Effects of mycorrhiza biofertilizer and additive intercropping with peanut on growth, bulb formation, N and P contents of several varieties of shallot

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Abstract. Application of mycorrhiza biofertilizer to rice intercropped with soybean could increase growth and yield of rice. This study aimed to examine the effects of mycorrhiza biofertilizer application and intercropping with peanut relay-planted between double-rows of shallot on growth, N and P content, and harvest bulb number of several shallot varieties. The experiment was designed according to Split Split-Plot Design, testing three treatment factors, i.e. intercropping with peanut as the main plots (I₀= without, I₁= with intercropping), application of mycorrhiza biofertilizer as the sub-plots (M₀= without, M₁= with mycorrhiza application), and shallot varieties as the sub-sub-plots (V₁= Bima Brebes, V₂= Ketamonca, V₃= Super Phillip). Results indicated that among the three treatment factors, mycorrhiza biofertilizer showed the most significant effects whereas intercropping did not show any significant effects. However, there were two-way interaction effects on some variables, and three-way interaction effect on harvest bulb number, with the highest average (12.8 bulb/clump) was on intercropped “Ketamonca” supplied with mycorrhiza biofertilizer whereas the lowest average (8.7 bulb/clump) was on monocropped “Bima Brebes” without mycorrhiza biofertilizer. Leaf N and P contents were also highest on peanut-intercropped shallot plants supplied with mycorrhiza biofertilizer, indicating the environmentally-friendly nature of using these treatments in increasing shallot productivity.

1. Introduction

Common onion including shallot (Allium cepa var. ascalonicum) and garlic are Allium species of worldwide economic importance, because all plant parts of alliums, especially those in the group of A. cepa may be consumed by humans, and based on their growing conditions, this genus is generally adapted to arid conditions [1]. However, bulb yield and quality of shallot are very low under low availability of soil moisture, and the highest yield and quality can be achieved under soil moisture content of 50% available moisture, while under high irrigation water (above 75% available moisture), both yield and its quality are very low [2].

Based on the FAO data of 2001 summarized by Currah [3], shallot productivity was much higher in some other countries, which reached an average of 43.5 ton/ha in Spain, 47.6 ton/ha in the United States, and 58.0 ton/ha in Korea, while in the same year, it was only 10.1 ton/ha in Indonesia. In 2019, based on data from the Central Bureau of Statistics of Indonesia, the average productivity of shallot in Indonesia in 2019 was 9.90 ton/ha [4], and this average is still very low compared with the average

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productivity in other countries reported by Churrah [3]. The average productivity in 2019 is also considered very low, because some varieties of shallot released by the Institute of Vegetable Research have a high yield potential, such as the Mentes variety (up to 27.58 ton/ha dry bulbs) and the Kramat-1 variety (up to 25.3 ton/ha dry bulbs) [5].

In addition to the use of superior varieties, increasing shallot productivity can be done through application of relevant fertilizers, either inorganic, organic, or bio-fertilizers, and combinations of them. Sumarni et al. [6] for example reported an interaction effect between NPK doses and variety of shallot on bulb yield, in which yield of “Bima Curut” variety was highest under 180-120-120 NPK doses (kg/ha N, P2O5, K2O) while that of “Bangkok” variety was highest under 270-120-120 NPK doses. These indicate high fertilizer requirements for shallot production.

Due to worries about the continued use of artificial fertilizers as the sole source of nutrients, as well as problems of their cost and supply, the use of biofertilizers was studied in India, in which the results of a three-year experiment (1993-1996) showed that the application of 50% N recommended dose combined with Azotobacter, by dipping roots of transplants in a solution of 1500 g Azotobacter in 50 litre of water per ha for 5 min prior to planting, resulted in the highest economic return while giving a marketable yield of 23.06 ton/ha bulbs of ‘Agrifound Light Red’ variety of shallot [7]. Thus, in this case, the Azotobacter biofertilizer was used as the source of N.

Another biofertilizer that has been used to increase the growth and yield of crops is a group of fungi called arbuscular mycorrhizal fungi (AMF). Charron et al. [8] reported that shallot plants whose seedlings were pre-inoculated with AMF reached marketable bulb size faster (2-3 weeks earlier) than those in other treatments. In addition, tissue P levels were significantly higher in AMF inoculated shallot plants, and it was reported that shallot inoculated with Glomus versiforme produced tubers that were denser than those inoculated with G. intraradices [8]. This indicates that shallot also has a significant preference for infection by certain AMF species. From another study, Charron et al. [9] reported that shallot plants that were not inoculated with AMF grown on irradiated soil media showed stunted growth compared with those inoculated with AMF. This means that shallot has a high dependency on symbiosis with AMF for optimal growth and bulb formation.

