapid and higher antimicrobial activity as it relates to the overall disease manifestation on the vegetative and foliar parts of soybean. The extracts reduced the soil microbial loads and inhibited the foliar diseases to an economically manageable level and can be used for sustainable and eco-friendly agricultural practices.

Keywords: Bioactive, lime peel extract, lemon peel extract, disease incidence and fungal pathogens

Introduction

Soybean (*Glycine max*) is a crucial crop globally, serving as a vital source of protein for both human consumption and animal feed (Hartman *et al*., 2011) [13]. However, its production is significantly threatened by various microbial diseases that reduce yield and quality (Tung *et al*., 2007) [29]. Literatures have shown that the yield and quality of soybean by these diseases among others; Noybean Cyst Nematode (SCN), Charcoal Rot, Brown Spot, Frogeye Leaf Spot, Sudden Death Syndrome, and Phytophthora Root and Stem Rot, chlorosis, necrosis, rust (Niblack *et al*., 2006 [23]; Wrather *et al*., 2001; Mengistu *et al*., 2007; Bradley and Pedersen, 2011; Leandro *et al*., 2013 [5, 17, 19]; Tylka and Marett, 2014; Hartman *et al*., 2015) [14].

Chemical pesticides and antimicrobials have been proven effective but often pose environmental and health risks due to their persistence and toxicity (Aktar *et al*., 2009) [2]. Therefore, there is a growing interest in researching for alternatives that are not just natural but effective and environmentally welcoming (Koul *et al*., 2008) [15]. Citrus fruits, notably lime (*Citrus aurantiifolia*) and lemon (*Citrus Limon*), are known for their powerful antibacterial effects, principally ascribed to their essential oils and bioactive components such as flavonoids and limonoids (Fisher and Phillips, 2008) [9]. The peels of lime and lemon, typically considered waste products but are rich in certain bioactive chemicals, making them a promising resource for producing natural antibacterial treatments (Karim *et al.,* 2016). These natural chemicals have showed efficiency against a broad spectrum of microbial diseases, including bacteria and fungi (Dhanavade *et al.,* 2011) [8]. The antimicrobial activity of these compounds helps protect plants from pathogenic microorganisms, thereby reducing the incidence of diseases and improving overall plant health (Abdel-Salam *et al*., 2019) [1]. For instance, limonene, a major component of citrus essential oils, has been shown exhibit inhibitory effect on the growth of various bacterial and fungal pathogens, which can otherwise adversely affect plant growth and yield (Al-Qahtani *et al.,* 2019) [3].

Researchers have documented that extracts derived from citrus peels possess the ability to impede the proliferation of several plant pathogens, resulting in a decrease in disease occurrence and an improvement in the overall well-being of crops (Barkai-Golan, 2001) [4]. Lime peel extract has a proven potent for antifungal properties against Aspergillus species, which are frequently found as contaminants in soybean storage (Tripathi and Dubey, 2004) [27]. It has also been shown to possess antibacterial activities that are effective against *Pseudomonas syringae*, a bacterium that is known to be the cause of soybean bacterial blight (Caccioni *et al.,* 1998) [7].

The study on the comparative antimicrobial activity of lime and lemon peel extracts on the disease prevalence of soybean was considered for several reasons. Firstly, soybean (*Glycine max*) is a globally significant crop, essential for food security and economic stability, especially in regions where it serves as a primary source of protein and oil (Hartman *et al.*, 2011) [13]. However, its production is frequently compromised by various microbial diseases, leading to substantial yield losses.

Also, the peels of citrus fruits, including lime (*Citrus aurantiifolia*) and lemon (*Citrus Limon*), contain a high concentration of bioactive chemicals that are recognized for their ability to inhibit the growth of microorganisms (Fisher and Phillips, 2008) [9]. Harnessing these natural resources is in line with the increasing worldwide movement towards organic farming and environmentally sustainable agriculture practices (Gurib-Fakim, 2006) [11].

Additionally, the antimicrobial action of plant extracts especially lime and lemon have been reported to reduce the incidence of bacterial blight and bacterial pustule, two prevalent bacterial diseases in soybean cultivation (Singh *et al.*, 2013) [26]. 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. 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) [27]. 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) [22].

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 (Worlu *et al*., 2026) [32].

