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Effectiveness of biofertilizer formula on soil chemical properties and shallot productivity in tidal swamp land

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Abstract. Low productivity is one of the main problems to increase shallot productivity in tidal swamp lands. Biofertilizer is an alternative to increase soil fertility, plant productivity, inorganic fertilizer efficiency, and decrease environmental pollution. The aim of this research was to test the biofertilizer formula containing decomposer (*Trichoderma sp*), P-solubilizer (*Bacillus sp*), and N-fixer (*Azospirillum sp* and *Azotobacter sp*) to increase soil chemical properties and shallot productivity in tidal swamp lands. This research was conducted from July – September 2018 in Wanaraya District, Barito Kuala Regency, South Kalimantan. The treatments involved (A) No fertilizer, (B) NPK (recommendation dose), (C) Biofertilizer, (D) Biofertilizer + NPK (50% of recommended dose), (E) Biofertilizer + NPK (75% of recommended dose). The treatment was arranged by randomized completely block design with four replications. Recommended dose of NPK fertilizer was NPK compound 500 kg ha⁻¹, SP-36 150 kg ha⁻¹, dan KCl 200 kg ha⁻¹. Research results showed that biofertilizer formula combined by inorganic NPK fertilizer as much as 50 to 75 % of recommended dose could increase soil chemical properties and yielded as much as 2.39 to 6.19% compared to NPK fertilizer with recommended dose. For further development, this biofertilizer need to be tested at several locations with broader plot size.

1. Introduction

Shallots are one of the seven priority food commodities in Indonesia's agricultural development program. The potential and opportunities for increasing shallot production through the utilization and optimization of tidal land management are very large and prospective. It is estimated that 2.80 million ha of 8.92 million ha of tidal land in Indonesia are suitable for agricultural cultivation [1]. The main problem faced in tidal swamp land development is low productivity. The average of shallot production is only around 2.3 t ha⁻¹ for the acid sulphate soil [2] and 11-12 t ha⁻¹ for peat soil [3]. This low productivity is due to high soil acidity, toxic substances (Al, Fe, H₂S) and relatively low nutrient availability [4].

Fertilization is a must to increase shallot productivity. However, fertilization which relies on the use of inorganic fertilizers can cause soil hardening, decrease organic matter content, increase certain pests and



diseases, and can eliminate predators and parasitoids [5], and also has a negative impact on microbes in the soil [6].

The use of biofertilizers is an alternative to increase soil and crop productivity, inorganic fertilizer efficiency, farmers' income, and decrease environmental pollution. Biofertilizers provide benefits for plant growth and increase yields through their role in fixing N in the soil, dissolving P and K, releasing plant growth regulators, and producing antibiotics, as well as decomposing organic matter [7]. When biofertilizers are applied to seeds or soil, the microbes will reproduce and play an active role in providing nutrition and increasing plant productivity [8]. However, the microbes contained in biofertilizers have special properties and different optimal environmental conditions that affect their effectiveness. Various research results showed that the use of indigenous soil-based microbes from swamps itself in the bio-fertilizer formula guarantees more adaptability and effectiveness to increase soil fertility and plant productivity in tidal swamp lands [9, 10].

The composition of microorganisms and its carrier is a biological fertilizer formula. Based on the process, the use of biofertilizers aims to increase the number of microbes and accelerate microbiological processes in increasing the availability of nutrients in the soil, so that they can be utilized by plants [11]. Until now, information on effective and adaptive biofertilizers for the development of shallot plants in tidal lands is still limited. Therefore, a biofertilizer formula that is adaptive to acidic and effective soil conditions is needed to increase soil fertility and plant productivity, decrease the use of inorganic fertilizers, and reduce the danger of environmental pollution in tidal swamp lands.

The aim of this research was to test the biofertilizer formula containing decomposer (*Trichoderma sp*), P-solubilizer (*Bacillus sp*), and N-fixer (*Azospirillum sp* and *Azotobacter sp*) to increase soil chemical properties and shallot productivity in tidal swamp lands.

