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Effect of additive intercropping with peanut and organic-silicate-biofertilizer combinations on growth and yield of shallots

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Abstract. *Allium* crops including shallot have been reported to have a high dependency on symbiosis with arbuscular mycorrhizal fungi (AMF), and have a high requirement for fertilizers. This study aimed to examine the effects of additively intercropping shallot with peanut and application of different combinations of organic-silicate-mycorrhiza-bio-fertilizer on growth and yield of several varieties of shallots. The field experiment for this study was designed according to Split Split-Plot design, with three blocks and three treatment factors, namely additive intercropping as the main plots (T0= without; T1= with shallot-peanut intercropping), shallot varieties as the subplots (V1= Bima Brebes; V2= Ketamonca; V3= Super Philip), and fertilizer combinations as the sub-subplots (P1= NPKS fertilizer only; P2= NPKS+organic+silicate; P3= NPKS+organic+silicate+mycorrhiza bio-fertilizer). Results indicated that among the treatment factors, fertilizer combination showed the most significant effects on growth and yield of shallot, and both fertilizer combinations containing silicate and organic fertilizer (P2 and P3) significantly increased yield of shallot, especially the P3 fertilizer combination, which contained mycorrhiza bio-fertilizer. Although intercropping with peanut showed no significant effects on all observation variables, there was a significant three-way interaction effect on shallot yield, which indicated different responses between varieties to intercropping and fertilizer combinations, in which yield of Ketamonca (V2) was not affected by intercropping but yield of Bima Brebes (V1) was reduced by intercropping, whereas yield of Super Philip (V3) was increased by intercropping it with peanut, especially under fertilizer combination containing mycorrhiza bio-fertilizer (P3).

1. Introduction

Shallot (*Allium cepa* var. *ascalonicum*) is one type of vegetable crops that are very important in Indonesia. Shallot is used as a daily cooking ingredient, which is often scarce in the market making the price sometimes become very high due to high demand coupled with insufficient domestic production, so that import is sometimes needed. In addition, the productivity of shallots in Indonesia only reached an average of 10.1 ton/ha [1], and this average is very low compared with the productivity achieved in other countries, such as in the United States it can reach an average of 47.6 ton/ha, while in Korea it can reach 58 ton/ha [2]. To balance the domestic needs and reduce imports, the productivity of shallots must be increased, and to increase productivity, it is necessary to develop shallot cultivation techniques that are capable of increasing shallot productivity.

For optimum production of shallot, certain soil conditions and fertilizers are needed, including soil pH, which should be in the range of 6-7, and P and K fertilizers should be applied before planting dose range from 26 – 129 kg/ha of P and from 50 – 250 kg/ha of K depending on the P and K contents of the soil, while for N fertilization, it is most effective to manage just two target N values in the top 30 cm of soil, i.e. 40 kg/ha N at sowing and 120 kg/ha N when the crop mass is about 1 t/ha [3]. According to results reported by Abbey and Kanton [4], for high bulb yield, it was not sufficient to apply only inorganic fertilizers and application of organic fertilizer of 3 ton/ha farm yard manure in combination with 50% doses of inorganic fertilizer could significantly increase bulb yield compared with full doses of inorganic fertilizer only.

Another way of increasing the availability of nutrients, especially N and P nutrients in the rhizosphere of shallot is through application of biofertilizers. In India, application of Azotobacter by dipping roots of shallot transplants in Azotobacter solution for 5 minutes before transplanting combined with application of N fertilizer of only 50% recommended dose in a three-year experiment could achieve higher bulb yield compared with application of full N fertilizer dose [5]. For P nutrition, application of biofertilizer containing arbuscular mycorrhizal fungi (AMF) could increase P content of shallot plants [6] or could reduce P fertilizer doses [7].

Many have reported that shallot plant is highly responsive to associations with AMF. It was reported that shallot plants whose seedlings were preinoculated with AMF reached marketable bulb size faster (2-3 weeks earlier) than those on other treatments [7]. In addition, tissue P levels were significantly higher in AMF inoculated shallot plants, and among plants inoculated with AMF, it was found that shallot inoculated with *Glomus versiforme* produced tubers that were denser than those inoculated with *G. intraradices* [7]. This indicates that, apart from being very responsive to inoculation with AMF, these shallot plants also have a significant preference for infection by certain AMF species.

