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Microbial Soil Enhancer: The Panacea to Land as a Limiting Resource in Agricultural Productivity

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ABSTRACT

Land is an inevitable resource in agricultural production and its health status determines the position of agriculture in the present and future. The study investigated the ability of microbial soil enhancer to increase yield and soil nutrients, maintain soil health for sustainable and continuity in agriculture. Two (2.5ml/liter) of microbial soil enhancer was applied to the soil before planting and thereafter, 2ml/liter was applied through foliar application after every four weeks till maturity, followed by treatments with different rates of inorganic fertilizer NPK15:15:15 (20g/plant, 15g/plant, and 10g/plant). The study revealed that microbial soil enhancer gave the best-improved yield (52.67 Ton/Ha), SOM and many primary nutrients when used with 50% (10g/plant) inorganic fertilizer. Microbial soil enhancer improved and balanced the soil microorganism's community, making the soil fit for sustainable use and continuity in agriculture. It generated pro-bacteria and fungi needed for plant protection and productivity. The study also revealed that microbial soil enhancer should not be used in a virgin or fertile soil to avoid disaster outbreak. It is also good for bioremediation. It should be encouraged and supplemented with a low rate of inorganic fertilizer to increase yield, sustainability, and continuity in agriculture and also for bioremediation, to reclaim agricultural lands lost to pollution.

1 INTRODUCTION

Land is an essential factor in agricultural productivity. Population increase, industrialisation, and urbanisation in the quest to development have drastically reduced the available arable land, and this will continue as population and industrial activities increase, and urbanisation expands on a daily basis. As the population is increasing, so is the demand for agricultural products especially food, which no one can do without (Ikuli, 2017). The drastically reducing available arable land will also affect agricultural productivity. Available land per capita (land per person) in Nigeria in the 1960s (1963 – 1969) ranged from 0.513 – 0.633 hectares (5130m^2 – 6330m^2), but now as at 2013, the available arable land was 0.197 hectares (1970m^2) and 2015 0.188 hectares (1880m^2) per person (FAO, 2017). Today farmers still practice shifting cultivation, to maintain the soil health for better productivity. With the continual reduction of available arable land, as a result of population increase and development, there is the tendency that a time will come, when there will be no more land for the farmers to shift to after cultivation on a particular land, which means they will continue to plant whatever they want on that same piece of land, whenever they want to plant, which will have negative effect on the health of the soil, and in turn reduce productivity as a result of loss of vigor.

The continuous use of inorganic nutrients sources; like inorganic fertilizers and other synthetic products also damage the soil life. This is because, most of these inorganic substances that are not utilised by the plants when applied, are leached into the soil, thereby increasing the level of contaminants and pollutants in the soil.

To prevent or control such unforeseen circumstances, there is the need to employ strategies that will mitigate the drivers of the soil health, which are the microbes. Activities of microbes in the soil increase the level of organic matter in the soil. Increase in soil organic matter (SOM) in the soil in turn; improve the health of the soil. In every 1% increase in the soil organic matter, a 1,000-pound weight of Nitrogen (N) is produced, a 100-pound weight of potassium, phosphate, and sulfur each are produced (www.bontera.com; www.motherearth.com). The activities of microbes balance and improve the soil structure and texture (Havlin *et al.*, 2006; Ikuli and Ogidi, 2017). Their activities help in increasing phosphorus mobility. Their activities reduce bulk density of the soil and improve the bufa capacity of the soil, due to the complication of organic matters. Increasing SOM reduces both chemical fertilizer runoff and nutrients leaching. Microbe-rich soil attracts organisms, help restore and maintain the natural balance of soil: Arthropods, Nematodes, Earthworms, Fungi, Bacteria and Protozoa (Havlin *et al.*, 2006; Grotz, 2014).

Microbial soil enhancers are natural sources of humic acid, fulvic acid, amino acid, minerals, vitamins, proteins and carbon for plants (Grotz, 2014). According to Havlin *et al.* (2006), they reported that Andersons Production Ltd said that Biological Farmers of Australia (BFA) recommended that all fertilizer inputs (solid or liquid) should be combined with a carbon source. This creates a stable carbon-nutrient bond. As a result, the nutrients will be less prone to leaching, volatilisation, becoming insoluble and causing damage to the soil life. Natural soil enhancers increase crop productivity, strengthen root growth and promote nutrients absorption. It increases the natural immunity of the crop, water holding capacity of the soil, and provide a conducive environment for soil microbial activities.

