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Comparative Study of the Effects of Two Organic Manures on Soil Physico-Chemical Properties, and Yield of Potato (*Solanum tuberosum L.*)

Muyang Rosaline Fosah[1, 2, *], Mbouobda Hermann Desire[1, 3], Fotso[1, 3], Foasung-Zah Elvis[1], Taffouo Victor Desire[2]

[1]Department of Biology, Higher Teachers Training College (HTTC), the University of Bamenda, Bamenda, Cameroon
[2]Department of Botany, Faculty of Science, University of Douala, Douala, Cameroon
[3]Laboratory of Plant Biology, Department of Biological Sciences, Ecole Normale Supérieure (ENS), University of Yaoundé 1, Yaounde, Cameroon

Email address:
wanfosah3@yahoo.com (M. R. Fosah)

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Abstract: A field experiment was conducted in Bambili, North West Region of Cameroon to evaluate the morphological and agronomic parameters of potato grown in soil treated with two organic manures as well as soil physico-chemical properties. A randomized complete block design (RCBD) with three treatments (EM manure, IMO manure and control), and four replications was conducted. Results showed significant differences ($P \leq 0.05$) in the height of plants and leaf area index throughout the period of experiment in plants treated with both manures. IMO manure produced taller plants (65.150 ± 17.850 cm) compared to EM manure (57.642 ± 12.146 cm) and the control plants (19.070 ± 4.215 cm). The highest leaf area index was recorded by plants treated with IMO manure followed by those treated with EM manure, and then the control. The fresh weight of tubers produced by IMO manured plants (241.64 ± 32.94 g) was higher than those of EM manured plants (227.62 ± 44.58 g), and control (125.66 ± 31.63 g). Both IMO and EM manures had significant positive effects on soil physico-chemical properties, morphological parameters, and yields. However, IMO manure had better effects. Soil physico-chemical properties revealed a decrease in electrical conductivity, total phosphorus, calcium content and magnesium content. IMO treated soil recorded the higher rate of decrease, followed by EM treated soil and control soil, total organic carbon increased while total nitrogen content did not change during experiment for manure soils.

Keywords: *Solanum tuberosum*, Manures, Yield, Soil, Properties

1. Introduction

Potato (*Solanum tuberosum*) is one of the most valuable and widely consumed tuber crops in Cameroon. The main production areas are localized in the highland zones of the West, Northwest, Southwest, Adamawa, Far north and Littoral regions [1]. In these Western Highlands of Cameroon, approximately over 200,000 smallholder farmers are involved in the production of potato. Their production makes up more than 80% of the national production, estimated at 142,000 tons per year cultivated on 45,000 ha [2]. In addition, between 1986 and 2009, these western highland farmers raised potato yields from 2.5 to 5 tons per hectare [3]. However, these yields per unit area and total production are still very low, looking at the existing potential in the area. Low yields are due to a number of restraining factors including high cost of inputs, low soil fertility and unsustainable farming practices [4].

The physico-chemical properties and microbial component of soil determines its fertility. The most important minerals needed for the growth of potato plants are N, P, K, and Mg [5]. Intensive cropping system heavily drains the available nutrients in the soil, thus reducing its productivity. Hence soil nutrients need to be replenished. It is estimated that more than 50% increase in yield is due to chemical fertilizers. However, they have also polluted the environment and caused slow deterioration of soil health. The chemical

residues in food produced also cause injury to human beings and cattle population [6]. Furthermore, the use of mineral fertilizers over a long period of time results in reduction in soil base saturation and increased acidity [7], while the application of organic amendments improves soil physico-chemical properties and crop yield over time [8].

