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EFFECTS OF BIOFERTILIZER "M-STAR" ON LAND PRODUCTIVITY AND GROWTH OF SWEET CORN IN ACID SULPHATE SOIL OF SWAMPLAND

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ABSTRACT

This research aims to test the effectiveness of biofertilizer "M-Star" in increasing land productivity, growth of sweet corn and the efficiency of inorganic fertilizer used in acid sulphate soil of swampland. Research was conducted from May – July, 2012 in acid sulphate soil of Barambai, Barito Kuala Regency, South Kalimantan. The treatments involved (B1) Biofertilizer 25 kg/ha, (B2) Biofertilizer 15 kg/ha, (P1) NPK (recommendation dose), (P2) NPK (1/2 recommendation dose), (B1P1) Biofertilizer 25 kg/ha + NPK (recommended dose), (B1P2) Biofertilizer 25 kg/ha + NPK (1/2 recommended dose), (B2P1) Biofertilizer 15 kg/ha + NPK (recommended dose), (B2P2) Biofertilizer 15 kg/ha + NPK (1/2 recommended dose), and (K) No fertilizer. The treatments were arranged by randomized completely block design with 3 replications. Recommended dose of NPK fertilizer was at 90-60-50 NPK kg/ha. Observations were conducted on soil pH, soil and plant nutrients, growth of sweet corn (plant height and biomass weight), and microbial population. Research results showed that 15 kg/ha biofertilizer "M-Star" combined with inorganic NPK fertilizer could increase soil nutrients and sweet corn growth. This biofertilizer also increased the efficiency of inorganic fertilizer by 50%.

Keywords: biofertilizer, sweet corn, swampland

INTRODUCTION

Swampland is one of the most potential lands for corn production in Indonesia. Acid sulphate soil, which predominantly occupies swampland, takes a total area of about 6.7 million ha and is spread out in Sumatera, Kalimantan, and Papua (Nugroho *et al*., 1992). This soil has a high iron sulphate mineral content of predominant pyrite. When the soil is drained, it releases sulfuric acid, which in turn will release Fe, Al and other heavy metals that are dangerous for plant. Dent (1986) reported that the most constraints for plant production in acid sulphate soil were: (a) low soil fertility (deficiency of macro elements such as N, P, K, Ca, Mg), and (b) toxicity of Al and Fe caused by soil acidity. This soil condition can be corrected by liming and high rate of chemical fertilizers, but small farmers are usually made suffered economically.

Biofertilizer has been identified as an alternative to substitute chemical fertilizer to increase soil fertility and plant production in acid sulfate soil (Mukhlis *et al*., 2010). Biofertilizer is a substance containing living microorganisms, which have an ability to make important elements available via biological process (Hegde *et al*., 1999; Vessy, 2003). The utilization of biofertilizer has several advantages over chemical fertilizer for agricultural purposes: (i) biofertilizer is considered the safest among many of the chemical fertilizers now in use; (ii) neither toxic substances nor microbes themselves will be accumulated in the food chain; (iii) self-replication of microbes circumvents the need for repeated application (Shen, 1997). The efficiency and effectiveness of microbes as active ingredient of biofertilizer is affected by several factors, i.e.: soil type, climate condition, and the quality of organic matter (Alexander, 1977).

In recent years, biofertilizer has emerged as an important component of the integrated nutrient supply system, and it holds a great promise to improve crop yields through environmentally better nutrient supplies. A biofertilizer "M-Star" containing decomposer (*Trichoderma* sp), N-fixer (*Azospirillium* sp), and

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P solubilizer (*Bacillus* sp) has been formulated by ISARI (Indonesia Swampland Agricultural Research Institute). The major objective of this experiment was to evaluate the effects of this biofertilizer on the promotion of sweet corn growth, improvement of soil properties, and reducing the use of chemical fertilizers in acid sulphate soil of swampland.

MATERIALS AND METHODS

The experiment was carried out in Barambai, Barito Kuala regency, South Kalimantan province from May – July, 2012. The soil type used was acid sulphate soil known to be acidic, low in macro nutrients, and high in Fe. Selected physicochemical characreristics of the soil are presented in Table 1.

Table 1. Selected physicochemical characteristics of acid sulfate soil before experiment, Barambai, Barito Kuala regency, South Kalimantan province, 2012.

