THE EFFECT OF COMPOST COMBINED WITH PHOSPHATE SOLUBILIZING BACTERIA AND NITROGEN-FIXING BACTERIA FOR INCREASING THE GROWTH AND YIELD OF CHILI PLANTS

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ABSTRACT

The effect of compost combined with phosphate solubilizing bacteria and nitrogen-fixing bacteria on chili plants has been investigated in an experiment using polybag. This research aims to examine the roles of phosphate solubilizing bacteria, nitrogen-fixing bacteria, and compost in increasing the growth and yield of chili plants. This research used a randomized block design with a two-factor factorial design consisting of R0: without Microbes, R1: Nitrogen-Fixing Bacteria (NFB), R2: Phosphate solubilizing bacteria + nitrogen-fixing bacteria (PSB + NFB). The second factor was a dose of organic fertilizer (compost), consisting of 4 dose levels, i.e.: P0: Control (Urea, SP-36, KCl), P1: 15 t ha⁻¹ compost, P2: 20 t ha⁻¹ compost, P3: 25 t ha⁻¹ compost. The research results showed that the use of compost at a dose of 20 t ha⁻¹ added by PSB and NFB significantly increased the growth (number of branches, number of leaves, leaf area, chlorophyll content, plant dry weight) and yield (number of fruits, weight of fruits) of chili plants. The average number of chili fruits increased from 37 fruits per plant to 78 fruits per plant.

KEY WORDS

Compost, phosphate solubilizing bacteria, nitrogen-fixing bacteria, chili.

Increase in population and the growing number of industries requiring chili raw materials causes the need for chili to increase every year. Agricultural statistics data in 2018 noted that harvested area and national chili productivity increased, but chili productivity was still far below its production potential. National harvested area of chili was 120,847 ha with the productivity of 8.65 t ha⁻¹ in 2015 and was 123,404 ha with the productivity of 8.47 t ha⁻¹ in 2016. Chili harvested area in Central Sulawesi was 844 ha with the productivity of 6.44 t ha⁻¹ in 2015 and was 872 ha with the productivity of 5.45 t ha⁻¹ in 2016.

Low organic matter content, water availability, and nutrient availability, as well as high air temperature (average air temperature is 26-35°C and in extreme conditions the air temperature can reach ± 37 °C) and low air humidity (± 65%), are factors able to influence low chili productivity in Palu Valley. As with other plants, chili plants will not provide maximum results if the environmental conditions give no supports, for example, low water and nutrient availability and poor soil structure. Therefore, efforts need to be made to improve cultivation technology that can support the growth and yield of chili plants in Palu Valley.

Benefits of organic fertilizer (compost) addition into the soil are to increase nutrients, restore soil properties through increased soil water content, soil organic carbon, cation exchange capacity (CEC) and pH, improve soil structure, aeration, and water-holding capacity, influence or regulate soil temperature, and enhance plant growth and production (Agegnehu et al. 2016; Karimuna et al. 2016; Zaman et al. 2016; Anhar et al. 2018).

METHODS OF RESEARCH

This research was conducted in Bulupountu Jaya Village, Biromaru District, Sigi Regency, Central Sulawesi Province, from November 2014 to April 2015.

This research was conducted using a Randomized Block Design (RBD) with a two-factor factorial design. The first factor was selective soil microbes (2 best treatments were chosen) obtained from phase I research, consisting of 3 levels, i.e.: R_0 : without (PSB + NFB), R_1 : Nitrogen-fixing bacteria (NFB), R_2 : Phosphate solubilizing bacteria + Nitrogen-fixing bacteria (PSB + NFB). The second factor was organic fertilizer (compost) consisting of 4 dose levels, i.e.: P_0 : Control (Urea, SP-36, KCl), P_1 : compost (15 t ha^{-1}), P_2 : compost (20 t ha^{-1}), P_3 : compost (25 t ha^{-1}). Of these two factors, 12 treatments with 3 replications were obtained, so there were 36 experimental units. Each treatment unit was represented by 8 plants in a polybag. Thus, there were 288 plants in this research.

