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Comparing the Effects of Indigenous, Effective Microorganisms and NPK Fertilizers on Soil Fertility and Productivity of Groundnut in the Western Region of Cameroon

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Abstract: Groundnut (*Arachis hypogaea*) is one of the main legumes consumed because of its nutritional importance to humans and animals, and is currently produced in Cameroon below the national demand. The objective of the study was to evaluate the effect of indigenous microorganism fertilizers (IMO), effective fertilizers (EM) and NPK on soil fertility and productivity of *Arachis hypogaea*. The experiment was conducted in the West region of Cameroon (Baboutcha-Fongam). It was based on a field trial with an experimental design consisting of completely randomized blocks with three treatments: Indigenous Microorganisms (IMO), Effective Microorganisms (EM) and NPK. The blocks were separated into plots, and each of them was enriched with different doses of EM, IMO and NPK (0, 10, 20, 40 g) and (3.2 g) with three replications each. Results showed that EM, IMO and NPK increased soil fertility. Overall, the application of EM, IMO and NPK significantly (p-value < 0.05) increased the growth parameters compared to the control. The best pod and seed yields were obtained at the 10 g (2.3 ± 0.2 and 2.05 ± 0.3 t/ha), 20 g (1.9 ± 0.3 and 1.99 ± 0.14 t/ha) and 3.2 g (2.3 ± 1 and 2.03 ± 0.24 t/ha) doses of IMO, EM and NPK respectively. These yields were higher or similar in plots amended with IMO and EM fertilizers than in plots amended with NPK. IMO and EM fertilizers worked at lower doses and can be considered as valuable fertilizers to serve as a suitable alternative to chemical fertilizers.

Keywords: *Arachis hypogaea*, IMO, EM, NPK Yield

1. Introduction

The population of Cameroon is estimated to be around 25 million by 2030 [1] therefore insinuating that food prodution should also be increased in order to feed this growing population. The contribution of crops with high nutritional value must be encouraged, and groundnut, is one of the main seed legumes consumed due to its importance in the dietary habits of the populations [2]. It's a source of lipid, proteins and minerals, with the seeds containing about 45-50% lipids, 25-30% proteins, 5-12% carbohydrates and 3% fiber, 92 mg Ca, 168 mg Mg, 376 mg P, 4.6 mg Fe, 3.3 mg Zn, 6.5 g water, 2374 KJ (567 Kcal) of energy and vitamins A, B and C [3]. Peanuts have a high nutritional value because of their content of amino acids and essential fatty acids that the human body cannot synthesize [4, 5]. In Cameroon, groundnut cultivation is of nutritional interest as a lipoprotein supplement to an exclusively cereal or starch-based diet [6, 7]. However, national production is insufficient to meet the demand for raw materials. To meet this challenge, farmers must acquire new knowledge, methods and tools to produce food in quantity and quality, while reducing chemical inputs of fertilizers and phytosanitary products that are harmful to natural resources and human health. An alternative approach, relatively innovative, is the use of biostimulants, biofertilizers and biopesticides that, integrated with the required precautions in the current cultivation systems, allow the optimization of the biological processes of the soil and the physiology of the plants to strengthen their immunity and taste quality, while guaranteeing good levels of yield. Biostimulants, biopesticides and biofertilizers, derived from natural products and processes, are a very promising alternative for producers, who need to revive innovative traditional agroecological practices and techniques. Biofertilizers IMO (Indigenous microorganisms), are made of beneficial soil microorganisms that can be collected from uncultivated soils and are often found in high concentrations in the presence of earthworms and in the undergrowth. Nutrient uptake by plants is stimulated when the diversity and activity of these IMO becomes intense, thus promoting rapid decomposition of organic matter [8]. These microorganisms increase the availability of nutrients for the host plants and increase the water holding capacity, which allows the plants to have enough water all the time. They catalyze chemical reactions produced in the soil by producing many enzymes, antibiotics, organic acids and various complexes. EMs (Effective microorganisms), consist of aerobic and anaerobic effective microorganisms, including different microorganisms such as lactic acid bacteria (Lactobacillus casei), photosynthetic bacteria (Rhodopseudomonas palustris), yeasts (Saccharomyces cerevisiae) and others. These are beneficial microorganisms that exist naturally in the environment in conjunction with harmful microorganisms, but can thrive in the right environment and can contribute to agricultural practices [9]. The microorganisms in EMs are not genetically modified. The perfect symbiosis of effective microorganisms creates significant regenerative forces that develop sometimes very surprising effects in different environments. These microorganisms can be diluted and used as a spray to improve plant growth, or combined with organic matter to make bokashi and compost. They can also be combined with plant extracts to suppress crop diseases [10] (Higa, 1991). Thus, inoculation of crops with EM and IMO could improve soil quality, growth, yield and crop quality [11]. However, the use of mixed cultures of beneficial microorganisms as a soil inoculant to enhance growth, and crop quality is still poorly understood [12]. Data to support the use of EM and IMO in the cultivation and production of peanut at Baboutcha-Fongam are still lacking.

2. Materials and Methods

2.1. Description of the Study Site

Baboutcha-Fongam is located in the Western region of Cameroon, Haut-Nkam Division and in the Bakou District. It lies between 5°02' N latitude and 10°09' E longitude with an altitude of 1030 m. Its climate is tropical, hot and humid. It is characterized by two seasons with a long rainy season (about 9 months) that runs from March to November and a short dry season that runs from December to February. The average annual rainfall is 1467.5 mm. The monthly temperature varies from 22.8°C in July and August to 27.7°C in February with an annual average of 22.5°C. Relative humidity varies from 70.5% in May to 89.8% in August with an annual average of 79.5%. The experimental soil is classified in the agro-ecological zone of the Western Highlands with monomodal rainfall. The soils are predominantly ferralitic, characterized by sandy-clay or silty-sandy formations containing permanent water. Granite rocks are dominant, with average organic matter and major mineral element contents. This results in a good cationic exchange capacity (CEC). Their pH is always acidic and increases with depth. The relief is that of lowlands surrounded by various hills and mountains [13].

