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# Growth and Biomass Yield of Maize Crop (Zea Mays L) In Response to Complimentary Inorganic and Organic Fertilizer Treatment under Farm Management Trial in Akure, Nigeria

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## ABSTRACT

A field experiment was carried out during the wet season of 2026 at the Teaching and Research Farm of the Federal University of Technology, Akure. The aim is to examine the response of maize growth and biomass yield to inorganic (NPK) and complimentary organic fertilizer treatments. Initial soil samples were collected randomly from the experimental site and analyzed for some nutrients (N, P, K, Ca, Mg, Na, pH) and microbial (bacteria, fungi) population. The experiment was carried out using four treatments, organic, inorganic, organic plus inorganic and control with each treatment replicated three times. Each plot has a dimension of 3 m x 4 m. Agronomic parameters measured were plant height (cm), stem circumference (cm) and biomass yield (g). The results shows that at 10WAS), plot treated with organic plus inorganic fertilizer had the highest stem height (284.67cm); stem circumference (11.32 cm); and leaf dry weight (69.50g). The control treatment which had no fertilizer application recorded the least value of all agronomic parameters measured. The use of the combination of organic and inorganic fertilizer is therefore recommended for smallholder farmers for increased crop yield and soil fertility improvement under intensive continuous cultivation.

**Key Words:** Growth, Biomass yield, Inorganic, organic, Fertilizer

## INTRODUCTION

The world is experiencing a population rise that calls for food production intensification. Sub-Saharan Africa (SSA) alone could have a projected 2.7 billion people by the year 2060 (Canning et al; 2015). By the year 2013, the region had 23% of its population being food insecure, while 40% of the children demonstrated stunted growth (UNICEF, 2013). Currently, approximately 815 million out of over 7 billion people globally endure chronic malnutrition (FAO, 2017). This projection translates to increased demand for food to feed the increasing population. The concern then is that, while crop productivity has increased elsewhere in the world, staple food production in Africa has not kept pace (FAO, 2015; World Bank, 2015). Cereal yields in Africa average less than 1.5MT/ha compared to an average yield in Asia and Latin America of 5 and 8MT/ha respectively (FAOSTAT, 2015). One of the main explanation for the difference is the relatively poor soil fertility in the smallholder farms. This problem of low soil fertility has plagued Africa’s soils for the last 40 years and is currently considered a crisis (AGRA, 2016). The low soil fertility is due to several decades of nutrient mining as a result of continuous cultivation with little or no fertilizer (organic or inorganic) application. Consequently the soils in Africa farmlands are often deficient in nutrients, with low or no organic matter, and have limited ability to hold water. The use of fertilizer to address the crisis has remained low compared to the rest of the world because of unaffordability, of fertilizers by the farmers due to high prices of mineral fertilizers and lack of credit facilities. As farmers continue to experience these challenges, soil fertility decline continues, causing low crop production and making the efforts to attain sustainable food security to remain elusive. The low use of fertilizer below recommended rates for sustaining soil fertility coupled with nutrient losses, is not only a treat to agricultural productivity but also raises pertinent sociopolitical and environmental concerns (Canning et al; 2015). Hence, securing present and future food security depends on how effectively and sustainably soil fertility and sociopolitical and environmental concerns are addressed. Over the years, soil scientists have developed new approaches and technologies for increasing crop yields in smallholder farms. Integrated soil fertility management (ISFM) approaches developed in the 70's offer great potential for tackling soil fertility and sociopolitical and environmental problems. Integrated soil fertility management is defined as a set of fertility management practices that necessarily include the use of mineral fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions. The aim is to maximize agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe et al; 2010, Saginga and Woomer 2009). In the year 2002, Sanchez and Jama (2002) stated that soil fertility depletion in smallholder farms is the fundamental biophysical cause of declining per capita food production in Africa. They further affirmed that, no matter how effectively other conditions are remedied, per capita food production would continue to decrease unless soil fertility depletion is adequately addressed. However, several years after this expose, soil fertility decline and declining per capita food production are still a disturbing situation in Africa. This is despite efforts made in promoting ISFM intervention to address soil fertility decline. The pertinent question then is: Why is the adoption of ISFM technologies still low in SSA? There is need for researchers and policy makers to seek answers to this disturbing scenario. Therefore the current research explores the results of ISFM interventions and the role of legumes in ISFM on smallholder farms using demonstration plot. The aim is to facilitate the adoption of ISFM technologies by smallholder farmers in the study area.