The seeds to be sown were soaked in warm water ($\pm 50^\circ\text{C}$) for 1 hour (Sumarni et al. 2005). The immersion aimed to eliminate pests or diseases attached to the seeds and to speed up germination. The chili seeds were sown in $5 \times 8 \text{ cm}$ polybags containing mixed media (soil + sand + compost = 1: 1: 1). The seedbeds were placed in the shade and watered every day with enough water. The seeds were considered ready to be planted at 4 weeks after seedling or had 3-4 leaves. Before the seeds were transplanted, sorting was done to select healthy and uniform seeds.

After the seeds germinated and the seedlings were 4 weeks old in the seedbeds, the seedlings were transplanted to $35 \text{ cm} \times 40 \text{ cm}$ polybags containing mixed media of soil and compost (without compost, 15 t ha^{-1} , 20 t ha^{-1} , and 25 t ha^{-1}), which has been arranged according to the treatments with a polybag distance of $60 \text{ cm} \times 50 \text{ cm}$.

Inorganic fertilizer (urea, SP-36, and KCl) application was performed when the plants were 7 days old after transplanting for the control treatment (R_0P_0). Organic fertilizer (compost) application was carried out when filling polybags and adjusted to the dose of compost treatment to be tested, i.e. 15 t ha^{-1} , 20 t ha^{-1} , and 25 t ha^{-1} . Application of soil microbes was conducted on chili plants by applying 15 ml of soil microbial isolates namely phosphate solubilizing bacteria (*Bacillus subtilis* and *Pseudomonas fluorescens*) and nitrogen-fixing bacteria (*Azotobacter sp.*) or according to the treatments on 25 g of compost as a carrier medium. Each polybag was given 25 g of compost applied with soil microbes (bio-compost) and given at planting.

The first chili harvest was done at the age of 80 days after planting, gradually with 4 days harvest intervals. Chili fruits were harvested after the fruits had a $\geq 80 - 100\%$ red color.

To determine the effect of the treatment given, observations were conducted on plant growth and yield. Components observed were growth component, yield component, and soil microbial analysis.

1. Growth component consisting of: number of branches, number of leaves, leaf area, plant dry weight, and leaf chlorophyll content;
2. Yield component consisting of: flowering speed, number of fruits, and weight of fruits per plant;
3. Soil microbial analysis.

Observation data were analyzed by the F test. In terms of significant differences between treatments, the results were further tested using Tukey's Honestly Significant Difference (HSD) test at 5%.

RESULTS OF STUDY

The results of HSD test at an α of 0.05 on the number of branches (Table 1) show that the R_1P_2 (NFB + 20 t ha^{-1} compost) treatment had the highest average number of branches of 17 branches. It was significantly different from other treatments but not significantly different from the R_1P_3 , R_2P_2 , and R_2P_3 treatments.

Table 1 – Responses of Chili Plant Growth to phosphate solubilizing bacteria, nitrogen-fixing bacteria, and compost application