In addition, from other research it was also found that shallot plants that were not inoculated with AMF grown on irradiated soil media showed stunted growth compared with those inoculated with AMF [8]. This means, that shallot plant has a high dependency on symbiosis with AMF; which means that in order for shallot plants to achieve optimal bulb formation and growth, they must be in symbiosis with effective AMF. According to other research results, from several varieties of shallots, there were differences between varieties in response to inoculation with AMF [9]. This could mean that dependency levels may different between varieties of shallot, which could also resulted in different levels of benefits obtained by different shallot varieties from their symbiosis with AMF. In addition, application of mycorrhiza biofertilizer significantly increased N and P concentration of shallot leaves [6]. In maize, AMF inoculation was reported to significantly increase soil N and P status and uptake by the maize plants, and increased biomass and grain yield of the maize plants [10]. In soybean, application of biofertilizer containing AMF combined with Rhizobium inoculant on soybean during the dry season in vertisol land could significantly increase growth and grain yield of soybean compared with application of NPK fertilizer only or *Rhizobium* only [11]. Not only increased grain yield, application of mycorrhiza biofertilizer on amphibious red rice under aerobic irrigation systems also increased grain yield and anthocyanin concentration in the grains [12].

In addition to symbiosis with AMF, there are also some benefits obtained by non-legume crops from intercropping them with legume crops. From an intercropping experiment, it was found that nutrient uptake and grain yield were higher in rice intercropped with peanut compared with monocropped rice plants, and there was also a significant N transfer from peanut to rice. In upland red rice grown in aerobic irrigation system, intercropping with soybean also increased grain yield and anthocyanin concentration in the grains [14]. It was also reported that intercropping shallot with peanut increased N concentration of the shallot leaves [6].

This study aimed to examine the effects of intercropping several varieties of shallot with peanut and application of several fertilizer combinations including inorganic, organic and biofertilizer on growth and yield of shallot.

2. Material and Methods

2.1. Material

The materials used in this study included shallot bulb-seeds of three varieties (Bima Brebes, Ketanmonca, Super Philip), "Technofert" biofertilizer containing mixed species of AMF (supplied by the Biotechnology Research Office ("BPPT") Serpong, Jakarta, Indonesia), silicate fertilizer (containing 25% SiO_2, 35% CaO, 2% MgO), organic fertilizer in the form of "Bokashi" (EM-4 fermented cattle manure), NPK fertilizer (NPK 15-15-15), ammonium sulphate fertilizer (21% N and 24% S), and systemic insecticides.

2.2. Methods

The field experiment in this study was conducted in the experimental farm of the Faculty of Agriculture, University of Mataram, located in Narmada (West Lombok, Indonesia), from June to September 2016. The experiment was designed according to Split Split-Plot design, with three blocks and three treatment factors, namely additive intercropping as the main plots (T0= without; T1= with shallot-peanut intercropping), shallot varieties as the subplots (V1= Bima Brebes; V2= Ketamonca; V3= Super Philip), and fertilizer combinations as the sub-subplots (P1= NPKS fertilizer only; P2= NPKS + organic + silicate fertilizer; P3= NPKS + organic + silicate + mycorrhiza bio-fertilizer). The complete procedures used for the implementation of the experiment are as described in Wangiyana et al. [15], except for the shallot varieties used, and application of inorganic, organic and bio-fertilizers.

The application of NPKS fertilizers for shallots in P1 treatment was carried out with Phonska 2.1 g/plant (700 kg/ha) at 7 days after planting (DAP) and ZA 0.9 g/plant (300 kg/ha) at 30 DAP, by dibbling the fertilizers 7 cm distance from plant stem at 7 cm depth, and while peanuts were fertilized with Phonska 1.2 g plant (200 kg/ha) by dibbling it at 7 DAP. Bokashi fertilizer for P2 and P3 treatments was applied in the base of shallot planting holes (30 g/hole or equivalent to 10 t/ha) at planting, whereas Silicate ("Agrosil") fertilizer 1.5 g/plant (500 kg/ha) was dibbled in the opposite hole of Phonska at 7 DAP. The mycorrhiza biofertilizer ("Technofert") for P3 treatment was applied below the Bokashi fertilizer (5 gram per planting hole).

