Organic matter and mixed biofertilizer for plant growth and yield of shallot grown in fertile soil

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Abstract. Nowadays, shallot is important horticultural crops in Maluku include in Tual City, Maluku Province. For ensuring the macronutrients level in soil and yield during shallot cultivation, fertilization composed of chemical, organic and bio fertilizer is needed. The objective of field experiment was to evaluate the effect of mixed biofertilizer integrated with organic matter on total nitrogen and available phosphorous in soil as well as shallot yield grown in Vertisols of Tual. The experiment was setup in randomized block design with four treatments of compost and chicken manure amendment with and without biofertilizer containing N-fixing bacteria and P-solubilizing. At the vegetative stage, consortia biofertilizer combined with either compost or chicken manure increased plant height and soil reaction but decreased the available phosphate (P) and didn't change nitrogen (N) total in soil. Chicken manure amendment combined with biofertilizer inoculation increased dry weight of shoots and bulbs even though didn't significantly differ with other treatments. Nonetheless, that treatment resulted in high yield of shallot bulbs up to 14 t/ha.

1. Introduction

Maluku, an archipelago province, has a significant step to self-sufficiency of shallot (Allium cepa var. aggregatum) in order to decrease shallot trade from another province and increase the farmer’s welfare. Traditionally, shallots have been cultivated in Buru, Tanimbar Island (formerly Maluku Tenggara Barat) and Maluku Barat Daya Regency. Nowadays, shallot is produced in another area include Tual City located in Maluku Tenggara Regency. The contraint of crops production in the island might be low availability of agricultural inputs due to limited transportation when the weather become worst.

In order to reduce chemical fertilizer utilization, another nutrient source such as organic and biofertilizer is considered to fulfill the nutrient sufficiently. In Tual city, some farmers have already produce, commercialized and utilized agricultural-waste compost but they rarely applied chicken manure in shallot cultivation. Organic fertilizer is considering to contribute in nutrient availability and increase the nutrient efficiency utilization of chemical fertilizer in shallots cultivation [1] and hence decrease the dose of chemical fertilizer up to 50% [2,3]. The effectivity of the organic matter combined with reduced dose of NPK fertilizer to increase soil beneficial microbes and yield of shallot was evidence [4].
Another nutrient source to support shallot production is biofertilizer; the newest eco-friendly technology for supporting the sustainable agriculture. The biofertilizer usually contain the plant growth promoting microbes of nitrogen-fixing bacteria and phosphate-solubilizing mirobes as well. Both microbes enable to enhance the availability of nitrogen (N) and phosphate (P) enzymatically [5,6]. Moreover, they produce significant amount of phytohormones to function on plant growth coordination [7,8,9]. Although the biofertilizer is purchased, actually farmers can proliferate the microbes in biofertilizer by using simple liquid organic matter that locally available such as liquid waste of sago starch production [10].

Intensive agriculture in tropics always face the rapid decrease of available macronutrient in soil after being taken up by the crops. Organic matter amendment is able to support biofertilizer microbes during plant cultivation as well as after the harvest since the microbes utilized organic carbon for their heterotrophic metabolisms [11]. The microbial inoculation combined with organic matter application resulted in the presence of macronutrient and soil beneficial mirobes for next crops [12,4].

In general, tropical soil contained low macronutrients mainly N and P due to very intense weathering process [13]. In tropics, high temperature might constantly induce the enzymatic degradation of soil organic matter by soil inhabitants although organic carbon degradation was less sensitive to high moisture [14]. Low soil organic carbon (C) in turn depressed the microbes function for providing plant nutrients. In rainy season, the loss of ionic nutrient is intensive due to leaching; in dry season with high temperature the volatilization of N from N fertilizer is evidence [15,16]. In order to prevent the significant loss of nutrients, the application of balance composition of chemical, organic as well biofertilizer is needed. The objective of this field experiment was to evaluate the positive effect of mixed biofertilizer combined with organic matter and integrated with NPK fertilizer on N and P content as well as yield of shallot grown in Entisols of Tual.