### Research Problem

Many technological and institutional innovations that can solve soil fertility degradation have been developed and yet, these innovations do not generally appear successful at the level of the smallholder farmers. Findings from prior agro - economic research on ISFM have demonstrated its efficacy under both research – station and on –farm managed trials (Vanluawe et al; 2010). Although the positive benefits of ISFM are well established in scientific literature, the practice and adoption of ISFM principle by smallholder farmers has been either less desired or less successful than desired in Nigeria.

### Research objectives

The general objective of the study is to promote the adoption of effective soil fertility management practices in smallholder farming communities in Nigeria. The specific objectives are (i) to test the soil fertility status of the study site (ii) to produce organic fertilizer from locally available resources (poultry waste and Gliricidia leaves), and (iii) evaluate maize crop growth and biomass yield in response to complimentary use of inorganic and organic fertilizer treatment.

### Research question

1. What is the status of major soil nutrients in the experimental site?
2. Can organic fertilizer be produced from locally available resources?
3. How will growth and biomass yield of maize crop respond to complimentary use of inorganic and organic fertilizer in smallholder farm?

### Justification for the research

About 65% of the agricultural lands in Africa is degraded mainly due to low nutrients application, soil erosion and soil acidification (Zingore et al; 2017). Unless the soils are regenerated to good soil health, any gains in agricultural production will rely on bringing additional land under cultivation (extensification) which evidently leads to rising deforestation. By combining a proven set of concepts, principles and practices that lead to efficient use of available organic and inorganic resources to maintain or improve soil fertility, we can improve sustainable crop production for household food and income security and enhance local livelihood.

# MATERIALS AND METHODS

## Study Area

The study was carried out in Akure, the capital city of Ondo State, in southwestern Nigeria. Akure is located at approximately 705' N latitude and 501' E longitude. Akure lies about 356 metres above sea level. The local terrain is gently undulating, studded with massive granite inselbergs and surrounded by a vast expanse of natural forest. Akure experiences a hot humid tropical climate with a mean annual temperature of roughly 26.70C and high relative humidity (averaging 77-80%). There are two distinct rainy seasons (March to July and late August to November), providing excellent climatic conditions for agricultural trials and field experiments (Olajumoke et al 2016). The major agricultural crops include cash crops like cocoa and oil Plam, alongside staple food crops such as cassava, yams, maize and plantains, hence the major occupation of the people is farming.

## Soil Sampling and analysis

Information on the current fertility status and properties (chemical and biological) of the soil in the experimental site is critical for linking the current crop growth on the farm with soil and to collect evidence- based data in the study site that will be used as baseline. For soil sampling, three (3) sample plots of 5 m x 5 m in size were demarcated at the center of the farm. Soil samples were collected at three equidistant points located diagonally across each sample plot at 0-30 cm depth, using soil auger. The soil samples were thereafter taken to the laboratory and analyzed for Organic carbon total nitrogen, exchangeable cations and microbial population (bacteria and fungi). Soil carbon was determined by Walkley – Black wet oxidation method (Walkley and Black 1934); total N by Kjheldahl method (AOAC, 1993) and exchangeable cations by ammonium acetate method. The bacteria and fungi population were determined by culture –based method (dilution plate technique.

## Production of organic fertilizer from locally available resources (Gliricidia leaves and poultry waste

The technical process for the production of organic fertilizer used in this study is farmers' friendly. The production involves the following processes:

i. Procurement of raw material: Poultry waste was collected fresh from poultry farms while Gliricidia leaves were collected freely from the wild.

ii. Curing and drying: The fresh Gliricidia leaves and poultry waste were spread on polythene sheets separately in a well ventilated space and air dried to constant weight (completely dried).

iii. Grinding: In this third process, the dried Gliricidia leaves was milled using milling machine while the dried poultry waste was crushed using mortar to particulate sizes. Thereafter, the products were spread on polythene sheet to cool in a ventilated room.

