# Increasing the Effectivity of Liquid Organic Fertilizer Enriched with *Enterobacter cloacae* to increase Phosphate Availability and Yield of Maize in Inceptisols

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**Abstract.** Inceptisols have problems of low availability of phosphorus. To improve soil phosphate and P fertilizer efficiency, it is necessary to develop fertilizer enriched with phosphate solubilizing bacteria (PSB). Liquid organic fertilizer enriched with PSB is expected to increase the efficiency in fertilization and improve the yield of sweet corn plants. This study was aimed to determine the effectiveness of liquid organic fertilizer enriched with *Enterobacter cloacae* on phosphate availability and increase the yield of maize (*Zea mays* L.) in Jatinangor Inceptisols. This experiment has been carried out at the Laboratory and Experimental Garden, Jatinangor, West Java, Indonesia with altitude of ±725 m above sea level. This experiment was conducted from March to September 2021. This experiment used Randomized Block Design (RBD) with three repetitions. The experiment showed the 10 L $ha^{-1}$ of liquid organic fertilizer enriched with *Enterobacter cloacae* indigenous from Inceptisols enhanched the availability of phosphate (22,48 mg $kg^{-1}$) and yield of maize (14,11 ton $ha^{-1}$). Liquid organic fertilizer enriched with *Enterobacter cloacae* can reduced 50% of P fertilization and proposed as an alternative corn fertilizer and increased the yield of maize up to 55%, because *Enterobacter cloacae* to increase P solubility that caused soil available P increased.

## 1 Introduction

Agricultural lan in Indonesia very extensive, but predominantly by acidic land, with acidic soil covering an area of 146.46 million hectares or 76% of the total land area in Indonesia [1]. One type of acidic soil found in Indonesia is Inceptisols, which has the largest distribution potential for agricultural development, covering 70.52 million hectares or 37.5% of Indonesia's land area, with 2.119 million hectares located in West Java Province [2]. The management of these soils faces limiting factors such as relatively low fertility, low availability of nutrients, and low organic matter content.

Phosphorus (P) availability is one of the limiting factors in Inceptisols. The low availability of P in Inceptisols is primarily due to the relatively low pH or acidic nature of the

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soil. In soils with low pH, P tends to be fixed by aluminum (Al) and iron (Fe), forming insoluble compounds such as Al-P and Fe-P, which are not easily absorbed by plants. This can affect the nutrient balance in the soil and inhibit plant growth. According to [3], the limited availability of P in the soil can also restrict the uptake of nitrogen (N) and potassium (K). As a result, fertilizer application becomes inefficient.

One of the strategies to overcome the limited availability of P and improve agricultural productivity is the use of organic materials. Organic matter plays a crucial role in improving and maintaining soil fertility by enhancing its physical, chemical, and biological properties. Organic matter undergoes decomposition, forming highly reactive colloid compounds. These colloid properties enable organic matter to improve the chemical and physical characteristics of the soil. Organic matter can enhance P availability in the soil and reduce P retention [4]. The decrease in P retention occurs due to the reaction of organic acids, produced during the decomposition of organic matter, with metal ions that can fix P in the soil [5,6]. In addition to organic matter, phosphate-solubilizing bacteria (PSB) can also be used to increase P availability.

Organic matter can be applied to the soil in the form of solid or liquid organic fertilizers. To optimize P availability in the soil, organic fertilizers can be enriched with indigenous PSB derived from maize rhizosphere. The population of rhizosphere bacteria is higher than that of endophytic bacteria in maize roots [7]. Rhizosphere bacteria can increase root length and plant height. The higher population of rhizosphere bacteria is due to the fact that plant roots are the center of interaction and ecosystem processes, and they release various complex compounds that serve as a nutrient source for rhizosphere bacteria [8]. Using indigenous bacteria is more effective compared to other bacteria because indigenous bacteria can better adapt to new environmental conditions. Indigenous microorganisms are more adapted to plant and soil conditions such as moisture, temperature, pH, fertility, and even pollutants [9]. Moreover, the quantity and effectiveness of indigenous microorganisms influence the response to inoculation given to the soil. Using indigenous inoculants is more effective and competitive in enhancing plant growth and crop yields, thereby reducing fertilizer usage [10]. Reduced fertilizer usage, especially P fertilizers, can be achieved by optimizing P availability in the soil.

Phosphate-solubilizing bacteria produce organic acids that react with bound inorganic phosphate as $AlPO_4$ and $FePO_4$, forming chelates (stable complexes) with P-binding cations in the soil, such as $Al^{3+}$ and $Fe^{3+}$. These complexes reduce ion reactivity and facilitate effective dissolution, making fixed P available to plants. The activity of phosphate-solubilizing bacteria also increases the content of phosphatase, lactic acid, and soluble P [11]. Phosphatase, as a soil enzyme, plays a role in the mineralization of organic P compounds into inorganic P or available forms for plants.