2. Material and Methods
The field experiment was carried out in the agricultural area of Ohoitel Village, Dullah Utara District, Tual City of Maluku Province (Fig 1) on April to June 2018. The soil was Entisols (Alluvial) has been cultivated for vegetable production since decade and contained high \( \text{P}_2\text{O}_5 \) and \( \text{K}_2\text{O} \) (Table 1) that might be due to intensive chemical fertilization. Agricultural-waste compost was produced by local farmer while the manure was provided by local chicken husbandry with the properties depicted in Table 1.

![Figure 1. Tual City located in Kai Kecil Island in eastern part of Maluku Province, Indonesia](image)

Mixed biofertilizer was provided by Soil Biology Laboratory, Faculty of Agriculture, Universitas Padjadjaran. Biofertilizer contained N-fixing bacteria \textit{Azotobacter chroococcum}, \textit{A. vinelandii}, \textit{Azospirillum} sp., endophytic \textit{Acinetobacter} sp. and P-solubilizing microbes \textit{Balkholderia} sp. and \textit{Penicillium} sp. The cell count of bacteria was \( 10^7 \) CFU/mL while fungal population was \( 10^5 \) CFU/mL.
2.1. Experimental Establishment

The experiment was setup in randomized block design to test five treatments each with five replications. The treatments was compost and manure application with and without biofertilizer inoculation. Control treatment was compost application. The rates of organic matter and biofertilizer were 20 t/ha and 3L/ha respectively. The single bulb of shallot cv Bauji were grown in a bed of 100 x 200 cm covered with polyethylene mulch with planting hole of 15 x 20 cm.

Side dress application of biofertilizer was carried out once a week from 10 days to 35 days to maintain their population and activity. To prepare 1% biofertilizer dilution, biofertilizer was mixed with ground water just before inoculation. A total of 20 mL of diluted biofertilizer was applied by soil dressing around the shallot stems. The NPK compound fertilizer at 250 kg/ha was applied at 14 and 30 days after planting (DAP), 0.5 g each in the hole near the stem. During the experiment, purple blotch disease caused by Alternaria alii was found at day 27 so that pesticide Dithane M-45 (Mankozeep 80 %) was sprayed at the rate of 4 g/L every two weeks. This pesticide enabled repress the Alternaria and also to control fusarium wilt.

Table 1. Properties of soil, agricultural-waste compost and chicken manure before trial

| Nutrients traits | Soil pH | Agricultural-waste Compost Organic C (%) | Agricultural-waste Compost N (%) | Agricultural-waste Compost P2O5 (mg/kg) | Agricultural-waste Compost K2O (mg/kg) | Agricultural-waste Compost P (%) | Agricultural-waste Compost K (%) | Chicken Manure
|------------------|---------|-------------------------------------------|---------------------------------|-----------------------------------------|--------------------------------------|---------------------------------|---------------------------------|---------------------|
| pH               | 8.2     | 7.3                                       | 42.1                            | 2.38                                   | 30.21                                | 0.12                            | 0.012                           | 6.7                  |
| Organic C (%)    | 1.54    |                                           |                                  |                                         |                                      |                                  |                                  | 15.2                |
| N (%)            | 0.26    |                                           |                                  |                                         |                                      |                                  |                                  | 1.1                  |
| P2O5 (mg/kg)     | 30.21   |                                           |                                  |                                         |                                      |                                  |                                  | 2.1                 |
| K2O (mg/kg)      | 25.32   |                                           |                                  |                                         |                                      |                                  |                                  | 2.7                 |
| P (%)            | -       |                                           | 2.1                              |                                         |                                      |                                  |                                  | 0.9                 |

2.2. Experimental parameter and statistical analysis

Soil and plant samples were collected by composite method from four block consisted of 6 plants. Plant height of sample plants was measured at day 21 and day 49 while the shoot dry weight was only analyzed at day 49. At the harvest time, 56 DAP, the number and fresh weight of bulbs of single plant were measured. All bulbs were store at the room at 24-29°C for 14 days prior to measure their air-dried weight. The average yield in a plot was determined based of fresh and air-dried weight.