2. Materials and methods

2.1. Biofertilizer formulation

Biofertilizer formulation was carried out in the microbiology laboratory of Indonesian Swampland Agriculture Research Institute (ISARI), Banjarbaru. The biofertilizer formula consists of a decomposer (*Trichoderma sp*), P-solubilizer (*Bacillus sp*), and N-fixer (*Azospirillum sp* and *Azotobacter sp*, and molasses as a carrier. The initial population of each microbe was 10^9 cfu ml⁻¹. These microbes were isolated from tidal swamp lands of South Kalimantan. Observation on the population of each microbe was done at 30 days after incubation.

2.2. Field effectiveness test

This research was conducted from July to September 2018 in tidal swamp lands type C, Wanaraya District, Barito Kuala Regency, South Kalimantan. The treatments involved (A) Control (No fertilizer), (B) NPK (recommendation dose), (C) Biofertilizer, (D) Biofertilizer + NPK (50% of recommended dose), (E) Biofertilizer + NPK (75% of recommended dose). The treatment was arranged by randomized completely block design with four replications. Recommended dose of NPK fertilizer was 500 kg ha⁻¹, 150 kg ha⁻¹, and 200 kg ha⁻¹ for NPK compound, SP-36, and KCl, respectively. Biofertilizer dose was 6 L ha⁻¹.

The experimental plot was a bed with a width of 1.2 m and a length of 10.0 m. Plant space was 15 x 20 cm. The shallot variety used was Bauji. Before planting, the seeds were given the seed treatment. Every 10 kg of seeds, 1 tablespoon of fungicide was sprinkled and mixed by stirring in the sack until evenly distributed. Watering is done if it does not rain for 3 to 4 days using ground water. Pest and disease control were carried out intensively using insecticides (active ingredients chlorantraniliprole and thiamethoxam) and fungicides (active ingredients azoxystrobin, difenoconazole, and propineb) alternately every 3 days.

Weed control was carried out manually three times, namely at 15, 30, and 45 days after planting. Shallots are harvested at 60 days after planting.

The observation of shallot growth and production was done on plant height, number of leaves, and number of tillers at 2, 4, and 6 weeks after planting, as well as wet weight and dry weight. The plant nutrient was observed at the age of 6 weeks. Soil sampling was carried out in a composite manner to analyze soil chemical and physical parameters at a depth of 0 to 15 cm. Soil analysis after the experiment was carried out on pH, C-organic, N-total, P-extractable, K-exchangeable, Ca-exchangeable, and Mg-exchangeable. The data obtained were analyzed using SAS package (SAS Institute Inc.) for analysis of variance (ANOVA) and the significant difference among the treatment analyzed by Least Significant Different (LSD) test ($p=0.05$).

3. Results and discussion

3.1. Biofertilizer formulation

Carrier is one of the requirements that determine the quality of biofertilizers. At biofertilizer formula, carrier must be able to provide a good living environment for the microbes during production, transportation, and storage before the biological fertilizers are used so that the minimum population of living microbes is fulfilled. The results showed that the populations of *Trichoderma sp*, *Azospirillum sp*, *Azotobacter sp*, and *Bacillus sp* on the molasses carrier showed high populations, namely 3.33×10^5 , 11.62×10^8 , 17.5×10^8 , 6.10×10^8 cfu ml⁻¹, respectively.

3.2. Field effectiveness test

Soil analysis before the biofertilizer application showed that the soil was classified as acidic with medium C_{org} and high CEC. The availability of N and P is moderate, K is very low, Ca is very low, Mg is low. In terms of soil chemistry, the soil is less fertile. The soil chemical characteristics are presented in table 1.

Table 1. The initial soil characteristics of tidal swamp lands, Wanaraya, Barito Kuala regency, South Kalimantan province.