Organic farming encourages the use of environmentally friendly organic manures such as Effective Microorganism (EM) manure and Indigenous Microorganism manure (IMO) which are made up of effective and beneficial microorganisms [9]. These microorganisms have been shown to be effective in improving soil health and quality, and raising the growth, yield and quality of crops [10]. IMO is made up of a local group of microbes which have the propensity to regenerate very fast because of their adaptations to the local conditions of the environment. However, the use of mixed cultures of beneficial microorganisms as soil inoculants to enhance growth, health, yield and quality of crops is still questionable by researchers since the claim lacks conclusive scientific proof [11]. EM is a fermented mixed culture of naturally occurring species of microorganisms living together in acidic medium. Plants grown with EM manure were only as good or better, and quality of plant products was superior compared to those of conventional farming [12, 13, 14]. In addition, the effect of EM on crop yield was usually not evident or even negative particularly in the first test crop [15, 16, 17, 18]. The purpose of this experiment was therefore to evaluate some soil physico-chemical properties, plant morphological parameters, and agronomic parameters of potato grown in soil treated with two organic manures, EM manure and IMO manure.

2. Materials and Methods

2.1. Location

The experiment was carried out at a research farm in a quarter in Bambili, called "Mekele" along the road to Ndop during the period of April to August 2013. It is located at Latitude 05°59'18.5''north and longitude 010°17'15.4'' east, and 1578 meters above sea level. Bambili is situated in Tubah Sub-Division, Mezam Division of the North West Region of Cameroon. Bambili has a false guinnean monsoon wind and a mixture of Cameroonian and continental guinnean climate. There is great variation in the monthly temperatures with the maximum in February (27°C) and the minimum in December (17°C) [19].

2.2. Preparation of Manures, Application and Planting

EM manure was prepared according to the method of [20], whereas IMO manure was prepared according to the method of [21], using local farming field material. 38 g of each treatment was applied 1 week before planting per hole. Potato seed tubers with 3 to 6 eyes were planted at 30 cm apart. Weeds were controlled manually and by mulching done 4 and 8 weeks after planting (WAP).

2.3. Land Preparation and Field Management

A piece of land was cleared using a cutlass and raked. Thereafter, the land was ploughed and beds (5 m long and 1 m wide) were made using a hoe. The experimental design was the randomized complete block design (RCBD) with three treatments (EM manure, IMO manure and control) and 4 replications. The crops were sprayed against late blight disease (*Phytophthora infestans*) with a fungicide (Manizan) every week from the fourth to the twelfth WAP.

2.4. Evaluation of Morphological Parameters

Plant height and leaf area index were measured using a tape every week from the 4^{th} to the 10^{th} WAP. Plant height was taken from the base to the terminal bud, and leaf area index was calculated according to [22].

2.5. Harvesting

Potato tubers were harvested 12 WAP after planting, when the leaves and stems had turned yellowish brown. The weight of tubers per treatment was recorded.

2.6. Soil Sampling and Analysis

Soil sampling was done with a sampling auger at a depth of 0− 15 cm at five points on each bed before application of manures, and one and 9 weeks after application. The soils were air dried, ground, and sieved using a 2 mm sieve and then analyzed for total phosphorus (TP), total organic carbon (TOC), total nitrogen content (TNC), calcium (Ca^{2+}) and magnesium (Mg^{2+}) contents using standard procedures of [23].

2.7. Data Analysis

The data obtained were expressed as means ± SD and were statistically analysed using the SPSS statistical software Version 17.0 (SPSS Inc., Chicago). The significant difference between mean values was determined using analysis of variance (ANOVA). Student Newman-Keuls (SNK) test was used to compare means at 0.05 level of significance.

Table 1. *Variation of height of potato plants (cm) under different treatments with time.*

Duration	Parameters		
	EM	**IMO**	**Control**
4	20.485±5.88a	21.600±4.489a	19.070±4.215a
5	29.345±6.574b	29.225±5.388b	25.940±8.029ab
6	36.510±9.118c	37.265±7.937c	32.068±11.444bc
7	42.480±8.813c	46.675±9.061d	37.761±12.712cd
8	53.126±11.253d	61.385±13.752e	51.212±20.925e
9	57.642±12.146d	65.150±17.850e	52.382±17.716e
10	54.563±18.123d	60.295±12.227e	50.535±15.849e
P value	32.479	48.258	17.305
Sign	0.000	0.000	0.000

Means with same letter in the same column are not significantly different P≤ 0.05 (SNK Test).

