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# Effects of Solid Vinasse-Based Organic Mineral Fertilizer on Some Growth Indices of Tomato Plant

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## Abstract

Vinasse, which is commonly referred to as stillage, is a aqueous by-product of bioethanol processing. This side-product is yielded in a very large quantity in bioethanol industry since the production of 1 L of ethanol will generate 13 L of vinasse. Hence it is become a problem of bioethanol industry since vinasse waste doesn't have economic value and harmful to the environment. This industrial waste has high COD and BOD, high acidity, and high temperature when discharged from the bottom of distillation unit. To overwhelmed this drawbacks, it is crucial to attempt the reduction of the negative characteristic of vinasse as well as production of added value of vinasse. In fact, vinasse contains a considerable amount of potassium and organic matter which is beneficial for plant growth and improving the soil fertility. Thus, in this work, vinasse was utilized as a raw material for organic fertilizer. Vinasse waste was formulated with other sugarcane industrial waste (filter cake and boiler ash), and NPK fertilizer in various composition yielding solid Organo-Mineral Fertilizer (OMF). Among all the composition of OMF, It was demonstrated that vinasse formulated with 3, 6, and 9% of NPK fulfilled the Indonesian National Standar (SNI) of solid fertilizer. Thus these types of OMF were used to fertilize tomato plant. The effects of vinasse-based OMF on some growth indices of tomato plant were examined. It was revealed that vinasse fertilizer formulated with 9% of NPK exhibited the best impact to the tomato plant growth.

## INTRODUCTION

Bioetanol plays an important role in industrial sector since it is necessitated as organic solvent, industrial feedstock, compounds in parmaceutical products, and also used as alternative energy blended with gasoline. This situation has increased the demand on bioethanol. Bioethanol can be produced from various raw material, such as traditional sugar cane molasses and emerging raw materials, for example materials rich in starch (corn, cassava, wheat) and material containing cellulose (straw, stalk, wood, etc.). However, the major bioethanol production to date is based on sugarcane molasses (Rudolf et al., 2009). Sugarcane molasses-based bioethanol is among a strategic agroindustry. On the other hand, it faces big challenge related to the massive liquid waste resulted from the bioethanol process, in which the production of 1 liter of bioethanol will generate 13 liter of vinasse (Garcia et al., 2017). Vinasse is the bottom product of crude distillation column (*maische column*) which has high temperature (100$^{o}$C) and high pollutant characteristic since it has high organic content with BOD value of 20.000-40.000 mg/L, COD value of 80.000-90.000 mg/L, strongly acid, and corrosive (Kusumaningtyas et al., 2016). Vinasse residue shows a dark color slurry and bad odor characteristic (Silva & Abud, 2016). Thus, this liquid residue cannot be directly disposed to the environment (river and land) since it will reduce dissolved oxygen and this condition is harmful for the biota inside.



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Several treatment methods have been proposed to diminish the negative impact of vinasse waste, such as applying activated sludge, anaerobic filter, ozonation process, as well as other bioprocessing, anaerobic digestion (AD), and chemical-based processes (coagulation and flocculation, chemical precipitation, chemical oxidation), to reduce COD color and turbidity (Cabrera-Diaz et al., 2016). On the other hand, there also some alternative of vinasse conversion into value-added product, i.e source of energy (biogas, cofiring with coal) , adsorbent, animal feed, and fertirrigation or irrigation to fields, by the percolation of vinasse liquid to the soil, with the simultaneous fertilization, transferring its nutrients to the plants.

Utilization of vinasse as fertilizer is among the easiest and prospective way to significantly reduce the discharge of this liquid waste. Vinasse is potential to be converted to fertilizer since it contains nutrients elements such as N, P, K, Ca, Mg, S, and Na (Alavi et al., 2017; Garcia et al., 2017; Reis & Hu, 2017). Those elements are beneficial for improving soil quality and potential for bioremediation. The common form of vinasse-based fertilizer is organic liquid fertilizer (OLF). OLF can be produced and applied easily. However, vinasse based OLF exhibits some disadvantages such as it has upleasant odor to human, tend to coagulated for a prolonged time of storage, shorter shelf life than the solid one, as well as problem in product handling, packaging, and transportation. Therefore, it is necessary to develop an innovation on vinasse utilization as solid fertilizer.

