Can organic soil ameliorant and foliar organic fertilizer improve maize yield and reduce inorganic fertilizers input in a dryland semiarid?

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Abstract. There is still room for improving maize yield and cultivation practices in dryland semiarid areas since the current production is still low and the inorganic fertilizers (IF) input is high. This study aimed to assess possible roles of a commercially available organic soil ameliorant (OSA) and foliar organic fertilizer (FOF) to improve maize yield and to reduce IF input in a dryland semiarid area. One experiment with seven treatments were tested, namely: (A) 100% of IF doses, that consisted of 500 kg of urea and 360 kg of NPK Phonska (15-15-15) per hectare, (B) Treatment A plus OSA and FOF, (C) 70% of IF doses plus OSA and FOF, (D) Treatment A plus OSA, (E) 70% of IF plus OSA, (F) Treatment A plus FOF, and (G) 70% of IF plus FOF. The size of each treatment plot was 10.1 m² and there were 90 plants in each plot. All the treatments were replicated three times and were arranged in a randomized block design. The results showed that the IF treatment (A) produced 11.0 kg per plot, equal to 10.9 ton/ha. Adding OSA or FOF on top of IF (D and F), produced only 3% higher than the IF alone. However, when OSA and FOF were applied together with IF (B), the yield was 6% higher than the IF alone. The 30% reduction of inorganic fertilizer could not be replaced by both OSA and FOF (E and G) in producing yield. OSA improved soil nutrients, such as available phosphorous, potassium and C-organic but not the total nitrogen.

1. Introduction
Maize (Zea mays L.) is one of the most cultivated crops in drylands semiarid. Dryland is known to have low soil fertility and its fertility degrades fast when intensive cultivation is practiced [1]. The low level of soil fertility in dryland is caused by the low content of organic carbon in the soil. As is known, organic carbon in the soil has the function of maintaining the physical, chemical and biological properties of the soil [2]. Unfortunately, current conditions indicate that soil organic carbon continues to decrease due to various reasons, including soil erosion by both water and wind [3], or intensive crop cultivation practices, such as soil tillage and the use of excessive inorganic fertilizers, inappropriate irrigation techniques and lack of crop rotation [4]. In West Nusa Tenggara, especially in North Lombok Regency, it was reported that the organic carbon content in the soil is categorized as a low category, which is around 1.04% [5]. A more environmentally friendly practices are needed to sustain the dryland productivity in dryland semiarid areas.

Efforts to implement sustainable agriculture practices by maintaining carbon in the soil can be done...
by adding organic matter, both in the form of plant residues, cover crops and livestock manure. However, previous studies have shown that the addition of organic matter alone (such as the use of cover crops) has not been sufficiently effective in increasing organic carbon in the soil. High effectiveness in increasing organic carbon, especially the dissolved organic carbon in the soil, will be obtained if the addition of organic matter is accompanied by high microbial activity [6].

The microbial population in the soil, especially microbes that are beneficial for plant growth or known as plant growth promoting bacteria, can be increased by inoculating them into the soil. It was previously reported that the microbes inoculated into the soil could increase the growth of maize plants better in soil conditions that were poor in nutrients compared to the fertile one [7]. This finding gives a hope that the dryland with semiarid conditions in North Lombok Regency, with low fertility levels, can be increased its productivity if there are microbes in the soil that are beneficial for plant growth in sufficient numbers. Microbes that can increase the growth of maize plants have been identified and mostly come from the genus Pantoea, Bacillus, Burkholderia and Klebsiella [8].

Currently, there are many agricultural industrial products that act as biostimulants, such as to stimulate the presence or the activity of microbes in the soil and to increase plant growth [9]. The local existing products are, such as BeKa Plus, a decomposer plus or soil ameliorant and Pomi, a foliar organic fertilizer containing beneficial microbes for plants. BeKa is called soil ameliorant because the compost produced from decomposition process using BeKa decomposer can improve soil organic carbon, improve cation exchange capacity and water holding capacity, neutralized soil pH as well as contains high macro and micro nutrients. The microbes contained in BeKa Plus and Pomi are Azospirillum sp., Azotobacter sp., Pseudomonas sp., Bacillus sp., Streptomyces sp, Trichoderma sp., and Aspergillus sp. Apart from microbes, Pomi also contains macro nutrients (N, P and K) and micro nutrients, such as Fe, Mn, Cu, Zn, B, Co and Mo and an organic carbon content of 28.53% (https://www.acidatama.co.id/produs-agro.php?id=5, https://www.acidatama.co.id/product-agro.php?id=6).