In addition to the application of Azotobacter biofertilizer, the inclusion of legume crops in an intercropping system can be a source of N transfer for non-legume crops in legume and non-legume intercropping systems, especially through hyphae of AMF infecting roots of both crops [10]. Chu et al. [11] also found a significant transfer of fixed-N from peanut to rice in intercropping. In red rice intercropped with soybean under aerobic irrigation systems, application of biofertilizer containing mixed species of AMF to the rice plants not only increased grain yield of the red rice but also increased anthocyanin contents in the grains [12].

This study aimed to examine the effects of the application of mycorrhiza biofertilizer and additive intercropping with peanut relay-planted between double-rows of shallot on growth, N and P contents, and harvest bulb number of several varieties of shallot.

2. Materials and Method

The materials used in the experiment included the “Technofert” biofertilizer containing mixed species of arbuscular mycorrhizal fungi (AMF), shallot varieties (Bima Brebes, Keta Monca, and Super Philip), inorganic fertilizers, including Urea (45% N), ZA (21% N, 24% S), and Phonska (15% N, 15% P2O5, 15% K2O, 9% S), organic fertilizer in the form of “Bokashi” (EM-4 fermented cattle manure), and some insecticides (Decis 25 EC and Amcothene 75 SP). The “Technofert” (mycorrhiza biofertilizer) was supplied by the Biotechnology Research Office (“BPPT”) Serpong, Indonesia.

2.1. The treatments and implementation of the experiment

The field experiment in this study was carried out on entisol rice fields in the Narmada experimental farm belonging to the Faculty of Agriculture, University of Mataram, located in Narmada, West Lombok, Indonesia, from June to September 2016, which was arranged according to the Split Split-Plot design, with three blocks and three treatment factors, namely additive intercropping of shallots
with peanuts as the main plots (I0= without intercropping; I1= intercropping shallot with peanuts). Mycorrhiza application to shallots as the subplots (M0= without; M1= with mycorrhiza application), and shallot varieties (V) as the sub-subplots (V1 = Bima Brebes, V2 = Ketamonca, V3 = Super Philip). The complete procedures used for the implementation of the experiment, except for the shallot varieties used, are as described in Wangiyana et al. [13].

2.2. Observation variables and data analysis
Observations were made on growth variables, i.e. plant height, leaf number, tiller number at 7 weeks after planting (WAP), and average growth rates of plant height, leaf number, and tiller number calculated from their weekly measurements from 1-6 WAP, total nitrogen (N) and phosphorous (P) concentration of the shallot leaves, and harvested bulb number at 65 days after planting (DAP). To measure leaf N and P content, samples of shallot plants harvested at 7 WAP were analyzed chemically at the Soil Chemistry Laboratory of the Faculty of Agriculture, University of Mataram, but the field replications were bulked. Data were analyzed with analysis of variance (ANOVA) and Tukey’s HSD at 5% level of significance, using the statistical software “CoStat for Windows” version 6.303.

3. Results and Discussion
The ANOVA results summarized in Table 1 indicated that there were significant effects of mycorrhiza application on plant height and leaf number at 7 WAP, average growth rates (AGR) of plant height and leaf number, and harvest bulb number at 65 DAP, whereas varieties were different only in plant height and leaf number at 7 WAP, and in harvest bulb number, while intercropping did not have any significant effects on all observed variables. However, there were two-way interaction effects between mycorrhiza and intercropping on AGR plant height and AGR leaf number, and a three-way interaction effect on harvest bulb number. These interaction effects indicate different responses of shallot varieties to different treatment factors, i.e. to intercropping with peanut and to the application of the biofertilizer containing mycorrhizal fungi. Many have reported the potentials of AMF in increasing the growth and yield of shallots [14], [15]. In addition, it was also reported that there are some dependencies of shallot to AMF symbiosis [9], which means that shallot growth and yield will not be optimum without symbiosis with AMF. There are also some preferences of shallots to specific species of AMF [8].

