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Efficacy of Organic Fertilizers Produced Using Locally Formulated Effective Microorganisms on the Growth and Yield Responses of Maize

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Authors' contributions

This work was carried out in collaboration between all authors. Author GGE carried out the laboratory analyses and wrote the first draft of the manuscript. Authors UJJI and OPA wrote the protocol and managed the analyses of the study. Authors OPA and BEND performed the statistical analysis, managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: A study was conducted on growth and yield responses of maize to organic fertilizers produced from organic municipal solid wastes (MSW) using locally formulated effective microorganisms (EM-A and EM-B), commercial effective microorganisms (EM-C), Neem-based organic fertilizers and inorganic fertilizers.
Study Design: The study was laid out in a Completely Randomized Block Design with three replicates each.
Place and Duration of Study: Research was sited at Department of Works, Bosso Campus of Federal University of Technology Minna, Nigeria between July and October, 2016.
Methodology: Maize was planted in the experimental plot and four organic fertilizers as well as one inorganic fertilizer (NPK15:15:15) were applied as treatments. Growth parameters were monitored and recorded weekly while yield parameters were determined after harvest.
Results: Plant height, leaf number, leaf area, cob length, cob diameter and number of grains per cob differed significantly ($P < 0.05$). M_F (Soil with inorganic fertilizer, NPK15:15:15), recorded the

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highest plant height of 259 cm. M_B and $M_{C,}$ (organic fertilizers produced with EM-A and EM-B respectively), recorded the highest leaf number of 16, while $M_{E,}$ which contained Neem-based organic fertilizer had the highest leaf area. On yield responses, M_D,(organic fertilizers with commercial EM), recorded the best yield with cob length of 20.85 cm, cob diameter of 15.90 cm and a mean number of grains per cob of 623. This was followed by M_B with cob length of 18.25 cm, highest cob diameter of 16.30 cm and second highest mean number of grains per cob of 500.

Conclusion: The organic fertilizers demonstrated more adequacies for crop use than the inorganic fertilizers. Although the maize plants where inorganic fertilizers were applied recorded highest plant height, the crop yield was lower than that of organic fertilizers-based treatments. The organic fertilizers produced from solid organic wastes also demonstrated both higher growth and yield responses than the Neem-based organic fertilizers.

Keywords: Maize; Fertilizers; plant height; cob length; grain yield.

1. INTRODUCTION

The current practice in agriculture is basically chemical-based farming that makes a considerable contribution to the degradation of the natural resources, particularly soils. Chemical fertilizers, which have been claimed as the most important contributor to the increase in world agricultural productivity over the past decades, have negative effects on soil and environment and this limits its usage in sustainable agricultural systems [1]. Inorganic fertilizers pollute soil as well as surface and groundwater, which leads to the deterioration of the soil characteristics and fertility and as a result, reduces the nutritional values and edible qualities of products; hence, humans are being fed with chemicals [1]. It causes eutrophication and makes water unfit for use by living organisms. [2] reported that chemical fertilizers cause health risks to consumers as well as to the soil itself by altering the soil structure. Therefore, organic fertilizer can be an effective alternative to chemical fertilizers. With the increasing interest in organic farming due to its health and environmental benefits both locally and globally, intensified research on all aspects of organic farming is timely and urgent [3].

Organic fertilizers by their nature, increase physical and biological nutrient storage mechanisms in soil and militate risks of over-fertilization. According to [4], the nutrient content, solubility and nutrient release rates of organic fertilizers are typically much lower than that of inorganic fertilizers. The acidity of chemical fertilizer also adversely affects the soil pH, upset beneficial microbial ecosystems, thereby changing the kinds of microorganisms that can live in the soil. The objective of this study was to assess the efficacy of organic fertilizers produced using locally formulated effective microorganisms on the growth and yield responses of maize.

2. MATERIALS AND METHODS

2.1 Sample Collection and Analysis

Soil samples were collected from three points at 6 cm – 10 cm depth at the experimental site. The samples were bulked, air-dried and used for analysis of pH, soil texture, organic matter, available nitrogen, potassium, phosphorus using standard methods according to [5]. The maize variety used was SDM-2 from MASLAHA SEEDS BRAND obtained from Agricultural Development Project (ADP), Minna, Niger State.