In order to acknowledge and make judicious use of the important roles microbes play in soil improvement for better productivity, sustainable maintenance of the soil health and control to an extent, the possible effect of limited land for agricultural cultivation, it is therefore necessary to examine the effect of microbial soil enhancers on cassava production in this region. This is because cassava is a major crop grown in this region.

The objective of this study is to provide alternative sources of nutrients that will maintain soil health and enhance productivity.

2 MATERIALS AND METHOD

The research was conducted in the Faculty of Agriculture Teaching and Research Farm, Abuja campus, University of Port Harcourt, Port Harcourt. Latitude 4º 54¹ 34¹¹ N, Long. 6º 55¹ 24¹¹ E. With a temperature range from 23ºC to 35ºC and a total rainfall range of 2000 – 3000mm per annum from May 2017 to May 2018.

2.1 Land Preparation and Plot Layout

A total land area of 477m^2 was cleared, ploughed and was partitioned into 24 plots. Each plot's size was 5m x2m, with eight treatments and three replicates. The distance in-between treatments and replicates were 1.5m apart. Treatments were arranged in a randomized complete block design.

2.2 Planting Material and Planting

Cassava (*Manihot esculenta* C.) stem cuttings; TME 419 and TMS3168/UMUCASS/36 (YELLOW ROOT) were obtained from University of Port Harcourt Faculty of Agriculture Teaching and Research farm, Choba Port Harcourt, Rivers State, Nigeria.

2.3 Treatment Material

A microbial soil enhancer "Bontera", a liquid concentrate was obtained from Organico, A division of Amka Products in South Africa.

2.4 Planting

Cuttings of cassava stems were planted 1m apart giving a plant population of 25 plants per plot (10,000 plants/ha).

2.5 Treatments

Only water was required (control).
To the second treatment only Bontera was added (1L/ha at planting, foliar application 4 weeks after planting- every 4 weeks until maturity).
One hundred (100%) percent fertilizer (farmer standard) + 1 L Bontera/ha at planting, foliar application 4 weeks after planting- every 4 weeks until maturity.
Only 100% fertilizer was applied.
Seventy-five (75%) percent fertilizer + 1 L Bontera/ha at planting, foliar application 4 weeks after planting- every 4 weeks until maturity.
Seventy-five (75%) fertilizer only
Fifty (50%) percent fertilizer + 1 L Bontera/ha at planting, foliar application 4 weeks after planting- every 4 weeks until maturity
Fifty (50%) percent fertilizer only.

2.6 Treatment Dilution and Application

Soil Application- 2.5ml of Bontera was added to a liter of water and applied to each plot designated for microbial soil enhancer treatments at planting.
Foliar Application – 2ml of Bontera per liter of water was sprayed onto the leaves and crop.

2.7 Fertilizer Application

NKP 15:15:15 fertilizer was applied at the designated rates on the eighth week after planting. 20g/plant was applied to 100% fertilizer rate, 15g/plant was applied to 75% fertilizer rate and 10g/plant to 50% rate of fertilizer application.

3 DATA COLLECTION

3.1 Soil Sample

Before commencement of the study, soil samples were randomly collected from the experimental site. The collection depth was 0-15cm and 15-30cm. Some of the soils were instantly taken to the laboratory for microbial flora/fauna analysis.
Some soil samples were viewed under OLYMPUS electronics microscope, and micro fauna were identified and counted. Menica (2005) method was adopted for microbial flora identification and count. While some were air-dried, crushed and sieved to pass through 2mm sieve and used to conduct a complete physical and chemical soil analysis adopting Olsen *et al*, 1954; Mehlich, 1984; Stewart, *et al*, 1974 methods and Atomic Absorption Spectrophotometer (AAS). After harvest, soil samples were also collected from each treatment in all replicates for microbial soil flora/fauna and complete physical and chemical soil analysis.

4 GROWTH ANALYSIS/ MEASUREMENT

The plant height, leaf area, growth rate, plant canopy, canopy volume, and leaf area index of the plants were measured. The measurement started four weeks after planting. The measurement was taken in four weeks interval. Measurements were made on ten (10) plants and the averages taken from each unit.

5 HARVESTING/YIELD

At maturity, harvest was done manually. After harvesting, the fresh weight of each was taken immediately using a manual weighing balance. The length, circumference, and number of roots from 10 stands from each treatment were also taken.