The theories say that the benefits of organic matter for increasing soil organic carbon and plant growth can be increased by increasing the microbial consortium in the soil using soil amendments and foliar organic fertilizers [10,11]. Therefore, it is deemed necessary to conduct research on the effectiveness of organic soil ameliorant and foliar organic fertilizers which contain microbes, macro and micro nutrients and organic carbon in reducing the use of inorganic fertilizers in maize crops in a dryland semiarid.

2. Materials and methods

2.1. Sampling location

One field experiment was carried out in Gumantar Village, Kayangan District, North Lombok from April to September 2020. The inorganic fertilizers used by maize farmers in the Gumantar region are urea fertilizer at a dose of 500 kg/ha and NPK Phonska (15-15-15) with a dose of 360 kg/ha. These fertilizer doses were used as a reference for 100% inorganic fertilizer (IF) in this study. Meanwhile, the organic soil ameliorant (OSA) used was BeKa Decomposer Plus and the foliar organic fertilizer (FOF) used was yellow Pomi. BeKa and Pomi are both produced by PT. Indo Acidatama Tbk.

2.2. Treatments and experimental design. The treatments tested were: A. Inorganic fertilizers (IF) 100%; B. IF 100% + OSA + FOF; C. IF 70% + OSA + FOF; D. IF 100% + OSA; E. IF 70% + OSA; F. IF 100% + FOF and G. IF 70% + FOF. All the treatments were replicated three times and were arranged in a randomized block design. Collected data were analysed using analysis of variance in Minitab 15. Significant difference between means of the treatments was compared using Duncan’s Multiple Range Test (DMRT) at 95% confidence interval.

2.3 Crops establishment and management. In the experimental site, the land had been used to grow maize and after harvesting the maize, mungbean seeds then were broadcasted to utilized the remaining of rain water effectively. The mungbean crops (biomass) then were incorporated into the soil along with soil preparation at 3 weeks after broadcasting. Apart from the mungbean biomass, there were also remains of leaves and basal stems of maize from the previous crop. Immediately after land
preparation, BeKa Decomposer Plus, as an organic soil ameliorant (OSA), was sprayed onto the surface of the land that was receiving OSA treatment. The concentration of the BeKa solution used was 5 ml/liter of water and is sprayed evenly over the soil surface. The land then was left for 2 weeks while maintaining the soil moisture to maintain the live of microbial consortium that was already in the soil. Finally, plots were made with a size of 455 x 200 cm² for each treatment. Maize seeds, NK007 variety (PT. Syngenta Indonesia) were planted at a density of 9 plants/m². The 70 x 35 x 20 cm double-row planting pattern was used for planting maize crops, which meant that the distance between the two double rows was 70 cm, the distance within the double row was 35 cm, and the spacing in a double row was 20 cm. With such a planting pattern and plot size, three double rows of maize were planted in each plot with one single row in each edge of the plot. The planting orientation was east–west.

Maize plants were fertilized with inorganic fertilizers according to the treatment. The fertilization stages were as follows; basic fertilizers were given during planting in the form of urea and NPK (15-15-15) Phonska at a dose of 150 and 190 kg/ha, respectively. The first supplementary fertilization was applied when the plants were at 35 days after planting (DAP) with 200 and 190 kg/ha of urea and Phonska, respectively. The third urea fertilizer, with a dose of 150 kg/ha was given according to the treatment at tasseling, around 56 DAP. Irrigation and other crop maintenance, such as protection against pests and diseases are tailored to the needs of the plant.

2.4 Application of the treatments. Foliar organic fertilizer (FOF) of Pomi was dissolved with a concentration of 5 ml/liter of water and sprayed on all parts of the plant that received FOF treatments. Spraying started at the age of 15 DAP and was repeated once every 15 days until the ear filling development stage. The spraying treatments were carried out in the afternoon to prevent the death of the microbes contained in both OSA and FOF as a result of a direct sunlight during the day.