Characteristics	Value	Criteria
pH (H_2O)	3.91	Very acid
C-organic (%)	2.97	Moderate
N-total (%)	0.20	Low
P-Bray1 (ppm P_2O_5)	12.93	Low
Al-dd (Cmol(+)/kg)	8.59	Low
Ca-dd (Cmol(+)/kg)	0.13	Very low
Mg-dd (Cmol(+)/kg)	0.25	Very low
K-dd (Cmol(+)/kg)	0.28	Very low
Na-dd (Cmol(+)/kg)	0.17	Low
CEC (me/100 g	81.50	Very high
Fe (ppm)	152.85	High

Land preparation was done by cutting the weed and plowing with minimum tillage. The weed was sown on sites and used as sources of organic matter. The 6 m x 8 m planting beds were made. There were nine treatments of biofertilizer and NPK inorganic fertilizer: (B1) Biofertilizer 25 kg/ha, (B2) Biofertilizer 15 kg/ha, (P1) NPK (recommended dose), (P2) NPK (1/2 recommended dose), (B1P1) Biofertilizer 25 kg/ha + NPK (recommended dose), (B1P2) Biofertilizer 25 kg/ha + NPK (1/2 recommended dose), (B2P1) Biofertilizer 15 kg/ha + NPK (recommended dose), (B2P2) Biofertilizer 15 kg/ha + NPK (1/2 recommended dose), and (K) No fertilizer (control). The dose of NPK inorganic fertilizer recomended for sweet corn was 90 kg N – 60 kg P_2O_5 – 50 kg K_2O per ha. A Randomized Completely Block Design with three replication was applied in the research.

The biofertilizer used for this experiment was made in Soil Microbiology Laboratory of ISARI. It consisted of a decomposer (*Trichoderma* sp), a nitrogen-fixing bacterium (*Azospirillium* sp), a phosphate solubilizer (*Bacillus* sp), and rice husk biochar as carrier. They were originally isolated from acid sulphate soil of swampland in South Kalimantan. Sweet corn seeds (Bonanza variety) were sown in each hole with the 25 cm x 75 cm planting distance. Biofertilizer was applied directly into the planting hole before planting, while NPK fertilizer was applied one week after planting. Weed control was done manually. Insect pest was control by spraying insecticide.

The growth of sweet corn was studied based on plant height and dry biomass weight at 75 days after planting. After the plants were harvested, shoot tissues were oven dried at 60^oC until constant weight was attained. After the dry weight was taken, the samples were ground to a size less than 2.0 mm and used for determination of N, P, K, Ca, and Mg uptake by plant. The soil samples were collected for chemical analysis before the experiments and after harvesting the plants. After air-dried, soil samples were sieved (by means of 2.0 mm screen) and analyzed for following : pH (1:5 water extraction), total organic carbon, total nitrogen by using Kjeldahl method, available P content by using Bray and Kurt I extract, exchangeable K, Ca, and Mg by using Morgan-Wolf extract (Balittanah, 2009). Enumeration and isolation of *Trichoderma sp* (organic matter decomposer fungi), *Azospirillium sp* (N-fixing bacteria), and *Bacillus sp* (P-solubilizing bacteria) from the fresh soil samples were determined using the total plate count techniques with different media (Trichoderma medium E, Okon medium, and Pikovkaya medium for isolating *Trichoderma sp*, *Azospirillium sp*, and *Bacillus sp*, respectively).

The data obtained from soil and plant at each observation were analyzed using SAS package (SAS Institute Inc.) for analysis of variance (ANOVA) and mean comparison using LSD (least significant difference) test.

RESULTS AND DISCUSSION

Plant Growth

Figure 1 and 2 present the effect of biofertilizer and NPK inorganic fertilizer on sweet corn growth. Compared to control (no fertilizer), biofertilizer or NPK inorganic fertilizer treatment increased biomass dry weight. However, such an observation was not made for plant height. Biofertilizer combined with NPK inorganic fertilizer showed that plant height and biomass dry weight were higher than the treatment of biofertilizer or NPK inorganic fertilizer only. The decreasing of biofertilizer rate as much as 40% (25 kg/ha to 15 kg/ha) didn't affect plant growth.

Similar to the trend in crop growth, nutrient uptake by shoot of sweet corn was significantly influenced by biofertilizer and NPK inorganic fertilizer treatments (Table 2). Application of biofertilizer only didn't increase the nutrient N, P, K, Ca, and Mg uptake. Except for nitrogen, the same result was also shown by NPK inorganic fertilizer only. However, a significant increase was observed for the combined biofertilizer with NPK inorganic fertilizer treatments. This result also showed that statistically similar nutrients uptake was found between the treatment of biofertilizer combined with a half of recommendation dose and recommendation dose of NPK inorganic fertilizer.