3. Results

3.1. Variation of the Height of Potato Plants

Results showed a gradual and significant ($P \leq 0.05$) increase in height of plants for all treatments up to week 9 but decreased slightly at week 10. At week 9, IMO manure recorded the longest plant heights (65.15 ± 17.85 cm) followed by those treated with EM manure (57.64 ± 12.14 cm), and then control plants (52.38 ± 17.71cm) (Table 1).

3.2. Variation of Leaf Area Index of Potato Plants

The leaf area index increased in all treatments till the 7th WAP for EM manure plants and till 8th WAP for IMO manure plants and Control plants with recorded values of 152.217 ± 40.88 cm^2; 183.21 ± 43.05 cm^2 and 135.379 ± 48.158 cm^2 as highest leaf area index respectively. Significant differences ($P \leq 0.05$) were noted within plants of each treatment; control plants recorded the shortest leaf area index (Table 2).

Table 2. *Variation of leaf area index (cm2) of potato plants under different treatments with time.*

Duration	Parameters		
	EM	IMO	Control
4	119.322±42.488a	105.348±36.564	91.655±30.612a
5	123.005±38.064a	157.191±59.362bc	107.366±42.871ab
6	133.681±38.446ab	180.236 ±49.315c	117.856±55.890b
7	152.217±40.881b	177.564±50.637c	128.094±48.020b
8	143.357±39.746ab	183.216±43.081c	135.379±48.158b
9	136.214±40.838ab	154.201±41.713bc	119.036±28.351b
10	133.768±44.654ab	137.427±48.706b	116.955±40.113b
P value	1.523	6.940	3.062
Sign	0.000	0.000	0.000

Means with same letter in the same column are not significantly different $P \leq 0.05$ (SNK Test).

3.3. Evaluation of Productivity

Plants treated with IMO manure produced potato tubers with the heaviest weight (241.64 ± 32.94 g), followed by EM manure (227.62 ± 44.58 g), and the control produced tubers with the least weight (125.66 ± 31.63 g). Statistical analysis revealed significant differences ($P \leq 0.05$) in terms of average weight of tubers for all the treatments (Fig. 1).

