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THE EFFECT OF BIOFERTILIZER AND INORGANIC FERTILIZER TOWARD THE NUTRIENT UPTAKE IN MAIZE PLANT (*Zea mays* L.)

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Abstract. *The productivity of land and plants has decreased slowly, due to the use of inorganic fertilizers continuously. Efforts to improve productivity is reducing inorganic fertilizers and returning organic matter to the soil. The aim of this research are (1) to identify the chemical characteristics of biofertilizer with an indigenous microorganism as bio-activators and (2) to study the effect of biofertilizer on nutrient uptake of the maize plant. The research was conducted at Laboratory, Greenhouse, and Experimental Field of Politeknik Pertanian Negeri Payakumbuh, West Sumatra Indonesia. The first step experiment in the Laboratory was produced by indigenous microorganisms from banana humps. The second step of making bio-fertilizers in Greenhouse used a Completely Randomized Design with four treatments of indigenous microorganism (IMO) level 0%, 10%, 20%, 30% in biofertilizer with five replications. The third step of biofertilizer application on the Experimental Field used Randomized Block Design Factorial arranged with two factors and three replications, the first factor IMO level in biofertilizer (M) 0%, 10%, 20%, 30%, and the second factor was the dosage of inorganic fertilizer (P) 0%, 50%, 100% of the recommended dosage, 12 combinations of treatments were obtained. Results showed that microbe consortium (Enterobacter cloacae, Bacillus subtilis, Pseudomonas fluorescens, Aspergillus niger, and Trichoderma asperellum) in biofertilizers with different levels would affect the chemical characteristics of biofertilizer. Biofertilizers influences nutrient uptake of P and K maize plant, while inorganic fertilizer influences nutrient uptake of N and P maize plant.*
Keywords: *bacillus subtilis*, *biofertilizer, maize, nutrient uptake*

1. Introduction

The provision of biofertilizer is an effort to fix the soil fertility physically, chemically, and biologically. The provision of organic fertilizer can increase the efficiency of inorganic fertilizer to support the optimal production. The using of single inorganic fertilizer is no longer effective because most of the fertilizer will be bound by the soil colloidal or washed by water, so it becomes unavailable in the plant, consequently disturbed soil nutrient balance and crop production is not optimal. Chen (2006) states that the use of microbial inoculation can reduce the dosage of inorganic fertilizer, increase the nutrient that can be absorbed from the soil (Chen, 2006 ; García-Fraile et al., 2015), increase crop productivity, and improve the quality of land sustainably. Malusá & Vassilev (2014) define biofertilizer as a formulated fertilizer product containing several microbes to improve plant nutrient status.

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Nowadays, the use of organic fertilizer that inoculated by indigenous microbes, is the right technology. Microbes inoculation aims to utilize the ability of microbes as decompose (Pan et al., 2012) and biofertilizers (Qasim et al. 2014). The utilization of indigenous microbes have a positive impact in control the balance of nature, produce healthy products for the environment, and enrich the soil and plants nutrients. Indigenous microbes consist of bacteria that can bind nitrogen and dissolve phosphorus, and contribute macronutrients (Sondang et al. 2015), decomposing organic matter (Sondang & Anty, 2017).

Nitrogen (N), Phosphorus (P), and Potassium (K) are necessary macronutrients for plants. The deficiency one of these elements will cause an unbalance of soil nutrients as a whole. Nutrient uptake of N, P, K plants depend on N, P, K nutrient that available in the soil (Weih et al. 2018). Partial supply of nutrients that needed by plants can be done by endophytic and rhizosphere microbes which have the ability to bind N from the air and dissolve phosphate to be available to plants, but plants still need inorganic fertilizers because the amount of nutrients available in the soil is limited. Zhang et al., (2016) state that the use of manure combined with N fertilizer increases nutrient uptake of N, P, K in wheat crops.

The aim of this research are (1) to identify chemical characteristic of biofertilizer and (2) to study the effect of biofertilizer and inorganic fertilizer toward N, P, and K nutrient uptake in maize plant.

2. Materials and Methods

Research Location

The research was conducted at Laboratory, Greenhouse, and Experiment Farm of Politeknik Pertanian Negeri Payakumbuh.