Furthermore, smallholder farmers, who are often disproportionately affected by crop losses due to microbial diseases, stand to benefit significantly from the findings of this study as it is notably clear that chemical pesticides can be grossly expensive and inaccessible to many subsistent and peasant farmers (Gurjar *et al*., 2012) [12]. In contrast, lime and lemon peels are readily available and cost-effective, especially in tropical regions where citrus fruits are abundant and would provide farmers with an affordable and accessible means to protect their crops, thereby enhancing the livelihoods and food security of the populace (Burt, 2004) [6]. The study examined the antimicrobial effectiveness of lime and lemon peels extracts in order to offer a natural and environmentally friendly method for controlling soybean diseases. This would help decrease the need for dangerous chemical treatments, aids in safeguarding the environment but and fosters sustainable agriculture 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) [28].

Materials used for this research work were; Hoe and cutlass, Spade, Polythene bag, soybean seeds, meter rule, weighing balance, lemon and lime. Others are 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, and 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) [32]

Collection of Soil Sample

Soybean seeds were obtained from the market 16th July 2024. The soil samples were collected from ten different points (18×18cm ^{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, and Port Harcourt and transferred to the Plant Science and Biotechnology demonstration plot beside the Screen house at Faculty of Science, Rivers State University, and 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.,* 2026a) [24, 32].

Preparation and Application of Lemon and Lime Dried Peel Extract

Citrus peels powder were 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; Worlu *et al.,* 2026) [24, 32].

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.

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

Number of colony 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 Plant Disease Symptoms and Incidence

Visual assessment method was used to describe and estimates the quantitative damage that manifested in plant leave. The percentage disease incidence was derived thus;

$$DI = \frac{x}{y} \text{X} \frac{100}{1}$$

Where;
DI = Disease Incidence
X = Total number of Each Organism
Y = Total Number of All Identified Organism
This formula measures the number of new cases of a disease that occur within a population over a specific time or period, providing insights into the disease's spread/impact or providing a measure for disease incidence.

Results

Fungal isolates form Treated Soil (Lemon and Lime Extracts) and Control

The fungi identified were Mucor sp, Rhizopus sp, *Aspergillus flavus, Penicillium notatum, Fusarium sp, Candida sp.*

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

Table 1 presents the microbial load of soil treated with lemon peel extracts. Based on the microbial load analysis of the soil, the microbial load generally decreased as the concentration of lemon peel extract increased from 5mgl $^{-1}$ to 15mgl $^{-1}$ for most microorganisms 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.	3.0 x 10^{-3}	4.0 x 10^{-3}	2.0 x 10^{-3}	5.0 x 10^{-3}
Mucor sp.	3.0 x 10^{-3}	3.0 x10^{-3}	4.0 x 10^{-3}	6.0 x 10^{-3}
P. notatum	2.0 x 10^{-3}	3.0 x 10^{-3}	3.0 x 10^{-3}	5.0 x 10^{-3}
Rhizopus sp.	3.0 x 10^{-3}	1.0 x 10^{-3}	1.8x 10^{-3}	1.1x10^{-3}
A. niger	6.0 x 10^{-3}	1.0 x110 $^{-3}$	3.0 x10^{-3}	Nil
Fusarium sp.	Nil	4.0 x10^{-3}	Nil	Nil

Table 2 presents the microbial load of soil treated with lime peel extracts. Candida sp., Mucor sp. had a decrease in microbial load with increasing lime concentration, while *P. notatum,* Fusarium sp. and *A. Niger* showed inconsistent patterns. The microbial load in control samples varies across microorganisms, but generally, the lime treated samples show different patterns compared to the control.

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	8.0 x 10^{-3}	Nil	Nil	5.0 x 10^{-3}
Mucor sp	4.0 x 10^{-3}	Nil	Nil	6.0 x 10^{-3}
P. notatum	6.0 x 10^{-3}	9.0x10^{-3}	3.0 x 10^{-3}	5.0 x 10^{-3}
Rhizopus sp.	Nil	Nil	7 x 10-^{3}	1.0 x 10^{-3}
A. niger	7.0 x 10^{-3}	2.9 x 10^{-3}	8.0 x 10^{-3}	Nil
Fusarium sp	5.0 x 10^{-3}	8.0 x 10^{-3}	Nil	Nil

Table 3 shows the microbial load of soil treated with combination of lime and lemon peel extracts. Rhizopus, *P. notatum* and Candida sp. had decreased microbial load with increasing extract concentration. It also observed that Fusarium sp., *A. flavus,* and *A. Niger* showed increased load even at higher concentrations of the extracts. Mucor sp. was inhibited across the concentrations. The microbial loads in the control samples varied in an increased order across microorganisms at the various concentrations.