In this work, an innovative technique of vinasse conversion into solid organo-mineral fertilizer (OMF) has been conducted. OMF is fertilizer which is produced from organic raw material combined with mineral to improve soil fertility and quality. In this research, vinasse was formulated with other sugarcane industry wastes (filter cake and boiler ash), and it was then blended with small amount of urea and NPK fertilizer in various formulation. The various formulation of OMF produced were subsequently tested to determine their characteristics. Among the important properties of organic fertilizer are the content of N, P, and K elements, C/N ratio, and water content. NPK is important nutrients for plants (Lombardo et al., 2017). N is absolutely required for the continuous growth and development of the plant. P is needed to help photosynthesis, respiration, energy transfer and saving, as well as cell division and enlargement. K is activator of enzyme which involves in the plant metabolism and photosynthesis. C/N ratio is the ratio of mass C (carbon) to mass of N (nitrogen) in a substance. The balanced ratio of C/N will affect the equilibrium of the vegetative and generative phases. If the C/N ratio is too low, then the plan remains in the vegetative stage, which means that the plant will encounter a problem in flowering and bearing the fruit. The higher C/N ratio will carry the plant to enter the generative phase, which enables the plant to flower and produce fruit. However, too higher C/N ratio will cause the plant's death and stop producing fruit on the next sessions (Jeng et al., 2006).

OMF formulation which fulfills the Indonesian National Standar of solid fertilizer was then applied to fertilize tomato plant. To ascertain the effectiveness of OMF as fertilizer, the effects of solid OMF on the tomato plant growth (height of the plant, number of leaves, diameter of the tomato plant's stem, age of flowering, and age to produce fruit) were observed. Conversion of vinasse combined with other sugarcane wastes into solid OMF is a novelty to overcome the problem of sugarcane-based industry waste, which also support the development of organic farming and contribute to improving agricultural sector.

## EXPERIMENTAL

Vinasse waste used as the main feedstock of OMF formulation in this work was obtained from PS Madukismo PT Madubaru, Indonesia. OMF synthesis was conducted through three steps as stated in our previous work (Kusumaningtyas et al., 2016), i.e. pH neutralization of vinasse, evaporation, and mixing. Neutralization of vinasse was carried out to increase the pH from 3.9-4.3 to 7 by adding NaOH. Evaporation was then performed at 80-90ºC for 30 minutes to remove as much as 80% water content. Water removal through evaporation aims at obtaining concentrated vinasse and preventing the growth of fungi and bacteria. The last step was raw materials mixing. Vinasse was mixed with other feed-stocks (boiler ash, filter cake, urea and NPK fertilizer) in a certain formulation. The OMF formulation was varied as follows: OMF A types were composed from vinasse, which were blended with 0, 3, 6, and 9% of NPK, and labeled as OMF A, OMF A3, OMF A6 and OMF A9,

Table 1. OMF Characteristic (NPK content, C/N ratio, and Water Content) (Kusumaningtyas et al., 2015)

| No | OMF Formulation | N Content, % | P Content, % | K Content, % | C/N Ratio | Water Content, % |
|---|---|---|---|---|---|---|
| 1 | OMF A | 0.73 | 0.70 | 0.49 | 24.89 | 35.10 |
| 2 | OMF B | 0.68 | 0.65 | 0.51 | 22.94 | 36.25 |
| 3 | OMF C | 0.65 | 0.64 | 0.51 | 22.58 | 30.25 |
| 4 | OMF D | 0.62 | 0.59 | 0.48 | 26.05 | 32.23 |
| 5 | OMF E | 0.62 | 0.51 | 0.51 | 25.65 | 05.02 |
| 6 | OMF F | 0.51 | 0.61 | 0.54 | 24.76 | 05.10 |
| 7 | OMF A3 | 0.63 | 0.45 | 0.38 | 10.30 | 19.20 |
| 8 | OMF A6 | 0.59 | 0.52 | 0.41 | 13.66 | 19.08 |
| 9 | OMF A9 | 0.68 | 0.52 | 0.45 | 14.16 | 20.03 |