2.2. Preparation of the Experimental Plot

An experimental plot of 400 m² was cleared, ploughed and divided into two blocks. Each block was divided into three subplots (representing the replications) with five treatments each. Plot size was 4 m x 2 m in area. The spacing between blocks was 1 m and between subplots within each block 0.5 m and 0.4 m between peanut plants.

2.3. Preparation and Application of IMO, EM and NPK Biofertilizers

IMO (Indigenous Microorganisms) was prepared using local materials as described by the method of Park and DuPont (2008) [14], while EM (Effective microorganisms) was prepared by the method of Higa (1991) [10]. In addition, NPKs were purchased from a plant protection products sales store. One input was applied to the soil one week before sowing, the second input was applied at 5 weeks after sowing, and 6 weeks after the first amendment. The third application was applied 10 weeks after sowing, and 11 weeks after the first amendment. Each subplot received 5 treatments repeated three times with the following doses: 0, 10, 20, 40 g of IMO, EM and 3.2 g of NPK. Sowing took place one week after application of fertilizers, the seeds of A. hypogaea were sown at a rate of one seed per hole buried at a depth between 3 to 5 cm. From germination to the appearance of the first flowers, weeding was regularly carried out with a hoe every two weeks. From flowering to pod maturity, weeding was done by hand. Hoeing was done 20 days after sowing followed by weeding to limit weed competition. Ridging was done between 45-50 days after sowing at flowering to facilitate pod formation in the soil [15]. Slug pellets were applied at plot intervals. No phytosanitary treatments were applied.

2.4. Evaluation of Morphological Parameters

Collection of data (morphological parameters) was carried out at 4, 6, 9 weeks after sowing. Stem height, collar diameter, total number of leaves of the considered plant, leaf area were measured on 9 plants randomly selected on each block, either 3 plants per subplot and per treatment.

The height of the stem was measured with a tape from the collar to the end of the main stem. Collar diameter was measured with a caliper. The leaf area was calculated using the formula of Kumar *et al*. (2002) [16] as S = L x l x 0.80 x N x 0.662 (cm^2) where N is the total number of leaves of the plant under consideration, 0.80 and 0.662 are the old and new proportionality factor proposed by Murray (1960 and 2002), respectively. (l) is the sum of the maximum widths of the leaflets of the third leaf from the apex and (L) is the distance from the base to the tip of the blade of the main leaflet. The number of leaves represents the total number of leaves in an *Arachis hypogaea* plant.

2.5. Effects of Fertilizers on the Yield

After three months of cultivation, 9 plants were randomly selected from each plot to determine the number of pods per plant and the number of seeds per pod. Pod, seed and 100-seed weight yields were determined after all pods per plot were harvested.

2.5.1. Determination of Dry Weight of 100 Seed

After harvest, pods from each plot were dried under the same conditions in the sun for two months. The seeds were separated from the pods and the weight of 100 seeds was determined by weighing a batch of 100 seeds per plot using a precision balance (KERN).

2.5.2. Determination of the Number of Pods Per Plant

After harvest, the number of pods per plant was determined by hand counting in each plot.

2.5.3. Determination of Pod and Seed Yield

After harvest, the pods from all plots were sun-dried for two months, then weighed and the pod yield was calculated and reported per hectare. Next, the seeds were separated from the pods and sorted. The normal seeds were weighed and their yield was calculated and reported per hectare according to the formula [34]:

Pod yield = Total pod mass (t)/area (ha)

Seed yield = Total seed mass (t)/area (ha)

2.6. Statistical Analysis

Data were entered into an Excel sheet (Microsoft Office, USA) and analyzed with Statview version 5.0 (SAS Institute, Inc., USA) and Graphpad Prism 5.0 software. Data were presented as mean ± standard deviation (SD) in graphs and tables. One-factor ordered analysis of variance (ANOVA) was used to make comparisons of parameters (height, number of leaves, leaf area, diameter). Dunnett's test and Student's T-test were then used to make pairwise comparisons. Repeated measures ordered analysis of variance (ANOVA) was used to study the variation of these parameters. Nonparametric Mann-Whitney, Wilcoxon, and Kruskal Wallis tests were used to compare mean values when the assumptions of the above tests were not met. The significance level was set at p-value < 0.05.