iv. Product formulation: The organic fertilizer was formulated by simply combining the particulate products from Gliricidia and poultry waste (50:50;v/v)

v. Packaging: The formulated organic fertilizer formulated were parked in 2kg customized cellophane bag for proper storage and latent use

## Laboratory analysis of organic fertilizer sample

The blended organic fertilizer produced was analyzed in the laboratory for N, P, K concentration using standard laboratory methods

## Field Demonstration experiment

For early season maize cultivation commencing April, 2026, viable and certified maize seeds was procured from Agricultural Development Project (ADP) in Akure, Ondo State. In a selected farmer's farm, a land area measuring 20 mx 20 m was demarcated and cleared of existing vegetation. Thereafter, the cleared land was demarcated into plots of 1 mx 1 m size with 1 m space between plots to serve as buffers. Thereafter the

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experimental treatment which include (i) Organic fertilizer only (100g/plant) (ii) Organic fertilizer (100g/plant) + micro-dose NPK fertilizer (15g/plant); (iii) NPK fertilizer only (30g/plant) (iv) no fertilizer application (control) were randomly distributed into the demarcated plots at three replicates per treatment. The inorganic fertilizer was NPK 20-10-10 while the organic fertilizer composed of a mixture of Gliricidia leaves and poultry waste in equal volume. Three seeds were sown per hole which were later thinned to two seedling per hole after germination at a spacing of 50 cm x 75 cm within and between rows respectively during the rainy season (April – May). After seed germination and at 2 weeks after sowing (WAS), the fertilizer treatments were applied in a ring form around the maize plants. The experimental plots were left as rainfed and all cultural practices including weed and pest control were adequately applied.

### Data collection

During the maize growing period, and specifically starting from 2WAS, plant height and stem circumference were measured per treatment and per replicate up till 10WAS. At 10WAS, one maize plant per treatment per replicate were harvested for estimation of biomass yield. The harvested maize plants were separated into root, leaf and stem. In the laboratory, the fresh weights (root, leaf, stem) were measured and sub-sample of each plants part taken and oven dried at 650C for 6-8 hours. Thereafter the plant biomass was cooled in desiccator and biomass weight taken and expressed as total dry weight per plant.

### Computation

Total dry wt. (g) = sub-sample dry wt. (g) x Total fresh wt. (g) / sub-sample fresh wt. (g)

### Design of Experiment

The design of experiment was a completely randomized (CRD) at three replicates per treatment.

### Research hypothesis

Null hypothesis (Ho): There is no significant difference between the growth and biomass yield of maize crop in response to varying fertilizer treatments

Alternative hypothesis (HA): There are significant differences between the growth and biomass yield of maize in response to varying fertilizer treatments

### Statistical analysis

Data obtained on the variable measured (plant height, stem circumference, biomass yield) in response to experimental treatments was subjected to analysis of variance (ANOVA) using SPSS statistical package. Significant difference in the treatment was further subjected to Duncan Multiple Range Test (DMRT) for the separation of treatment means (Steel et al; 1997)

## RESULT AND DISCUSSION

### Status of Experimental site

The selected soil properties of the experimental site indicates a very high sand particles, low silt content and moderately high clay particles. The N, P, K, Mg, Ca and Na content in the soil are generally low in status compared to standard classification in agricultural soils. (Table 1). Similarly, the bacteria and fungi count in the soil of the experimental site is also considered very low. As indicated, the experimental site is considered a non - fertile soil with poor health status. The site is therefore considered adequate for the soil fertility experiment.

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Table 1. Status of Soil properties in the experimental site

| Soil Property | Content | status |
|---|---|---|
| Sand | 69.52% | High |
| Silt | 6.56% | Low |
| Clay | 27.92% | High |
| N | 0.1% | Low |
| P | 6.74 mg/Kg soil | Low |
| K | 4.74 mg/Kg soil | Low |
| Mg | 4.50 mg/Kg soil | Low |
| Ca | 4.60 mg/Kg soil | Low |
| Na | 7.22 mg/Kg soil | Low |
| pH | 4.78 | Slightly acidic |
| Bacteria count | 6.25 x 105 cfu/g soil | Low |
| Fungi count | 11.1 x 104 cfu/g soil | Low |