Note : A : OMF from vinasse only; B : OMF from vinasse and 3% urea; C : OMF from vinasse and boiler ash 2:2; D : OMF from vinasse and filter cake 1:1; E : OMF dari vinasse dan abu boiler; F : OMF from vinasse, filter cake, and boiler ash 1:1:1 ; A3 : OMF from vinasse and NPK 3% ; A6 : OMF from vinasse and NPK 6%; A9 : OMF from vinasse and NPK 9%;

Table 2. Standard Quality of Organic Fertilizer (SNI 19-7030-2004)

| No | Parameter | Unit | Min. | Max. |
|---|---|---|---|---|
| 1 | Water Content | % | - | 50 |
| 2 | N | % | 0.40 | - |
| 3 | P | % | 0.10 | - |
| 4 | K | % | 0.20 | - |
| 5 | C/N Ratio | | 10 | 20 |

respectively. OMF B was composed from vinasse blended with 3% of urea. OMF C were composed from vinasse mixed with boiler ash at the ratio of 2:2, OMF D was formulated by mixing vinasse with filter cake at ratio of 1:1, and OMF E was resulted by mixing vinasse with boiler ash at the ratio of 2:4. OMF F is vinasse which was mixed with boiler ash and filter cake with the ratio of 2:2:1. All the raw materials of OMF were well-mixed and subsequently dried using oven at 110ºC. After drying, OMF products were smoothed to obtain OMF in a powder form. Various types of OMFs resulted in this experiment were then analyzed to determine the NPK content and C/N ratio]].

Analysis of OMF was carried out to reveal the quantity of N, P, and K elements and the C/N ratio of OMF products. The properties of OMF were then compared to the Indonesian Standard of fertilizer SNI 19-7030-2004. The NPK elements of OMF were tested using Kjehdal method to determine the N content. Meanwhile the P and K elements were determined using spectrophotometry instruments. C/N ratio was analyzed by standard C-organic and N-organic method analysis. The value of C-organic and N-organic were then compared to obtain C/N ratio. OMF types which fulfill the Indonesian Standard were applied on tomato plants to observe their effects on the plant's growth. The selected OMFs were applied to tomato plants in the pot, starting at their age of 10 days. OMF with amount of 3.5 g was applied to the tomato plant once a week until they reached 40 days old. Observation on the tomato plants was conducted every day to find out the effects of OMF on tomato plant's growth (height, number of leaves, stem diameter, age to start flowering, age to begin bearing the fruit and number of fruits). The result was also compared to the control plant.

## RESULT AND DISCUSSION

Raw materials utilized for the formulation of Organic Mineral Fertilizer (OMF) were vinasse, filter cake, boiler ash, urea, and NPK. Vinasse used in this work contains of 29% mineral content, 11% reducing sugar, 21% gum, phenol wax, and 17% lignin. Vinasse also contains macro and micro nutrients, such as N, P, K, Ca, Mg, Fe, Mn, Zn, Cu. This bioethanol industry liquid effluent is characterized with pH of 3.9 - 4.3 and dark brown color. Other raw materials added were boiler ash and cake filters which are solid waste from sugar mills. Boiler ash has some content as follows: 7.1% $K_2O$, 3% CaO, 2.6% MgO, and 1.7% $P_2O$. The feedstocks were formulated to produce vinasse-based Organic Mineral Fertilizer (OMF). There were 9 types of solid OMF formulation which have