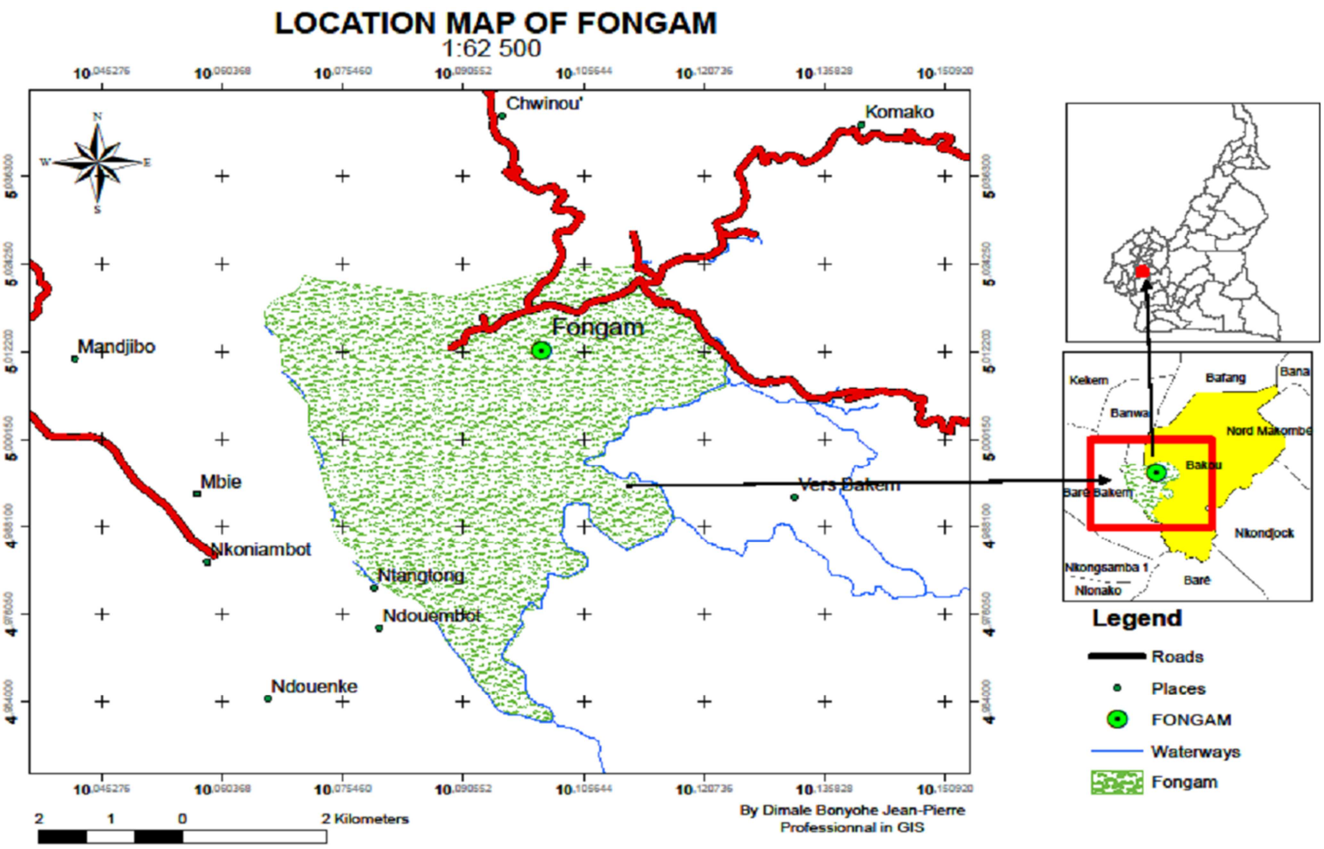

Figure 1. *Location map of Baboutcha-Fongam.*

3. Results

3.1. Evaluation of the Effect of IMO and EM on Soil Fertility

3.1.1. Physical Analyses

The granulometric analyses made it possible to determine the texture of the soil samples. The Baboutcha-Fongam soil shows a predominance of sand (71.5% = 41.5 + 30) and clay (17%) (table 1).

Table 1. *Soil texture of the experimental site.*

Granulometry (%)				
Clay	**Coarse sand**	**Fine sand**	**Coarse silt**	**Fine silt**
17 ± 1	41,5 ± 1,5	30 ±1	7 ±1	4,5 ± 1,5

3.1.2. Chemical Analysis

From a chemical point of view, the average values of the main chemical characteristics of the analyzed soil samples are presented in the tables.

a) pH

The soil of Baboutcha-Fongam, had a pH-H_2O of 6.5 before application of fertilizers. However, these pH values decreased with the application of IMO, EM and NPK fertilizers in the plots where they were applied. From 5.4 in the plots amended with IMO, from 5.3 in the plots amended with EM, and from 5.5 in the plots amended with NPK.

b) Total Nitrogen Content and C/N Ratio

The Baboutcha-Fongam soil, before fertilizer application, had very poor nitrogen contents of 0.042 ± 0.001% with a very high C/N ratio of over 14. In this zone, plots treated with IMO had very high nitrogen contents ranging from 0.34 ± 0.006% with a normal C/N ratio of 10.61 ± 0.05. However, plots treated with EMs had rich nitrogen contents of 0.28 ± 0.004% with a high C/N ratio of 13.35 ± 0.4. While the plots treated with NPK showed rich nitrogen contents of 0.21 ± 0.006 with a very high C/N ratio of 16.34 ± 0.7 (Table 2).

c) Organic Matter Content

The organic matter content of the soil was 3.8 ± 0.01% in 2019 to 6.4 ± 0.1 before fertilizer application. It increases from 5.5 ± 0.01 in the plots amended with IMO, 4.5 ± 0.1 in the plots amended with EM and 6.7 ± 0.1% in the plots amended with NPK (Table 2).

d) Saturation Rate of Exchangeable Bases and CEC

In the Baboutcha-Fongam soil, the saturation rate was 0.32 Cmol/kg for calcium; 0.18 for magnesium; 0.5 for potassium; 0.01 for sodium; and 0.1 for aluminum with an average CEC of 13.88 ± 0.6 cmol/Kg before fertilizer application. After application of fertilizers, the plots treated with IMO presented a saturation rate of 2.74 cmol/kg for calcium; 0.42 for magnesium; 1.93 for potassium; 0.12 for sodium; 0.97 for aluminum with an average CEC of 13.68 ± 0.3 cmol/Kg. While the plots treated with EM presented a saturation rate of 3.71 Cmol/kg for calcium; 1 for Magnesium; 0.45 for potassium; 0.021 for sodium; 1.1 for aluminum with an average CEC of 15.22 ± 0.6 cmol/Kg. For the plots treated with NPK, the saturation rate was 2.64 Cmol/kg for calcium; 0.67 for magnesium; 1.2 for potassium; 0.021 for sodium; 0.07 for aluminum with an average CEC of 12 ± 0.5 cmol/Kg (Table 2).