Observation variables included plant height, number of leaves and number of tillers, which were observed at 7 weeks after planting (WAP), and crop yields of sample plants was harvested at 8 WAP. Data were analyzed with analysis of variance (ANOVA) and Tukey's HSD at 5% level of significance, using the statistical software CoStat for Windows ver. 6.303. The interaction between treatment factors is displayed with a bar graph accompanied with error bar using standard error (SE) using the method of Riley [16].

3. Results and Discussion

The ANOVA results summarized in Table 1 show that among the treatment factors tested, fertilizer combinations had a significant effect on all observation variables whereas varieties of shallot show differences only on fresh weight of shallot plants harvested at 8 WAP, but intercropping with peanut did not have a significant effect on all observation variables. However, there were two-ways interaction effects between varieties and intercropping on leaf number and plant fresh weight per clump, and between fertilizers and intercropping on plant height and leaf number per clump. There was also a significant three-way interaction effect on plant fresh weight per clump.

If we look at the pattern of interactions between the treatment factors tested, in relation to the interaction between fertilizer combinations and intercropping with peanut, it can be seen from Figure 1 that shallot plant height (7 WAP) was in general higher in intercropping with peanuts than in monocrop. However, plant height in the intercropping system was higher in P3 than in P1 and P2, while in monocropping systems, plant height in P2 and P3 treatments was higher than in P1 (Figure 1.A). In contrast to plant height, the number of leaves per clump was generally higher in the monocropping system than in the intercropping system (Figure 1.B). In addition, in the monocropping system there was a significant difference between fertilization treatments (P3> P2> P1) whereas in the intercropping system there was no difference in the number of leaves between P1 and P2 but P3 was still the highest in the number of shallot leaves at 7 WAP. This indicates that intercropping shallots with peanut plants increases plant height, which was probably due to etiolation of shallot plants imposed by shading of dense growth of peanut leaves and branches. On the other hand, intercropping reduced the number of leaves per clump (Figure 1.B).

Table 1 Summary of ANOVA result for all observation variables

Source of variation	Plant height at 7 WAP	Tiller number per clump at 7 WAP	Leaf number per clump at 7 WAP	Plant fresh weight per clump at 8 WAP
Intercropping (I)	ns	ns	ns	ns
Varieties (V)	ns	ns	ns	**
Fertilizer combination (F)	**	***	***	***
Interactions:				
VxI	ns	ns	***	***
FxI	*	ns	**	ns
FxV	ns	ns	ns	ns
FxVxI	ns	ns	ns	***

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

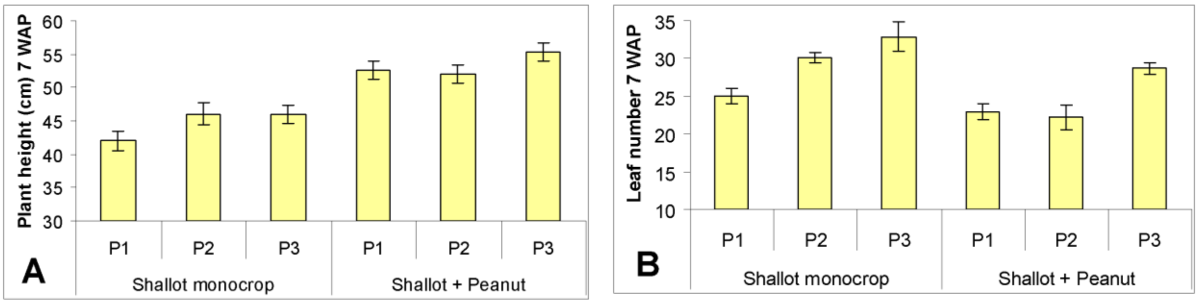

Figure 1. The interaction effect between fertilizer combination and intercropping treatments on plant height at 7 WAP **[A]** and leaf number at 7 WAP **[B]** based on its averages (Mean ± SE)

In relation to the interaction between varieties and intercropping with peanuts on the number of leaves at 7 WAP, it can be seen that only the Bima Brebes (V1) and Ketamonca (V2) varieties decreased due to intercropping with peanuts while the number of leaves of the Super Philip (V3) variety was not affected by the intercropping treatment (Figure 2.A). On the other hand, the fresh harvest weight of the Super Philip variety (V3) was much higher in the intercropping system with peanuts than in the monocropping system, while that of Bima Brebes (V1) variety was significantly reduced by intercropping but Ketamonca (V2) variety was not affected by the presence peanut plants in an intercropping system (Figure 2.B). This means that Super Philip variety was the most suitable for intercropping with peanut plants.