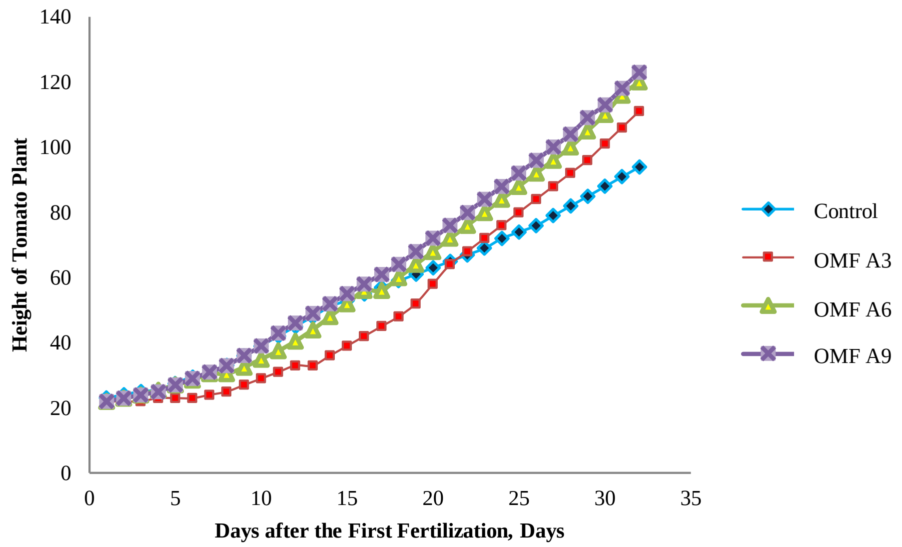


Figure 1. Effect of OMF fertilization on the height of tomato plant

been synthesized in this work. However, only those that fulfilled the Indonesian standard of organic fertilizer which were applied on tomato plants. Therefore, solid OMF were characterized to determine the properties. The properties of each OMF formulation has been reported in our previous work as shown in Table 1.

OMF Characteristic should be compared to the Indonesian standard (SNI) as depicted in Table 2. It was found that OMF formulation which fulfill the SNI were OMF A3, OMF A6. And OMF A9 (Kusumaningtyas et al, 2016). Hence, those types of OMF was then applied as fertilizer to nourish tomato plants in pot. The influence of OMF application on the plant growth was then observed.

Tomato plant was chosen as the medium of solid OMF fertilizer application since it has a relatively fast growth period. Fertilizer was added every 7 days with the dose of 3.5 g for each fertilization application, starting from the tomato's age of 10 days for 32 days. At the age of 10 days, tomato plant already has complex growth organs. To reveal the influence of OMF application on the tomato plant growth, observation was then conducted every day. Parameters to be observed are vegetative plant growth (i.e. height of plant, number of leaves, and diameter of plant's stem) and generative growth aspects (i.e. flower and fruit).

**Effects of Solid OMF Application on the Height of Tomato Plant**

The growth rate of tomato plant can be denoted by the height of the plant. Height of plant is one among important indicator to determine the fertilizing response to vegetative growth. Effect of several types of solid OMF fertilization compared to the control is depicted in Figure 1.

Figure 1 exhibits the difference height of the tomato plants which have been fertilized by OMF A3, OMF A6, and OMF A9 to the height of control tomato plants. It was shown that the best plant growth based on the height measurement was presented by tomato plant fertilized by OMF A9. OMF A9 was composed of the mixture of vinasse and NPK fertilizer with the amount of 9%. Thus, OMF A9 contained higher NPK than the other types OMF. The N, P, and K content of OMF A9 were 0.68%, 0.52% and 0.45%, respectively. Tomato plants require nitrogen, phosphorus, and potassium compound in relatively large quantities. Therefore, these three nutrients must be available in sufficient quantities in accordance with the needs of the plant. Insufficient quantities of these three nutrients will cause the slow plant growth (Sarwono, 1995). Thus, the control plant exhibited the slowest growth since it didn't obtain additional nutrients from fertilizer.

**Effects of Solid OMF Application on the Number of Leaves of Tomato Plant**

Beside plants' height, the other important indicator of plant growth is number of leaves. Gardner et al. (1991) stated that part of plants contributing most to the plant growth and development are leaves. Assimilation takes place in leaves and some assimilation product remains in plant tissue for cell maintenance of the plant. When the movement of materials from leaves to other