6 STATISTICAL ANALYSIS: SAS Soft word was used for the statistical analysis.

7 RESULT

7.1 Microbial Flora/Fauna

For the soil health to be optimal, the population of the different general or class of microbes must be balanced. To obtain a balanced statue, nutrients and environmental conditions must be conducive. A balanced statue is when the microorganisms are in a well-rationed population of bacteria, fungi, protozoa, nematode and earthworm (www.motherearth.com). The microbial flora and fauna of the soil before planting and treatment were 80.64% bacteria, 19.05 fungi, 0.16% protozoa, and 0.15% nematode. After the treatment, it revealed that in control; 86.21% and 79.30% of bacteria constituted the microorganism population in plots that TME419 and TMS1368/UMUCASS/36 popularly known as YELLOW ROOT were planted respectively. For the plot that TME419 was planted, 2.59% fungi, 8.62% protozoa and 2.59% of nematode made up the microorganism population. While for YELLOW ROOT, 15.42% fungi, 0.88% protozoa, and 4.41% nematode made up the microbial population. For the soil treated with microbial soil enhancer only, the plot which TME419 was planted constituted of 91.46% bacteria, 3.66% fungi, 1.22% protozoa, and 3.66% nematode, while the plot planted with YELLOW ROOT constituted 92.86% bacteria, 3.57% fungi, 2.14% protozoa, and 1.43% nematode. For the soil treated with microbial soil enhancer and 100% NPK fertilizer, 74.77% bacteria, 18.69% fungi, 1.87% protozoa, and 4.67% nematode constituted the soil microbial flora and fauna that TME

419 was planted. While 93.02% bacteria, 3.10% fungi, 2.33% protozoa, and 1.55% nematode made up the microbial population in the plot that YELLOW ROOT was planted. In the soil that only 100% fertilizer was applied; and in the plot where TME 419 was planted, 98.04% bacteria, 0.33% fungi, 0.65% protozoa, and 0.98% nematodes made up the soil microbial population. While the plot where YELLOW ROOT was planted constituted of 46.48% bacteria, 43.48% fungi, 6.21% protozoa, and 3.73% nematodes. For the soil treated with microbial soil enhancer and 75% fertilizer, 40% bacteria, 56% fungi, 2.40% protozoa, and 1.60% nematodes constituted the microbial flora and fauna population. While 90.09% bacteria, 0.45% fungi, 6.76% protozoa, and 2.76% nematodes made up the population of the microbial community in the plot that YELLOW ROOT was planted. In the soil where only 75% fertilizer was used for treatment, and for the plot with TME419, 77.52% bacteria, 11.63% fungi, 7.75% protozoa and 3.10% nematode made up the microbial population while for the plot that YELLOW ROOT was planted, 87.91% bacteria, 5.49% fungi, 3.30% protozoa and 3.30% nematodes constituted the microbial community. For the soil treated with microbial soil enhancer and 50% fertilizer, 95% bacteria, 1.59% fungi, 1.59% protozoa and 1.59% nematodes made up the microbial flora/fauna population in the plot where TME419 was planted and 83.33% bacteria, 11.91% fungi, 2.38% protozoa, and 2.38% nematodes made up the soil microbial population in the plot YELLOW ROOT was planted. For the soil treated where only 50% fertilizer, 60% bacteria, 35% fungi, 3%protozoa, and 2% nematodes summed up the microbial community in the plot that TME419 was planted. While 84.75% bacteria, 3.39% fungi, 6.78% protozoa, and 5.08% nematodes constituted the microbial flora/fauna population where YELLOW ROOT was planted as presented in table 1 and 2.

Table 1: Microbial Flora/Fauna Counted in the Soil before Planting and after Harvest in Various Treatments

TREATMENT	CULTIVAR	THB $X10^3$	THF $X10^3$	No. of protozoa	No. of nematode	No. of Earth worm
INITIAL SOIL		250	60	2	2	_
CONTROL	TME 419	100	3	10	3	_
	TMS 3168	180	35	2	10	_
BONTERA ONLY	TME 419	150	6	2	6	_
	TMS 3168	130	5	3	2	_
B+100% F	TME 419	80	20	2	5	_
	TMS 3168	120	4	3	2	_
100% F	TME 419	300	1	2	3	_
	TMS 3168	75	70	10	6	_
B+75% F	TME 419	50	70	3	2	_
	TMS 3168	200	1	15	6	_
75% F	TME 419	100	15	10	4	_
	TMS 3168	80	5	3	3	_
B+50% F	TME 419	120	2	2	2	_
	TMS 3168	70	10	2	2	_
50% F	TME 419	60	35	3	2	_
	TMS 3168	50	2	4	3	_

B +100%F: Bontera + 100% Fertilizer; 100%F: 100% Fertilizer; B+ 75%F: Bontera + 75% Fertilizer; 75%F: 75% Fertilizer; B+ 50%F: Bontera + 50% Fertilizer and 50%F: 50%Fertilizer