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}	1.0×10^{-3}
A. flavus	Nil	Nil	1.0×10^{-3}	Nil
Fusarium sp.	Nil	Nil	1.0×10^{-3}	Nil

Table 4a shows the effect of combination of lime and lemon peels extracts at 5g/ml on disease incidence of soybean at 4WAP. Leaf blight had the highest number of disease incidence (44%) followed by chlorosis (31%), leaf spot (25%) rust and leaf curling showed (0%) disease incidence. The same observation was made in the control, where leaf blight had the highest number of disease incidence (44%) followed by chlorosis (31%), leaf spot (25%) leaf rust and curling showed (0%) disease incidence.

Table 4a: Combined Effect of Lime and Lemon Peels Extracts (5g/ml) on Disease Incidence of Soybean at 8WAP

Infection/ symptoms	Total number of leaves assessed		Total number of disease incidence		% Disease incidence contribution	
	Treatment	Control	treatment	control	treatment	control
Chlorosis	36	36	5	5	31	31
Leaf Blight	36	36	7	7	44	44
Leaf Spot	36	36	4	4	25	25
Rust	36	36	Nil	Nil	0	0
Leaf Curling	36	36	Nil	Nil	0	0
Total	36	36	16	16	100	100

Table 4b shows the effect of combination of lime and lemon peels extracts at 5g/ml on disease incidence of soybean at 4WAP. Chlorosis had the highest number of disease incidence (67%) followed by leaf blight (27%), leaf spot (6%) rust and leaf curling showed (0%) disease incidence. While in the control, where leaf blight had the highest number of disease incidence (44%) followed by chlorosis (31%), leaf spot (25%) leaf rust and curling showed (0%) disease incidence.

Table 4b: Combined Effect of Lime and Lemon Peels Extracts (5g/ml) on Disease Incidence of Soybean at 8WAP

Infection/ symptoms	Total number of leaves assessed		Total number of disease incidence		% Disease incidence contribution	
	Treatment	Control	treatment	control	treatment	Control
Chlorosis	35	36	10	5	67	31
Leaf Blight	35	36	4	7	27	44
Leaf Spot	35	36	1	4	6	25
Rust	35	36	Nil	Nil	0	0
Leaf Curling	35	36	Nil	Nil	0	0
Total	35	36	15	16	100	100

Table 4c shows the effect of combination of lime and lemon peels extracts at 5g/ml on disease incidence of soybean at 4WAP. Leaf blight had the highest number of disease incidence (36%) followed by leaf curling (27%), leaf spot and rust had (18%) each and chlorosis showed (0%) disease incidence. While in the control, where leaf blight had the highest number of disease incidence (44%) followed by chlorosis (31%), leaf spot (25%) leaf rust and curling showed (0%) disease incidence.

Table 4c: Combined Effect of Lime and Lemon Peels Extracts (5g/ml) on Disease Incidence of Soybean at 8WAP

Infection/ symptoms	Total number of leaves assessed		Total number of disease incidence		% Disease incidence contribution	
	Treatment	Control	treatment	control	treatment	Control
Chlorosis	48	36	Nil	5	0	31
Leaf Blight	48	36	4	7	36	44
Leaf Spot	48	36	2	4	18	25
Rust	48	36	2	Nil	18	0
Leaf Curling	48	36	3	Nil	27	0
Total	48	36	11	16	100	100

Discussion

Examination of bioactive effect of lime and lemon peels extracts on soil microflora load and disease incidence on soybean revealed that fungal pathogens such as Mucor sp, Rhizopus sp, *Aspergillus flavus, Penicillium notatum,* Fusarium sp, Candida sp. were present in a varying amount at the various concentrations. The microbial load was not determined by the concentration but by the viability of the inocula or propagules optimizing to trigger infections. This however, reflected on the foliar diseases of soybean. The fungal isolates agrees with the works of Tylka and Marett, (2014) as well as Hartman *et al.* (2015) [14] who reported that soybean production is significantly threatened by various microbial diseases that reduce yield and quality.

The microbial load of the soil treated with lemon and lime peel extracts generally decreased as the concentration of the extracts increased from 5mgl $^{-1}$ to 15mgl $^{-1}$ for most microorganisms. Candida sp., Mucor sp. had a decreased in microbial load with increasing lime concentration, while *P. notatum,* Fusarium sp. and *A. Niger* showed sporadic microbial counts. However, Mucor sp. was inhibited across the concentrations. Whereas, the microbial load in the control samples was generally higher than soil samples treated with lemon and lime peels extracts, indicating an overall inhibitory effect of the microbial load and invariably spread. This observation agrees with Saeed *et al*, (2018) [25] who reported that high bioactive components in the 15g is likely to be responsible for the inhibition and that lemon peel at extract at a concentration of 20mg/ml inhibited the growth of *E. coli.* This is also in line with Mahmoud *et al.* (2016) [18] who reported that antimicrobial activities of dried fruit peel of lime and lemon was as a result of alkaloids, saponin, sterols, terpenoids which makes it possible to inhibit a wide range of microorganisms than modern therapy. Wrather *et al.* (2001) also proved that the methanolic extract of peels of lemon and lime were highly successful in producing the desired result against most fungi and bacteria. In the same manner, Tung *et al*. (2007) [29] submitted that fungi such as Mucor, Rhizopus, Fusarium, *A. Niger, A. flavus* and bacteria were successfully inhibited by various concentration of extracts from dried fruit peels of lemon and lime. Peels of citrus fruits, including lime and lemon contain a high concentration of bioactive chemicals that are recognized for their ability to inhibit the growth of microorganisms (Fisher and Phillips, 2008) [9]

