Improving Maize (*Zea mays* L.) growth and yield by the application of inorganic and organic fertilizers plus

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**Abstract.** Maize or corn is the most important crop as a staple food in many places in the world. It is mostly grown in dryland area with very low in soil fertility. Therefore this study aimed to investigate the effect of inorganic and organic fertilizers plus on the soil chemical changes, growth and yield of maize. The experimental designed was Randomized Complete Block Design (RCBD) in the pattern of factorial, which consisted of two factors. The first factor was Organic fertilizer plus (P), which consisted of three levels namely: P0 (without organic fertilizer plus), P1 (10 ton ha⁻¹), P2 (20 ton ha⁻¹), and the second factor was inorganic fertilizer (A), which consisted of three levels, namely: A0 (without inorganic fertilizer), A1 (150 kg ha⁻¹) and A2 (300 kg ha⁻¹), with three replication. Data collected were analyzed by using analysis of variance at 5% level and significant treatments effect were separated with honestly significant difference at P ≤ 0.05. Results indicated that there were no interaction between inorganic and organic fertilizers plus rates on growth, yield and soil chemical changes. The use of organic fertilizers plus significantly improved the growth, yield and soil chemical properties. Dealing with the agronomic properties of maize showed that the application of inorganic fertilizer significantly increased the plant weight by increasing the plant height, leaf numbers and leaf area.

**Keywords:** inorganic, organic fertilizer plus, maize growth, yield

1. **Introduction**
Maize (*Zea mays* L.) is an important annual cereal of the world after rice and wheat and it is considered as staple food crop for many people especially Africa and it is cultivated widely throughout the world. Due to its highest yield potential among the cereals it is known globally as queen of cereals [1]. In ancient Greek word *Zea* means “sustaining life” and *mays* is a word from Taino language meaning “life giver.” It contains about 72% of starch, 10% of protein, 4% of fat and 365 Kcal 100 g⁻¹ energy density. Maize production has shown a steady increase over the year for food (consume as vegetable), feed and industry product including oil, livestock feed, glue, industrial alcohol and fuel ethanol. In tropical countries, maize is mainly produce by small scale farmers [2].

In Lombok, most of maize was grown in soil with course in texture or sandy soil with very low soil fertility, such as low in soil organic matter, cation exchange capacity (CEC), nutrients and water retention. Therefore, it needs, to increase the soil fertility including soil characteristics for maize growth and yield. Inorganic fertilizers play a crucial role in modern agriculture, to increase maize growth and production, but it is also known that dependence on inorganic fertilizers results in decrease in soil organic matter, acidity, soil degradation through soil nutrient imbalance, nutrients uptake, acidity, or...
increasing environmental pollution. To overcome this problem, nutrients management by applying inorganic and organic fertilizer (biochar + manure + EM-4, fermented for 4 weeks) were needed. The uses of inorganic fertilizer is to fulfill the nutrients requirement by maize plant growth and yield. The decline of soil organic matter content enhances nutrient losses caused nutrients leaching or by soil erosion. So that, it is important to add organic fertilizers to ensure fertilizers uses efficiency. The evaluation of soil fertility is perhaps the most basic decision making tool in order to impose appropriate nutrient management strategies [3]. In this case with understanding of the rapid decomposition of soil organic matter or material, it had found that more recalcitrant organic material sources for soil management. This material is made from agricultural waste has been known as biochar. Biochar is a carbon-based compound that is relative stable and derived from agricultural waste or biomass pyrolysis, that has a positive impact on both soil characteristics and crop performance, such as reducing soil acidity, reducing soil nutrient leaching by increasing the buffering capacity, avoiding carbon dioxide release, and also reducing pesticide runoff and organic pollutant bioavailability, which is important to improve soil quality physical, chemical and biological, particularly for sandy soil [4][5][6].