Source: Author's Data

Table 2: THB and THF Organisms Identified in the Soil before Planting and after Harvest in Various Treatments

TREATMENT	CULTIVAR	THB Organism Identified	No. of Colonies	THF Organism Identified	No. of Colonies
BEFORE PLANTING		*Proteous spp.* *Bacillus spp.*	210 40	*Aspergillus* *Rhizopus spp.*	20 40
CONTROL	TME 419	*Staphylococcus spp.* *Proteus* spp.	80 20	*Mucor*	3
	TMS 3168/UMUCASS/36	*Pseudomonas spp.* *Staphylococcus* spp.	80 110	*Mucor* *Aspergillus* spp.	30 5
.BONTERA	TME 419	*Proteus spp.* *Bacillus spp*.	50 100	*Rhizopus spp*	6
	TMS 3168/UMUCASS/36	*Micrococcus spp.* *Bacillus* spp.	20 110	Mucor	5
BONTERA + 100% F	TME 419	*Bacillus subtilis* *Citrobactar* spp.	50 30	*Fusarium* *Aspergillus spp.*	15 5
	TMS 3168/UMUCASS/36	*Actinomycetes* *Staphylococcus aureus*	20 100	*Mucor*	4
100% F	TME 419	*Citrobacter spp.* *Proteus mirabilis*	250 50	*Rhizopus spp.*	1
	TMS 3168/UMUCASS/36	*Klebsiella spp.* *Bacillus spp.*	25 50	*Aspergillus spp.* *Yeast*	40 30
BONTERA + 75% F	TME 419	*Aeromonas spp.* *Staphylococcus spp.*	10 40	*Yeast* *Fusarium*	60 10
	TMS 3168/UMUCASS/36	*Actinomycetes* *Staphylococcus spp.*	50 150	*Rhizopus spp.*	1
75% F	TME 419	*Pseudomonas spp.* *Staphylococcus spp.*	20 80	*Aspergillus spp.* *Rhizopus spp.*	10 5
	TMS 3168/UMUCASS/36	*Bacillus spp.* *Staphylococcus spp.*	60 20	*Mucor*	5
BONTERA + 50% F	TME 419	*Bacillus subtilis* *Staphylococcus spp.*	70 50	*Rhizopus spp.*	2
	TMS 3168/UMUCASS/36	*Actinomycetes* *Klebsiella spp.*	20 50	*Fusarium* *Aspergillus*	6 4
50% F	TME 419	*Staphylococcus aureus* *Pseudomonas spp.*	40 20	*Aspergillus sp* *Rhizopus spp*	15 20
	TMS 3168/UMUCASS/36	*Actinomycetes* *Staphylococcus spp.*	10 40	*Rhizopus spp.* *Mucor*	20 2

B +100%F: Bontera + 100% Fertilizer; 100%F: 100% Fertilizer; B+ 75%F: Bontera + 75% Fertilizer; 75%F: 75% Fertilizer; B+ 50%F: Bontera + 50% Fertilizer and 50%F: 50%Fertilizer

Source: Author's Data

7.2 Soil Physiochemical

The pH of the soil was lowest in the soil sample collected before planting and highest in the soil treated with only Bontera. The pH of the soil ranged from 4.71 (initial/before planting and treatments) to 5.18 (only Bontera; TME419). The percentage organic carbon (%OC) ranged from 1.45 (Bontera + 100% F; TME419) to 4.12 (Bontera + 50%F; TMS3168/UMUCASS/36). The ECEC ranged from 4.572Cmol/kg (control; TME419) to 6.747Cmol/kg (initial soil) as presented in table 3.

7.3 Nutrients Status

Nitrogen (N) ranged from 0.15mg/g (Initial and Bontera + 100%F; TME419) to 0.43mg/g (Bontera + 50%F; TMS3168/UMUCASS/36). Phosphorus (P) ranged from 11.58mg/g (control; TME419) to 24.65mg/g (Bontera +50%F; TME419). Potassium (K) ranged from 0.072 Cmol/kg (Bontera + 75%F; TMS/3168/UMUCASS/36) to 0.184 Cmol/kg (initial soil). Calcium (Ca) ranged from 2.451 Cmol/kg (Bontera + 100%F; TMS1368/UMUCASS/36). Magnesium (Mg) ranged from 0.534 Cmol/kg (Bontera + 100%F; TME419) to 0.957Cmol/kg (initial soil). Sodium (Na) ranged from 0.631 Cmol/kg (Bontera + 75%F and Bontera +50%F; TMS3168/UMUCASS/36). Iron (Fe) ranged from 16.74mg/g (initial soil) to 34.24mg/g (Bontera + 50% F; TME419). Zinc (Zn) ranged from 1.89mg/g (only Bontera; TMS3168/UMUCASS/36) to 2.56mg/g (initial soil). Manganese (Mn) ranged from 17.98mg/g (only Bontera; TMS3168/UMUCASS/36). Copper (Cu) ranged from 0.64mg/g (only 75%F; TMS3168/UMUCASS/36) to 1.62mg/g (Bontera + 100%F; TMS3168/UMUCASS/36). There was no Aluminum in all the soil treatments. All the results are presented in table 3.