**Maize crop growth in response to fertilizer application**

The results of the Analysis of variance (ANOVA) and mean separation of the growth response of maize crop to fertilizer treatments at week 2,4,6,8 and 10 are presented in Tables 2, 3, 4, 5, 6,7,8,9 and 10 respectively. At week 2, the maize stem height and circumference were not significantly different ($P > 0.05$) in response to the different fertilizer treatments (Table 2). However, at week 4, the maize stem height and circumference respectively, were significantly higher in organic fertilizer and NPK combined treatment (131.3 cm; 9.3 cm) than organic fertilizer alone and NPK fertilizer treatments which were not significantly different (Table 3). The maize stem height and circumference for the No Fertilizer treatment (Control) were significantly low (79.67; 5.67) compared with other fertilizer treatments. The same trend of results were observed at week 6, 8, and 10 respectively (Tables 4, 6, 7, 8, 9and 10).

Table 2: ANOVA for Stem Height and Stem Circumference at Week 2

| | | Sum of Squares | df | Mean Square | F | P | Sig. |
|---|---|---|---|---|---|---|---|
| Stem Height | Treatment | 33.667 | 3 | 11.222 | 0.922 | 0.473 | ns |
| | Error | 97.333 | 8 | 12.167 | | | |
| | Total | 131 | 11 | | | | |
| Stem Circumference | Treatment | 2.396 | 3 | 0.799 | 1.322 | 0.333 | ns |
| | Error | 4.833 | 8 | 0.604 | | | |
| | Total | 7.229 | 11 | | | | |

** (Significant) $p \leq 0.05$; ns (Not Significant) = $p > 0.05$*

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Table 3. Effect of Fertilizer Treatments on Stem Height and Stem Circumference at Week 2

| Fertilizer Treatment | Stem Height (cm) | Stem Circumference (cm) |
|---|---|---|
| Organic Fertilizer (100 g/plant) | $42.67 \pm 5.51^{a}$ | $4.67 \pm 1.26^{a}$ |
| Organic Fertilizer + NPK (100 g + 15 g/plant) | $46.33 \pm 2.08^{a}$ | $4.00 \pm 0.87^{a}$ |
| NPK (30 g/plant) | $46.00 \pm 2.65^{a}$ | $3.67 \pm 0.29^{a}$ |
| Control (No Fertilizer) | $47.00 \pm 2.65^{a}$ | $3.50 \pm 0.00^{a}$ |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at $p \leq 0.05$.*

Table 4. ANOVA for Stem Height and Stem Circumference at Week 4

| | | Sum of squares | df | Mean square | F | P | sig |
|---|---|---|---|---|---|---|---|
| Stem Height | Treatment | 4009.667 | 3 | 1336.556 | 10.524 | 0.004 | * |
| | Error | 1016 | 8 | 127 | | | |
| | Total | 5025.667 | 11 | | | | |
| Stem Circumference | Treatment | 20.167 | 3 | 6.722 | 8.491 | 0.007 | * |
| | Error | 6.333 | 8 | 0.792 | | | |
| | Total | 26.5 | 11 | | | | |

* *(Significant) = $p \leq 0.05$; ns (Not Significant) = $p > 0.05$*

Table 5. Effect of Fertilizer Treatments on Stem Height and Stem Circumference at Week 4

| Fertilizer Treatment | Stem Height (cm) | Stem Circumference (cm) |
|---|---|---|
| Organic Fertilizer (100 g/plant) | $107.00 \pm 10.54^{b}$ | $7.50 \pm 1.32^{b}$ |
| Organic Fertilizer + NPK (100 g + 15 g/plant) | $131.33 \pm 10.12^{a}$ | $9.33 \pm 0.58^{a}$ |
| NPK (30 g/plant) | $106.67 \pm 3.51^{b}$ | $7.50 \pm 0.87^{b}$ |
| Control (No Fertilizer) | $79.67 \pm 16.80^{c}$ | $5.67 \pm 0.58^{c}$ |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at $p \leq 0.05$.*