2.2 Experimental Design and Treatment

The study was conducted at the Department of Works, Main Yard, Bosso Campus of the Federal University of Technology Minna, Nigeria. The experiment was laid out in a Completely Randomized Block Design (CRBD) with six levels of treatments each with three replicates which included: $M_{A:}$ Control (soil without fertilizer); $M_{B:}$ Soil with organic fertilizer EM A; M_C: Soil with organic fertilizer EM B; $M_{D:}$ Soil with organic fertilizer EM C; $M_{E:}$ Soil with commercial organic fertilizer (Neem-based organic fertilizer); $M_{5:}$ Soil with inorganic fertilizer (NPK 15:15:15).

A field size of 10.3 m × 5.3 m, was used for the experiment. Ridges were made manually with hoe at 5 m length and at a distance of 0.55 m between ridges. Maize was hand-sowed by planting 2 seeds in each hole of about 5 cm deep at a space of 40 cm apart which was thinned to one plant per stand at one week after planting.

Organic fertilizer EM-A, organic fertilizer EM-B and organic fertilizer EM-C (organic fertilizers produced with effective microorganisms EM-A, EM-B and EM-C respectively) were produced as described previously in a Journal submitted for publication. Effective microorganisms (EM-A consists of *Lactobacillus plantarum*, *Saccharomyces cerevisiae*, *Aspergillus oryzae, Streptomyces griseus, Rhodopseudomonas palustrus),* EM-B consists of *Bacillus subtilis, Streptomyces rochei, Saccharomyces cerevisiae, Aspergillus niger*. Effective microorganism, EM-A and EM-B were applied as originally formulated while EM-C (commercial EM) was activated using water and molasses. A 10 cm layer of shredded organic waste materials (vegetables, fruits, food wastes, dried grasses, dried and green leaves, twigs ,corn cobs and stalks) was made in the compost bin and 150 ml of effective microorganism was sprayed on it and this was repeated after every layer until the bin was filled.

The compost was turned every three days for aeration throughout the composting period and was moisturized by sprinkling water whenever necessary. Samples of the compost were collected from different points of the heaps and were mixed thoroughly for microbiological and physicochemical analyses. The outcome of the physical (colour, smell, appearance) and chemical parameters which were monitored was used to confirm the stability of the compost.

Commercial organic fertilizer (Neem-based organic fertilizer) as well as inorganic fertilizer (15:15:15 NPK) were obtained from Agricultural Development Project (ADP) Minna, Nigeria.

2.3 Application of Fertilizers

Organic fertilizer was applied by broadcast method before planting at (25 t/ha) 25,000 $kgha^{-1}$. 50 $kgha^{-1}$ of inorganic fertilizers was applied at one week after planting by ringing around the maize plant. The application of both organic and inorganic fertilizers was repeated four weeks after planting. Weeds were removed manually whenever necessary throughout the period of experiment.

2.4 Determination of Growth Rate Parameters of Maize

Three maize plants were measured for every row and the average reading was recorded.

2.4.1 Plant height

Plant height was measured from the soil surface to the highest point of the arch of the uppermost leaf whose tip is pointing down using a meter rule.

2.4.2 Leaf number

Leaf collar method was used to count the number of leaves on a plant. The number of leaves with visible leaf collars (the light-coloured collar-like band located at the base of an exposed leaf blade near the spot where the leaf comes in contact with the stem of the plant) was counted, beginning with the lowermost and ending at the uppermost leaf, excluding leaves within the whorl but not yet fully expanded and with no visible collar [6].

2.4.3 Leaf length

Leaf length was measured manually to the nearest centimeter from the leaf tip to the point at which the lamina is attached to the petiole using measuring tape.

2.4.4 Leaf width

Leaf width was measured from edge to edge at the widest part of the leaf lamina using measuring tape.

2.4.5 Leaf area

Leaf area was measured with the formula L× W × A, where L = Leaf length, W = Leaf width while A is a constant (A = 0.75) according to [7].

2.4.6 Cob length

The length of six dehusked maize cob per plant was measured with a tape and the mean value taken.