e) Assimilable Phosphorus Content

The soil had very low levels of available phosphorus at 4.9 ± 0.1 ppm. In this zone, plots amended with IMO and EM had very low levels of available phosphorus, while plots amended with EM had low levels of available phosphorus. On the other hand, the plots amended with NPK have a very low content of assimilable phosphorus (Table 2).

f) Electrical Conductivity

The electrical conductivity (EC) of the soil was 0.15 ms/cm before fertilizer application. The plots amended with IMO had an EC of 0.09 ms/cm, that of EM had 0.08 ms/cm, and with NPK had an E.C. of 0.07 ms/cm (Table 2).

Table 2. *Soil analysis of Baboutcha-Fongam before and after ferlitizer application.*

Parameter	Units	T0	T1	IMO	EM	NPK
Nitrogen	%	0.88 ± 0.2^c	3.59 ± 0.02^a	3.61 ± 0.02^a	3.74 ± 0.08^a	3.415 ± 0.04^b
Organic C	%	0.042 ± 0.001^d	0.21 ± 0.004^b	0.34 ± 0.001^a	0.28 ± 0.004^c	0.21 ± 0.006^b
C/N Ratio		20.95 ± 0.26^a	17.1 ± 0.6^b	10.61 ± 0.05^c	13.35 ± 0.7^a	16.26 ± 0.7^b
Organic matter	%	3.8 ± 0.01^e	6.1 ± 0.14^b	5.5 ± 0.01^c	4.5 ± 0.1^d	6.7 ± 0.1^a
Phosphorus ass	(ppm)	4.9 ± 0.1^d	17.12 ± 0.5^c	20.4 ± 1.5^b	$35.\ 33 \pm 1.03^a$	20.121 ± 12.83^b
pH water		6.5±0.1a	5.5± 0.15b	5.4± 0.1b	5.3± 0.15b	5.5± 0.1b
CEC	(Cmolc/Kg)	13.88 ± 0.6^b	13.56 ± 0.25^b	13.68 ± 0.3^b	15.22 ± 0.6^a	12 ± 0.5^c
Ca^{2+}	(cmol/kg)	0.32 ± 0.01e	1.64 ± 0.01d	2.74 ± 0.01b	3.71 ± 0.015a	2.64 ± 0.015c
Mg^{2+}	(cmol/kg)	0.18± 0.01e	0.45± 0.015c	0.42± 0.02c	1± 0.12a	0.67± 0.01b
K^+	(méq/100g)	0.5± 0.01d	2.35± 0.01a	1.93± 0.02b	0.45± 0.01e	1.2± 0.01c
Na^+	(méq/100g)	0.01±0.006c	0.025± 0.001b	0.12± 0.01a	0.021±0.004b	0.021± 0.1b
Al^{3+}	(méq/100g)	0.1±0.01c	0.9±0.1a	0.97 ±0.01a	1.1± 0.1a	0.07±0.01c
EC	(ms/cm)	0.15±0.015a	0.09±0.01a	0.09±0.01a	0.08±0.01a	0.07± 0.005a

The values are expressed as mean ± SD. Means in the same column followed by different letters are significantly different according to Duncan's multiple tests at 5%. SD: Standard deviation; T0: Control; T1: Control after fertilizer application; P0: Sampling before fertilizer application; P: Mean sampling after fertilizer application; CE: Electrical conductivity.

3.2. Influence of IMO, EM and NPK on Peanut Productivity

3.2.1. Influence of IMO, EM and NPK on Growth Parameters

a). Stem Height

The stem height of *A. hypogaea* plants grown at Baboutcha-Fongam according to the different treatments is presented in Figure 2. Overall, there was a significant increase ($p < 0.05$) in this height as a function of time. The amendment of these plants with IMO, EM and NPK fertilizers resulted in a significant increase ($p < 0.05$) in the height of the stem compared to the control. The height of the controls evolved from 13 cm at the first week (S1) to 33 cm at the third week (S3) while with IMO this height varied from 20 cm at the first week (S1) to 59 cm at the third week (S3). Similarly with EM, this height increased from 19 cm in the first week (S1) to 57 cm in the third week (S3). With NPK, the height was increased from 19 cm in the first week (S1) to 50 cm in the third week (S3). In addition, the plants treated with IMO and EM fertilizers showed the highest heights (59.22 ± 0.59 cm) and (57.47 ± 1.65 cm) respectively compared to the plants treated with NPK fertilizer (50.17 ± 2.41 cm). However, the plants treated with IMO biofertilizer at 10 g dose recorded the highest heights compared to the plants treated with EM biofertilizer (Figure 2).