2.5 Variables observation
The observed variables were grouped into three parts. The first part was soil variables which included C-organic, total N, available P and available K in the soil, bacterium population and fungi density at 60 DAP. The second part was the variable of the maize plant. The parameters observed were plant height, number of leaves and the N total in plant leaf tissue measured at the tasseling. Crop yield variables, such as ear length, ear weight, seed weight per ear and dry seed weight per plot were observed after the seeds were dried at a moisture content of around 16%. The data from the observations were analyzed using the Analysis of Variance and followed by Duncan's Multiple Range Test for treatments that had a significant effect on the parameters observed.

3. Results and discussion

3.1 Crops performance
Maize crops received sufficient amount of water during their early establishment. Up to 14 days after planting (DAP), there were 58 mm of rainfall in the experimental site. The rest of water requirement for the crops to grow up to harvest was provided by irrigation from a deep-well pump located nearby. The maize crops grew well with a maximum temperature of 37°C and the minimum temperature was 25°C during the period of May to August 2020. Pesticide with an active ingredient of Spinoteram 120g/l was applied three times since there were eggs of Spodoptera frugiperda sighted in some of the crops’ leaves between 30 to 45 DAP.

3.2 Observation results
3.2.1 Soil variables. The soil organic carbon (SOC) at 60 DAP was affected by the treatments (table 1). The highest increased in SOC was recorded in the treatment of 70% of inorganic fertilizer (IF) combined with organic soil ameliorant (OSA). Compared to the 100% IF, there was 27.5% increase in SOC in the 70% IF plus OSA. The values in table 1 show that whenever the dose of IF reduced, the amount of SOC increased. The decomposition of organic matter available in the soil to became SOC was affected by exogenous organic carbon [12] contained in OSA. The activity of microbe consortium
to decompose organic matter was better in the lower inorganic fertilizer application than in the high one. Type of the organic materials available in the experimental site were maize leaves and basal stems from the previous experiment. Maize leaves and basal stems contain a high hemicellulose that its degradation by microbes might be retarded by the high availability of nitrogen [12,13] from the high rate of the inorganic fertilizations.

The highest total nitrogen (N) in the soil was recorded in IF 100% plus OSA plus FOF but not significantly different to IF 100% and all treatments with OSA. For the available phosphorous (P) and available potassium (K) in the soil, the highest values were recorded in the same treatment that resulted in the highest N and not significantly different to those treatments with IF 100% (table 1). Decomposition of organic matter (mungbean crops residues, some maize leaves and basal stems from the previous maize crops) with the application of a decomposer plus, and in this paper is called OSA, resulted in not only SOC but also available P and K in the soil. Earlier study showed that adding organic materials to the soil can improve soil physical, chemical and biological properties and usually, it takes a long time to make organic amendments improve soil properties properly [14]. In some cases, however, the beneficial effects of organic amendments can be gained in a short term, when there is sufficient nutrient applied [15]. In this study, sufficient amount of NPK Phonska was applied to all the treatment plots.

Table 1. Organic carbon, total N, available P, available K in the soil, bacteria colony and fungi density as affected by inorganic fertilizer (IF), organic soil ameliorant (OSA) and foliar organic fertilizer (FOF) applications

| Treatments        | C-organic (%) | Total N (ppm) | Available P (ppm) | Available K (meq%) | Bacteria Colony/m | Fungi density (CPU/g) |
|-------------------|---------------|---------------|-------------------|--------------------|-------------------|----------------------|
| A. IF 100%        | 0.69 ab       | 0.14 abc      | 168.50 bc         | 0.58 bc            | 12×10^10         | 3.47×10^4           |
| B. IF 100% + OSA + FOF | 0.69 ab | 0.17 c        | 194.66 d          | 0.76 d             | 16×10^11         | 3.90×10^4           |
| C. IF 70% + OSA + FOF | 0.77 cd      | 0.15 abc      | 172.88 bc         | 0.65 c             | 4×10^11          | 4.27×10^4           |
| D. IF 100% + OSA  | 0.63 ab       | 0.15 abc      | 177.79 cd         | 0.67 cd            | 4×10^11          | 3.87×10^4           |
| E. IF 70% + OSA   | 0.88 d        | 0.16 bc       | 169.30 bc         | 0.55 b             | 23×10^11         | 6.73×10^4           |
| F. IF 100% + FOF  | 0.62 a        | 0.13 ab       | 160.32 ab         | 0.52 ab            | 16×10^10         | 3.40×10^4           |
| G. IF 70% + FOF   | 0.71 bc       | 0.13ab        | 155.30 a          | 0.44 a             | 3×10^11          | 3.80×10^3           |