2.4.7 Cob diameter

The diameter of six dehusked maize cob per plant was measured and the mean values taken.

2.4.8 Number of grains per cob

The number of grains of six cobs from each treatment was counted after they had been dried and shelled and divided by the number of cobs to determine the mean according to [8].

2.5 Statistical Analysis

All data generated were subjected to Analysis of variance (ANOVA) and correlation analysis using

Statistical Package for Social Sciences (SPSS version 20). The Least Significant Differences (LSD) in the effects of variable treatments was considered at 5% Probability level (P< 0.05).

3. RESULTS AND DISCUSSION

The physicochemical characteristics of the experimental soil is presented in Table 1. The soil was loamy sand with acidic pH of 5.9. It was low in organic carbon, total Nitrogen, available phophorus, sulphate, potassium and Cation exchange capacity.

Table 1. Physicochemical properties of the experimental soil

Parameters	Values (Mean ± S.D)
Physical properties	
Soil Texture	Loamy Sand
Sand (g/kg)	86.30±0.2
Silk (g/kg)	6.10±0.01
Clay (g/kg)	7.60±0.02
Chemical properties	
pH	5.93±0.02
Organic Carbon (%)	1.35±0.01
Total Nitrogen (g/kg)	0.05±0.01
Available Phosphorus (mg/kg)	0.45±0.01
Na^+	0.38±0.02
K^+	0.09±0.01
Mg^{2+}	0.18±0.01
Ca^{2+}	0.25±0.01
Organic Matter (%)	2.34±0.02
ECEC(cmol/kg)	1.23±0.01
Exchangeable acid(cmol/kg)	0.08±0.01

The NPK content of each of the compost are as follows: 2.48 g/kg, 2.48 mg/kg, 2.51 cmol/kg respectively for OF_1; 2.55 g/kg, 2.41 mg/kg, 2.11 cmol/kg for OF_2; 1.06 g/kg, 1.06 mg/kg, 1.05 cmol/kg for OF_3; 1.14 g/kg, 1.00 mg/kg, 1.16 cmol/kg for OF_4 respectively. OF_1: Organic fertilizers with EM-A, OF_2: Organic fertilizers with EM-B, OF_3: Organic fertilizers with commercial EM, OF_4: Organic fertilizers without EM.

3.1 Plant Height

(Table 2) shows the plant height recorded at weekly intervals during the study. The plant height increased across the treatments at all stages of growth. Statistical analysis revealed that there were significant differences in the treatments at 5% probability level which demonstrated the effects of the different fertilizers based on their nutrient contents. The minimum plant height of 197 cm was recorded in treatment M_A (soil without fertilizer), which served as the control and this is a reflection of the low nutrient content of the experimental soil. The tallest mean plant height of 259 cm in the study was recorded in M_F (Soil with inorganic fertilizer, NPK 15:15:15), which received inorganic fertilizers and this might be due to the readily availability of nitrogen required for plant growth and development since inorganic fertilizer releases nutrients faster than organic fertilizers [9]. Plant height is an important yield component as the more green area, the more will be photosynthetic activity and share to grain yield [10]. The shortest mean plant height among the treatments that received organic fertilizers, was 226 cm in treatment M_C (Soil with the organic fertilizer EM-B) and this is about 15% higher than the control and is also higher than the plants of the neem-based commercial organic fertilizer that recorded a mean height of 222 cm. The results could be due to special effects of organic fertilizer which acted as store house of different plant nutrients, reduce phosphorus fixation, improve cation exchange capacity, aeration, root penetration, water storage capacity of the soil as well as being host of different microbes [11]. The plant heights recorded in the organic fertilizer-treated maize plants in this study were higher than that recorded by [12], where the tallest plant height recorded was 190.83 cm. Plant height had a strong correlation (r= 0.77) with cob length and this is in agreement with the report of [11], which stated that plant height is an important parameter of yield in maize as usually taller plant bears more cobs and offers more yield.