Soil samples were taken at harvest time from the samplings blocks. A total of 50 g soil was taken up from each root zone of the six plants. All soil then mixed evenly, put in sealed transparent polyethylene bags and air-dried in the laboratory. The soil reaction, total N and potential P analysis were done by using AOAC proximate analysis methods [17].

All plant and soil data were then subjected to analysis of variance (F test) with p ≤ 0.05. If the sum square of parameter was significant then Least significant different test (p ≤ 0.05) was done. Statistical analysis has performed by used of Minitab 18.

3. Results and discussion

The performance of shallot in the experimental plots didn’t show either nutrient deficiency nor diseases incidence. The pesticide application was carried out once at 27 DAP when the plants experienced very light attack of purple blotch disease in some plots.

The field experiment results indicated that application mixed non-chemical fertilizer significantly affected plant height but have no effect on shoot dry weight and yield traits as well. Compost with biofertilizer resulted in the highest shoot dry weight over the control and another treatment (Table 2). In general, the shoot dry weight of individual plant was 54 g - 73.33 g. Chicken manure amendment
combined with biofertilizer inoculation increased dry weight of shoots and tuber even though didn't significantly differ with other treatments.

**Table 2.** Effect of organic matter and biofertilizer on Shoot height and dry weight of shallot

| Treatments               | Shoot height (cm) Day 21 | Shoot height (cm) Day 49 | Shoot dry weight (g) at day 49 |
|--------------------------|--------------------------|--------------------------|-------------------------------|
| Compost (control)        | 26.26 ± 0.97 b           | 35.37 ± 0.59 ab          | 59.80 ± 7.56 a                |
| Compost and Biofertilizer| 28.83 ± 1.32 a           | 38.46 ± 1.30 a           | 61.67 ± 7.31 a                |
| Manure                   | 24.11 ± 0.42 c           | 32.49 ± 3.71 b           | 54.00 ± 4.81 a                |
| Manure and Biofertilizer | 26.93 ± 0.27 b           | 36.37 ± 0.42 a           | 73.22 ± 10.78 a               |

*Number followed by the same letter in a column were not significantly different base on Least significant different at p ≤ 0.05.*

Based on analysis of variance, fertilizer treatments affect potential P$_2$O$_5$ and soil reaction at harvest time but didn’t influence total N in soil (Table 3). At the harvest time organic matter application combined with biofertilizer inoculation surprisingly decreased the available phosphate (P) compared to the control treatment and chicken manure. Slight increase on soil acidity was recorded in soil treated with either compost and chicken manure with biofertilizer.

**Table 3.** Change in total N, potential P$_2$O$_5$ and soil reaction at harvest time after organic matter and biofertilizer application on shallot

| Fertilizer Treatments | Total N   | Potential P$_2$O$_5$ (mg/kg) | Soil reaction |
|-----------------------|-----------|-------------------------------|---------------|
| Compost (control)     | 0.456 ± 0.006 a | 39.3 ± 1.3 a                  | 6.26 ± 0.11 c |
| Compost and Biofertilizer | 0.453 ± 0.015 a | 26.0 ± 7.3 b                  | 6.53 ± 0.05 b |
| Manure                | 0.467 ± 0.040 a | 39.2 ± 2.6 a                  | 6.46 ± 0.05 b |
| Manure and Biofertilizer | 0.423 ± 0.015 a | 27.8 ± 0.8 b                  | 6.83 ± 0.05 a |

*Number followed by the same letter in a column were not significantly different base on Least significant difference test at p ≤ 0.05.*

Fertilizer treatments have not affected plant yield traits. Regardless of statistical analysis, control treatment resulted in highest number of bulb per plant, but the highest bulbs weight of was showed by shallot treated with compost and manure with biofertilizer (Fig 2). Biofertilizer inoculation followed manure amendment has a potency to enhance air-dried bulbs up to 24.5% compared with the control and compost+biofertilizer (Fig 1).