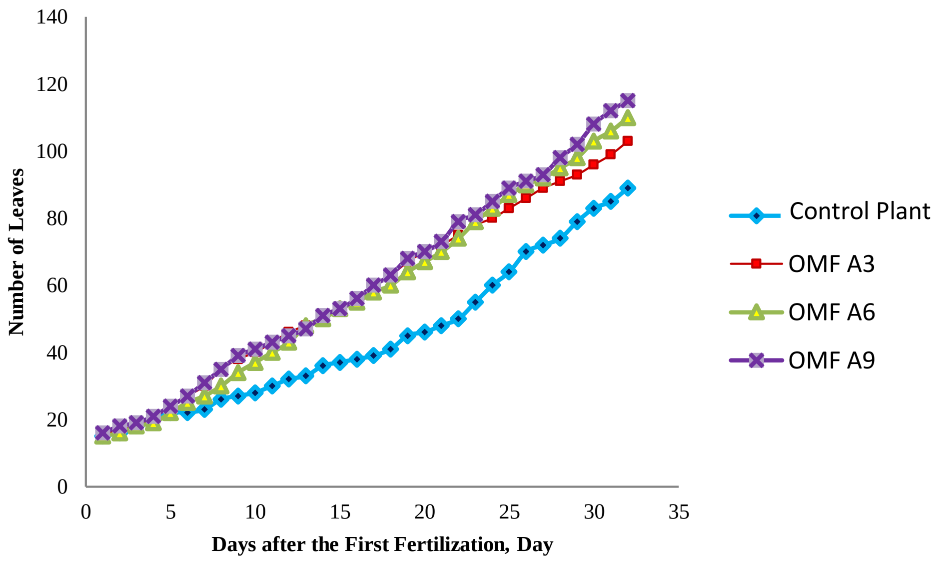


Figure 2. Effect of OMF fertilization on the number of leaves of tomato plant

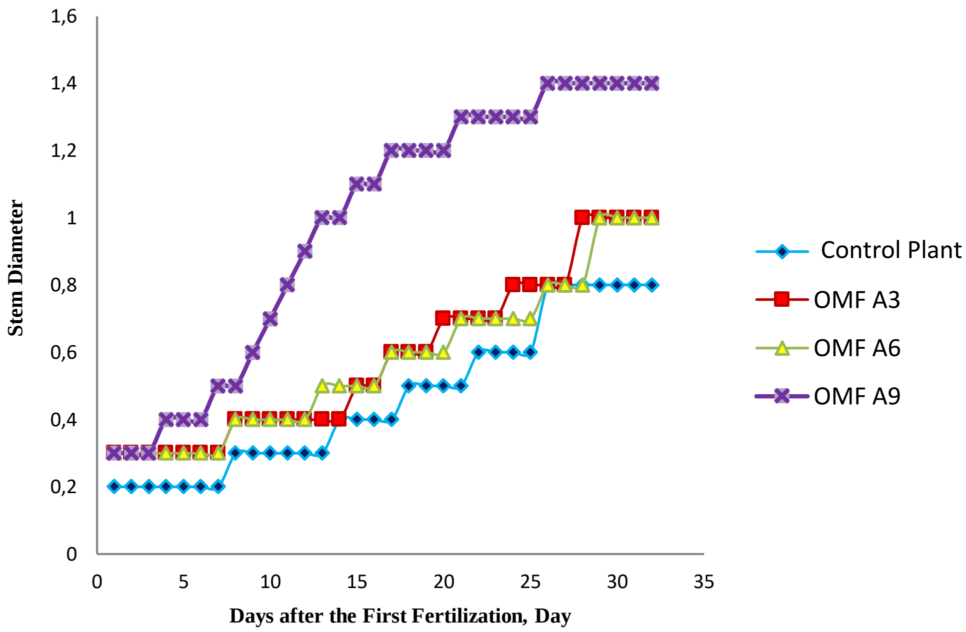


Figure 3. Effect of OMF fertilization on the stem diameter of leaves of tomato plant

tissues throughout the plant **(**translocation) is slow, the assimilation deposit can be converted to flour or other form of food reserve in plants, and the remainder is exported to the vegetative utilization area, which consists of the growth, maintenance and food reserves functions. Leaf formation itself is actually influenced by plant genetic properties, but a good growing environment will accelerate the leaf formation. In this work, the effect of OMF fertilization on vegetative growth of tomato plant indicated by the number of leaves is presented n Figure 2.