Treatment	Number of branches	Number of leaves	Leaf area (cm ² plant ⁻¹)	Leaf chlorophyll content (SPAD unit)	Dry weight (g plant ⁻¹)
R ₀ P ₀	6 ^a	42 ^a	380.80 ^a	55.90 ^a	7.03 ^a
R ₀ P ₁	8 ^{abc}	51 ^b	565.00 ^b	61.80 ^{bc}	8.13 ^a
R ₀ P ₂	11 ^{cd}	56 ^{cd}	753.01 ^{cd}	67.20 ^{def}	7.67 ^a
R ₀ P ₃	10 ^{bc}	56 ^{cd}	776.74 ^{cd}	66.06 ^{cde}	8.55 ^{ab}
R ₁ P ₀	7 ^{ab}	49 ^b	424.88 ^a	60.90 ^{ab}	7.79 ^a
R ₁ P ₁	8 ^{abc}	56 ^{cd}	688.15 ^c	71.43 ^{gh}	7.37 ^a
R ₁ P ₂	17 ^f	66 ^f	930.22 ^{ef}	74.13 ^h	10.97 ^{bc}
R ₁ P ₃	14 ^{ef}	62 ^{ef}	911.25 ^{ef}	69.33 ^{defgh}	11.91 ^{cd}
R ₂ P ₀	9 ^{bc}	53 ^{bc}	554.31 ^b	64.33 ^{bcd}	9.05 ^{ab}
R ₂ P ₁	13 ^{de}	60 ^{de}	818.82 ^{de}	68.83 ^{defg}	10.77 ^{bc}
R ₂ P ₂	16 ^{ef}	66 ^f	994.87 ^f	72.33 ^{gh}	13.97 ^d
R ₂ P ₃	16 ^{ef}	62 ^{ef}	839.38 ^{de}	70.13 ^{efgh}	13.46 ^d

Numbers followed by different letters in the same column indicate differences in the HSD test level at an α of 0.05 between treatment combinations of R₀ = Without soil microbes, R₁ = application of NFB, R₂ = application of PSB + NFB, P₀ = Without compost, P₁ = Compost dose of 15 t ha⁻¹, P₂ = Compost dose of 20 t ha⁻¹, P₃ = Compost dose of 25 t ha⁻¹.

Table 1 also shows that the R₁P₂ (NFB + 20 t ha⁻¹ compost) and R₂P₂ (PSB + NFB + 20 t ha⁻¹ compost) treatments had the same highest average number of leaves of 66 leaves. It was significantly different from other treatments but not significantly different from the R₁P₃ and R₂P₃ treatments. Likewise, on the observation of leaf area, the R₂P₂ treatment showed the highest average leaf area of 994.87 cm² plant⁻¹. It was significantly different from other treatments but not significantly different from the R₁P₂ and R₁P₃ treatments.

The results of HSD test at an α of 0.05 on plant dry weight (Table 1) show that the R₂P₂ treatment had the highest average plant dry weight of 5.36 g. It was significantly different from other treatments but not significantly different from the R₀P₂ treatment. This illustrates that the soil microbial activity (PSB + NFB) applied will increase by 20 t ha⁻¹ compost application. Thus, the treatment can fulfill nutrient needs in chili plants. Additionally, the highest average chlorophyll content was obtained from the R₁P₂ (74.13 SPAD units) treatment and the lowest average chlorophyll content was obtained from the R₀P₀ (55.90 SPAD units) treatment.

Figure 1 shows that there was a tendency for a faster flowering speed of chili plants reaching 50%, i.e. 26 days after transplanting in the R₁P₂ (NFB + 20 t ha⁻¹ compost), R₂P₂ (PSB + NFB + 20 t ha⁻¹ compost), and R₁P₃ (NFB + 20 t ha⁻¹ compost) treatments.

Figure 1 – Average Flowering Speed of Chili Plants (50%)

The results of HSD test at α of 0.05 on the number of fruits of chili plants (Table 2) show that the R_2P_2 (PSB + NFB + 20 t ha⁻¹ compost) treatment had the highest average number of fruits of 78 fruits (1st - 10th harvest). It was significantly different from other treatments.