Plant nutrient uptake and vegetative growth are greatly influenced by nutrient availability in the soil and plant characteristics [12]. One plant species that is responsive to nutrient availability is maize, making it a suitable indicator for assessing nutrient availability in the soil [17]. Maize (*Zea mays* L.) is a widely grown maize variety in Indonesia, known for its high productivity. The average annual productivity growth from 1980 to 2016 was 3.72%, with a productivity rate of 5.28 tons per hectare and a production volume of 23.19 million tons in 2016 [14]. However, the production of sweet corn still falls short of demand due to decreasing potential land availability and continuous land usage. Continuous land usage leads to a decline in soil nutrient content. Land intensification can be achieved through balanced application of inorganic and organic fertilizers. The addition of organic liquid fertilizers enriched with phosphate-solubilizing bacteria in this study is expected to provide a balanced dose that enhances P availability in the soil and improves maize crop yields. The aim of the present study is to explore such beneficial effectiveness of liquid organic fertilizer enriched of liquid organic fertilizer enriched with Enterobacter cloacae in comparison to the plants not treated with liquid organic fertilizer.

## 2 Method and Material

### 2.1 The liquid organic fertilizer

Making of Enriched Liquid Organic Fertilizer. First of all take 150 g of finely ground and heated chicken manure compost and dissolve it in 300 ml of distilled water. Then add 200 ml of molasses to the solution. Dissolve the enrichment ingredients (mineral materials) separately in different glass beakers, one at a time. Start with the easily soluble ingredients. Mix the enriched organic solution with distilled water until 1000 ml. Transfer the mixture of organic liquid and enrichment materials into a plastic bottle. Homogenize the solution using a shaker for 1 hour. Add Enterobacter cloacae and incubate the bacteria for 5 days and ready to use.

### 2.2 Experimental Design

Field experiments on organic liquid fertilizer enriched with phosphate-solubilizing bacteria were conducted to determine the effects of applying organic liquid fertilizer enriched with phosphate-solubilizing bacteria on phosphate availability in the soil and maize crop yields. The study also aimed to determine the effective and efficient dosage of organic liquid fertilizer for phosphate availability and maize crop yields in the field. The research utilized the Randomized Complete Block Design (RCBD) experimental method. Data analysis involved the utilization of the DMRT of Duncan's Multiple Range Test and F test. The experiment was conducted in polybags, consisting of ten treatment combinations replicated three times, resulting in a total of 30 polybags created in two experimental units. The first experimental unit was used for maize crop yield calculations, while the second plot was utilized for plant tissue analysis at the maximum vegetative stage. The polybags were placed with a planting distance of 75 x 25 cm, using Talenta maize seeds.

### 2.3 Application of liquid organic fertilizer in the field

The fertilizers used were single fertilizers, namely Urea (46% N) with a dosage of 300 kg $ha^{-1}$, SP-36 (36% $P_2O_5$) with a dosage of 150 kg $ha^{-1}$, and KCl (50% $K_2O$) with a dosage of 50 kg $ha^{-1}$. Fertilization was carried out according to the given treatment dosage. The application of Urea fertilizer was divided into three instances: at planting, 21 days after planting (DAP), and 35 DAP. SP-36 (36% $P_2O_5$) and KCl (50% $K_2O$) fertilizers were applied once at the time of planting. For the use of organic liquid fertilizer with a dosage of 10 L $ha^{-1}$, it was first diluted to a concentration of 10 ml $L^{-1}$. The application of organic liquid fertilizer was divided into two instances: at 14 DAP and 48 DAP.

## 3 Results

The application of Liquid Organic Fertilizer (LOF) enriched with *Enterobacter cloacae* has a significant influence on P availability in the soil and P uptake by plants. Table 1 shows that the treatment of ½ NPK + 1 LOF has the highest value and significantly higher than other treatments and the control in terms of P uptake. The treatment of ½ NPK + 1 LOF has the highest value and significantly higher than other treatment, but not significantly different from 3/4 NPK and 1 NPK.

The high values of P availability and P uptake in the treatment of ½ NPK + 1 LOF, compared to the treatment without the application of LOF enriched with *Enterobacter cloacae*, indicate that the addition of LOF enriched with *Enterobacter cloacae* to fertilization significantly affects soil P availability and plant P uptake. This is because contain of organic matter and *Enterobacter cloacae* in the LOF, which work optimally to dissolve and provide P for plant absorption. The addition of organic matter to the soil can enhance the cation exchange capacity of the soil and reduce nutrient losses added through fertilization, thereby improving nutrient availability in the soil and fertilization efficiency [15].