Research Methods

This research was done in three step, manufacture indigenous microorganism from banana humps, manufacture biofertilizer, and biofertilizer application in maize plant.The research started with indigenous microorganism (IMO) manufacture from banana hump. The materials IMO of banana hump, coconut water, and red sugar. The banana hump and red sugar sliced about 2-3 cm, and mashed, then mixed with coconut water. and fermented for two weeks. The research was conducted at Payakumbuh State Agricultural Polytechnic Laboratory and microbes identification at LIPI Bogor. The identification of microbes using molecular analysis based on 16S rDNA fragments. Selected microbes are made into microbial consortium.

Then, the manufacture of biofertilizer with the addition microbial consortium of IMO. Biofertilizer experiment design was Completely Randomized Design (CRD) with four treatments and five replications. The level IMO which was used 0%, 10%, 20%, and 30%. Research carried out in Greenhouse of Payakumbuh State Agricultural Polytechnic. Biofertilizer chemical analysis of is done at Soil Laboratory of Payakumbuh State Agricultural Polytechnic Laboratory. Nutrient analysis for N nutrient (Kjeldahl Method), P (Bray I Method), K (Bray I Method), C org (Walkley and Black Method), and pH meter. The base materials composed of water hyacinth, cow feces, and chemical analysis materials. Tools that were used are scales, oven, thermometer, equipment–laboratory instruments, buckets and fertilizer bags.

The research to study the effect of biofertilizer was conducted at Experiment Farm of Payakumbuh State Agricultural Polytechnic in Limapuluh Kota Regency, West Sumatra, Indonesia with altitude of 500 m above sea level. The experiment design using Factorial design in Randomized Block Design (RBD). Treatment consists of two factors. The first factor is biofertilizer with four levels of IMO 0%, 10%, 20%, and 30%. The second factor is inorganic fertilizer (Urea, SP-36, KCL) with three levels, zero (0%), half (50%), and full (100%) from the recommended dosage. Biofertilizer was applied in 200 m^2 field with 2 m x 2 m of experimental plot size (36 plot). The distance between treatment was 0,5 m and 1 m between block. The biofertilizer was applied for three times on 0, 21, 42 days after planting. After the first application, corn seed Pioneer 32 was planted in distance 75 cm x 20 cm with 3 cm depth, and covered by soil. The observations were conducted on biofertilizer chemical characteristic and N, P, K nutrient uptake on 9 weeks after planting.

3. Results and Discussion

Chemical Characteristic of Biofertilizer

Water hyacinth that fermented using decomposing microbial consortium (*Enterobacter Cloacae*, *Bacillus subtilis*, *Pseudomonas fluorescens*, *Aspergillus niger*, and *Trichoderma asperellum*) (Sondang et al. 2018) called biofertilizers. The chemical characteristics of biofertilizer produced can be seen in Table 1.

Table 1 shows that a microbial consortium originated from indigenous microorganisms (IMO) acts as a decomposer that can influence the quality of the biofertilizers. The diversity of chemical properties of biofertilizer as a result of granting a microbial consortium with different level is assumed as strongly influenced by the number of population and the ability of these microbes in decomposing organic material. The increasing level of IMO will not necessarily increase the number of the population of microbes to decompose organic matter. This is because the microbes that exist in the first IMO will adapt to the environmental conditions during the composting process. The increasing of IMO level will be increased competition between the existing microbes in organic material with microbes consortium. Therefore, it was assumed that only certain microba that can survive and perpetuate the decomposition process. The high level of competition between these microbes can be seen from the analysis of N element in biofertilizer which is fairly high for all treatment. The research by Simarmata et al., (2016) that the giving consortium of decomposers on straw compost can control pathogens in straw, accelerate composting, and improve compost quality.

Table 1. Chemical characteristic of biofertilizer produced

Biofertilizer	pH	C/N	Macro nutrient			
			C org	N	P	K
			%			
IMO 0%	6.55	20.7	42.9	2.07	1.79	1.69
IMO 10%	6.58	19.2	41.0	2.14	1.88	1.78
IMO 20%	6.83	19.8	42.2	2.13	2.00	1.64
IMO 30%	6.58	17.8	40.7	2.29	2.00	1.48

Microbes have dual role, in addition to acting as decomposers, they also act as microbes that can help dissolve and provide nutrients for plant growth. Sondang et al. (2015) stated that a indigenous microorganism solution contained nutrient N 1.220%, P 0.216%, K 0.889%, C org 5.452%, C/N 4.469, and pH 4.15. Phosphate Solubilizing Bacteria (BPF) is not only capable of dissolving phosphate, but also able to increase N nutrient availability. It is evident from the research conducted of some researcher that the Bacteria Solvents Phosphate (BSP) such as *Pseudomonas* spp. (Mehnaz et al., 2001), Enterobacteriaceae (Lin et al., 2012), and Bacillus lived freely in the root zone and plant tissues proved capable of N2 fixation.