3.2 Leaf Number

In the present study, the leaf numbers of treatments M_B - Soil with organic fertilizer EM-A and M_C - Soil with organic fertilizer EM-B were significantly higher than that of control as well as that of inorganic fertilizers (M_F - Soil with inorganic fertilizer, NPK 15:15:15) as shown in Table 3. The results of this study agrees with the report of [13] as most of the organic fertilizers recorded higher leaf numbers than the chemical fertilizers at different stages of growth.

The significance of leaf number in maize growth study is that an increase or decrease in number of leaves per plant has a direct bearing effect on the yield of crops and a function of fertilizer application [14]. These recorded differences in leaf number are factors of the different types of fertilizers applied as treatments.

Table 2. Plant height (cm) at weekly intervals

Time (Weeks)	Treatments					
	M_A (Control)	M_B	M_C	M_D	M_E	M_F
1	6.05±0.05^{a}	12.50±0.00^{e}	6.00±0.00^{b}	6.45±0.05^{c}	5.70±0.00^{a}	7.95±0.05^{d}
2	9.80±0.00^{a}	27.65±0.05^{e}	19.85±0.05^{c}	19.00±0.00$_{b}$	24.00±0.00^{d}	19.10±0.00^{b}
3	25.05±0.05^{a}	48.00±0.00^{f}	31.00±0.00^{b}	32.05±0.05^{c}	38.95±0.05^{d}	45.00±0.00^{e}
4	33.75±0.25^{a}	85.05±0.05^{f}	55.90±0.10^{b}	67.50±0.00^{c}	69.00±0.00^{d}	82.05±0.05^{e}
5	48.85±0.65^{a}	120.95±0.05^{e}	80.05±0.05^{b}	95.05±0.05^{c}	107.05±0.05^{d}	120.05±0.05^{e}
6	111.05±0.05^{a}	178.00±0.00^{f}	135.00±0.00^{b}	142.00±0.00^{c}	148.05±0.05^{d}	163.00±0.00^{e}
7	111.05±0.05^{a}	202.00±0.00^{e}	180.00±0.00^{b}	190.05±0.05^{c}	200.00±0.00^{d}	200.00±0.00^{d}
8	170.00±0.00^{a}	207.05±0.05^{c}	190.00±0.00^{b}	208.00±0.00^{d}	210.00±0.00^{e}	211.45±0.05^{e}
9	180.05±0.05^{a}	221.10±0.10^{d}	199.55±0.05^{b}	226.00±0.00^{e}	216.45±0.05^{c}	240.00±0.00^{f}
10	195.00±0.00^{a}	224.95±0.05^{d}	219.00±0.00^{c}	231.05±0.05^{e}	217.20±0.00^{b}	247.45±0.05^{f}
11	195.10±0.10^{a}	229.00±0.00^{d}	224.10±0.10^{c}	239.00±0.00^{e}	221.00±0.00^{b}	254.00±0.00^{f}
12	197.00±0.00^{a}	231.00±0.00^{d}	226.05±0.05^{c}	240.10±0.10^{e}	222.00±0.00^{b}	259.00±0.00^{f}

a,b,c,d,e : means denoted by different superscripts along the same row are significantly ($p<0.05$) different. MA: Control (soil without fertilizer), MB: Soil with organic fertilizer EM-A, MC: Soil with organic fertilizer EM-B, MD: Soil with organic fertilizer EM-C, ME: Soil with commercial organic fertilizer (Neem-based organic fertilizer), MF: Soil with inorganic fertilizer (15:15:15 NPK).