*Values in the same column followed by the same letter are not significantly different according to Duncan’s Multiple Range Test at 95% confidence interval

Bacteria colony and fungi density in the soil at 60 DAP increased with the application of OSA. The highest colony of bacterium and density of fungi was recorded at IF 70% plus OSA, while the lowest was recorded at IF 100% and IF 100% plus FOF, for bacterium and fungi, respectively (table 2). Earlier study showed that the application of bio-stimulant to a soil could increase the microbial biomass in the soil [16]. The OSA used in this experiment (BeKa) is an organic product that contains bacterium and fungi which meets one of the bio-stimulants categories [17]. Table 1 shows that both bacterium colony and fungi density were recorded higher in the less IF than in the higher one. In a soil with high organic carbon, the application of high dose of NPK fertilizer increase microbial colony [18]. However, a study in a rainfed area in India, which the soil in rainfed usually characterised by a low organic carbon content, showed that a high NPK fertilizer rate reduced the microbial population in the soil [19]. This finding supports our data that higher bacterium colony and fungi density was recorded in the lower NPK fertilizer application rate (IF 70%) than the higher one (IF 100%).

3.2.2. Maize plant variables. Plant height and leaf number at tasselling as well as maize biomass (without ears) at harvest were recorded the highest at IF 100% + OSA + FOF treatment but did not significantly different to IF 100% + OSA and IF 100 + FOF. The treatment of IF 70% + OSA showed the lowest value for the three parameters mentioned earlier (table 2). Treatment IF 100% + OSA + FOF provided the highest amount of nutrients for the maize crops, both from the soil and from the leaves. According to the producer, BeKa could produce quality compost that can improve water
holding capacity and cation exchange capacity in the soil as well as to provide macro and micro nutrients. Pomi on the other hand, as a foliar organic fertilizer, contains macro elements and micro element essentials for plant growth (https://www.acidatama.co.id/produk-agro.php?id=5, https://www.acidatama.co.id/product-agro.php?id=6).

A study in three provinces in Indonesia showed that 80.22% of rice paddy farmers satisfied with BeKa and POMI performance and these products have been recommended by Indonesia Ministry of Agriculture [20]. The advantages of using a foliar fertilizer, especially in vegetable crops, have been reviewed and mainly showed positive impacts on plant growth and yield [21]. On the other hand, BeKa contains bacteria, such as *Pseudomonas* and fungi, such *Streptomycetes* sp., *Trichoderma* sp., and *Aspergillus* sp that play a very important role as a plant growth promoting rhizosphere (PGPR). The association of *Pseudomonas* with fungi can improve nutrition in the soil and promote plant growth [22].

The application of FOF, both on top of IF and IF with OSA, did not improve total N in the leaf tissue. The lowest total N in the leaf was recorded in the treatment of IF 70% plus OSA (table 2). The total N in the leaf tissue was measured at 60 DAP or 4 days after silking. According to the previous research [23], nitrogen in the leaves at this stage has been mobilised to a new sink, the ear. This physiological activity had made the total N in the leaf tissue was not significantly different for almost the whole treatment. The only different (the lowest total N in the leaf) was observed in IF 70% plus OSA. The lower IF input and insufficient contribution of OSA to available N in the soil might the reason for this result.

### Table 2. Plant height, leaf number at 60 days after planting, N in leaves tissue and maize biomass at harvest (without ear) as affected by inorganic fertilizer (IF), organic soil ameliorant (OSA) and foliar organic fertilizer (FOF).

