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

Muyang Rosaline Fosah¹, ², *, Mbouobda Hermann Desire¹, ³, Fotso¹, ³, Foasung-Zah Elvis¹, Taffouo Victor Desire²

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

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

To cite this article:
Muyang Rosaline Fosah, Mbouobda Hermann Desire, Fotso, Foasung-Zah Elvis, Taffouo Victor Desire. Comparative Study of the Effects of Two Organic Manures on Soil Physico-Chemical Properties, and Yield of Potato (Solanum tuberosum L.). Plant. Vol. 4, No. 1, 2016, pp. 1-7. doi: 10.11648/j.plant.20160401.11

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 ≤ 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 guinean monsoon wind and a mixture of Cameroonian and continental guinean 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 4th to the 12th WAP. Plant height of tubers 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. 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 | Control |
|----------|------------|---------|
|          | EM         | IMO     |         |
| 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±12.712ed |
| 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, Sign: 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 ≤ 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 ± 17.71 cm) (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 152.21 ± 40.88 cm²; 183.21 ± 43.05 cm² and 135.379 ± 48.158 cm² as highest leaf area index respectively. Significant differences (P ≤ 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 manure | IMO manure | 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 |

Mean with same letter in the same column are not significantly different P ≤ 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 ≤ 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 (42.35). TP content was also highest in the IMO treated soil (71100.00 mg.kg⁻¹) compare to initial soil (31733.33 mg.kg⁻¹) with a rate of decrease of -70.83%. The highest Ca²⁺ content was observed in both the EM treated manure soil and the control soil (335.26 mg.kg⁻¹) and 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) Mg²⁺ 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 |
| pH                              | Week 1     | Week 9   | % V      | Week 1   | Week 9   | % V      | Week 1   | Week 9   | % V      | 0 WEEK   |
|                                 |            |          |          |          |          |          |          |          |          |          |
|                                 | 6.64       | 7.17     | 7.98     | 6.12     | 6.93     |          | 13.23    | 7.2      | 7.3      | 1.39     | 6.93     |
|                                 | -94.27     | 45       | 23.5     | -47.78   | 24.1     |
|                                 | 2008.03    | 2008.03  | 0        | 1004.02  | 1004.02  |          | 0        | 1204.82  | 1004.02  | -16.67   | 1003.02  |
|                                 | 49733.33   | 50566.67 | 1.67     | 71100.00 | 74833.33 |          | 5.25     | 41166.67 | 58600.00 | 42.35    | 31733.33 |
|                                 | 1466.67    | 1266.67  | -13.64   | 1600.00  | 466.67   |          | -70.83   | 1033.33  | 500      | -51.61   | 700      |
|                                 | 406.24     | 335.26   | -17.50   | 335.26   | 193.32   |          | -42.34   | 335.06   | 406.40   | 21.22    | 332.22   |
|                                 | 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 Mg$^{2+}$ (r = 1.000**) in another hand. Negative and significant correlation was recorded between EC and Mg$^{2+}$ (Table 4).

In control plots, positive and significant correlation was noticed between plant height and LAI (r = 0.287**) as well as a negative and significant correlation between pH and FW (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).

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).

** Corr. is significant at .01 level; * Corr. is significant at .05 level.

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

| EM           | Plant H | LAI   | FW     | 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** |
| Mg$^{2+}$    | 0.000   | 0.000 | 0.100  | 0.200 | -1.000** | 1.000** |
| pH           | -0.400  | 0.400 | 0.400  | 0.894 | -0.894 | -0.894 | 1.000    |
| EC           | 0.800   | -0.800 | -0.800 | -0.447 | 0.447 | 0.447 | 0.447 | -0.800 | 1.000 |

| IMO          | Plant H | LAI   | FW     | 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   | FW     | TNC   | TOC   | TP   | Ca$^{2+}$ | Mg$^{2+}$ | pH   | EC   |
|--------------|---------|-------|--------|-------|-------|------|-----------|-----------|------|------|
| Plant H      | 1.000   |       |        |       |       |      |           |           |      |      |
| LAI          | 0.287** | 1.000 |        |       |       |      |           |           |      |      |
| F W          | -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 till 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
outside 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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