Figure 2 demonstrated that the best number of leaves was provided by tomato plant fertilized by OMF A9. This result is strongly correlated to the nitrogen content in fertilizer since the number of leaves are affected by the supply of nitrogen to the plant. N element is indispensable in the early phases of plant growth since it is required for a period of vegetative growth such as the formation of leaves, buds, branch, and stem. The increasing dose of N leads to the better growth of the plant. Among the three types of fertilizer, OMF A9 contained the highest concentration of nitrogen

Tabel 3. Effects of OMF Fertilization on the Time to Flowering, Time to Bearing Fruits and Number of Fruit Yielded of Tomato Plant

| Treatment | Time to Flowering, Days* | Time to Bearing Fruit, Days | Number of Fruits** |
|---|---|---|---|
| Control | 14 | 27 | 6 |
| OMF A3 | 12 | 24 | 9 |
| OMF A6 | 11 | 21 | 9 |
| OMF A9 | 9 | 19 | 12 |

* Days after the First Fertilization
** at 32 Days after Fertilization


Figure 4. Development of Tomato Fruit at 32 Days after Fertilization (42 Days after Planting)

(0.68%) as shown in Table 1 (Kusumaningtyas et al., 2016), Therefore, it was not surprising that the addition of OMF A9 affected on the higher number of leaves of tomato plant compared to the addition of OMF A6, OMF A3, and control. In addition, nitrogen is a macro nutrient which is needed by the plant in large quantities. This element is a constituent of amino acid protein, nucleic, chlorophyll, and other important compounds for metabolism, N is used for chlorophyll formation and plants' vegetative growth stimulation, such as stems, branches, and leaves formation (Singh et al., 2016). Commonly, nitrogen is absorbed by the plant in the form of nitrate and ammonium ions. Therefore, it is not suprising that plant which was given fertilizer containing high nitrogen demonstrated the highest number of leaves.

**Effects of Solid OMF Application on Tomato Plant's Stem Diameter**

Plant stem is among the important indices of the vegetative growth of plant. The effects of the OMF application on the stem diameter of tomato plant is presented in Figure 3. It can be observed that the best growth was shown by the tomato plant provided with OMF A9. It was due to the fact that OMF A9 comprises the highest content of potassium (0.45%) compared to the other types of OMF. In the plant, potassium is commonly found in the form of K+ ion. Potassium plays an important role in regulating cell osmosis (Cochrane

& Cochrane, 2009). This element also essential for the modulation of plant stomata openings. The lack of potassium in a plant will bring about the translocation of K+ ions from old to new leaves to support the stomata aperture osmo-modulation in the new leaves. This condition will cause the breakdown of stomata in the old leaves and then death of cell or tissue. It accordingly causes the loss of leaf surface which is important for transpiration, gas exchange, and photosynthesis processes. Thus the higher content of potassium in fertilizer will support the healthy plant growth and strengthen the stem of the plant. Hence, it is not suprising that OMF A9 which contains the highest potassium element demonstrated the highest stem diameter of tomato plant.

**Effects of Solid OMF Application on Flowering and Bearing Fruits of Tomato Plant**

The other parameter of growth observed in this work were flowering and fruit yield of tomato plant. The impact of OMF fertilization on the days to flowering, days to bearing fruits, and number of tomato fruit produced is depicted in Table 3. It was shown that tomato plant treated with OMF A9 flowered and beared the fruit earlier than tomato plants provided with the other types of OMF and control. OMF A9 also demonstrated the best impact in term of the number of tomato fruits yielded by the plant. OMF A9 resulted in the best impact on flowering and bearing fruits since it contained the highest C/N ratio compared to the other fertilizers. C and N are the main nutrients for anaerobic microbes. The equilibrium of C/N ratio will accelerate flowering and bearing fruits process in the plants (Darjanto & Satifah, 1989). Sutejo & Kartasapoetra (2002) also stated that the deficiency of N on a mature plant leads to poor flower and fruit development. Furthermore, the lack of N element also results in the faster fruit ripening, which in consequence will decrease the tomato crops. The development of the fruits of tomato plants for each treatment is presented in Figure 4.

## CONCLUSION

Vinasse was formulated with other compounds at various formulation to produce vinasse-based Organo Mineral Fertilizer (OMF). OMF formulation which fulfill the Indonesian Standard for fertilizer quality were OMF A3, OMF A6, and OMF A9. Those types of fertilizer were applied for tomato plant fertilization. The observation on the impacts of OMF fertilization on the tomato plant shows that OMF A9 provide the best influences on the plant growth in term of height of the plant, number of leaves, stem diameter, days of flowering, days of bearing fruit, and number of fruits. The further research on the manufacturing of controlled-release OMF is recommended for the better application of this organic fertilizer.

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