Soil characteristics	Value	Criteria
pH H ₂ O	3.58	Acid
C-org (%)	2.98	Moderate
CEC (cmol kg ⁻¹)	43.81	High
N-total (%)	0.57	Moderate
P-total (%)	39.16	High
K-total (%)	32.00	High
P-extractable (ppm)	16.30	Moderate
K-exchangeable (cmol ⁽⁺⁾ kg ⁻¹)	0.46	Very low
Ca-exchangeable (cmol ⁽⁺⁾ kg ⁻¹)	1.89	Very low
Mg-exchangeable (cmol ⁽⁺⁾ kg ⁻¹)	1.83	Low

The results of soil analysis after the experiment showed that the treatments of biofertilizer combined with inorganic NPK fertilizers either 50% or 75% of recommended dose were higher in soil nutrient content and nutrient uptake in shallot plants compared to control treatment, inorganic NPK fertilizer or biological fertilizer alone (Table 2 and 3). This increase is made possible through the activity of the *Trichoderma sp* which is able to accelerate the breakdown of residues so that it can be readily available to plants, N-fixing bacteria that are able to fix free N, and P-solubilizing bacteria which can dissolve P bound with other

compounds becomes available. Similar results reported by Mukhlis [12] that the application of Biotara biofertilizer combined with inorganic NPK fertilizer was able to increase the nutrient content of acid sulfate soils in tidal swamp lands. The lowest nutrient content was shown in the control and biofertilizer treatments only. It is possible that biofertilizer requires available nutrients as a starter for its microbe growth optimally.

Table 2. The effect of biofertilizer and NPK fertilizer on soil nutrients in tidal swamp lands. Wanaraya, Barito Kuala regency, South Kalimantan province.

Treatments	pH H ₂ O	C _{total} (%)	N _{total} (%)	P _{extractable} (ppm P ₂ O ₅)	K _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)	Ca _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)	Mg _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)
A	3.98a	2.64a	0.34a	67.19a	1.58a	2.41a	0.64a
B	4.01a	3.77ab	0.67b	108.92b	1.92ab	2.56a	0.73a
C	3.99a	2.66a	0.40a	75.32ab	1.68a	2.47a	0.66a
D	4.12a	4.68b	0.85c	155.09c	2.66b	4.30b	2.39b
E	4.16a	4.71b	0.96c	171.44c	2.81b	4.32b	2.71b
CV (%)	9.13	12.47	9.70	13.58	8.40	10.31	11.22

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

A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose).

Table 3. The effect of biofertilizer and NPK fertilizer on shallot plant nutrients in tidal swamp lands. Wanaraya, Barito Kuala regency, South Kalimantan province.

Treatments	N _{total} (%)	P _{extractable} (ppm P ₂ O ₅)	K _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)	Ca _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)	Mg _{exchangeable} (cmol ⁽⁺⁾ kg ⁻¹)
A	1.33a	0.47a	0.14a	0.11a	1.29a
B	1.72b	0.66b	0.21b	0.16a	1.46a
C	1.38a	0.49a	0.15a	0.13a	1.27a
D	2.32c	0.91c	0.33c	0.22b	2.01b
E	2.48c	0.98c	0.39c	0.28b	2.20b
CV (%)	9.6	10.7	8.6	13.8	9.7

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

A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose).

The application of biofertilizers combined with inorganic NPK fertilizers either with 50% or 75% of recommended dose showed higher in plant height, tiller number, and leave number compared to the application of inorganic NPK fertilizer or biofertilizer alone (figure 1, 2, and 3), but there was no significant difference among treatments. This growth increase is in line with the results of soil analysis after the experiment.