Table 3: Physical and Physico Chemical Properties of the Soil before Planting and after Harvest

Treatment	Cultivar	pH (1:1) H_2O	% OC	% N	Mg/g P	Cmol/kg Ca	Cmol/kg Mg	Cmol/kg K	Cmol/kg Na	Cmol/kg Acidity	Cmol/kg Al	Cmol/kg ECEC	Mg/g Mn	Mg/kg Fe	Mg/kg Cu	Mg/kg Zn	% Clay	% Silt	% Sand
Before planting		4.71	1.484	0.154	23.110	4.218	0.957	0.184	0.748	0.64	0.00	6.747	31.26	16.74	0.96	2.56	8.6	17.4	74.0
Control	TME419	4.55	2.115	0.219	11.581	2.721	0.708	0.082	0.661	0.40	0.00	4.572	19.62	16.82	1.27	2.71	6.0	17.4	76.6
	TMS3168	5.09	1.781	0.185	12.264	3.640	0.838	0.084	0.648	0.40	0.00	5.611	21.63	17.74	1.39	2.52	6.0	13.4	80.6
Only Bontera	TME419	5.18	1.670	0.173	18.242	3.733	0.896	0.108	0.774	0.56	0.00	6.072	22.10	19.26	1.06	2.10	1.0	13.4	76.6
	TMS3168	5.13	1.855	0.192	12.605	2.759	0.655	0.093	0.961	0.56	0.00	5.028	17.98	18.60	0.65	1.89	12.0	15.4	72.6
Bontera + 100%F	TME419	4.87	1.447	0.150	18.157	3.009	0534	0.077	0.913	0.72	0.00	5.254	22.40	21.16	0.81	1.99	10.0	15.4	74.6
	TMS3168	4.84	1.707	0.177	14.484	2.451	0.549	0.088	0.709	0.80	0.00	4.597	18.01	18.07	1.62	1.89	8.0	17.4	74.6
100%F	TME419	4.72	2.189	0.227	17.986	2.572	0.594	0.095	0.822	0.56	0.00	4.643	22.03	23.06	1.47	2.16	10.0	15.4	74.6
	TMS3168	4.66	2.078	0.216	14.826	2.721	0.609	0.114	0.818	1.12	0.00	5.381	19.98	21.48	1.05	2.11	8.0	17.4	74.6
Bontera + 75%F	TME419	4.84	2.041	0.212	14.655	3.334	0.627	0.087	0.861	0.96	0.00	5.869	24.10	18.02	0.84	1.95	12.0	15.4	72.6
	TMS3168	4.89	2.041	0.212	16.619	3.027	0.604	0.072	0.631	0.96	0.00	5.294	21.52	18.65	0.83	2.36	10.0	19.4	70.6
75%F	TME419	4.80	2.152	0.223	15.851	3.651	0.701	0.093	0.918	0.96	0.00	6.232	19.63	19.23	0.82	2.39	12.6	29.4	68.0
	TMS3168	4.74	1.744	0.181	16.363	2.785	0.539	0.082	0.783	0.64	0.00	4.829	24.52	20.98	0.64	2.41	10.6	15.4	74.0
Bontera + 50%F	TME419	4.84	2.152	0.223	24.647	3.121	0.733	0.099	0.696	0.64	0.00	5.289	27.45	34.24	1.20	2.30	12.6	15.4	72.0
	TMS3168	4.73	4.118	0.427	23.025	3.542	0.775	0.085	0.631	0.64	0.00	5.673	20.46	23.80	1.12	2.73	12.6	17.4	70.0
50%F	TME419	4.72	1.670	0.173	19.267	3.285	0.767	0.093	0.787	0.40	0.00	5.333	21.76	17.93	1.29	2.12	10.6	17.4	72.0
	TMS3168	4.72	2.152	0.223	17.046	3.034	0.698	0.082	0.779	0.56	0.00	5.153	25.03	19.42	1.24	2.24	12.6	19.4	68.0