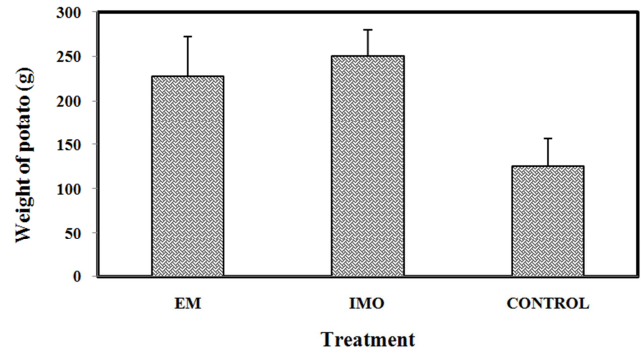

Figure 1. *Average weight of potato tubers produced (g) per treatment.*

3.4. Soil Physico-Chemical Properties

The highest pH was observed in the control soil (7.3) nine weeks after application of manures while the lowest pH was recorded in IMO-treated soil (6.12) one week after application (Table 3). IMO manure treated soil recorded the highest electrical conductivity (332mS.cm^{-1}) one week after application which decreased drastically at nine weeks after application of manure at a rate of -94.27% followed by EM manured soil (-80,62%). No variation of TNC was observed in both soils treated with EM manure and IMO manure while in the control soil, this TNC decreased between week 1 and week 9 (-16.67). TOC was highest in the soils treated with IMO manure (71100.00 mg.kg^{-1}) compare to initial soil (31733.33 mg.kg^{-1}); control soil recorded the higher variation rate (42.35). TP content was also highest in the IMO treated soil (1600.00 mg.kg^{-1}) and lowest in still the same soil (466.67 mg.kg^{-1}) with a rate of decrease of -70.83%. The highest Ca^{2+} content was observed in both the EM treated manure soil and the control soil (335.26 mg.kg^{-1} and 406.40 mg.kg^{-1}) while lowest was observed in the IMO treated manure soil (193.32 mg.kg^{-1}) nine weeks after application of manures. The highest (360.66 mg.kg^{-1}) and lowest (85.83 mg.kg^{-1}) Mg^{2+} contents were observed in the IMO treated manure soil one and nine weeks after application of manures respectively but this content decreased at the rate of -75.52%; -47.95% in IMO treated manure soil, EM treated manure soil respectively while no variation was observed in control soil (Table 3).

Table 3. *Soil physico-chemical properties of tests and control soils.*

Soil physico-chemical properties	TREATMENTS									
	EM manure			IMO manure			CONTROL			INITIAL
	Week 1	Week 9	% V	Week 1	Week 9	%V	Week 1	Week 9	%V	0 WEEK
pH	6.64	7.17	7.98	6.12	6.93	13.23	7.2	7.3	1.39	6.93
EC	157.9	30.6	-80.62	332	19.01	-94.27	45	23.5	-47.78	24.1
TNC (mg.kg^{-1})	2008.03	2008.03	0	1004.02	1004.02	0	1204.82	1004.02	-16.67	1003.02
TOC (mg.kg^{-1})	49733.33	50566.67	1.67	71100.00	74833.33	5.25	41166.67	58600.00	42.35	31733.33
TP (mg.kg^{-1})	1466.67	1266.67	-13.64	1600.00	466.67	-70.83	1033.33	500	-51.61	700
Ca^{2+} (mg.kg^{-1})	406.24	335.26	-17.50	335.26	193.32	-42.34	335.06	406.40	21.22	332.22
Mg^{2+} (mg.kg^{-1})	251.61	130.95	-47.95	350.66	85.83	-75.52	113.62	113.62	0.00	116.60

% V: Percentage of variation.

3.5. Correlation Between Morphological, Agronomic, and Soil Physico-Chemical Parameters

Analysis of correlation ($P < 0.01$) between the different parameters studied in the plots treated with EM manure revealed a positive and significant correlation between plant height and leaf area index (r = 0.265**) as well as a negative and significant correlation with fresh weight (r = -0.529*). TOC correlated negatively and significantly with TP, Ca^{2+} and Mg^{2+} (r = -1.000**) while TP positively and significantly correlated with Ca^{2+} and Mg^{2+} contents. There was also a positive and significant correlation between Ca^{2+} and Mg^{2+} (r = 1.000**).

In the plots treated with IMO manure analysis of correlation ($p < 0.01$) revealed a positive and significant correlation between plant height and LAI (r = 0.300**) and with pH of the soil. TNC also correlated positively and significantly with Mg^{2+} (r = 1.000**), while there was a negative and significant correlation between pH and TP (r = -1.000**) (Table 4).

In control plots, positive and significant correlation was noticed between plant height and LAI (r = 0.287**), while a negative and significant correlation between plant height FW of tubers was also recorded (r = -0.567**). Positive and significant correlation was noticed between TNC and TP in one hand and between pH and Ca^{2+} (r = 1.000**) in another hand. Negative and significant correlation was recorded between EC and Mg^{2+} (Table 4).