Biofertilizers inoculated by microbial consortium showed a pH value of 6.58–6.83%, C-org 40.7–42.2%, N 2,13–2,29, P 1,88–2,00, K 1.68–1.78, and C/N 17.8–19.2 conform the criteria of Indonesian National Standard (2014). Microbial inoculants can produce metabolites that help decompose organic waste and improve the quality of topsoil (Barker & Bryson, 2006). As a comparison from previous studies without microbial inoculation, by Sondang et al. (2014) organic fertilizers derived from water hyacinth and cow feces contains 1.37% N, 4.98% P, 0.06% K, 29.77 C-org, and C / N 21.73. Aleem et al., (2003) reported that the mechanism and workings of organic fertilizers in increasing nutrient and plant growth, immediately after decreasing plant pathogen activity.

The addition of biofertilizers containing microbial consortium to the experimental plots in addition to acting as nutrient suppliers, especially P and K, also improves soil physical properties. Biofertilizers play an important role in the vegetative growth period of plants (Wong et al., 2015) and plant tolerance to abiotic and biotic stress (Bhardwaj et al., 2014). The P enhancement will increase soil acidity (pH) (Table 1), reduce Al and Fe toxicity, and stimulate plant growth (Rahman et al., 2018). Wong et al., (2015) found that phytohormones produced by biofertilizers stimulated plant growth through the mechanism of N fixing and dissolving P by microbes to become available to plants.

The lack of influence of IMO levels on the chemical properties of biofertilizer can be assumed due to microbial that are antagonistic towards other microbial during the process of decomposition of biofertilizer. So, after a few days the application of IMO, the population of microbial decreased, so that with the reduction in the number of population of these microorganisms, the ability to provide nutrients and decompose organic material is on the wane. This is similar to the statement of Khare & Arora (2015) that physical, chemical, phytochemical properties of soil, and microbes and indigenous predators will affect the microbial population qualitatively and quantitatively. Competition or antagonistic/synergistic interactions and predators with microbial populations will determine the efficiency of inoculants.

The bacterial consortium (*Enterobacter cloacae*, *Bacillus substilis*, *Pseudomonas fluorescens*, *Aspergillus niger*, and *Trichoderma asperellum*) are potential to be N binder, P solvents, and plant growth stimulants. Phosphate Solvent Bacteria (BPF) such as Pseudomonas spp. (Sharma et al., 2013), Enterobacter spp (Lin et al., 2012) and Bacillus spp which live freely in root areas and plant tissues have are to be able to binding N2. It was assumed that organic matter derived from root zone such as banana hump can contribute as phosphate solvents bacterial and other fixing bacteria, so that the organic materials can be decomposed in a short time and contribute sufficient nutrients contributions, especially P nutrients.

Nutrient Uptake of Maize

There was an interaction between biofertilizer and inorganic fertilizer toward the content of N plant. The combination of biofertilizer and inorganic fertilizer showed a significant effect on nutrient uptake of N. Base on Table 2 it can be seen that IMO level 0%, 10%, 20%, 30% in biofertilizer provides the same effect on inorganic fertilizer 0%

and 50% toward N nutrient uptake, but significantly different on 100% dosage. The provision of biofertilizer has a positive impact on increasing inorganic fertilizer efficiency, this can be seen in the comparison between inorganic fertilizers 0% and 50%. The high nutrient uptake N of plant with the provision of IMO 20% and 30%, assumed because the population of the microbial consortium is more in mineralizing N from organic matter. According to Pidwirny, (2002) in the soil, N nutrient in organic matter is decomposed into ammonium (NH_4^+) by microbes through the mineralization process. The N content of plant includes very high criteria, more than 0.75% (Balai Penelitian Tanah, 2009). Lin et al. (2012) report that most Enterobacter genera other than binding N, also produce IAA, siderophore and phosphate dissolving. Result of statistic analysis from nutrient uptake N, P, K of maize plant with treatment of biofertilizer and inorganic fertilizer dosage are presented in Table 2 and 3.