Agricultural waste has potential as organic fertilizer which contain crude fiber this coarse fiber is very high and can be derived by fermentation with local microorganisms (MOL) or effective microorganism so called EM4 bioactivators. This two bioactivator especially EM4 is the microbes that can degrade crude fiber content because it has the ability to produce enzymes laccases and piroxidases can break down and dissolve the lignin contained in waste that serve as a source of energy, EM4 is also susceptible to decay and damage. The coarse fiber after fermented by EM4 can be directly uses as organic fertilizer and has the biggest contribution to the environment [7]. Therefore, the objectives of this present study were to investigate the effect of inorganic and organic fertilizers plus on the soil chemical changes, growth and yield of maize.

2. Materials and Methods
2.1. Design of Field Experimental and Treatment
The field experiment was conducted in Narmada village, West Lombok. The experimental design was established using CRBD (Completely Randomized Block Design) with arranged in a factorial pattern, consisted of two factors namely 3 rates of organic plus fertilizer was made from biochar, Caw manure and compost with EM-4 then fermented for four weeks. (P0= without organic fertilizer; P1 = 10 ton ha⁻¹; P2=20 ton ha⁻¹), inorganic fertilizer and 3 rates of phonska (A0= without phonska; A1= 150 kg ha⁻¹; A2 = 300 kg ha⁻¹ phonska). Each treatment repeated three times.

2.2. Sampling and Data Analysis
The data collected were biomass at harvest, grain yield and soil properties before and after experiment. The soil data analyzed were as follow: soil pH-H₂O measured by pH metre, organic carbon measured by Walkley and Black method, total nitrogen determined by Kjeldahl method, Available phosphorus extracted by Bray I using a UV Spectrophotometre, exchangeable potassium analyzed by using an atomic absorption Spectrophotometer.

Plant parameters were plant height, numbr of leaves, grain and biomass of maize was measured for fresh weight and dry weight determined after drying in a mechanical over dryer at 70 °C until a constant weight was attained.

2.3. Statistical Analysis
The mean values effect of treatments on changes in soil chemical properties and agronomis properties of maize were analyzing using analysis of variance (ANOVA) at 5% and significant difference of treatment was tested by Honestly significant difference at the same level. All statiscal test were performed using MiniTab.
3. Results and Discussions

3.1. Initial Soil characteristics

A bulk soil sample from the field was collected, the soil was air dried and sieved at 2 mm in size. The initial soil characteristics that used in this experiment that can be seen as follow:

| Variable          | Method             | Value  | Characteristic  |
|-------------------|--------------------|--------|-----------------|
| Texture : Sand (%)| Sedimentation      | 56.67  | Sandy loam      |
| Silt (%)          |                    | 32.67  |                 |
| Clay (%)          |                    | 10.66  |                 |
| pH-H₂O            | pH metre           | 5.68   | Acid            |
| Organic-C (%)     | Walkley & Black    | 1.04   | Low             |
| Total-N (%)       | Kjeldahl           | 0.20   | Low             |
| C/N ratio         | -                  | 10.2   | Moderate        |
| CEC               | Ammo-Acetat        | 10.28  | Low             |
| Avai-P (ppm)      | Bray I             | 21.57  | Low             |
| Exchg-K (ppm)     | Morgan Wolf        | 42.75  | High            |

Soil analysis assess the current fertility status and provides information regarding soil characteristic and nutrient availability in soils which forms, for maximizing maize yields and to maintain the adequate fertility in soils for maize growth. From Table 1. It can be seen that soil that used in this experiment had low soil fertility, with sandy loam in texture, 56.67% of sand, 32% of silt and 10.66% of clay. Soil texture Soil texture affects the soil sustainability. The sand, silt and clay are the three components of soil texture. It affects absorption of nutrients, microbial activities, the infiltration and retention of water, soil aeration, tillage and irrigation practices.

Soil pH is important chemical parameter of soil that affects nutrient availability [3]. The pH of soil was 5.68 (Table 1), this indicates acidic soil pH. The availability of various nutrients for plants rice, maize and vegetables may be reduced. Therefore, periodically applying biochar and cow manure incorporation is imperative for improvement of soil pH [8]. Organic carbon and soil nutrient were low except for potassium. Hence, by using organic fertilizer plus, which was made from cow manure, biochar than fermented by adding EM4 for 4 weeks can be expected that could increase the soil productivity and improve the maize growth and yield. The texture is important soil physical parameters. Similarly, soil reaction (pH), organic matter, macro and micronutrients are also important soil chemical parameters.