The differential and sporadic microbial count noticed with *P. notatum,* Fusarium sp. and *A. Niger* was due to their varying interactions and sensitivities to the phytochemical constituents of the extracts per milligram. However, results indicated that lime peel extract favored the microbial load of *A. Niger* at moderate concentration. This exponential increase in microbial load may be implicated to certain bioactive compounds that have been confirmed to be growth promoters of activities of some microorganisms in the soil. Oyebanji *et al.* (2019) [20] stated that the flavonoid and limonoid from plant extracts may act as growth promoters for *A. Niger.* Tripathi and Dubey, (2004) [27] reported that *Phytophthora sojae* and *Fusarium* spp., were susceptible to the antimicrobial effects of lime and lemon peel extracts as a result of phenolic compounds present in the extracts by interfering with the fungal cell wall synthesis and function thereby inhibiting fungal growth and spore germination.

The combined effect of lemon and lime peels extracts had positive inhibitory impact on the soil-borne fungal pathogens of soybean even at lower concentrations as against only lemon peels extracts and lime peels extracts in their respective treatments and the untreated soil. This proved that the synergistic effect of the extracts was more potent in the antimicrobial activities than the separate extracts. This observation aligns with Galmero and Glick, (2015) [10] who reported that the synergistic or combined effect of lemon and lime peels extracts can provide a broader spectrum of antimicrobial activity reducing disease incidence of fungi and bacteria than when used individually. Similarly, Kumar *et al*. (2019) [16] and Galmero and click *et al*. (2015) reported that the combination of lime and lemon showed higher antioxidant activity than when used individually.

The visual assessment of the foliar parts of soybean in the examined field revealed that disease symptoms such as chlorosis, leaf blight, leaf spot, leaf rust and leaf curling were prevalently predominant on the plant. The symptoms observed in this work align with Bradley and Pedersen, (2011) and Leandro *et al*. (2013) [5, 17] who showed that the yield and quality of soybean significantly reduced as a result of Noybean Cyst Nematode (SCN), Charcoal Rot, Brown Spot, Frogeye Leaf Spot, Sudden Death Syndrome, and Phytophthora Root and Stem Rot, chlorosis, necrosis, rust diseases among others. The physical manifestation of diseases in soybean was an indication of systemic debilitation of the plant due to microbial attacks. This corresponds to the works of Niblack *et al.* (2006) and Mian *et al.* (2008) [21, 23] who reported that soybean cyst nematode causes stunted growth, yellowing of leaves and leaf blight which reduced photosynthetic efficiency of soybean. Additionally, the antimicrobial action of plant extracts especially lime and lemon have been reported to reduce the incidence of bacterial blight and bacterial pustule, two prevalent bacterial diseases in soybean cultivation (Singh *et al.*, 2013) [26]. 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) [22].

Be that as it may, it is important to show that though the pathogens which were evidenced on the disease symptoms were susceptible to lemon and lime peels extracts at lower concentrations but had more inhibitory impact at higher concentrations. This simply means that the pathogens were sensitive to the extracts even at the lower concentration which indicated that the integrity of the plant defense was not negatively tampered with but enhanced positively.

Conclusion

Lime and lemon peels extracts exhibited bioactive effect on the soil-borne fungal pathogens associated with soybean by reducing Mucor sp, Rhizopus sp, *Aspergillus flavus, Penicillium notatum,* Fusarium sp, Candida sp. load in the soil thereby inhibiting disease incidences such as chlorosis, leaf spot, leaf blight, rust and curling to economically manageable level. The disease symptoms were susceptible to lemon and lime peels extracts at lower concentrations but had more inhibitory impact at higher concentrations. The combination of lime and lemon peels extracts showed rapid and higher antimicrobial activity as it relates to the overall disease manifestation on the vegetative and folia parts of soybean.

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