Table 1. Treatment effects on growth and yield variables of shallot.

| Growth and yield variables          | Main effects | Interaction effects |
|------------------------------------|--------------|---------------------|
|                                    | Intercropping | Mycorrhiza | Variety | MxI | VxI | VxM | VxMxI |
| Plant height at 7 weeks            | ns           | *           | ***     | ns  | ns  | ns  | ns  |
| Tiller number at 7 weeks           | ns           | ns         | ns      | ns  | ns  | ns  | ns  |
| Leaf number at 7 weeks             | ns           | *           | *       | ns  | ns  | ns  | ns  |
| AGR plant height                   | ns           | **          | ns      | **  | ns  | ns  | ns  |
| AGR tiller number                  | ns           | ns         | ns      | ns  | ns  | ns  | ns  |
| AGR leaf number                    | ns           | ***         | ns      | *   | ns  | ns  | ns  |
| Harvest bulb number                | ns           | *           | *       | ns  | ns  | ns  | *   |

Note: ns = non-significant; *, **, *** = significant at p<0.05, p<0.01 and p<0.001 respectively.

Based on the mean differences, varieties show significant differences in plant height and leaf number at 7 WAP as well as in harvest bulb number (Table 2). Although they are not significantly different among the varieties, there are significant interaction effects between intercropping with peanut and application of mycorrhiza biofertilizer on AGR leaf number (Figure 1) and AGR plant height (Figure 2), which shows that both AGR leaf number and AGR plant height are highest on shallot plants intercropped with peanut and supplied with mycorrhiza biofertilizer, while without application of mycorrhiza biofertilizer, intercropping shallot with peanut would reduce its growth rates, probably due to shading by the peanut plants.
The highest average of growth rates for leaf number and plant height on shallot plants intercropped with peanut and supplied with mycorrhiza biofertilizer are also supported by the highest concentrations of total N and total P in the leaves of shallot intercropped with peanut and supplied with mycorrhiza biofertilizer, as can be seen from Figure 3 for total N and Figure 4 for total P concentrations. It can be seen from Figure 3 that leaves of shallot plants intercropped with peanut and supplied with mycorrhiza biofertilizer contained significantly higher concentration of total N when compared with those without application of mycorrhiza biofertilizer even though under intercropping systems. This can be inferred from previously reported results that there is a significant transfer of fixed N from peanut to adjacent plants, such as rice [11] or maize [16], and the rates of the transfer can be increased by the involvement of AMF extra-radical hyphae infecting roots of adjacent legume and non-legume crops in intercropping systems [10]. In addition to higher total N, leaves of shallot plants intercropped with peanut and supplied with mycorrhiza biofertilizer also contain the highest concentration of total P. Charron et al. [8] also reported significantly higher tissue P levels in AMF inoculated shallot plants than in the uninoculated shallot plants.

These higher concentrations of total N and total P, coupled with higher averages of growth rates of plant height and number of green shallot leaves from 1 to 6 weeks after planting would be among the supporting factors in increasing bulb number at harvest (65 DAP) in shallot plants intercropped with peanut and supplied with mycorrhiza biofertilizer, as can be seen from Figure 5.

Table 2. Results of mean comparison of between levels of each treatment factor.

| Treatment factors | Plant height (cm) | Tiller number per clump | Leaf number per clump | AGR plant height (cm/day) | AGR tiller number per day | AGR leaf number per day | Harvest bulb number per clump |
|-------------------|------------------|-------------------------|-----------------------|---------------------------|---------------------------|--------------------------|-----------------------------|
| V1: Bima Brebes   | 39.48 b          | 7.52 a                  | 19.25 b               | 0.63 a                    | 0.13 a                    | 0.55 a                   | 10.50 a                    |
| V2: Ketamonca     | 45.87 a          | 8.19 a                  | 23.35 a               | 0.67 a                    | 0.14 a                    | 0.62 a                   | 10.46 ab                   |
| V3: Super Philip  | 47.73 a          | 8.13 a                  | 23.94 a               | 0.71 a                    | 0.14 a                    | 0.64 a                   | 9.42 b                     |
| HSD 0.05          | 4.17             | 0.85                    | 4.28                  | 0.08                      | 0.03                      | 0.12                     | 1.06                       |
| M0: without AMF   | 43.37 b          | 7.56 a                  | 19.53 b               | 0.61 b                    | 0.14 a                    | 0.48 b                   | 8.97 b                     |
| M1: with AMF      | 45.34 a          | 8.33 a                  | 24.83 a               | 0.74 a                    | 0.14 a                    | 0.73 a                   | 11.28 a                    |
| HSD 0.05          | 1.89             | 1.00                    | 3.92                  | 0.06                      | 0.03                      | 0.07                     | 1.58                       |
| I0: monocropped shallot | 43.93 a     | 7.93 a                  | 20.85 a               | 0.69 a                    | 0.14 a                    | 0.63 a                   | 10.03 a                    |
| I1: shallot + peanut | 44.78 a    | 7.96 a                  | 23.51 a               | 0.66 a                    | 0.13 a                    | 0.58 a                   | 10.22 a                    |
| HSD 0.05          | 3.77             | 1.25                    | 5.39                  | 0.06                      | 0.06                      | 0.15                     | 1.55                       |