3.2. Soil characteristics changes after harvesting

Effect of Organic and inorganic fertilizers on soil changes after harvesting can be seen in Table 2. provide information about the capacity of soil to supply mineral nutrients [9]. Table 1. indicated that the effect of inorganic and organic fertilizers on pH and CEC changes. Applying organic fertilizer showed a significant different for soil pH and CEC, and increasing soil pH from acid to neutral would influenced the nutrients availability of soil, while the increase of CEC in the soil could improve nutrients retention, reduce the nutrient losses and this lead to improve the soil fertility.

| Treatment | pH (H₂O) | CEC (cmol kg⁻¹) |
|-----------|----------|-----------------|
| A0        | 6.42 b   | 39.46 b         |
| A1        | 7.21 a   | 47.27 a         |
| A2        | 7.29 a   | 47.16 a         |
| **HSD (5%)** | **0.20** | **5.8**        |
| P0        | 6.57 c   | 40.52 b         |
| P1        | 6.80 b   | 46.72 a         |
Organic matter is an important source to sustaining soil fertility and for plant essential nutrients after their decomposition by microorganisms. It feeds soil micro-flora and fauna, supplies plant nutrient, retention and cycling of applied fertilizer [10]. From Figure 1. Showed that without organic fertilizer plus application contributed the lowest organic-C. In addition, this is simply that organic fertilizer plus have positive contribution to soil carbon stability, which can be expected that further contribute to greater soil productivity. The addition of inorganic fertilizers was also significantly influenced organic carbon after harvesting (Figure 2). This is due to biochar is rich in carbon material, and it is very important for improving soil quality.

There was a significant effect of organic and inorganic fertilizer on soil nutrients such as N, P and K. The result given in Table 3 showed that application of both organic plus and inorganic fertilizers enhanced total-N from 0.12 to 0.68% for inorganic fertilizer and from 0.18 to 0.76 for organic fertilizer. The increasing of total-N in organic fertilizer plus application was higher than in inorganic fertilizer. Possibly, it due to the higher soil organic matter in soil, and also N is slow release or control release. While, N in inorganic fertilizer is in available form which is easy to volatile or leach. As we know that almost 78% of N is from the atmosphere and organic materials. Beside that, nitrogen is one of the macro nutrient than and taken up by plants in greatest quantity. However, in the tropics for crop production it is one of the most deficient elements [11]. Available phosphorus (Table 3) is the master key to agriculture. The growth of both cultivated and uncultivated plants is limited by availability of P in the soils. The available phosphorus (P₂O₅) was ranged from 19.7 to 27.7 ppm. This showed high value of available phosphorus was obtain in soil by adding inorganic fertility. It is assume that P is relative stable in the soil, therefore P concentration was higher than in soil applied by organic fertilizer plus.

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| Fertilizer Type | Mean (± SE) | HSD (5%) | *p*
|-----------------|------------|----------|------|
| P₂O₅            | 0.18 ± 0.02| 0.010    | *   |

*Means followed by the same letter in the same column are not significantly different by HSD at 5%.*
Table 3. Effect of organic fertilizer plus and inorganic Soil nutrients N, P, After Harvesting.

| Treatment | Soil Nutrients in Soil | Total-N (%) | Avai-P (ppm) | Exch –K (%) |
|-----------|------------------------|-------------|--------------|-------------|
| A0        | 0.12 c                 | 19.7 c      | 0.80 c       |
| A1        | 0.53 b                 | 25.8 b      | 1.75 b       |
| A2        | 0.68 a                 | 27.7 a      | 2.05 a       |
| HSD 5%    | **0.08**               | **1.2**     | **0.23**     |
| P0        | 0.18 c                 | 18.3 b      | 0.78 b       |
| P1        | 0.54 b                 | 25.6 a      | 1.90 a       |
| P2        | 0.76 a                 | 26.5 a      | 2.15 a       |
| HSD 5%    | **0.07**               | **1.3**     | **0.56**     |

*Means followed by the same letter in the same column are not significantly different by HSD at 5%.