Table 2. Nutrient uptake N of maize with the treatments of biofertilizer and inorganic fertilizer

Biofertilizer	Inorganic fertilizer dosage		
	0% (P0)	50% (P1)	100% (P2)
IMO 0% (M0)	2.05 Ab	2,06 Bb	2.10 ABCa
IMO 10% (M1)	2.06 Ab	2,07 Bb	2.13 ABa
IMO 20% (M2)	2.06 Ab	2.07 Bb	2.15 Aa
IMO 30% (M3)	2. 06 Ab	2.07 Bb	2.16 Aa

The numbers followed by the same capital letters in each column and the same small letters on each row are not significantly different at 5% level of LSD

Table 3. Nutrient uptake P and K of maize with treatments of biofertilizer and inorganic fertilizer dosage

Treatment	**P (%)**	**K (%)**
Biofertilizer		
IMO 0% (M0)	0.221 B	1.516 B
IMO 10% (M1)	0.232 AB	1.517 B
IMO 20% (M2)	0.237 A	1.633 A
IMO 30% (M3)	0.237 A	1.628 A
Anorganic fertilizer dosage		
0% (P0)	0.218 C	1.531 A
50% (P1)	0.230 B	1.568 A
100% (P2)	0.249 A	1.614 A

The numbers followed by the same capital letters in each column and the same small letters on each row are not significantly different at 5% level of LSD

P > 60,0 ppm /0.006% : sangat tinggi
K 1,5-2,0% : tinggi
Source: Balai Penelitian Tanah (2009)

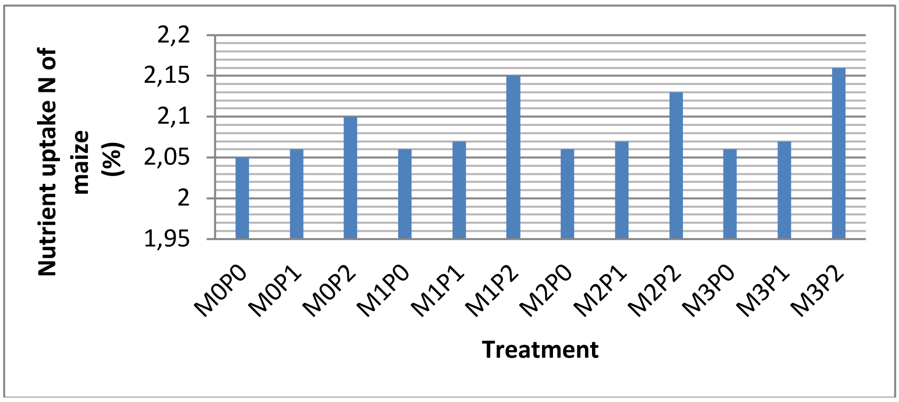

Figure 1. Nutrient uptake N of maize plant

Figure 1 shows the highest N content found in all treatments 100% inorganic fertilizer (M0P2, M1P2, M2P2, M3P2). This is due to a large contribution from Urea fertilizer. At high inorganic fertilizer dosages (100%), microbes cannot bind N from the air. Filip (2002) states that N binding bacteria, total microbial biomass, soil respiration, dehydrogenase activity, and decomposer microbial activity are indicators of soil quality.

The P and K of plants increase with increasing levels of IMO in biofertilizer, this is due to the population of more microbes with higher IMO levels. Karpagam & Nagalakshmi (2014) stated that some microbial species can mineralize and dissolve phosphate. The activity of dissolving phosphate is determined by the ability of microbes to release metabolites such as organic acids which are capable of releasing bound P cations. Zhang et al (2016) recorded that the P and K nutrients of wheat plants increased with a combination biofertilizer and Urea compared to without manure. Similarly, the P content of the plant increases with the increased dosage of inorganic fertilizer provided. The ability to dissolve phosphate compounds by phosphate solvent microbes differs depending on the content of P in the soil. The role of microbes in nutrient cycles are important because of the availability of nutrients is closely related to microbial activity involved (Pelczar & Chan, 2005).