Table 6: ANOVA for Stem Height and Stem Circumference at Week 6

| | | Sum of squares | df | Mean square | F | P | sig |
|---|---|---|---|---|---|---|---|
| Stem Height | Treatment | 10219.667 | 3 | 3406.556 | 12.037 | 0.002 | * |
| | Error | 2264 | 8 | 283 | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total | 12483.667 | 11 | | | | |
| Stem Circumference | Treatment | 27.167 | 3 | 9.056 | 9.659 | 0.005 | * |
| | Error | 7.5 | 8 | 0.938 | | | |
| | Total | 34.667 | 11 | | | | |

** (Significant ) = $p \leq 0.05$; ns (Not Significant) = $p > 0.05$*

Table 7. Effect of Fertilizer Treatments on Stem Height and Stem Circumference at Week 6

| Fertilizer Treatment | Stem Height ( cm) | Stem Circumference ( cm) |
|---|---|---|
| Organic Fertilizer (100 g/plant) | $154.33 \pm 25.48^{b}$ | $7.83 \pm 1.26^{bc}$ |
| Organic Fertilizer + NPK (100 g + 15 g/plant) | $201.00 \pm 12.29^{a}$ | $10.50 \pm 1.32^{a}$ |
| NPK (30 g/plant) | $168.33 \pm 10.69^{b}$ | $8.67 \pm 0.58^{b}$ |
| Control (No Fertilizer) | $119.67 \pm 14.74^{c}$ | $6.33 \pm 0.29^{c}$ |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at $p \leq 0.05$.*

Table 8: ANOVA for Stem Height and Stem Circumference at Week 8

| | | Sum of squares | df | Mean square | F | P | sig |
|---|---|---|---|---|---|---|---|
| Stem Height | Treatment | 14475.333 | 3 | 4825.111 | 7.356 | 0.011 | s |
| | Error | 5247.333 | 8 | 655.917 | | | |
| | Total | 19722.667 | 11 | | | | |
| Stem Circumference | Treatment | 22.833 | 3 | 7.611 | 8.303 | 0.008 | s |
| | Error | 7.333 | 8 | 0.917 | | | |
| | Total | 30.167 | 11 | | | | |

** (Significant ) = $p \leq 0.05$; ns (Not Significant) = $p > 0.05$*

Table 9. Effect of Fertilizer Treatments on Stem Height and Stem Circumference at Week 8

| Fertilizer Treatment | Stem Height (cm) | Stem Circumference (cm) |
|---|---|---|
| Organic Fertilizer (100 g/plant) | $222.00 \pm 41.33^{a}$ | $9.33 \pm 1.15^{a}$ |
| Organic Fertilizer + NPK (100 g + 15 g/plant) | $262.00 \pm 23.30^{a}$ | $10.83 \pm 1.44^{a}$ |
| NPK (30 g/plant) | $218.33 \pm 16.50^{a}$ | $9.50 \pm 0.50^{a}$ |
| Control (No Fertilizer) | $164.33 \pm 10.02^{b}$ | $7.00 \pm 0.00^{b}$ |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at p ≤ 0.05.*

Table 10: ANOVA for Stem Height and Stem Circumference at Week 10

| | | Sum of Squares | df | Mean Square | F | P | Sig. |
|---|---|---|---|---|---|---|---|
| Stem Height | Treatment | 9838.333 | 3 | 3279.444 | 4.317 | 0.044 | * |
| | Error | 6077.333 | 8 | 759.667 | | | |
| | Total | 15915.667 | 11 | | | | |
| Stem Circumference | Treatment | 13.563 | 3 | 4.521 | 7 | 0.013 | * |
| | Error | 5.167 | 8 | 0.646 | | | |
| | Total | 18.729 | 11 | | | | |

** (Significant) = p ≤ 0.05; ns (Not Significant) = p > 0.05*

Table 11. Effect of Fertilizer Treatments on Stem Height and Stem Circumference at Week 10

| Fertilizer Treatment | Stem Height (cm) | Stem Circumference (cm) |
|---|---|---|
| Organic Fertilizer (100 g/plant) | $248.67 \pm 42.02^{ab}$ | $9.67 \pm 1.04^{b}$ |
| Organic Fertilizer + NPK (100 g + 15 g/plant) | $284.67 \pm 16.17^{a}$ | $11.33 \pm 1.04^{a}$ |
| NPK (30 g/plant) | $250.00 \pm 30.00^{ab}$ | $9.83 \pm 0.29^{ab}$ |
| Control (No Fertilizer) | $204.00 \pm 10.58^{b}$ | $8.33 \pm 0.58^{b}$ |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at p ≤ 0.05.*