Data presented in Table 3 indicated that the application of inorganic and organic plus fertilizers have significant effect on improvement of potassium in the soil. Both nitrogen and phosphorus are constituents of the soil organic matter, but not for potassium, because soil organisms have a lower requirement of soil organic matter. Consequently, soil organic residues decompose, most of the potassium is released soon. In addition, the potassium in organic fertilizers is highly available because potassium is not organically bound when the plant died and decomposed potassium is released immediately. Meanwhile, animal manures and most agricultural residues, cocoa shells as biochar and wood ash commonly supply a significant amount of Potassium [12].

3.3. Growth and Yield of maize

Analysis variance show that there were a significant effect of Inorganic and Organic plus fertilizers on growth including plant growth rates in cm per week, and yield of maize can be seen as follows in Table 4. A number of studies have shown that application of inorganic and organic plus fertilizers can increase growth and yield components of maize. Table 4 pointed out that plant growth rates were strongly influenced by adding organic plus fertilizer. There were a significant difference

Table 4. Response of applications and inorganic fertilizers rates on soybean growth at maximum vegetative growth.

| Treatment | Growth and yield components |
|-----------|-----------------------------|
|           | Plant growth rates (cm week⁻¹) | Leaf numbers | Shoot fresh weight (g plant⁻¹) | Grain weight (g) |
| A0        | 30.35 b                     | 19.7 b       | 178.33 c                   | 7.81 b          |
| A1        | 32.62 a                     | 22.8 a       | 254.25 b                  | 13.32 a         |
| A2        | 33.87 a                     | 23.5 a       | 272.80 a                  | 18.56 a         |
| HSD 5%    | **0.34**                    | **1.2**      | **5.23**                   | **0.5**         |
| P0        | 29.82 b                     | 18.8 b       | 172.84 c                  | 7.42 b          |
| P1        | 32.41 a                     | 24.8 a       | 245.44 b                  | 16.74 a         |
| P2        | 32.90 a                     | 25.5 a       | 267.52 a                  | 18.17 a         |
| HSD 5%    | **0.23**                    | **1.70**     | **4.85**                   | **0.90**        |

*Means followed by the same letter in the same column are not significantly different by HSD at 5%.

growth and yield components between without and with inorganic and in organic fertilizer. Giving 150 kg ha⁻¹ of inorganic fertilizers combined with 10 ton ha⁻¹ of organic plus fertilizers did not show did not different with adding 300 kg ha⁻¹ combined with 20 ton ha⁻¹ of organic plus fertilizers for plant growth rate, leaf number and weight of 100 grain (g) of maize. Shoot fresh weight increased
significantly by the increase of inorganic and organic plus fertilizers. The highest shoot dry weight achieved at the highest of inorganic and organic plus fertilizers. Overall, this study confirms that the strategies used to minimize the loss of nutrients from soil and efficiencies used of inorganic fertilizer is to integrate the use of inorganic fertilizer and organic plus fertilizer that made from the combination of animal manures biochar and fermented with EM4 or Local Microorganisms. It seems that a valuable for improving soil fertility and to sustain maize production particularly for sandy soil.

4. Conclusion
It can be concluded that inorganic fertilizer combined with organic plus fertilizers could change the oil characteristics including soil pH, soil organic matter, cation exchange capacity and also for soil nutrients nitrogen, phosphor and potassium. Agronomic properties including plant growth rates, number of leaves, shoot fresh weight and weight of maize grain also significantly influenced by inorganic and organic plus fertilizers. Furthermore, to ensure food security in maize production, efforts are needed for exploring the best combination of inorganic and organic plus fertilizers on each soil type and the environment.

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