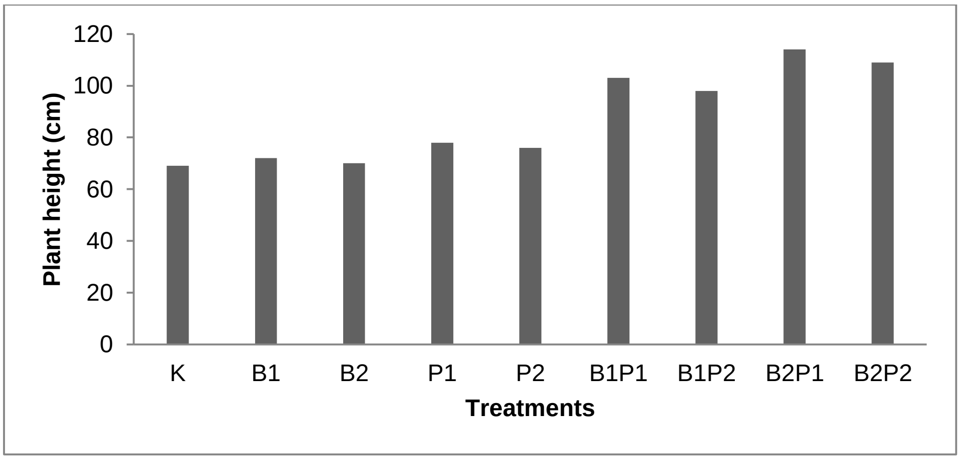

Figure 1. Plant height of sweetcorn caused by biofertilizer and NPK inorganic fertilizer, Barambai, dry season 2012

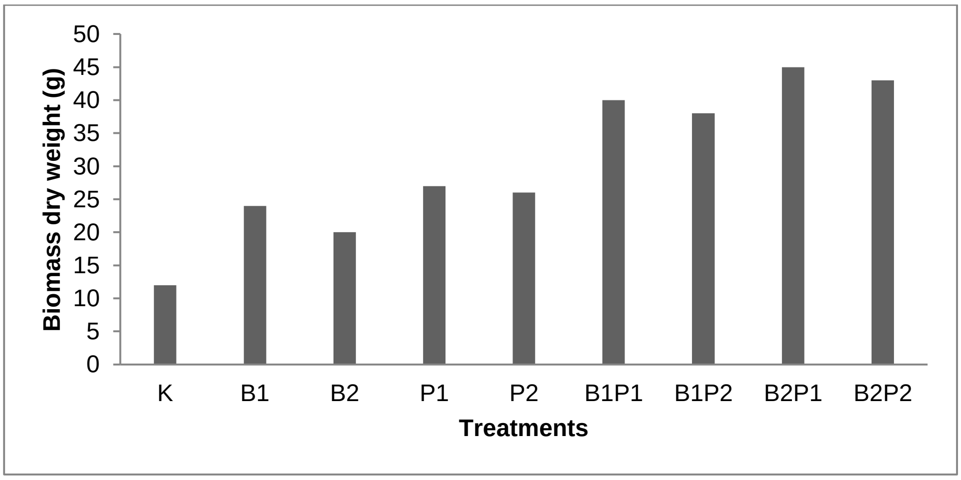

Figure 2. Biomass dry weight of sweetcorn caused by biofertilizer and NPK inorganic fertilizer, Barambai, dry season 2012.

Table 2. Nutrient content of sweet corn at 75 days after planting caused by biofertilizer and NPK inorganic fertilizer, Barambai, dryseason 2012.

Treatments	N_{tot} (%)	P (ppm P_2O_5)	K_{dd} (cmol(+)/kg)	Ca_{dd} (cmol(+)/kg)	Mg_{dd} (cmol(+)/kg)
Control	1.23a	0.41a	0.11a	0.14a	1.33a
B1	1.24a	0.41a	0.11a	0.12a	1.36a
B2	1.23a	0.40a	0.12a	0.13a	1.32a
P1	1.45b	0.40a	0.11a	0.13a	1.37a
P2	1.42b	0.38a	0.11a	0.17a	1.39a
B1P1	1.82c	0.61b	0.23b	0.31b	1.99b
B1P2	1.78c	0.54b	0.22b	0.28b	2.00b
B2P1	1.82c	0.54b	0.21b	0.26b	1.78a
B2P2	1.82c	0.55b	0.20b	0.24ab	1.79a

Remarks: Different letters in a column indicate significant difference at P≤ 0.05 by LSD