Table 3. Leaf number at weekly interval

Time (Weeks)	Treatments					
	M_A (Control)	M_B	M_C	M_D	M_E	M_F
1	3.00±0.00	3.00±0.00	3.00±0.00	3.00±0.00	4.00±0.00	3.00±0.00
2	4.00±0.00	6.00±0.00	5.00±0.00	5.00±0.00	5.00±0.00	5.00±0.00
3	5.00±0.00	9.00±0.00	10.00±0.00	11.00±0.00	9.00±0.00	10.00±0.00
4	7.00±0.00	10.00±0.00	11.00±0.00	9.00±0.00	10.00±0.00	11.00±0.00
5	9.00±0.00	13.00±0.00	12.00±0.00	10.00±0.00	11.00±0.00	12.00±0.00
6	11.00±0.00	14.00±0.00	12.00±0.00	13.00±0.00	14.00±0.00	13.00±0.00
7	12.00±0.00^{a}	16.00±1.00^{b}	13.00±1.00^{a}	13.00±1.00^{a}	12.00±0.00^{a}	13.00±0.00^{a}
8	14.00±0.00^{a}	13.00±0.00^{a}	14.00±1.00^{a}	15.00±0.00^{a}	15.00±0.00^{a}	15.00±0.00^{a}
9	14.00±1.00^{a}	13.00±0.00^{a}	16.00±0.00^{b}	14.00±0.00^{a}	14.00±0.00^{a}	14.00±0.00^{a}
10	13.00±0.00^{a}	14.00±0.00^{a}	15.00±0.00^{a}	14.00±0.00^{a}	14.00±0.00^{a}	14.00±1.00^{a}
11	12.00±0.00^{a}	13.00±0.00^{ab}	14.00±0.00^{bc}	14.00±0.00^{bc}	15.00±1.00^{c}	13.00±0.00^{ab}
12	12.00±0.00^{a}	14.00±1.00^{a}	14.00±0.00^{a}	14.00±1.00^{a}	14.00±0.00^{a}	13.00±0.00^{a}

a,b,c: means denoted by different superscripts along the same row are significantly ($p<0.05$) different. MA: Control (soil without fertilizer), MB: Soil with organic fertilizer EM-A, MC: Soil with organic fertilizer EM-B, MD : Soil with organic fertilizer EM-C, ME : Soil with commercial organic fertilizer (Neem-based organic fertilizer), MF : Soil with inorganic fertilizer (15:15:15 NPK)

3.3 Leaf Area

The leaf area in this study varied between a mean value of 8.80 cm in treatment M_A - Control (soil without fertilizer) at one week after planting and 1035.30 cm in treatment M_E - Soil with commercial organic fertilizer (Neem-based organic fertilizer) at the 12th week of the study (Table 4). There were no significant differences among all the treatments at 5% probability level. The results of the leaf area reflect the results of leaf length and leaf width in all the treatments. [8] reported that the leaf area is affected by the levels of nitrogen application as increased rate of nitrogen results in an increase in leaf area. The investigators also reported that high rate of nitrogen promotes leaf area during vegetative development and also help maintain functional leaf area during the growth period. Leaf area had a positive correlation ($r= 0.53$) with cob length. A strong correlation ($r= 0.91$) also existed between leaf area and cob diameter. With number of grains per cob, there was a positive correlation ($r= 0.59$). Leaf area could have caused an increase in the crop yield since most of the yield parameters studied had positive correlation with leaf area. This disagrees with the report of [15] as the treatment with the highest leaf area could not convert its vegetative mass to optimum grain yield.

4. EFFECTS OF ORGANIC FERTILIZERS ON MAIZE YIELD

4.1 Cob Length

The cob length were significantly affected by fertilizer application. The highest cob length of 20.85cm in this study was recorded in M_D (Soil with organic fertilizer EM-C), with M_A (control) recording the lowest length of 12.70 cm. The least cob length among the maize plants treated with organic fertilizers was 17.60 cm and has about 39% increase from the control. There were significant differences at 5% probability level among the cob length in all the treatments with two (M_B and M_D) out of the three locally made organic fertilizers recording higher than other fertilizers (Fig. 1). The highest cob length of 19.10cm recorded in the study of [12], using compost is lower than that of the present study. The significance of cob length in maize yield study is that it contributes to grain yield by influencing both number of grains per cob and grain size [16].

4.2 Cob Diameter

Among the various cob diameters recorded in this study, M_B had the highest cob diameter of 16.30 cm and was not significantly different from M_E (16.20 cm) at 5% probability level. There were however, significant differences among other treatments. The lowest cob diameter of 12.55 cm was recorded in control (M_A). M_F - Soil with inorganic fertilizer (NPK 15:15:15) recorded the least cob diameter of 14.80 cm among all the treatments that received fertilizers (Fig. 1). Cob diameter had a positive correlation (r= 0.85 with number of grains per cob). The highest cob diameter in the present study is higher than 13.48 cm, which was the highest cob diameter reported by [15].