Table 2 – Responses of Chili Plant Yield to phosphate solubilizing bacteria, nitrogen-fixing bacteria, and compost application

Treatment	Number of fruits (fruit plant ⁻¹)	Weight of fruits (g plant ⁻¹)
R_0P_0	52 ^{cd}	106.19 ^{ab}
R_0P_1	54 ^{cd}	130.62 ^c
R_0P_2	44 ^{ab}	107.46 ^{ab}
R_0P_3	53 ^{cd}	129.78 ^{bc}
R_1P_0	37 ^a	100.75 ^a
R_1P_1	49 ^{bc}	128.85 ^{bc}
R_1P_2	63 ^{ef}	170.02 ^d
R_1P_3	67 ^f	194.16 ^e
R_2P_0	57 ^{de}	116.77 ^{abc}
R_2P_1	53 ^{cd}	128.96 ^{bc}
R_2P_2	78 ^g	206.59 ^e
R_2P_3	65 ^f	163.22 ^d

Numbers followed by different letters in the same column indicate differences in the HSD test level at an α of 0.05 between treatment combinations of R_0 = Without soil microbes, R_1 = application of NFB, R_2 = application of PSB + NFB, P_0 = Without compost, P_1 = Compost dose of 15 t ha⁻¹, P_2 = Compost dose of 20 t ha⁻¹, P_3 = Compost dose of 25 t ha⁻¹.

The highest average weight of chili fruits per plant (Table 2) was found in the R_2P_2 (PSB+NFB + 20 t ha⁻¹ compost) treatment of 206.59 g. It was significantly different from other treatments but not significantly different from the R_1P_3 treatment. The lowest weight of chili fruits was obtained in the R_1P_0 (NFB + without compost) treatment combination.

Figure 2 shows that the highest average number of harvested chili fruits was found in the 6th harvest of the R_2P_2 treatment of 16 fruits, followed by the 7th harvest of the R_1P_3 treatment of 13 fruits, and the 7th harvest of the R_2P_3 treatment of 12 fruits, respectively.

Figure 2 – Average Number of Fruits of Chili Plants in the 1st - 10th Harvest

Soil microbial analysis results on the soil used in this research indicated that selective soil microbial treatment and compost doses caused an increase in the total soil microbial population before and after treatment.

Table 3 – Soil Microbial Populations Before and After Treatment

Treatment	N-fixing bacteria population (CFU ml ⁻¹)		Phosphate solubilizing bacteria population (CFU ml ⁻¹)	
	Before treatment	After treatment	Before treatment	After treatment
R ₀ P ₀	1.12x10 ⁷	1.34 x 10 ⁷	6.07x10 ⁴	11.30x10 ⁴
R ₀ P ₁	1.12x10 ⁷	5.36 x 10 ⁷	6.07x10 ⁴	15.00x10 ⁴
R ₀ P ₂	1.12x10 ⁷	5.13 x 10 ⁷	6.07x10 ⁴	14.30x10 ⁴
R ₀ P ₃	1.12x10 ⁷	2.23 x 10 ⁷	6.07x10 ⁴	10.20x10 ⁴
R ₁ P ₀	1.12x10 ⁷	3.68 x 10 ⁷	6.07x10 ⁴	15.40x10 ⁴
R ₁ P ₁	1.12x10 ⁷	4.69 x 10 ⁷	6.07x10 ⁴	11.90x10 ⁴
R ₁ P ₂	1.12x10 ⁷	11.90 x 10 ⁷	6.07x10 ⁴	14.40x10 ⁴
R ₁ P ₃	1.12x10 ⁷	6.81 x 10 ⁷	6.07x10 ⁴	10.20x10 ⁴
R ₂ P ₀	1.12x10 ⁷	4.80 x 10 ⁷	6.07x10 ⁴	14.20x10 ⁴
R ₂ P ₁	1.12x10 ⁷	8.26 x 10 ⁷	6.07x10 ⁴	23.20x10 ⁴
R ₂ P ₂	1.12x10 ⁷	11.40 x 10 ⁷	6.07x10 ⁴	15.60x10 ⁴
R ₂ P ₃	1.12x10 ⁷	4.35 x 10 ⁷	6.07x10 ⁴	14.40x10 ⁴

R₀ = no (PSB + NFB), R₁ = application of NFB, R₂ = application of PSB + NFB, P₀ = without compost, P₁ = 15 t ha⁻¹ compost, P₂ = 20 t ha⁻¹ compost, P₃ = 25 t ha⁻¹ compost.