**Biomass Yield of Maize in response to varying Fertilizer treatments**

The results of the maize biomass yield (root dry weight; stem dry weight; leaf dry weight) in response to varying fertilizer treatment is presented in Table 11. As shown, the maize root dry weight is significantly higher (P < 0.05) in NPK fertilizer treatment (133.27g) than organic fertilizer treatment and the combined NPK and organic fertilizer treatments. For the stem dry weight, the values for all the fertilizer treatments were not significantly different but were significantly (P < 0.05) higher than no fertilizer treatment (control) which had a significantly lower value of 38.87g compared to the what were recorded for organic fertilizer alone; combined organic fertilizer with NPK and NPK fertilizer treatments which were 145.63g; 133.47 and 102.27g respectively (Table 11). The same trend was observed for the maize leaf dry weight. Consistently, all the fertilizer treatments gave a significantly higher maize biomass yield than no fertilizer treatment (Control).

Table 12. Effect of Fertilizer Treatments on Root Dry Weight, Stem Dry Weight, and Leaf Dry Weight

| Fertilizer Treatment | Root Dry Weight (g) | Stem Dry Weight (g) | Leaf Dry Weight (g) |
|---|---|---|---|
| Organic Fertilizer (100 g/plant) | $80.83 \pm 60.79^{a}$ | $145.63 \pm 26.77^{a}$ | 53.67 ± 14.06a |

| | | | |
|---|---|---|---|
| Organic Fertilizer + NPK (100 g + 15 g/plant) | 118.07 ± 43.48a | 133.47 ± 42.36[a] | 69.50 ± 5.27[a] |
| NPK (30 g/plant) | 132.27 ± 64.01b | 102.27 ± 77.54[b] | 58.00 ± 13.08[a] |
| Control (No Fertilizer) | 13.97 ± 4.17c | 38.87 ± 22.61c | 20.87 ± 5.80b |

*Means within each column followed by the same superscript letter are not significantly different according to Duncan's Multiple Range Test at $p \leq 0.05$.*

The result obtained in this study have proved that the application of organic and inorganic fertilizer increased maize growth and biomass yield relative to control. Combining NPK (Nitrogen, Phosphorus and Potassium) and organic fertilizer creates a synergistic effect that boosts maize growth, biomass yield and enhances soil health. While mineral fertilizer (NPK) provides immediate, concentrated nutrients, organic inputs release nutrients slowly and improve soil structure, buffers soil pH, enhances water retention and microbial activity. This explains the significantly higher stem height, stem circumference and biomass yield recorded in NPK and complimentary organic fertilizer treatments in the present study. The results obtained in this study corroborate the study by Ogunweide et al (2022) who reported similar observation in maize yield. In a similar study, Olatunji and Ayuba (2012) observed that a combination of poultry manure and NPK 20 -10 -10 gave the highest grain yield. Also in a study by Adepoju (1997), it was observed that a combination of organic and inorganic fertilizer is required for increased grain yield and sustainable soil productivity under intensive continuous cultivation. Also studies carried out in southwest Nigeria by Eneji et al (1997) and Ojeniyi (1999) recommended combination of farmyard manure and NPK fertilizer for sole and intercropped maize. Reports from several authors in the tropics had indicated that farmers must not assume that soil can be made productive by chemical fertilizer alone but by combining organic and inorganic fertilizer that can build up soil organic matter.

## CONCLUSION

The result obtained from the research have proved that the application of organic and inorganic fertilizer increased maize growth and biomass yield relative to control. This would help to reduce the bulkiness of sole organic manure application and also reduce the high cost of inorganic fertilizer. Also the combined use of organic and inorganic fertilizer could reduce the possible acidic effect of nitrogen while improving nutrient status of the soil and ensuring a balanced plant nutrition as well as preserving environmental impact of synthetic fertilizer. The use of the combination of organic and inorganic fertilizer is therefore recommended for smallholder farmers for increased crop yield and soil fertility improvement under intensive continuous cultivation.

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