4.3 Number of Grains Per Cob

The results (Fig. 2). showed that M_D produced 623 grains as the highest number of grains per cob. The number of grains per cob was significantly different among all the treatments with M_A, which is the control recording 273 grains as the least number of grains per cob in this study. The highest mean number of grains per cob reported in the present study is higher than that which was reported by [11] to be a mean value of 486, where they combined compost with nitrogen and sulphur fertilizers. The number of grains per cob in the study of [12], which was a mean value of 381.50 using compost, was lower than the results of this study which recorded 500, 409.5 and 623 for treatments M_B, M_C and M_D respectively (Fig. 2). The number of grains per cob recorded using organic fertilizer in this research is higher than 461 which was the highest number of grains per cob recorded by [17] even when the compost was combined with nitrogen at different stages of plant growth. There was a strong correlation (r= 0.94) between cob length and number of grains per cob in the present study.

Table 4. Leaf area at weekly intervals

Time (Weeks)	Treatments					
	M_A (Control)	M_B	M_C	M_D	M_E	M_F
1	8.80±0.00^a	18.90±0.00^e	11.75±0.05^b	14.55±0.05^d	14.00±0.00^c	14.65±0.05^d
2	20.40±0.00^a	99.80±0.00^f	56.05±0.05^b	60.85±0.05^c	70.55±0.05^e	68.85±0.15^d
3	64.05±0.05^a	216.05±0.05^f	147.55±0.05^c	134.40±0.00^b	216.85±0.05^e	180.00±0.00^d
4	92.30±0.00^a	532.75±0.25^f	269.70±0.00^b	349.85±0.15^c	503.85±0.15^e	456.05±0.05^d
5	376.85±0.05^a	705.00±0.00^d	667.25±0.25^c	614.30±0.00^b	727.55±0.05^f	708.80±0.00^e
6	461.75±0.25^a	820.75±0.05^e	772.45±0.05^d	697.45±0.05^b	825.05±0.05^f	730.30±0.00^c
7	642.00±0.00^a	829.70±0.00^e	823.15±0.05^d	717.45±0.05^b	912.15±0.05^f	793.80±0.00^c
8	657.85±0.05^a	872.05±0.05^e	857.55±0.05^d	755.30±0.00^b	915.55±0.05^f	808.50±0.00^c
9	693.00±0.00^a	902.15±0.05^e	874.95±0.05^d	791.50±0.50^b	924.00±0.00^f	856.75±0.05^c
10	708.85±0.05^a	952.45±0.05^f	898.45±0.05^d	816.05±0.05^b	949.20±0.00^e	859.65±0.35^c
11	723.95±0.05^a	984.85±0.05^e	940.45±0.05^d	862.20±0.00^b	1017.80±0.00^f	905.60±0.00^c
12	719.45±0.05^a	987.35±0.05^e	919.95±0.05^d	883.60±0.00^c	1035.30±0.00^f	883.01±0.00^b

a,b,c,d,e,f : means denoted by different superscripts along the same row are significantly (p<0.05) different. MA: Control (soil without fertilizer), MB: Soil with organic fertilizer EM-A, MC: Soil with organic fertilizer EM-B, MD : Soil with organic fertilizer EM-C, ME : Soil with commercial organic fertilizer (Neem-based organic fertilizer), MF : Soil with inorganic fertilizer (15:15:15 NPK).