B +100%F: Bontera + 100% Fertilizer; 100%F: 100% Fertilizer; B+ 75%F: Bontera + 75% Fertilizer; 75%F: 75% Fertilizer; B+ 50%F: Bontera + 50% Fertilizer and 50%F: 50%Fertilizer

Source: Author's Data generated

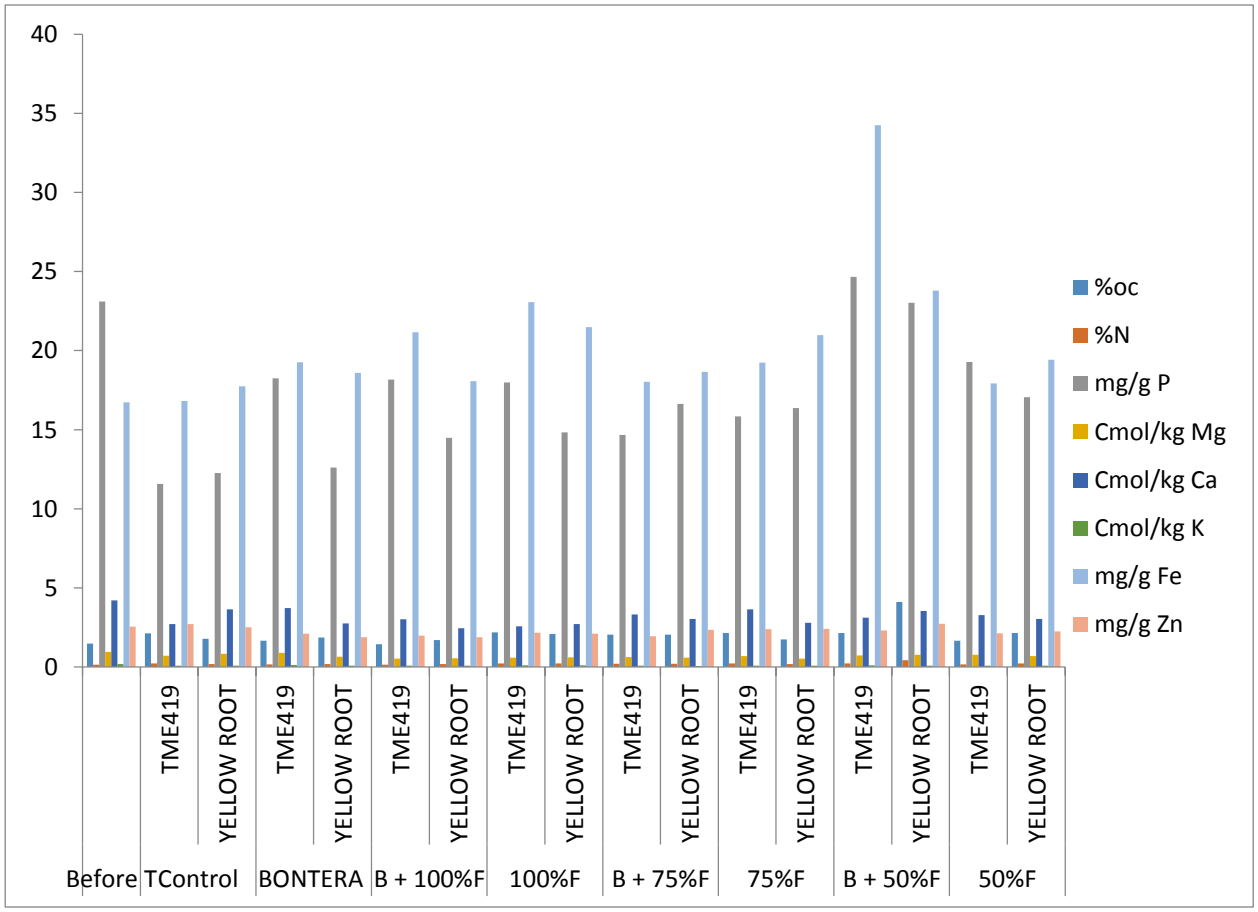

Fig. 1: Showing the Nutrients Status before and after Treatment of Some Primary Nutrients