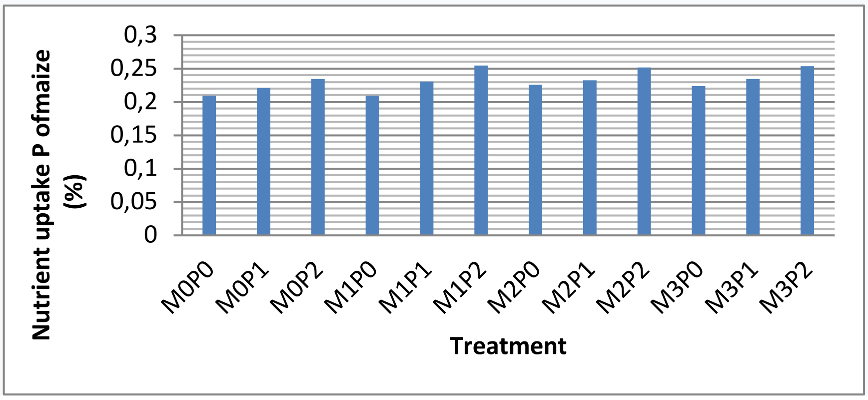

Figure 2. Nutrient uptake P of maize plant

Figure 2 shows the P content that is not too different between all treatments, this is because the inorganic fertilizer P given is more bound by colloidal soil and only a little can be absorbed by the plant. In accordance with the results of Sharma (2012) study that phosphate fertilizer added to the soil, as much as 75–90 % will be bound to the metal cation complex. Phosphate solvent bacteria are able to convert insoluble phosphate to dissolve by secreting organic acids (Prijambada et al. 2009) such as formic acid, acetate, propionate, lactate, glycolate, fumarate, and succinate.

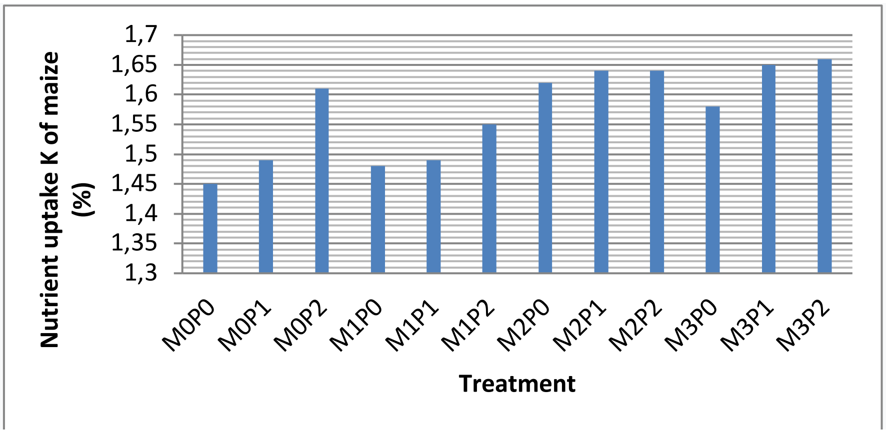

Figure 3. Nutrient uptake K of maize plant

Mehnaz et al. (2001) reported the results of research on *Enterobacter cloacae* isolated from Basmati varieties of rice stems capable of producing IAA phytohormones and being able to bind 41% of nitrogen from the air. Liu et al. (2013) stated based on comparative genome analysis, E. cloacae which have an antagonistic relationship to several species of fungi and pathogenic bacteria through siderofore secretion and several antimicrobial species such as bacteriocine, chitin and protein.

Bacillus subtilis includes bacteria that can help phosphate which is bound as dissolved and can be utilized by plants. Yao et al. (2006) recorded that *B. subtilis* was able to increase the root capacity to mobilize and extract nutrients from the soil. Kumawat et al. (2017) stated that *Bacillus* spp microbes can be used as biofertilizers because in addition to disolving phosphate, they also dissolve micro-nutrients such as zinc (Zn) and silicate (Si). According Yao et al. (2006) there was an increase in cotton growth and yield by 30% by using FZB 24 *Bacillus subtilis* compared to the use of NPK fertilizer.