In relation to the three-way interaction effect, namely between intercropping, varieties and fertilizer combinations, although intercropping did not have a significant effect in the main effects (Table 2), the three-way interaction effect was significant on the harvest fresh weight of shallot plants (Figure 3).

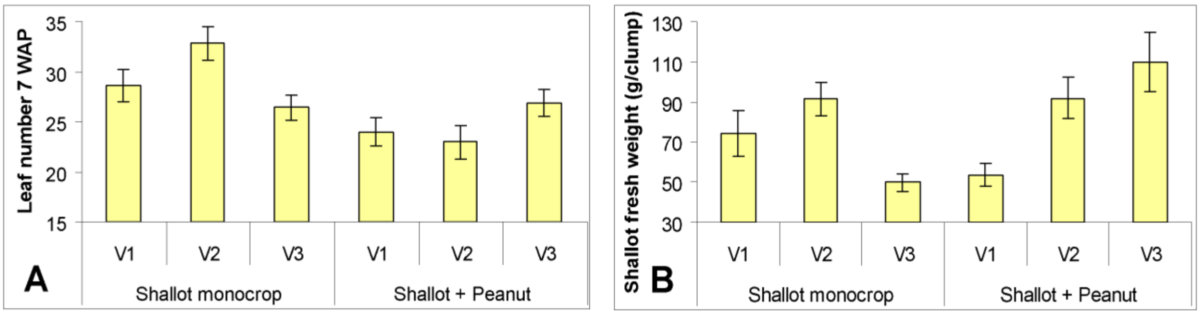

Figure 2. The interaction effect between varieties and intercropping treatments on leaf number at 7 WAP **[A]** and fresh weight of plant harvest **[B]** based on its averages (Mean ± SE)

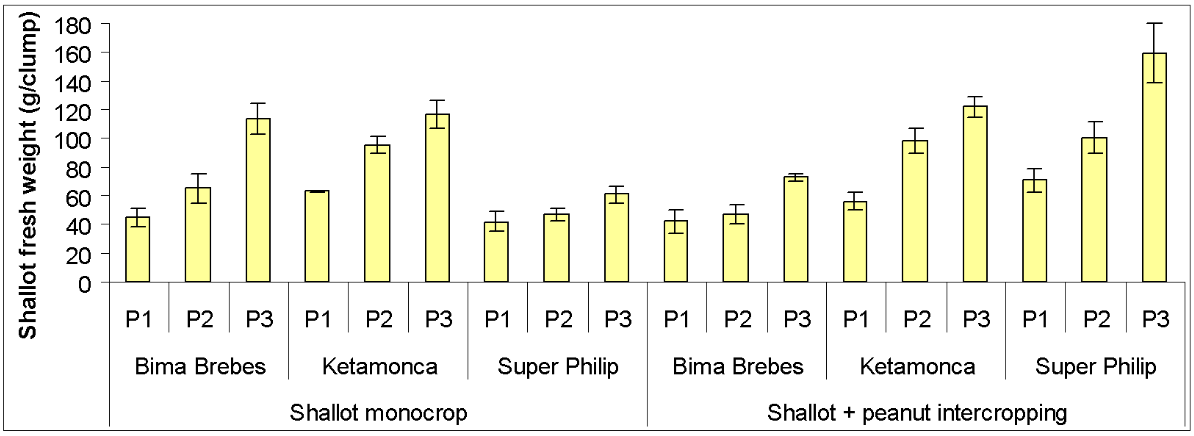

Figure 3. The three-way interaction effect between intercropping, varieties and fertilizer combinations on plant fresh weight (g/clump) based on its averages (Mean ± SE)