**Figure 2.** Yield of shallot grown with organic matter amendment with and without biofertilizer. C: compost, CB: compost with biofertilizer; M: manure; MB: manure with biofertilizer
Based on air-dried bulb per plant and the plot dimension, shallot yield in a plot and productivity in a hectare were calculated (Table 4). Manure application with biofertilizer resulted in the highest air-dried shallot weight per plot. The yield per ha was determined for 7,500 m$^2$ instead of 10,000 since in general some area in the field has been used for access road, space between beds and other utilities. This extrapolated data has not analyzed statistically. The value in Table 4 showed that the plot received chicken manure integrated with biofertilizer has highest yield per ha. Despite of insignificant effect of that treatments on air-dried weight of shallot, the increase of productivity up 24.5% when manure and biofertilizer were used can significantly increase farmer’s revenue.

**Table 4. Productivity of shallot treated with different organic matter with and without biofertilizer**

| Fertilizer treatments       | Yield of air-dried shallot (kg) |
|-----------------------------|---------------------------------|
|                            | per plot (kg) | per ha (ton) |
| Compost (control)          | 3.20 b         | 12.02        |
| Compost and Biofertilizer  | 3.43 b         | 12.89        |
| Manure                      | 2.92 c         | 10.95        |
| Manure and Biofertilizer   | 3.99 a         | 14.97        |

Shoot growth increment following biofertilizer inoculation was caused by the increase of available of N and P in soil. Mixed biofertilizer contained N-fixers and P-solubilizer microbes. Both microbial group also reported elsewhere to produce phytohormone which is important secondary metabolite to regulate plant growth. This results agree with the positive effect of microbial consortia to stimulate root development and shoot growth of maize by 25% compared to the control [18]. However, nutrient content in chicken manure was lower than compost resulted in lower available nutrient for roots uptake and caused delayed growth.

The total N, potential P and pH in soil were measured at the harvest time when most part of available nutrient has been uptake by plant. Biofertilizer treatment caused the decrease in potential P in soil. Phosphate solubilizing bacteria and fungi in biofertilizer provide available P for plant growth and hence bulbs production. Increase in soil microbes due to inoculation might take place but the count of soil microbes at the end of experiment has not been performed. The change of microbial composition might affect the nutrient turnover in which a part of P could be immobilized in the microbial cell.

The treatments only slightly influenced soil reaction. Irrespective of treatments, the soil acidity was neutral which is ideal for plant growth include shallot in Indonesian low land [19]. Neutral soil resulted in high availability of P and optimal proliferation and function of all bacteria in mixed biofertilizer that prefer neutral pH instead of alkaline or acid. The positive effect of biofertilizer was clear even though the soil was rich in N and P before trial. The function of microbes in the mixed biofertilizer didn’t only increase the availability of N and P but also produce secondary metabolites phytohormones [20]. It is reported elsewhere that Azotobacter and Pseudomonas synthesize and then excrete the exopolysacharides that is important for soil aggregation and hence nutrient uptake.

At the harvest time, N and P content in soil were average and high respectively since the NPK compound fertilizer was added beside organic matter and biofertilizer. This verified that in fertile soil, decreased doses of NPK is needed. The yield of bulb in this experiment was slightly lower than potential yield of Shallot cv Bauji [21]. However, the yield in plot with chicken manure amendment and biofertilizer inoculation was more than 14 t/ha dried bulbs. Genetically, shallot cv Bauji can produce 13-14 t/ha dried bulbs in the optimal environment. The residue of N and P after the shallots being harvested will be benefit for next plant during entire growth [22]. The nutrient residual effect in our experiment verified that the reduced chemical fertilizer is recommended.
4. Conclusion
The increment of plant height and soil reaction were recorded after consortia biofertilizer inoculation combined with either agricultural-waste compost or chicken manure but both treatments decrease the available phosphate in soil and didn't affect total nitrogen in soil. Chicken manure amendment integrated with biofertilizer inoculation increased dry weight of shoots and yield of shallot bulbs even though didn't significantly differ with the control and other treatments. Application of chicken manure integrated with mixed biofertilizer mostly increase yield of shallot either fresh weight of bulb or air-dried weight. The yield of air-dried bulbs weight following that treatment enhanced up to 24.5 % compared to the control.

5. Acknowledgement
This field experiment was funded by former Maluku Corner of Universitas Padjadjaran and Agricultural Office of Tual City.

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