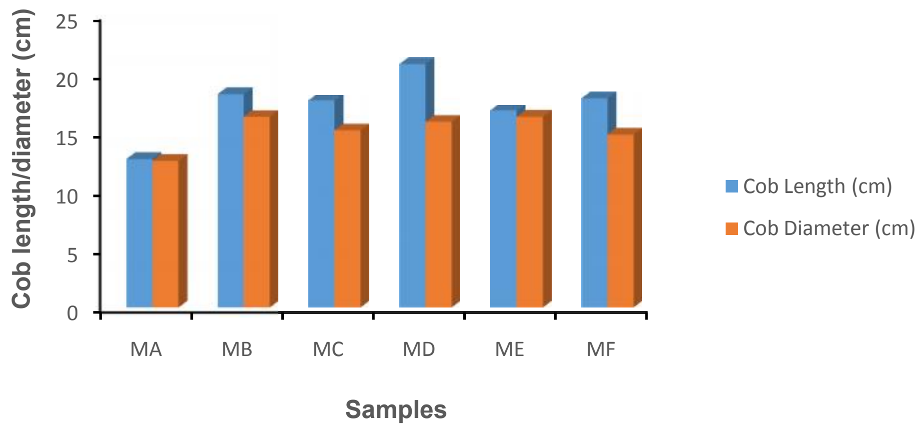

Fig. 1. Cob length and diameter

M_A: Control (soil without fertilizer), M_B: Soil with organic fertilizer EM-A, M_C: Soil with organic fertilizer EM-B, M_D : Soil with organic fertilizer EM-C, M_E : Soil with commercial organic fertilizer (Neem-based organic fertilizer), M_F : Soil with inorganic fertilizer (15:15:15 NPK).

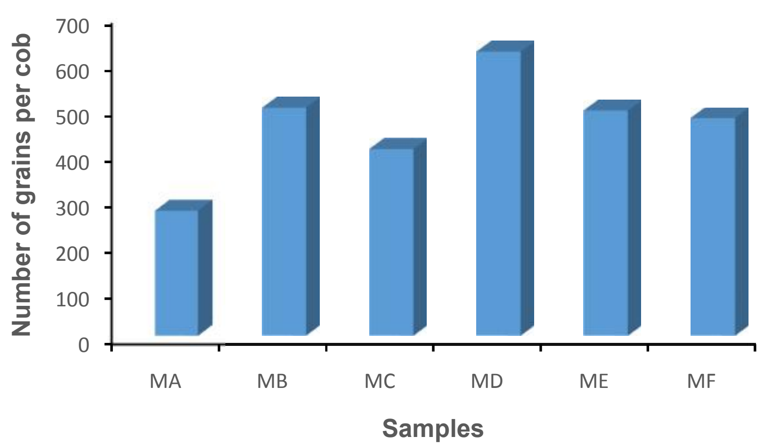

Fig. 2. Number of grains per cob

M_A: Control (soil without fertilizer), M_B: Soil with organic fertilizer EM-A, M_C: Soil with organic fertilizer EM-B, M_D: Soil with organic fertilizer EM-C, M_E: Soil with commercial organic fertilizer (Neem-based organic fertilizer), M_F: Soil with inorganic fertilizer (15:15:15 NPK).

4. CONCLUSION

Organic fertilizers in this study have shown to be more adequate for crop use than the inorganic fertilizers. This was evident in the crop yield reports of this study. Although the maize plants where inorganic fertilizer was applied recorded highest plant height, the crop yield was lower than that of organic fertilizers-based treatments. The organic fertilizers produced from solid organic wastes also supported both higher growth and yield responses than the Neem-based organic fertilizers. This may be as a result of direct effects of the effective microorganisms used in the production of the organic fertilizers and/or indirect effects of microbially-synthesized metabolites. Plant height and leaf area are growth parameters that showed positive correlation with cob length, cob diameter and number of grains per cob of maize. Cob length and cob diameter also showed positive correlation with number of grains per cob.

Organic manure as sole nutrient source is superior to inorganic fertilizer when only 30% nitrogen, 40% phosphorus and 60% potassium become available to crop during current season.

The higher grain yield in the present study can be attributed largely to the activity of the introduced effective microorganisms which enhanced the decomposition of organic materials and the release of nutrients for plant uptake [18]. The activity of photosynthetic bacteria such as *Rhodopseudomonas palustris* present in EM solution can be largely responsible for this [19]. These bacteria are a group of independent, self-supporting microbes. They synthesize useful substances from secretions of plant roots, organic matter and harmful gases such as hydrogen sulfide, by using sunlight and the heat of soil as sources of energy [20]. The useful substances produced by these bacteria include amino acids, polysaccharides, nucleic acids, bioactive substances, and sugars, all of which promote plant growth and development. The metabolites developed by these microbes are absorbed directly by plants [21,22,23].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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