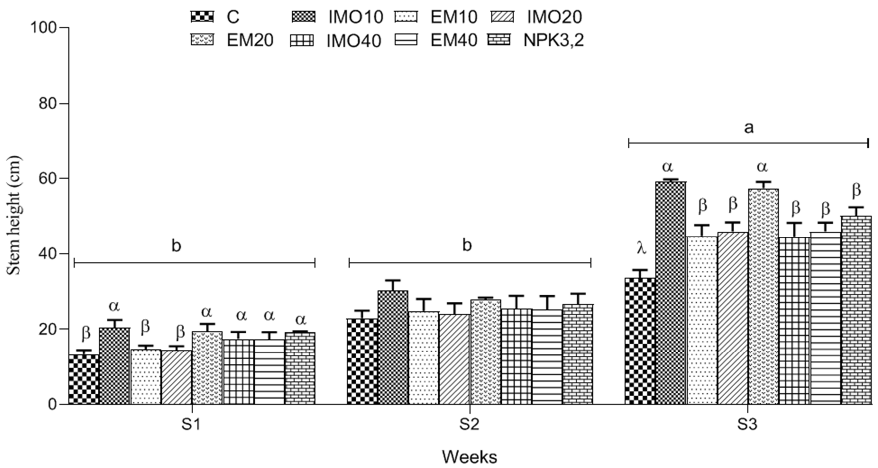

Figure 2. Effect of fertilizers on Stem height of A. hypogaea plants. Bands with the same letters, and the same symbols within the same group do not differ significantly based on the turkey test at (LSD, p < 5%).

b). Number of Leaves

There was a significant increase at ($p < 0.05$) in the number of leaves as a function of time. The average number of leaves of the control was 21 at week S1 to 82 at week S3 while with the IMO the number of leaves was already 30 at week S1 to 104 at week S3. Similarly with EM, the number of leaves increased from 29 in week S1 to 95 in week S3. With NPK, the number of leaves was 30 at week S1 to 107 at week S3. Overall the number of leaves increased with the doses of these fertilizers compared to the control. There was a significant difference ($P < 0.05$) between the treatments and the controls, except for the IMO and EM fertilizers at the 40 g dose in week S3, which resulted in a decrease in the number of leaves compared to the control. Plants treated with NPK and IMO fertilizers showed the highest leaf number values (107 ± 3.59) and (104 ± 5.3) compared to plants treated with EM biofertilizer (95 ± 2.41) (Figure 3).

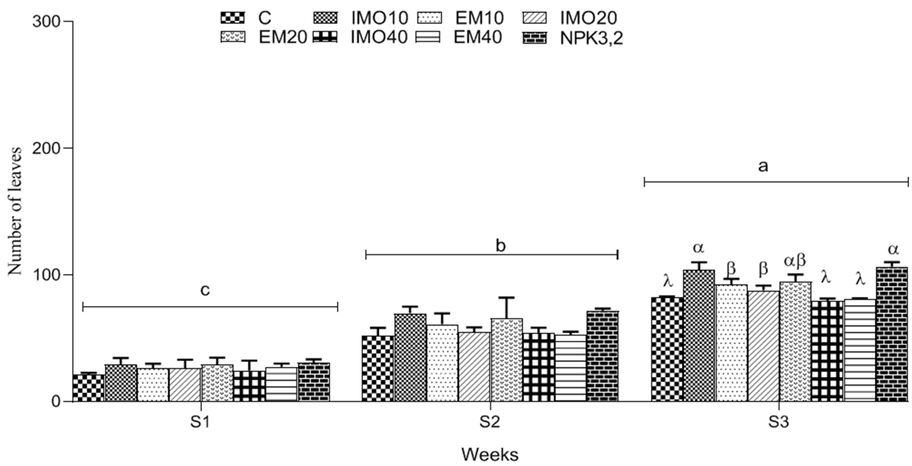

Figure 3. Effect of fertilizers on number of leaves of A. hypogaea plants. Bands with the same letters, and the same symbols within the same group do not differ significantly based on the turkey test at (LSD, p < 5%).

c). Collar Diameter

The amendment of groundnuts with these fertilizers led to an increase in the collar diameter compared to the control. That of the control increased from 0.21 cm at week S1 to 0.32 cm at week S3 while with the IMO the diameter of the collar was already 0.24 cm at week S1 then 0.53 cm at week S3. EM had an increase in the collar diameter from 0.23 cm at week S1 to 0.53 at week S3. With NPK, the collar diameter was 0.23 cm at week S1 and 0.55 cm at week S3. Plants amended with NPK (0.55 ± 0.01 cm) showed the highest values of crown diameter compared to those treated with IMO (0.53 ± 0.01cm) and EM (0.53 ± 0.01cm). There was a significant difference (P < 0.05) between IMO (20 and 40 g), EM (20 and 40 g) and control treatment and other treatments on the other hand at week S3 and S2 (Figure 4).

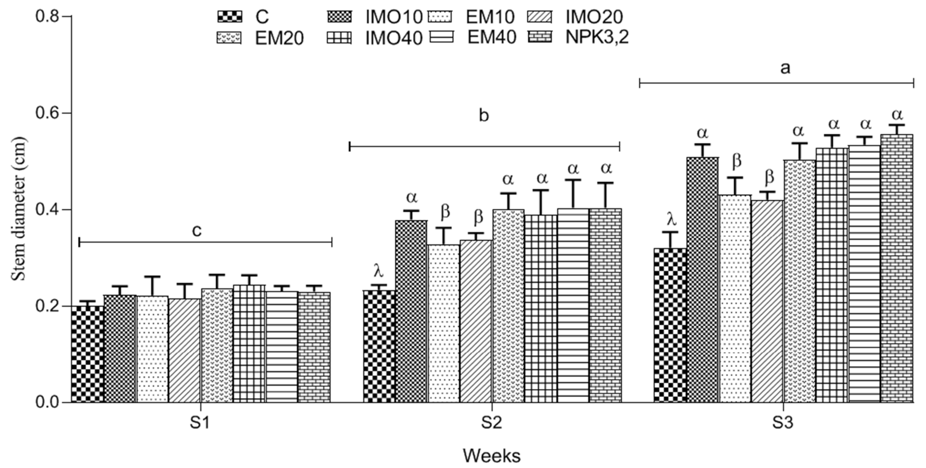

Figure 4. Effect of fertilizers on diameter at the collar of A. hypogaea plants. Bands with the same letters, and the same symbols within the same group do not differ significantly based on the turkey test at (LSD, p < 5%).

d). Leaf Area

There was an increase in leaf area as a function of time. The leaf area of the controls was 2555.35 cm² at week S1 and 4731.68 cm² at week S3 while with IMO this area was already 3284.15 cm² at week S1 and 4785.96 cm² at week S3. Similarly with EM, the leaf area increased from 3268.57 cm² at week S1 to 5111.94 cm² at week S3. For NPK, the leaf area was 3369.71 cm² at week S1 and 4821.69 cm² at week S3. The plants treated with EM biofertilizer showed the highest leaf areas (5111.94 ± 1455.42 cm²) compared to the plants treated with NPK (4821.69 ± 1095.21 cm²) and IMO (4785.96 ± 891.94 cm²) fertilizers (Figure 5).