| Treatments          | Plant Height (cm) | Leaf Number | N in tissue (%) | Biomass at harvest (kg/m²) |
|---------------------|-------------------|-------------|-----------------|---------------------------|
| A. IF 100%          | 205.13 ab*        | 15.5 abc    | 2.65 b          | 3.57 b                    |
| B. IF 100% + OSA + FOF | 225.00 d         | 16.9 d      | 2.78 b          | 4.10 c                    |
| C. IF 70% + OSA + FOF | 208.87 bc        | 15.7 abc    | 2.45 b          | 3.67 b                    |
| D. IF 100% + OSA    | 221.33 d          | 16.2 cd     | 2.72 b          | 3.83 bc                   |
| E. IF 70% + OSA     | 198.33 a          | 15.1 a      | 1.78 a          | 3.17 a                    |
| F. IF 100% + FOF    | 216.50 cd         | 15.9 bcd    | 2.77 b          | 3.83 bc                   |
| G. IF 70% + FOF     | 204.27 ab         | 15.3 ab     | 2.51 b          | 3.50 b                    |

*Values in the same column followed by the same letter are not significantly different according to Duncan’s Multiple Range Test at 95% confidence interval

**3.2.3. Maize yield variables.** Maize yield from this study, ranged from 10.50 to 11.67 kg/10.1m² or equal to 10.4 to 11.6 ton/ha, was categorized as very high. The maize variety used in this study, NK007 is a new variety produced by PT. Syngenta Indonesia, seemed very suitable to grow in a dryland semi-arid condition in North Lombok. Yield and yield components of maize as affected by all the treatments are presented in table 3. The length of the ear was not much affected by the treatments but ear weight and weight of kernels per ear were affected by the treatments that led to the significant different effect of treatments on maize yield. There was a 6% improvement of maize yield when the crops were given OSA and FOF on top of IF 100% as compared to those crops given IF 100% alone. A 3% yield improvement was achieved when the crop fertilized with IF 100% were given either OSA or FOF. However, the reduction of 30% of IF with an integration of either OSA or FOF treatment could not make the maize yield comparable to that as in IF 100%. These results showed that the role of IF in affecting maize yield could not be replaced by either OSA or FOF in a short term. The improvement of microbial consortium in the soil along with an improvement in available P and K
(table 1), contributed to the improvement in maize yield when the maize crops received sufficient amount of nutrients from IF.

**Table 3.** Ear length, ear weight, kernels weight per ear and kernels weight per plot (10.1 m$^2$) of maize as affected by inorganic fertilizer (IF), organic soil ameliorant (OSA) and foliar organic fertilizer (FOF).

| Treatments                     | Length of Ear (cm) | Weight of Ear (g) | Weight of kernels per Ear (g) | Weight of Kernels per plot (kg) |
|--------------------------------|--------------------|-------------------|-----------------------------|---------------------------------|
| A. IF 100%                     | 15.2 ab*           | 183.26 ab         | 142.42 ab                   | 11.00 b                         |
| B. IF 100% + OSA + FOF         | 16.6 b             | 210.11 c          | 169.91 c                    | 11.67 c                         |
| C. IF 70% + OSA + FOF          | 15.1 a             | 189.67 bc         | 149.08 bc                   | 11.17 bc                        |
| D. IF 100% + OSA               | 15.7 ab            | 195.00 bc         | 156.35 bc                   | 11.33 bc                        |
| E. IF 70% + OSA                | 14.6 a             | 172.38 a          | 129.99 a                    | 10.50 a                         |
| F. IF 100% + FOF               | 15.6 ab            | 192.31 bc         | 152.25 bc                   | 11.33 bc                        |
| G. IF 70% + FOF                | 15.1 ab            | 180.18 ab         | 138.78 ab                   | 10.50 a                         |

*Values in the same column followed by the same letter are not significantly different according to Duncan’s Multiple Range Test at 95% confidence interval

4. **Conclusion**

In a short-term experiment in a dryland semi-arid, organic soil ameliorant (OSA) and foliar organic fertilizer (FOF) were able to improve maize yield up to 6% only when the crops received sufficient amount of inorganic fertilizer. When the dose of inorganic fertilizer was reduced to 70% of the normal dose, the integration of organic soil ameliorant or foliar organic fertilizer failed to reach equal yield of maize crops as in the normal dose. The same yield as in normal dose of inorganic fertilizer can be achieved by applying both organic soil ameliorant and foliar organic fertilizer on crops that had received 70% of inorganic fertilizer. To sustain soil health and to improve maize yield productivity in drylands semi-arid, a long-term use of organic soil ameliorant and foliar organic fertilizer is suggested.

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