This study demonstrated that the growth of sweet corn (in terms of biomass dry weight) increased significantly with the application of biofertilizer, NPK inorganic fertilizer, or the combined biofertilizer with NPK inorganic fertilizer treatment, as compared with control. However, the highest biomass dry weight was found in the combined biofertilizer with NPK inorganic fertilizer treatment. The increase in plant growth was consistent with the increase in nutrient uptake. It was found that N, P, K, Ca, and Mg in the corn plant increased with application of the combined biofertilizer with NPK inorganic fertilizer. Growth enhancement by biofertilizer containing beneficial microbes may be also associated to their ability to produce hormone, especially IAA. The decrease of a half of recommended dose of NPK inorganic fertilizer didn't affect plant growth and nutrient uptake. This implies that biofertilizer can substitute the need of NPK inorganic fertilizer as much as 50%. Therefore, biofertilizer may increase the efficiency of fertilizer use. The present result is in agreement with Adesemoye and Kloepper (2009) and Ekin (2010), who reported that the microbial inoculants could be used as an economic input to increase crop productivity with chemical fertilizers.

Soil pH and Nutrients

Soil pH, total carbon, nitrogen, and exchangeable Ca were significantly influenced by the combined biofertilizer with NPK inorganic fertilizer, but they were not significantly different among biofertilizer, NPK inorganic fertilizer, and control treatments (Table 3). The decreasing rate of biofertilizer was as much as 40% (25 kg/ha to 15 kg/ha) and a half of recommended dose of NPK inorganic fertilizer didn't affect soil pH, total carbon, nitrogen, and exchangeable Ca.

The treatment of NPK inorganic fertilizer and the combination of biofertilizer and NPK inorganic fertilizer significantly increased the amount of extractable P and exchangeable K in soil compared to that of biofertilizer and control treatments. Biofertilizer and control treatments were similar in the amount of extractable P and exchangeable K in soil. The highest amount of extractable P and exchangeable K was found on the combined biofertilizer with NPK inorganic fertilizer. This result also shows that there was no difference between biofertilizer rate 25 kg/ha and 15 kg/ha or recommended dose and a half of recommended dose of NPK inorganic fertilizer. There was no significant effect among all treatments on exchangeable Mg.

Addition of biofertilizer or NPK inorganic fertilizer alone into the soil only caused slight non-significant increases in available N, P, K, Ca, and Mg, respectively. This might occur because the characteristics of acid sulfate soil were poor in nitrogen, phosphorus and potassium nutrient and therefore biofertilizer or NPK inorganic fertilizer alone was not quite significant to increase the availability of nutrients. When applied together, biofertilizer and NPK inorganic fertilizer resulted in the highest availability of C, N, P, K, and Ca in soil. These results were consistent with previous reports, in which application of biofertilizer combined with NPK inorganic fertilizer increase soil and rice plant nutrients in tidal swamplands (Mukhlis, 2012).

Table 3. Soil nutrient contents at 75 days after planting caused by biofertilizer and NPK inorganic fertilizer, Barambai, dryseason 2012.

Treatments	pH H_2O	C_{tot} (%)	N_{tot} (%)	P(ppm P_2O_5)	Kdd (cmol (+)/kg)	Ca_{dd} (cmol (+)/kg)	Mg_{dd} (cmol (+)/kg)
Control	4.21a	0.47a	0.25a	45.67a	2.67a	1.23a	0.10a
B1	4.22a	0.57a	0.25a	46.13a	2.71a	1.32a	0.09a
B2	4.22a	0.52a	0.25a	47.85a	2.70a	1.27a	0.10a
P1	4.27a	0.55a	0.29a	60.32b	3.23b	1.21a	0.10a
P2	4.23a	0.47a	0.30a	74.80c	3.40b	1.42a	0.11a
B1P1	4.43b	1.57b	0.38b	83.44c	3.59c	1.93b	0.09a
B1P2	4.44b	1.14b	0.33ab	77.83c	3.54c	1.84b	0.12a
B2P1	4.46b	0.95b	0.33ab	79.55c	3.51c	1.86b	0.10a
B2P2	4.46b	1.89b	0.33ab	63.35b	3.17b	1.77b	0.10a

Remarks: Different letters in a column indicate significant difference at $P \leq 0.05$ by LSD

The result of pH measurements indicated that addition of biofertilizer increased soil pH. Biofertilizer (in term of *Trichoderma sp*) consume a considerable amount of organic matter to generate the energy for maintenance and growth. According to Farrell and Campbell (1970) that the increase in pH is generally thought to be the result of volatilization and microbial decomposition of organic acids which were originally present, and the release of ammonia by microbes mineralizing organic nitrogen sources. Tan (1998) stated that soil pH was one the most important soil characteristics that might influence other soil properties. It may affect the solubility of mineral and therefore it governs several soil processes. It influences many soil chemical and biochemical reactions. Soil reactions may affect plant growth directly or indirectly because it affects the solubility and availability of plant nutrients.