Table 4. *Correlation between morphological, agronomic and soil parameters.*

EM	**Plant H**	**LAI**	**F W**	**TNC**	**TOC**	**TP**	**Ca^{2+}**	**Mg^{2+}**	**pH**	**EC**
Plant H	1.000									
LAI	0.265**	1.000								
F W	-0.529*	0.100	1.000							
TNC	-0.800	0.800	0.800	1.000						
TOC	0.200	0.000	0.200	0.000	1.000					
TP	0.100	0.200	0.300	0.100	-1.000**	1.000				
Ca^{2+}	0.000	0.200	0.000	0.150	-1.000**	1.000**	1.000			
Mg^{2+}	0.000	0.000	0.100	0.200	-1.000**	1.000**	1.000**	1.000		
pH	-0.400	0.400	0.400	0.200	0.894	-0.894	-0.894	-0.894	1.000	
EC	0.800	-0.800	-0.800	-0.400	-0.447	0.447	0.447	0.447	-0.800	1.000
IMO	**Plant H**	**LAI**	**F W**	**TNC**	**TOC**	**TP**	**Ca^{2+}**	**Mg^{2+}**	**pH**	**EC**
Plant H	1.000									
LAI	0.300**	1.000								
F W	-0.289	-0.396	1.000							
TNC	-0.800	-0.400	0.800	1.000						
TOC	0.949	0.632	-0.632	-0.949	1.000					
TP	-1.000**	-0.800	0.400	0.800	-0.949	1.000				
Ca^{2+}	-0.600	0.000	0.400	0.800	-0.738	0.600	1.000			
Mg^{2+}	-0.800	-0.400	0.800	1.000**	-0.949	0.800	0.800	1.000		
pH	1.000**	0.800	-0.400	-0.800	0.949	-1.000**	-0.600	-0.800	1.000	
EC	-0.400	-0.200	-0.600	0.000	-0.211	0.400	0.400	0.000	-0.400	1.000
Control	**Plant H**	**LAI**	**F W**	**TNC**	**TOC**	**TP**	**Ca^{2+}**	**Mg^{2+}**	**pH**	**EC**
Plant H	1.000									
LAI	0.287**	1.000								
FW	-0.567*	0.046	1.000							
TN	-0.200	-0.400	0.400	1.000						
TOC	-0.400	0.000	-0.200	-0.800	1.000					
TP	-0.200	-0.400	0.400	1.000**	-0.800	1.000				
Ca^{2+}	0.400	0.800	0.200	-0.800	0.600	-0.800	1.000			
Mg^{2+}	0.400	0.200	-0.800	-0.800	0.400	-0.800	0.400	1.000		
pH	0.400	0.800	0.200	-0.800	0.600	-0.800	1.000**	0.400	1.000	
EC	-0.400	-0.200	0.800	0.800	-0.400	0.800	-0.400	-1.000**	-0.400	1.000

** Corr. is significant at .01 level; * Corr. is significant at .05 level.
PH: Plant height; LAI: Leaf area index; NS: Number of stems; FW: Fresh weight.
TOC: Total organic carbon; TNC: Total nitrogen content; TP: Total phosphorus.
EC: Electrical conductivity; pH: logarithm of H+ concentration.

4. Discussion

The purpose of this experiment was to evaluate soil physico-chemical properties, morphological parameters, and agronomic parameters of potato grown in soil treated with two types of organic manures (EM and IMO). Results showed that plots treated with EM and IMO manures produced taller plants and larger leave area index than the control. In fact nutrient availability notably nitrogen, phosphorus, magnesium, calcium and organic carbon, and soil electrical conductivity were higher in these treated plots as revealed by soil analysis. However, IMO manure produced taller plants and larger leaves than EM manure. This could be because beneficial microorganisms in IMO cause increased rates of decomposition of soil organic matter and associated increases

in nutrient availability, improved plant nutrient status, a decrease in the prevalence of pathogenic microorganisms and an increase in levels of natural inducible plant defences [21]. Maximum height, increased leaf growth and chlorophyll contents were obtained in IMOs-treated plants compared to chemical fertilizers-treated and control plants by [24] while working on okra, cowpea realized that. Also, [25] found out that beneficial microorganisms in IMO manure significantly suppressed the activity of fungal pathogens in crops of mildly susceptible *Rhododendron* cultivars thereby enhancing growth.