Table 3 shows that the highest total microbial population was found in the R₁P₂ (NFB + 20 t ha⁻¹ compost) treatment, followed by the R₂P₂ (PSB + NFB + 20 t ha⁻¹ compost) treatment, the R₂P₁ (PSB + NFB + 15 t ha⁻¹ compost) treatment, and the R₁P₃ (NFB + 25 t ha⁻¹ compost) treatment respectively.

DISCUSSION OF RESULTS

The growth and yield of chili plants are strongly influenced by the role of organic matter (compost) in increasing applied selective soil microbial activity. Application of 20 t ha⁻¹ compost combined with phosphate solubilizing bacteria and nitrogen-fixing bacteria application can increase the growth and yield of chili plants. Besides being able to increase nutrients in the soil, organic matter or compost can also increase microorganism activity, enhance humus levels, and improve soil structure (Frimpong et al. 2017; Agbede et al. 2017).

At the beginning of growth, the effect of compost and selective soil microbial application was not evident in all observation variables. It was probably due to shoot dominance at the beginning of growth, causing the branching of chili plants at the beginning of growth to not indirectly form intensively. According to Taiz and Zeiger (2002), apical dominance can inhibit lateral bud growth. Thus, the increase in number of branches at the beginning of growth will also be inhibited.

Increase in branch formation has a significant effect on the increase in number of leaves, leaf area, and plant dry weight. Increase in number of leaves and leaf area will influence photosynthesis process occurring in chloroplasts inside the leaves. Plant dry weight in the form of total biomass is a manifestation of metabolic processes occurring in the plant's body, in which dry weight can indicate plant productivity because 90% of photosynthesis results are in plant dry weight (Gardner et al. 1991).

The treatment of nitrogen-fixing bacteria and phosphate solubilizing bacteria application combined with 20 t ha⁻¹ compost application in this research was not only able to increase plant growth, but also increase chili plant yield. Table 2 shows that the highest number of fruits and weight of fruits of chili plants were obtained in the treatment of nitrogen-fixing bacteria and phosphate solubilizing bacteria application combined with 20 t ha⁻¹ compost application. It is supported by Wiguna's statement (2011) that one way to increase the production of red chili plants is by using environmentally friendly fertilization such as bio-fertilizers and organic fertilizers (Elekhtyar et al. 2017; Frimpong et al. 2017). Organic fertilizers and bio-fertilizers with various processes support each other in fertilizing the soil and at the same time conserving and nourishing soil ecosystems as well as avoiding the possibility of environmental pollution. In addition to increasing nutrient content in the soil, organic fertilizers also contain a number of growth-regulating substances and vitamins needed to stimulate plant growth and microorganisms (Khan et al. 2017; Coa et al. 2017).

These research results also showed that 20 t ha⁻¹ compost application can increase soil microbial population (Table 3). It is in line with Pranoto et al.' (2015) research stating that organic matter has a positive effect on the increase in *Azotobacter sp* population. Thus, it can be interpreted that 20 t ha⁻¹ compost application will influence the increase in microorganism activity (phosphate solubilizing bacteria and nitrogen-fixing bacteria) in the soil so that nutrient availability in the soil, especially the N and P elements, will also increase (Xiaohou et al. 2008; Hernández et al. 2014; Barajas-Aceves 2016).

CONCLUSION

The use of compost at a dose of 20 t ha⁻¹ combined with the PSB and NFB application significantly increased the growth and yield of chili plants. Soil microbial analysis results showed that nitrogen-fixing bacteria increased from 1.12 x 10⁷ CFU ml⁻¹ to 8.26 x 10⁷ CFU ml⁻¹ and phosphate solubilizing bacteria increased from 6.07 x 10⁴ CFU ml⁻¹ to 23.20 x 10⁴ CFU ml⁻¹. Additionally, the average number of chili fruits increased from 37 fruits per plant to 78 fruits per plant.

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