8 DISCUSSION

From the results shown in table 3, the pH of all the treatments is in the range that all nutrients will be accessible by plant easily. The result simply indicates that the activities of the microbes, generated in the soil, resulting from the application of the microbial soil enhancer, which is a prebiotic, improved the availability of these nutrients. It clearly showed that the number of nutrients removed was highest in the control where neither fertilizer nor microbial soil enhancer was applied, especially, Nitrogen (N), phosphorus (P) and potassium (K) that are needed in large quantity in a crop like cassava in this study. It was also observed that the treatment with both microbial soil enhancer and inorganic fertilizer (NPK), at 50% (10g/plant) rate had the highest yield (52.92 ton/ha), the highest organic matter, and increase in other nutrients especially, P, Fe, and Zn that are essential for plant growth, development, and productivity. This indicates that with microbial soil enhancer and 50% fertilizer, both the plants and microorganisms were favored. The nutrients available were sufficient for both groups, and facilitated immobilisation; which is the conversion of nutrients from inorganic (soluble) form to organic form, making it not readily available to plants and microorganisms, to control excesses and mineralisation; which is the conversion of nutrients from not readily available state, to readily available state through microbial activities, in the forms plants take them up. The result also revealed that among the cultivars used, Yellow Root (TMS 3168/UMUCASS/36) was more favored and does better than TME 419 in most of the treatments. The prebiotic applied, facilitated the multiplication of microbes which in turn increased the nutrient status of the soil, through immobilisation and mineralisation. The humic and fulvic substances, in this microbial soil enhancer, facilitated the increase of many essential nutrients and organic matter. However, there was no significant difference at 0.5 level of probability, in the nutrients and organic matter levels, irrespective of increase and decrease among all the treatments.

8.1 Microbes and Soil Improvement

These microorganisms, bind soil particles together through their secretion activities. These activities improve the soil structure, increases soil water infiltration and also improve the water holding capacity of the soil (Ingham, 2009; Hoorman, 2016). They decompose

organic remains through enzymes released into the soil. The microbial waste that protozoa and nematodes excrete is ammonia ($NH+_4$), which is one of the forms through which plants take up nitrogen. Nitrite bacteria (Nitrosomonas spp.) convert the ammonia into nitrites ($NO-_2$) and Nitrate bacteria (Nitrobacter spp.) convert nitrites to nitrate ($NO-_3$).

According to Lowenfels and Lewis (2006), aerobacteria of the different genus; Aerobacter and actinomycetes bacteria of the genus Streptomyces, give a soil a good earthy smell. Aerobic bacteria use oxygen to decompose most carbon compounds. Azobacter, Azospirillum, and Clostridium do not need a host plant to fix nitrogen into the soil (Hoorman *et al*, 2011). They live freely in the soil. The soil structure is also improved by the polysaccharides or glycoproteins produced by bacteria, which coats the surface of the soil particles by cementing sand, silt, and clay into a stable structure (Hoorman, 2016). Bacteria in the genera, like Bacillus, Sporosarcina, Spoloactobacilus, Desulfotomaculum, and Clostridium produce urease enzyme and is used for bio mediation and soil rehabilitation techniques (Kucharski *et al*, 2006). Penicillium possesses an important property, which is its ability to act in as low as 3-4ºC where root development and phosphorus availability are usually limited. Rhizobacteria are good plant growth promoters. They colonize the plant roots and stimulate growth. Bacillus spp. Are good in solubilizing phosphorus (P) and have the advantage of forming stress-resistant in plants. According to Umar *et al* (2016), Fusarium enhanced root enlargement. Fusarium also facilitated the development of tap and lateral roots in the plant (Yigit and Dikilitas, 2008) which means for a crop like cassava, Fusarium will facilitate an increase in the number of roots and enlarge root size which are key components of yield determination. Hence, for crops like cassava in which the root is the major economic need, the presence of Fusarium which was introduced by the application of the microbial soil enhancer, will improve yield. Staphylococcus checks and balances the growth and multiplication of other microbes. According to Jacquemyn *et al* (2013), Staphylococcus has been found to be a nectar- inhibiting/preventing microbes. Staphylococcus is associated with inorganic fertilizers. And its multiplication is favored at a lower rate or an average quantity of fertilizer applied. Hence, when microbial soil enhancer is applied with 50% rate of fertilizer that is supposed to be applied to a soil, it provides an atmosphere where the microbes are generated in a moderate rate, not becoming overpopulated to cause harm to the soil but an average population whose activities, will enhance the soil structure, texture, bulk density and improve the soil organic matter and fertility, through immobilisation and mineralisation. In the treatment where only microbial soil enhancer was applied, the microbial soil enhancer eradicated staphylococcus, likewise where 100% fertilizer was applied staphylococcus was eradicated. In other words, excess nutrients prohibit staphylococcus and this may lead to an excess multiplication of microbes, or accumulation of not utilised synthetic substances, that might turn to be disastrous to plant and the environment instead of its main purpose, of sustaining soil for better productivity and agricultural continuity.