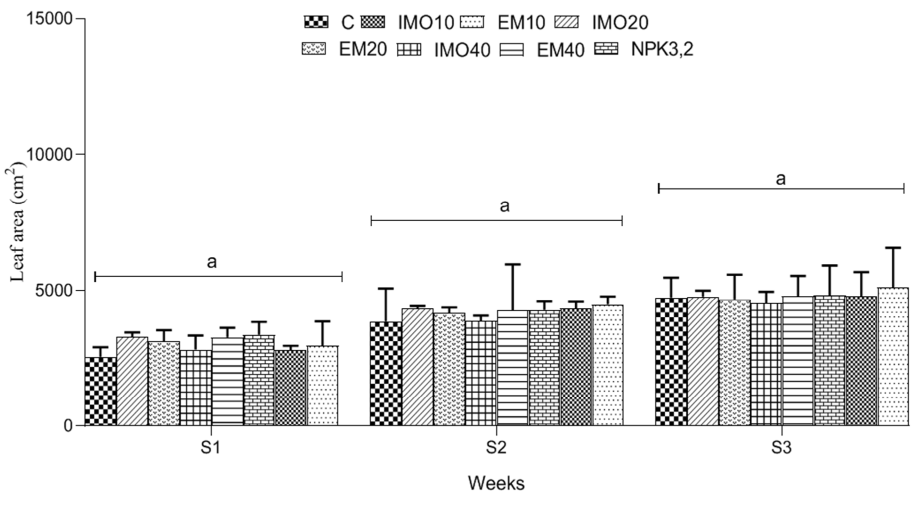

Figure 5. Effect of fertilizers on leaf area of A. hypogaea plants. Bands with the same letters, and the same symbols within the same group do not differ significantly based on the turkey test at (LSD, p < 5%).

3.2.2. Evaluation of the Yield

The application of IMO, EM and NPK fertilizers positively influenced the yield of *A. hypogaea*. The number of pods per plant, 100-seed weight, pod and seed yields increased with the different doses of the fertilizers compared to the control.

Overall, a significant increase (p< 0.001) in these parameters was observed after application of increasing doses of EM biofertilizer except for the 40 g dose for the 100-seed dry weight parameter. The number of pods per plant for example increased from 24 ± 1 at the control dose (0 g) to 35.3 ± 3.5 at the 20 g dose. Pod and seed yields increased from 0.915±0.1 t/ha and 0.83±0.02 t/ha at the control dose (0 g) to 1.9 ±0.03 t/ha and 1.99±0.14 t/ha at the 20 g dose, respectively (Table 3).

For the biofertilizer IMO, a significant increase (p<0.001) in all parameters at the different doses was observed except the 40 g dose. Then, the latter underwent a decrease at the 20 and 40 g doses for the 100-seed dry weight parameter. The number of pods per plant increased from 25.33 ± 3.2 for the control dose (0 g) to 35.7 ± 2.5 at the 10 g dose, then it was 30.3 ± 5.1 and 25.7 ± 6 respectively at doses 20 and 40 g (Table 3). Regarding the yields, the highest values were obtained with the 10 g dose of IMO. They increased from 0.92 ± 0.3 t/ha and 0.85 ± 0.3 t/ha to 2.3 ± 0.2 t/ha and 2.05 ± 0.3 t/ha representing pod and seed yields respectively (Table 3). For NPK fertilizer, the number of pods per plant, dry weight of 100 seeds increased significantly (p<0.001) from 25 ±1 to 36 ± 2 and from 53.3 ± 2.6 g to 62.7 ± 4.1 g respectively. While pod and seed yields increased from 0.82 ± 0.1 t/ha and 0.63 ± 0.1 t/ha to 2.3 ± 1 t/ha and 2.03 ± 0.24 t/ha respectively (Table 3).

Table 3. *Influence of fertilizers on agronomic parameters at Baboutcha-Fongam. maens bearing the letters different are significantly different at the significance level of (* = P < 0.05; ** = P < 0.01; *** = P < 0.001). According to the student test.*

Fertilizers	Doses (g)	Variété améliorée (JL24)			
		Number of pods per plant	Dry weight of 100 seeds (g)	Yield in pods (t/ha)	Seeds yield (t/ha)
IMO	0	$25,33\pm 3,2^{e}$	53 ± 3^{c}	$0,92 \pm 0,3^{d}$	$0,85 \pm 0,3^{d}$
	10	$34,33 \pm 2,52^{b}$	$48,4 \pm 4,5^{d}$	$2,3 \pm 0,2^{b}$	$2,05 \pm 0,3^{b}$
	20	$30,3 \pm 5,1^{c}$	$52,2 \pm 1,6^{c}$	$2,2 \pm 0,4^{b}$	$1,8 \pm 0,1^{b}$
	40	$25,7 \pm 6^{e}$	$52,2 \pm 2,8^{c}$	$2,1 \pm 0,3^{c}$	$1,7 \pm 0,2^{b}$
EM	10	$31 \pm 3,5^{c}$	$61,3 \pm 6^{b}$	$1,6 \pm 0,4^{c}$	$1,05 \pm 0,04^{c}$
	20	$34,33 \pm 3,21^{b}$	$47,5 \pm 0,6^{d}$	$1,9 \pm 0,03^{c}$	$1,99 \pm 0,14^{b}$
	40	$20,3 \pm 5,5^{f}$	$57,9 \pm 2,5^{b}$	$1,9 \pm 0,4^{c}$	$1,4 \pm 0,4^{c}$
NPK	3,2	$28 \pm 10,82^{d}$	$50,9 \pm 4,6^{c}$	$2,3 \pm 1^{b}$	$2,03 \pm 0,24^{b}$