The yield was greater in the treated soils than the control soil with IMO manure having a greater and more significant yield than EM manure. This could be because EM and IMO manures are organic manures and having a significant role in maintaining and improving the chemical, physical, and biological properties of soils and in sustaining crop yield [26]. IMO manure produced plants with a higher mean leaf area index which perhaps led to a higher synthesis rate of starch stored in the tubers. Beneficial microorganisms in IMO were indigenous to the soil and environmental conditions of the farm and could more easily adapt, unlike those in EM manure which were only imported from abroad [27]. According to [28], earthworms and mycorrhizae could be contributing to increases in soil tilt in IMO plots.

Soil analysis one week after manure application revealed a decrease in pH in manured soils and an increase in the control soil. This could be due to a higher rate of decomposition of organic matter in the test soils by the microbes in the manures leading to increased soil acidity. Soil pH affects the ability of plant roots to absorb nutrients and when the level is adjusted out of the tolerance, it can affect negatively plant nutrition, plant growth and susceptibility to pests. The discharge of cane sugar residues from cane sugar industry for example decreased the soil pH [29]. Increase in pH noticed with all the treatments nine weeks after application could be due to depletion of organic matter with time.

The higher EC in the test soils could be attributed to their greater water-holding capacity due to the added manures, which was more evident in IMO manure soil than EM manure soil [30]. Increased water-holding capacity may be due to accumulation of organic residues [06]. The result agrees with the reports of [6, 31, 32], who had increased electrical conductivity. Nine weeks after manure application, the decrease in EC in all the soils could be due to decreased water-holding capacity as a result of reduced organic residues [06]. In fact, soil EC is affected by water management of soil, which in turn affects crop yields, crop suitability, plant nutrient availability and activity of soil microorganisms.

The higher Mg^{2+}, TP, and TOC in the test soils compared to the control soil could be as a result of a higher rate of mineralization in the test soils. Soils treated with EM and IMO manures showed higher values in organic carbon, total N, K, and Mg as compared to urea treatment [33]. These nutrients were higher in the IMO treated soil compared to the EM manure soil probably due to a higher rate of mineralization since the microorganisms in IMO manure were indigenous to the environment and could easily adapt. Mg is a structural component of the photosynthetic pigment, chlorophyll; and phosphorus increases water use efficiency, encourages vigorous root and shoot growth, and promotes early maturity [34]. Hence the higher Mg and TP contents in IMO manure-treated soil perhaps explains why the plants had longer stems, higher leaf area index and consequently greater yield compared to EM manure and control. Similar reports were made by [32, 24] that in the IMOs treated soil, the discharge of effluents from cotton ginning mill enhanced the soil total phosphorus contents and increased plant chlorophyll content than control soil. EM manure soil showed the highest TNC throughout the study period perhaps was due to the fact that the manure had the highest number of nitrogen fixing bacteria. Application of EM had a positive effect on the net mineralization of nitrogen [35]. The higher calcium content one week after application in EM manured soil compared to IMO manured soil could be attributed to the higher pH in the EM manured soil.

A progressive increase in soil TOC over time was observed in all the treatments. These results could be due to increased decomposition which increases the level of soil humus that favors root growth to better explore soil phosphorus and calcium. [36].

The soil Mg content of EM manure was the highest throughout the study period. EM manure enhances mineralization of organic matter and improves soil quality [37], and Mg functions in sugar synthesis, starch translocation, nutrient uptake control and as a carrier of phosphorus in plants.

5. Conclusion

Both EM and IMO manure had a positive effect on the growth parameters (plant height and leaf area index) as well as yields of potato in Bambili when compared with the control plants. However plants treated with IMO manure had better results in terms of growth and yield when compared to those treated with EM manure. Soil inoculation with EM and IMO manures improved soil physico-chemical properties. Therefore EM and IMO manures can be used for effective growth and yield of potato, and also to improve soil physico-chemical properties.

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