8.2 Microbes and Plant Protection

Beneficial microbes also known as rhizospheric microorganisms suppress diseases in the soil (Grotz, 2014; Hoorman, 2016). They reside in the rhizosphere of the soil, and participate in active plant growth, by inducing root exudation, enhancing the availability of nutrients to plants, and releasing growth regulators, and help in soil-borne disease suppression or control. Many soil bacteria produce antibodies that protect plants from disease-causing organisms and plant pathogens. Different types of bacteria compete for the same soil nutrients, and water which tends to balance the system by reducing the population of disease-causing organisms, since the population of pro-bacteria are more than the pathogenic bacteria population. Actinomycetes produce more than 50 different antibiotics, to protect plants from pathogenic bacteria (Sylvia *et al*, 2005). They have large filaments or hyphae, and act similar to fungus in processing soil organic remains, which are difficult to decompose (Chitin, lignin, etc.). When actinomycetes die, maybe during processing the land through tillage, they release "geosmin" which is the cause of smell as a characteristic of newly plowed soil (Hoorman, 2016). According to Ingham (2009), Actinomycetes are more active and decompose many substances at high soil pH levels. Actinomycetes play an important role in forming stable humus, which enhances soil structure, improves nutrient storage, and increase water holding capacity of the soil (Hoorman, 2016). Many photosynthetic bacteria colonize the soil, recycle N, C, P, and other soil nutrients to produce organic matter.

Pseudomonas species are a group of pro-bacteria required for biological control of pathogens and bioremediation (Ganeshan and Kumar, 2007). They promote growth in a plant, protect and reduce severity in plant fungal diseases (Hoffland *et al*, 1996; Wei *et al*, 1996). O'Sullivan and O'Gara (1992), also reported that pseudomonas control pathogens, by the secretion of some secondary metabolites (antibodies, siderophores and hydrogen cyanides). They also produce urease. Bacillus spp. and Klebsiella aerogens are good in urea production and for environmental soil bioremediation.

8.3 Microbial soil enhancer and Bioremediation

Many agricultural lands are lost to pollution. They are contaminated or polluted with compounds that are difficult to decompose (recalcitrant). But with the use of microbial soil enhancer that introduces many microbes, such lands can be remediated. Microbes like Actinomycetes have the ability to break down such hard to decompose compounds (Hoorman, 2016). Mucors are

good in loosing bonds of many hard compounds that are hazardous to the environment. Ane *et al* (2013), reported that fungi like Aspergillus, mucor spp. and Fusarium are good in degrading synthetic substances like herbicides, organophosphate compounds like glyphosate, and developing in culture media containing herbicides mainly as a source of carbon and phosphorus. They said that the degradation occurs by glyphosate oxidoreductase which breaks off the glyphosate C-N bond to produce aminomethylphosphonic acid and glyoxylate. Mucor rouxii can be used for the stereoselective reduction of β-keto-esters. Hence, mucor is a good bioremediation source. *Rhizopus aryzae* is capable of exhibiting versatility in the transformation of a wide range of xenobiotics as steroids, terpenes and aromatic compounds (Dijksterhius and Samson, 2006).

8.4 Microbial Soil Enhancer and Cost Management

The use of microbial soil enhancer will reduce the cost of labor. It will reduce the cost of nutrients sources like fertilizers and solid organic nutrients sources like manure, poultry droppings, cow dungs, etc. The transportation of microbial soil enhancer to farm or location to be used is very easy compared to other nutrients sources. Only one person can carry the whole microbial soil enhancer to be used in a whole hectare of farmland with ease, but fertilizers, manure, poultry droppings and cow dungs to be used in a hectare will involve more labors. The use of microbial soil enhancer for bioremediation will not involve labor and cost as an ex-situ bioremediation process will.

9 CONCLUSION

To maintain high productivity and sustain the soil health for sustainable production and agricultural continuity, the use of microbial soil enhancer should be encouraged. For effective utilisation of microbial soil enhancer and to prevent disaster, microbial soil enhancer should not be used in a virgin soil or a fertile soil. It can be used from the second or third time of cultivating on that same piece of land depending on the crop planted and the level of nutrients removed. Supplementing it with inorganic fertilizer at lower rate gives a better result. Microbial soil enhancer should be encouraged, because it is also good for bioremediation. And it will help to reclaim more agricultural lands lost to pollution, which in turn will increase the available arable land.

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