Table 2. Results of mean comparison of between levels of each treatment factor.

| Treatment factors | Plant height (cm) | Tiller number per clump | Leaf number per clump | AGR plant height (cm/day) | AGR tiller number per day | AGR leaf number per day | Harvest bulb number per clump |
|-------------------|------------------|-------------------------|-----------------------|---------------------------|---------------------------|--------------------------|-----------------------------|
| V1: Bima Brebes   | 39.48 b          | 7.52 a                  | 19.25 b               | 0.63 a                    | 0.13 a                    | 0.55 a                   | 10.50 a                    |
| V2: Ketamonca     | 45.87 a          | 8.19 a                  | 23.35 a               | 0.67 a                    | 0.14 a                    | 0.62 a                   | 10.46 ab                   |
| V3: Super Philip  | 47.73 a          | 8.13 a                  | 23.94 a               | 0.71 a                    | 0.14 a                    | 0.64 a                   | 9.42 b                     |
| HSD 0.05          | 4.17             | 0.85                    | 4.28                  | 0.08                      | 0.03                      | 0.12                     | 1.06                       |
| M0: without AMF   | 43.37 b          | 7.56 a                  | 19.53 b               | 0.61 b                    | 0.14 a                    | 0.48 b                   | 8.97 b                     |
| M1: with AMF      | 45.34 a          | 8.33 a                  | 24.83 a               | 0.74 a                    | 0.14 a                    | 0.73 a                   | 11.28 a                    |
| HSD 0.05          | 1.89             | 1.00                    | 3.92                  | 0.06                      | 0.03                      | 0.07                     | 1.58                       |
| I0: monocropped shallot | 43.93 a     | 7.93 a                  | 20.85 a               | 0.69 a                    | 0.14 a                    | 0.63 a                   | 10.03 a                    |
| I1: shallot + peanut | 44.78 a    | 7.96 a                  | 23.51 a               | 0.66 a                    | 0.13 a                    | 0.58 a                   | 10.22 a                    |
| HSD 0.05          | 3.77             | 1.25                    | 5.39                  | 0.06                      | 0.06                      | 0.15                     | 1.55                       |

1) Mean values in each column followed by the same letters indicate non-significant different between levels of each treatment factor.
Here, it was proven that intercropping with peanut and application of mycorrhiza biofertilizer significantly increased growth and harvest bulb number, as well as concentration of total N and P in the leaves compared with no application of mycorrhiza biofertilizer. These indicate that increasing shallot yield through intercropping with peanut and application of mycorrhiza biofertilizer would be more environmentally-friendly than increased use of inorganic fertilizers only. However, since one variety seems to be adversely affected by peanut shading, further research needs to be done by trying to intercrop shallot with peanuts having runner growth habits in order not to shade the shallot plants.

4. Conclusion
It can be concluded that among the three treatment factors, mycorrhiza biofertilizer showed the most significant effects while intercropping did not show any significant effects, but there was a three-way interaction effect on harvest bulb number, in which the highest average (12.8 bulb/clump) was on “Ketamonca” variety intercropped with peanut and supplied with mycorrhiza biofertilizer, whereas the lowest average (8.7 bulb/clump) was on monocropped “Bima Brebes” variety supplied with no mycorrhiza biofertilizer. Leaf N and P contents were also highest on intercropped shallot supplied with mycorrhiza biofertilizer, indicating that using these treatments in increasing shallot productivity would be more environmentally-friendly than using inorganic fertilizers only.

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