Pseudomonas fluorescens contained in the biofertilizer act as decomposers of organic matter and help dissolve and provide nutrients for plant growth, such as the phosphate solvent bacteria and the phosphate solvent fungi. Parani & Saha (2012) suggest that bacteria from the Pseudomonas strain can increase plant growth and development due to increase nutrient uptake of P by plants, and the growing GA3 contribution. García-

Fraile et al. (2015) bacteria can increase plant growth through a mechanism of nutrient synthesis or phytohormone. Beneficial bacteria produce phytohormones which play a role in plant growth promotion (Spaepen, 2015).

Bacteria working with fungi in increasing the macronutrient solubility of N, P, and K. Aspergillus niger from a bacterial consortium bred on PDA media shows a strong halo. Sharma (2012) identified Aspergillus niger as a phosphate solvent microbes (PSM) whose solubility was influenced by many factors. Aspergillus sp. NPF7 strains isolated from rhizosphere of wheat were able to dissolve phosphate, resulting in IAA, GA, and Siderofor which can stimulate plant growth (Pandya et al., 2018).

Trichoderma asperellum is a fungus that dissolves phosphate. Trichoderma spp is a bio-control that inhibits many plant diseases (Partanen et al. 2010) . Wu et al. (2017) reported that *T. asperellum* GDFS1009 was able to produce primary metabolites as precursors of antimicrobial compounds and antimicrobial secondary metabolites capable of inhibiting pathogens that cause corn disease. Microbes in biofertilizer have a function as a decomposer of organic matter, solvent assist and an adequate supply of nutrient on plant growth, like phosphate solvent bacteria and phosphate solvent fungus. The function of microbes in nutrient cycle is so important because it is related to the microbe activity that used. Trichoderma species include microbes that can increase growth and development, and suppress disease in some plants (Sharma, 2018).

Giving biofertilizer (0%, 10%, 20%, 30%) and inorganic fertilizer (0%, 50%) had no significant effect on N nutrient uptake (Table 4), but it was significantly different toward uptake of P and K plants (Table 5). Uptake P at the IMO level of 20% and 30% shows the same number. Increasing of IMO level is not directly proportional to the increase in N and K plant, but gives a fluctuating effect. This is due to the adaptation of microbes consortium that is different when fermented.

Inorganic fertilizer dosage has a significant effect on the uptake of N and P of maize, but it has no significant effect on the K content. This is because of the total K concentration in the soil is quite high and K is relatively immovable in the soil, so the addition of KCl fertilizer does not significantly affect available K. Besides that microbes that can change K insoluble into K dissolved in biofertilizers are probably not present. Etesami et al. (2017) reported that solubility of K can be carried out by bacteria such as *B. mucilaginosus*, *B. edaphicus*, *B. circulans*, *Pseudomonas* sp, Burkholderia, Acidithiobacillus ferrooxidans, and Paenibacillus spp. Overall, the increase in inorganic fertilizer dosage is directly proportional to the uptake of N, P, and K of maize plants (Table 2 and 3).

Biofertilizer fermented with the help of bacterial consortium containing endophyte and rhizosphere microbial that can ability to bind N from the air and mine the phosphate becomes available to the plant, there by enhancing the growth of the plant and the efficiency of inorganic fertilizers. Partanen et al. (2010) stated that the most efficient composting process was achieved by a mixed community of bacteria, and fungi rather than just a bacterial community. The function of microbe soil are to help nutrient cycle, to fix the structure of the soil, and to stimulate the plant growth (Filip, 2002). According Chen (2006), qualities and characteristics of nutrient release by chemical fertilizers, organic fertilizer, and biofertilizer are different.

4. Conclusions

Based on result of the research, it can be concluded that biofertilizers inoculated by microbial consortium showed a pH value of 6.58– 6.83%, C-org 40.7–42.2%, N 2,13–2,29, P 1,88–2,00, K 1.68–1.78, and C/N 17.8–19.2 conform the criteria of Indonesian National Standard. Biofertilizer with various levels of indigenous microorganisms significantly affects the nutrient uptake of P and K in maize plant, but there is no affect toward N nutrient uptake in maize. Inorganic fertilizer dosage significantly affect the uptake of N and P, but there is no effect toward K nutrient uptake in maize. Nutrient uptake of N, P, and K is found to increase along with the increasing of N, P, and K in biofertilizer.

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