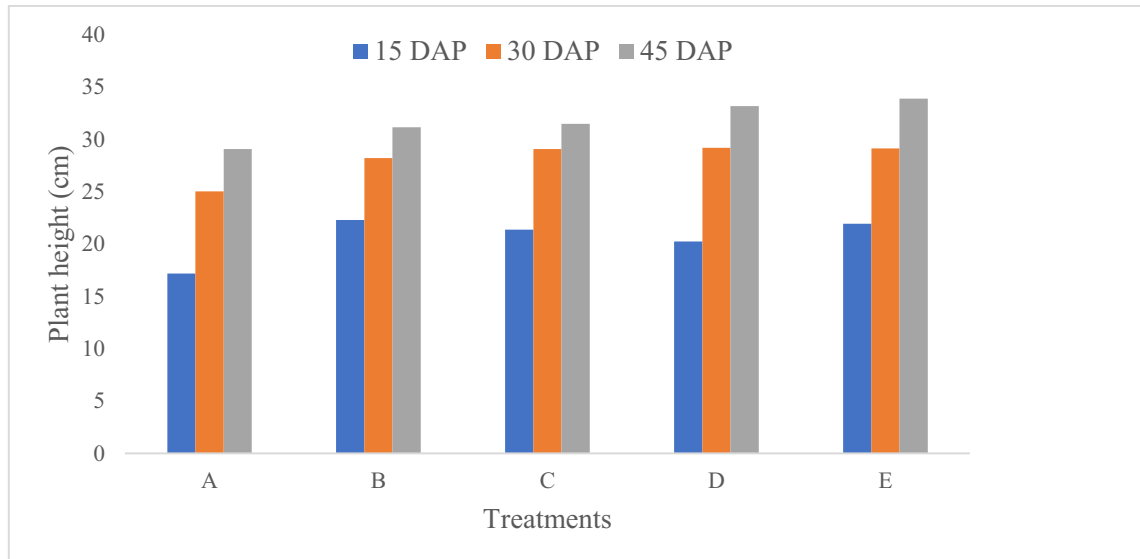


Figure 1. Plant height of shallot caused by biofertilizer and NPK inorganic fertilizer. Wanaraya, Barito Kuala regency, South Kalimantan province (A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose); DAP=Days after planting.

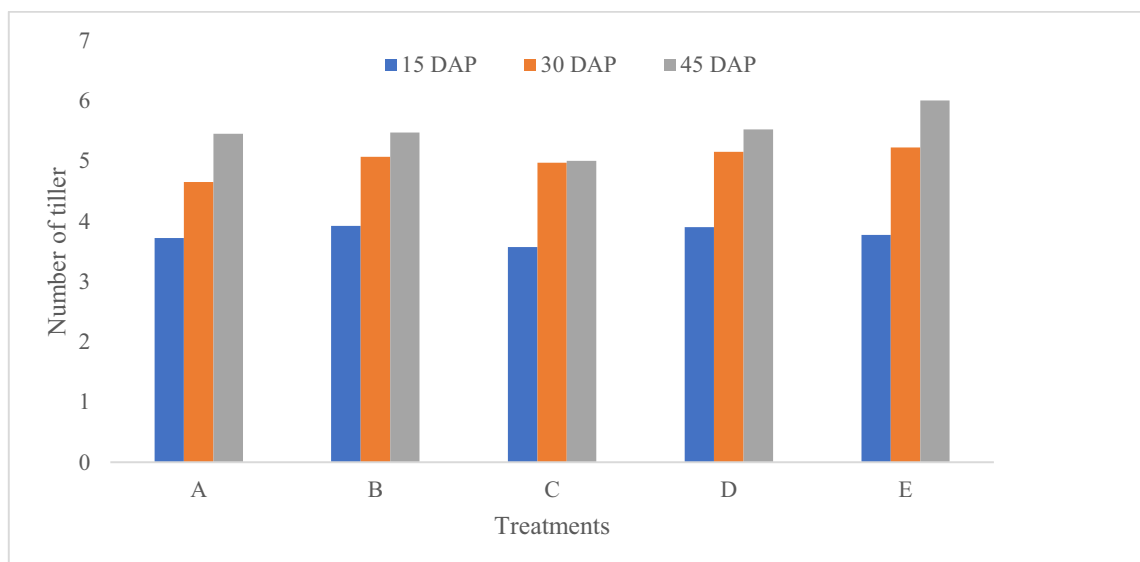


Figure 2. Tiller number of shallots caused by biofertilizer and NPK inorganic fertilizer. Wanaraya, Barito Kuala regency, South Kalimantan province (A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose); DAP=Days after planting.