Increasing the availability of C, N, P, K, Ca, and Mg in soil with combined biofertilizer and NPK inorganic fertilizer, which may lead to increase nutrient uptake and plant growth, is related to the ability of microbes to provide nutrient for optimal plant growth. Biofertilizer used in this study contained *Trichoderma* sp, *Azospirillium* sp, and *Bacillus* sp. *Trichoderma* sp is widely known as an organic matter decomposer because its potential ability to mineralize waste of high C/N and encourage the availability of nutrient (Raimbult, 1998). It also exhibits plant-growth-promoting activity (Chet, 1987; Kleifeld and Chet, 1992). *Azospirillium* sp is a prokaryote capable of fixing atmospheric N in association with non-leguminous crop. *Azosprillium* sp can promote growth and development of the host plants, e.g.: wheat, corn, and sorghum, probably through secretions of plant growth hormones (Okon *et al*., 1988). The beneficial effect of *Azospirillium* may derive both from its nitrogen fixation and stimulating effect in root development (Lynch, 1990). *Bacillus* sp is capable of increasing availability of phosphorous to plants either by mineralization of organic phosphate or by solubilization of inorganic phosphate through the production of acids (Rodriguez and Fraga, 1999).

Soil Microbial Population

Microbial population in the soil was found to be affected by the application of biofertilizer and NPK inorganic fertilizer (Figure 3). Compared to control, application of biofertilizer, NPK inorganic fertilizer, or the combination of biofertilizer and NPK inorganic fertilizer increased the population of *Trichoderma* sp, *Azospirillium* sp, and *Bacillus* sp in the soil. However, their population in the combination of biofertilizer and NPK inorganic fertilizer treatment was higher than that in biofertilizer or NPK inorganic fertilizer treatment.

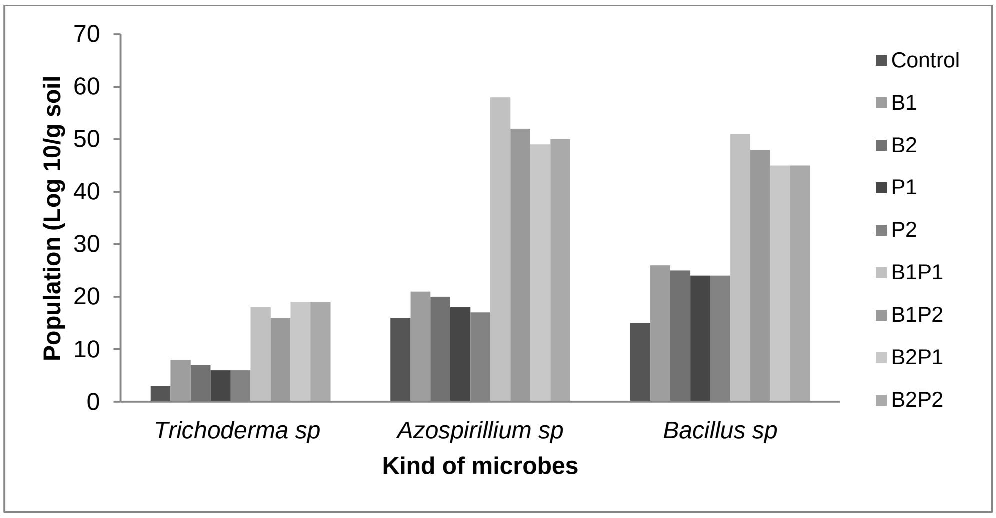

Figure 3. Soil microbial population on 75 days after planting affected by biofertilizer and NPK inorganic fertilizer

This indicates that the microbes used can compete with existing natural microbes, which is understandable as they are isolated from similar acid sulfate soil condition. Good indigenous species are preferable to be selected as inocula in order to ensure a successful colonization of microbes since the possible competition may occur between introduced and autochthonous populations in field soil conditions. This is consistent with Mukhlis (2012) who reported that biofertilizer (containing *Trichoderma* sp, *Azospirillium* sp, and *Bacillus* sp) and NPK inorganic fertilizer which was applied on rice plant in tidal swampland enhanced the population size of *Trichoderma* sp, *Azospirillium* sp, and *Bacillus* sp.

CONCLUSIONS AND SUGGESTIONS

The application of biofertilizer containing decomposer, N-fixer, and P-solubilizer as much as 15 kg/ha combined with inorganic NPK fertilizer increased the growth of sweet corn and improved soil properties. This biofertilizer also increased the efficiency of inorganic NPK fertilizer until 50% and can be applied for suboptimal land, such as acid sulphate soil of swampland.

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