4. Discussion

4.1. Evaluation of the Effect of IMO and EM on Soil Fertility

The results of this study show that the Baboutcha-Fongam soil has a sandy-clay texture according to the USDA textural triangle [17]. The presence of clay observed in this area is believed to be the result of the strong presence of secondary minerals. On the other hand, texture controls the accumulation and cycles of organic matter, which through its humic acids, determines the stability of the soil structure [18]. Therefore, the variation in organic content in the soil depends largely on the content of clay, silt and sand.

The soil chemical analysis showed that it was characterized by an acidic to neutral pH. The acidic to neutral pH is favorable for peanut cultivation [19]. It prefers soils with pH close to neutrality. At Baboutcha-Fongam the pH decreased in the amended plots compared to the control plot. Indeed, the Babouctha-Fongam soil has a sandy-clay texture that releases more Al^{3+} ions, thus allowing for soil acidity. Also, organic matter in this type of soil is rapidly degraded by soil microorganisms and those contained in the EM and IMO fertilizers. Consequently, this degradation leads to the production of substances such as organic acids capable of inducing an increase in soil acidity while making soil minerals bioavailable [20]. These results are in confirmity with those obtained by Crozier and Hardy (2003), Zuraihah *et al*. (2012), Muyang *et al*. (2016) [21, 22, 23]. These authors showed that soil pH decreases after application of EM and IMO fertilizers. However, they point out that the pH of this soil increases with time by depletion of organic matter in the medium. The application of base-rich amendments is necessary to improve the soil response for good yields.

The electrical conductivity of the soil decreases with the application of different fertilizers. However, it remains higher in the plots treated with IMO, followed by the plots treated with EM and finally the plots treated with NPK. The EC values obtained are relatively low which explains the pH values obtained in this area. When the ionic concentration in solution exceeds a certain value the plants will undergo a "salt effect", and will no longer be able to control their osmotic pressure within their cells which will swell or dry out and then die (osmosis phenomenon). According to Fardeau (2015) [24], the EC for which plants begin to suffer is above 80 mScm-1. Only plants adapted to saline environments, such as halophytes, are able to grow above 160 mScm1.

There was an increase in available phosphorus in all amended plots compared to unamended plots. This increase can be explained by the increase in mineralization of organic matter by soil microorganisms and those contained in these fertilizers (IMO, EM). According to the Bray-2 1945 [25] method defining a fertility scale for assimilable phosphorus described by Boyer (1982) [26] and applied to our values of assimilable phosphorus indicates a very low fertility because the values obtained are lower than 40 ppm. According to Fotso *et al*. (2019) [27], phosphorus poverty is characteristic of tropical soils.

Nitrogen content remained higher in the amended plots than in the unamended plots, and higher in IMO followed by the EM and finally the NPK amended plots. Based on standards for interpretation of organic matter, nitrogen and C/N ratio (Schäfer, 1975; Calvet and Villemin, 1986; LCA,

2008) [28, 29, 30]. However, the high nitrogen levels in the plots amended with IMO can be explained by the fact that IMO is made of indigenous microorganisms. The latter adapt more easily to the mineralizing processes of organic matter, which could justify the lower pH value in the plot treated with IMO. These results are in agreement with those of Zuraihah *et al*. (2012) [22] who through their studies on *Brassica alboglabra*, *Brassica chinensis* and *Lactuca sativa* showed that the mineralization of organic matter was more in the soil treated with IMO and therefore acidic.

According to the Memento de l'agronome (1991), the Baboutcha-Fongam soil has a varying C/N ratio. Before the application of fertilizers, this ratio was higher than 14, reflecting a very slow decomposition rate of organic matter. In the plots treated with IMO, the C/N ratio is 10.61, corresponding to a well-decomposed organic matter, with a good organic matter reserve. Indeed, the level of mineralization of this organic matter reflects its level of evolution and microbial activity in the soil. In the plots amended with EM, this C/N ratio is 13.35, reflecting a reduced biological activity with slow decomposition of the organic matter. In the plots amended with NPK, this C/N ratio is 16.26, reflecting a poorly developed organic matter. Increase decomposition of organic matter in the plots amended with IMO could be explained by the high presence of nitrogen in the IMO biofertilizer. These results are in agreement with Anyanwu *et al*. (2013) [31] who showed that the application of IMO fertilizers for bioconversion in agriculture produces metabolites that facilitate the decomposition of organic wastes and increase humus quality.

The average content of the CEC is a reflection of a good level of exchange of soil minerals and therefore a good nutrition of plants. This can also be explained by the quality of the clay-humus complex, which guides the transfer of minerals between the soil solution and the crops. The Baboutcha-Fongam soil had a good organic matter content accompanied by an average nitrogen content ranging from poor before fertilization to very rich after fertilization. The high organic matter content, according to the criteria defined by Calvet and Villemin (1986) [29], would give this soil a higher nutrient storage capacity. This observation attests to the low mineralization of this organic matter also expressed by the high C/N ratio value indicating poor mineralization and especially a low nitrogen content in the control plots.