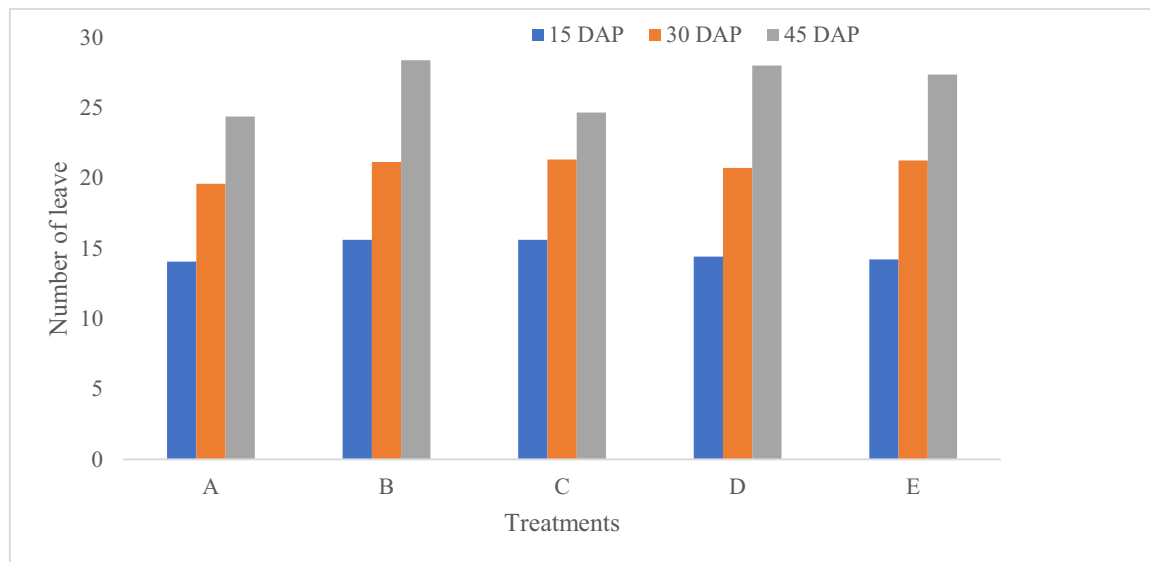


Figure 3. Leave number of shallots caused by biofertilizer and NPK inorganic fertilizer. Wanaraya, Barito Kuala regency, South Kalimantan province (A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose); DAP=Days after planting).

A significant yield increase was shown in the treatment of biofertilizer combined with inorganic NPK fertilizer, both 50% of recommended dose and 75% of recommended dose compared to treatment of biofertilizers and control; but there were not significant different compared to NPK fertilizer treatment. Reducing the dose of inorganic NPK by 25% to 50% of the recommended dose does not reduce the effectiveness of biofertilizer in increasing the yield of shallot bulbs. Results of wet weight obtained in the treatment of biofertilizer + NPK (50% of recommended dose) and biofertilizer + NPK (75% of recommended dose) were 12.40 t ha^{-1} and 12.86 t ha^{-1} respectively, while NPK fertilizer treatment yielded 12.11 t ha^{-1} . This yield increase is closely related to plant growth and is influenced by improvements in soil chemical properties due to the application of biofertilizers and inorganic NPK fertilizers. This means that the biofertilizers produced are able to decrease the use of inorganic NPK fertilizers. This is supported by the results of soil chemical analysis (pH, C, N, P, Ca, Mg, and K) which are generally higher in the treatment of biofertilizer + inorganic NPK fertilizer compared to the treatment of biofertilizers, NPK fertilizers and control. While the result of plant analysis also showed that the application of biofertilizer + inorganic NPK fertilizer was able to increase the nutrient content of shallot plants and had a significant effect compared to the treatment of biological fertilizers, inorganic NPK fertilizers, and controls. These results indicate that N-fixing bacteria and P-solubilizing bacteria can do their activities optimally, so that the N and P nutrient content increases. Likewise, *Trichoderma* fungus can accelerate the process of organic matter decomposition which cause the pH increase and result in higher available nutrient elements.