**Table 1**. Effect of LOF enriched with *Enterobacter cloacae* on Soil P Availability and Plant P Uptake

| Treatment combination | Phosphate available (mg. kg $^{-1}$) | Phosphate uptake (g. plant$^{-1}$) |
|---|---|---|
| Control | 3,03 e | 0,53 d |
| 1 recommended dosage N, P, and K | 6,70 de | 1,83 c |
| 1 dosage LOF enriched *Enterobacter cloacae* | 8,02 d | 0,90 d |
| ¼ NPK + 1 LOF enriched *Enterobacter cloacae* | 10,47 d | 2,38 c |
| ½ NPK + 1 LOF enriched *Enterobacter cloacae* | 22,48 a | 4,00 a |
| ¾ NPK + 1 LOF enriched *Enterobacter cloacae* | 20,65 ab | 2,40 c |
| 1 NPK + 1 LOF enriched *Enterobacter cloacae* | 19,12 abc | 2,58 b |
| ¾ NPK + ¼ LOF enriched *Enterobacter cloacae* | 17,18 bc | 2,48 bc |
| ¾ NPK + ½ LOF enriched *Enterobacter cloacae* | 16,27 c | 2,42 bc |
| ¾ NPK + ¾ LOF enriched *Enterobacter cloacae* | 18,10 c | 2,23 bc |

Note : Numbers followed by the same letter are not significantly different based on Duncan's multiple distance tests at the 0.05 level

**Table 2.** Effect of LOF enriched with *Enterobacter cloacae* on yield of maize

| Treatment combination | Yield of Maize (ton ha$^{-1)}$ |
|---|---|
| Control | 6,43c |
| 1 recommended dosage N, P, and K | 9,80bc |
| 1 dosage LOF enriched *Enterobacter cloacae* | 6,53c |
| ¼ NPK + 1 LOF enriched *Enterobacter cloacae* | 9,17bc |
| ½ NPK + 1 LOF enriched *Enterobacter cloacae* | 14,11a |
| ¾ NPK + 1 LOF enriched *Enterobacter cloacae* | 11,21ab |
| 1 NPK + 1 LOF enriched *Enterobacter cloacae* | 12,16ab |
| ¾ NPK + ¼ LOF enriched *Enterobacter cloacae* | 9,73bc |
| ¾ NPK + ½ LOF enriched *Enterobacter cloacae* | 8,92bc |
| ¾ NPK + ¾ LOF enriched *Enterobacter cloacae* | 9,17bc |

Note : Numbers followed by the same letter are not significantly different based on Duncan's multiple distance tests at the 0.05 level

The analysis of yield (Table 2), the treatment of ½ NPK + 1 LOF showed the highest and significantly different value compared to other treatments and the control. The yield of maize parameter exhibited the highest value in that treatment. This is believed to be due to the interdependence of cob diameter, length, and weight. The longer and larger the diameter of the corn cob, the more seeds can form on the cob, which consequently contributes to an increase in cob weight**.** The availability of nutrients is closely related to the seed-filling process [16]. The absorbed nutrients are accumulated in the leaves and transformed into proteins that form the seeds. The accumulation of metabolized substances during seed formation increases, resulting in seeds with optimal size and weight. This occurs when the nutrient requirements are met, allowing for optimal metabolic processes.

## 4 Discussion

The combination of organic materials into fertilizer can retain and supply nutrient availability in the soil, as well as enhance P uptake by plant. The process of organic material mineralization breaks down organic phosphate compounds into available inorganic phosphate forms for plants, aided by the enzyme phosphatase [17]. High production of phosphatase enzymes assists in the mineralization process of organic P and the dissolution of organic P [11].

The high level of available P in the soil is directly related to an increase in P uptake by plants. That increasing P dosage enhances the P content in the soil and has a strong correlation with P uptake, as higher P levels result in increased P uptake [18]. The use of LOF, which can enhance both available P and P uptake, can also improve fertilization efficiency. According to [19], he use of molasses as a fertilizer can promote microbial growth and activity, leading to improved nutrient absorption efficiency.

The influence of enriched LOF (Liquid Organic Fertilizer) with *Enterobacter cloacae* on the yield of maize is believed to be due to the organic material's ability to improve soil properties that support plant growth and development. The application of LOF enriched with *Enterobacter cloacae* and inorganic fertilizers can create favorable conditions for soil health, thereby increasing crop productivity and optimizing the use of inorganic fertilizers [20]. The addition of organic materials to the soil can enhance the efficiency of chemical fertilizer utilization by improving the physical, chemical, and biological properties of the soil, resulting in significant effects on crop yields [21]. Optimal soil conditions also affect the availability of nutrients that can be absorbed by plants. Liquid organic fertilizers can enhance nutrient supply to plants compared to inorganic fertilizers [22]. Thus, it can be concluded that liquid organic fertilizers can be utilized to increase crop production [20].

## 4 Conclusion

The application of the combination of enriched LOF with *Enterobacter cloacae* and NPK independently and in combination can enhance agronomic efficiency, with the highest efficiency observed in the ½ NPK + 1 LOF combination at 29.54%. This treatment shows that the application of enriched LOF with PSB can reduce the use of inorganic fertilizers by 50% of the recommended dosage. Furthermore, it positively affects P availability and plant growth due to the balanced fertilization between enriched LOF with PSB and NPK fertilizers. Balanced fertilization aims to provide a balanced supply of essential nutrients according to the plant's needs, leading to optimal plant growth, increased yield and quality, improved fertilization efficiency, soil fertility preservation, and environmental pollution prevention.

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