The major exchangeable elements: Potassium (K^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Sodium (Na^+) and Al^{3+} were observed with high proportions in the amended soils compared to the unamended soils. This availability of these elements in soils treated with IMO, EM and NPK fertilizers compared to the control is the result of mineralization of organic matter by the microorganisms present in these fertilizers and the addition of NPK [3]. However, these elements are higher in soils treated with IMO. On the other hand, the high values of Al^{3+} ions justify the pH and EC values observed in this area. These results could also be explained by the fact that the organic matter in the amended soil is rapidly degraded by the microorganisms contained in EM and IMO and the NPK input. Consequently, this degradation leads to the production of substances that can increase soil acidity while making soil minerals bioavailable, such as organic acids. These results are in line with those obtained by Muyang *et al*. (2016) [23]. Indeed, these authors working on the comparative study of the effects of two organic fertilizers on the physicochemical properties of the soil and the yield of potato (Solanum tuberosum. L) in the northwest region of Cameroon /(Bamenda) were able to show that these fertilizers when applied to the soil increases the availability of nutrients which boosts the fertility of these soils.

4.2. Influence of IMO, EM and NPK on Peanut Productivity

4.2.1. Effects of IMO, EM and NPK on the Growth Parameters

The study showed that IMO, EM and NPK fertilizers have a positive impact on growth parameters compared to the control. However, the IMO fertilizer was more efficient followed by the EM fertilizer and finally the NPK fertilizer for the height of the stem. Regarding the number of leaves, the NPK fertilizer had the highest number of leaves followed by IMO and finally the EM fertilizer. On the other hand, the application of these fertilizers at high dose resulted in the highest values of crown diameter and leaf area. In addition, overall, EM fertilizers recorded the highest values of crown diameter and leaf area followed by NPK and finally IMO. This may be due to the fact that EM application in the soil is generally associated with microbial biomass growth [32, 3]. In addition, inoculation of EM into the soil could improve the nutritional quality of roots which would promote good leaf photosynthesis [33]. These fertilizer inputs improve the soil fertility level, including reducing acidity and exchangeable aluminum levels and increasing exchangeable element reserves [34].

4.2.2. Determination of the Influence of IMO and EM on the Yield Parameters

Inoculation with IMO, EM and NPK fertilizers resulted in a significant increase in yield parameters (number of pods per plant, and pod and seed yields) compared to the control. The optimal fertilization rate for better growth and yield of A. hypogaea was 10 g for IMO fertilizer; 20 g for EM fertilizer and 3.2 g for NPK fertilizer. This would correspond to an optimum fertilization rate of 500 kg ha-1 of IMO; 1 t ha-1 of EM and 150 kg ha-1 of NPK. Average pod and seed yields were estimated at: 2.3 ± 0.2 and 2.05 ± 0.3 t ha-1 for IMO fertilizer; 1.9 ± 0.03 and 1.99 ± 0.14 t ha-1 for EM fertilizer; 2.3 ± 1 and 2.03 ± 0.24 t ha-1 for NPK. These results show that these fertilizers act at low doses. This could be explained by the level of CEC observed in the soil where these doses were applied. These inputs improve the level of soil fertility. Plants fertilized with IMO have a higher yield than those fertilized with NPK and EM. Plants fertilized with EM have a similar yield to those fertilized with NPK. This would be due to the fact that IMO and EM fertilizers act as soil amendments by preventing rapid mineralization followed by leaching of organic matter, which is an important source of mineral elements necessary for the good development of the plant [35], which particularly improves the structure of the soil and its capacity to retain water and nutrients which are then available for the plant [36, 37]. This would in turn justify the yields obtained with NPK fertilizers. In addition, the study showed that IMO and EM fertilizers have properties comparable to those of NPK fertilizers and can be substituted for the latter. However, application of IMO and EM fertilizers above 500 and 1000 kg ha-1 respectively resulted in lower yields. A negative plant response for excess macronutrients was explained by the plant's energy expenditure to process and remove excess osmotic solutes associated with macronutrient accumulation, energy that would have been used for growth [34]. According to Nyembo *et al*. (2012) [38] the grain filling phase is a crucial stage in the development of yield and would have been disrupted by excessive doses of mineral fertilizers producing large amounts of biomass, whose development and maintenance require a greater amount of water lead to the fall in maize yield. In this context, the treatments corresponding to low inputs of IMO and EM fertilizers lead to the best yields.

5. Conclusion

The shoot length, number of leaves, stem diameter, leaf area, pod and grain yield, nitrogen and phosphorus contents, and soil fertility were positively influenced by the IMO and EM fertilizers supply. However, the use of IMO fertilizer could be considered more to the extent that the mineralization of organic matter is more accentuated in IMO. The optimal fertilization rates for growth and yield traits of the JL 24 peanut variety studied were 10 g for IMO fertilizer and 20 g for EM fertilizer. The pod and grain yield were estimated at 2.3 ± 0.2 and 2.05 ± 0.3 t/ha respectively for IMO; 1.9 ± 0.03 and 1.99 ± 0.14 t/ha for EM.

All these results show that the use of organic fertilizers (IMO and EM) at doses of 10 g and 20 g respectively, constitutes a key element in the success of programs to improve soil fertility for good agricultural yields and thus guarantee a balanced management of natural resources. Moreover, IMO fertilizers show similar or even better results than NPK mineral fertilization. Indeed, chemical fertilizers have adverse effects on human health when used in unregulated doses. However, since IMOs are local and therefore adapted to environmental conditions, they could be a promising biological means of improving soil fertility in Cameroon.

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