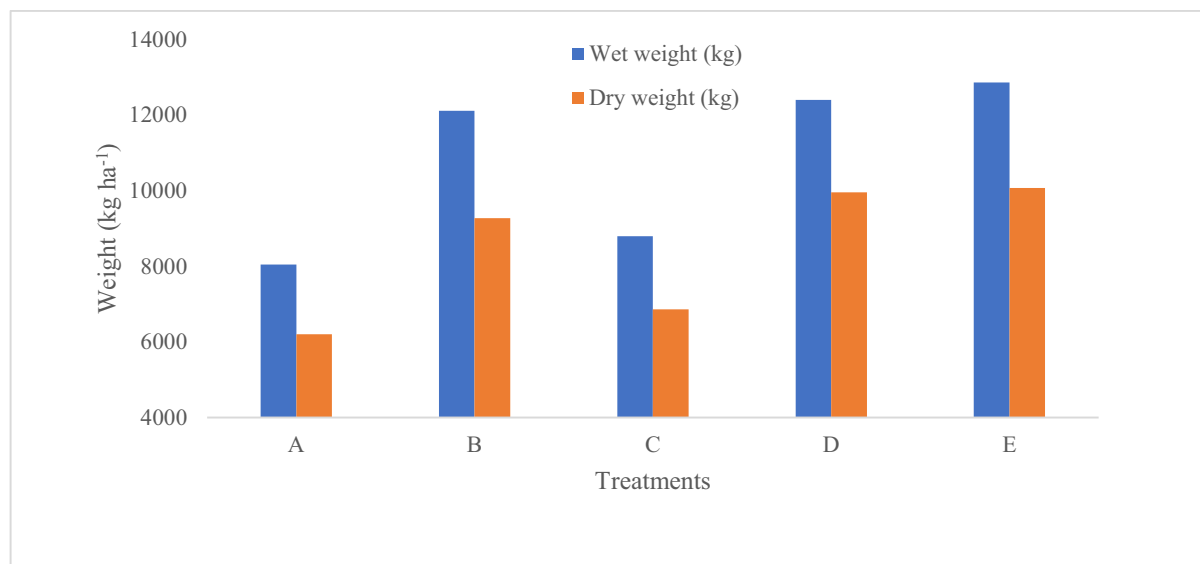


Figure 4. Weight of shallot bulbs caused by biofertilizer and NPK inorganic fertilizer. Wanaraya, Barito Kuala regency, South Kalimantan province (A=No fertilizer, B=NPK (recommendation dose), C=Biofertilizer, D=Biofertilizer + NPK (50% of recommended dose), E=Biofertilizer + NPK (75% of recommended dose); DAP=Days after planting.

4. Conclusions

Biofertilizer formula consisting of *Trichoderma sp*, *Azospirillum sp*, *Azotobacter sp*, *Bacillus sp* are effective in increasing soil chemical properties especially pH, C, N, P, K, Ca, Mg and the growth and yield of shallots in tidal swamps. Application of biofertilizer formula as much as 6 L ha⁻¹ with inorganic NPK fertilizer 50 to 75% of the recommended dose gives a yield of 12.40 to 12.86 t ha⁻¹ and is significantly higher than that of NPK fertilizer with recommended dose. For further development, this biofertilizer need to be tested at several locations with broader plot size.

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