Among the three shallot varieties tested, it can be seen from Figure 3 that the harvest weight of the Ketamonca variety was not affected by the insertion of peanut plants between the double rows of shallots (additive intercropping) both in the P1 and P2 fertilization treatments. However, under P3 treatment with the presence of mycorrhiza (AMF) biofertilizer in the fertilizer combination, there was a tendency for intercropping to increase the fresh weight of the shallot harvest in P3 compared with in P3 without intercropping. Unlike the case of Ketamonca variety, the harvest weight of Bima Brebes variety was significantly decreased due to the insertion of peanut plants, when compared to without intercropping with peanuts. On the other hand, the fresh weight of the Super Philip variety (V3) was significantly increased due to the insertion of peanut plants, especially in the P3 fertilization package, which contained AMF inoculant, indicating that Super Philip variety was the most responsive to application of the mycorrhiza biofertilizer. These results are supported by the results reported by Charron et al. [7, 8] that shallots have a high dependency on symbiosis with AMF, and there are some preferences among varieties of shallots.

Thus, there were two shallot varieties that showed a very high positive response to AMF application (P3> P2), namely V1 and V3, but V1 (Bima Brebes) showed the highest response in the monocropping system (without intercropping with peanut), while V3 (Super Philip) showed the highest response to AMF application in the intercropping system with peanuts. In contrast, the Ketamonca variety showed a similar response to AMF inoculation between monocropping and intercropping with peanuts (Figure 3).

Table 2 Average shallot plant height, tiller number and leaf number per clump at 7 WAP, and harvest fresh weight per clump at 8 WAP

Treatments	Plant height (cm)	Tiller number per clump	Leaf number per clump	Harvest fresh weight (g/clump)
P1: NPKS	47.3 b	4.6 b	24.0 c	52.9 c[1)]
P2: NPKS+Org+Si	49.0 ab	4.7 b	26.1 b	75.4 b
P3: NPKS+Org+Si+AMF	50.6 a	6.5 a	30.8 a	107.4 a
HSD 0.05	2.0	0.8	2.1	10.8
V1: Bima Brebes	47.4 a	4.8 a	26.3 a	64.0 b
V2: Ketamonca	50.9 a	5.6 a	27.9 a	91.7 a
V3: Super Philip	48.6 a	5.4 a	26.7 a	79.9 ab
HSD 0.05	3.8	1.0	2.4	16.6
T0: Shallot monocrop	44.7 a	5.4 a	29.3 a	71.9 a
T1: Shallot + Peanuts	53.3 a	5.1 a	24.6 a	85.2 a
HSD 0.05	10.6	1.1	5.2	26.9

[1)] Mean values in each column followed by the same letters are not significantly different between levels of each treatment factor

However, all shallot varieties tested showed a positive response to AMF application in all treatment combinations (Figure 3), as was in the main effect, where the average values in P3 were higher than in P2, especially the fresh harvest weight of the shallot plants (Table 2). This indicates that the cultivation of shallots using the three varieties, i.e. Bima Brebes, Ketamonca, and Super Philip, requires a symbiosis with AMF, so it requires the availability of an adequate AMF propagules in the soil. From previous studies, although they did not use these three varieties, some researchers also reported that various shallot varieties showed a high degree of dependency on symbiosis with AMF, as reported by Charron et al. [7, 8] that application with AMF accelerated growth and enlargement of shallot bulbs, while shallots grown in sterilized soil had stunted growth. Of the various shallot varieties tested by Powell et al. [9], although there were differences in response between the varieties tested, all tested varieties were reported to have a high level of symbiosis with AMF.

Thus it can be concluded that shallot cultivation really requires the presence of AMF propagules in the soil, which can quickly infect the root system of shallots. From the results of this study it can be seen that the cultivation of shallots in Narmada rice fields is not sufficient just by providing N-P-K-S fertilizers. Although after the fertilizer combinations have been supplemented with organic and silicate fertilizers, the fresh harvest weight was also significantly lower than that in the fertilizer combination supplemented with mycorrhiza (AMF) biofertilizer. This shows the importance of a suitable and adequate AMF propagules, as what was reported by Powell et al. [9] that there are differences in the response of shallots to different AMF isolates, so it is also necessary to find isolates that are effective in establishing effective symbiosis with various shallot varieties in Indonesia in order to achieve adequate productivity, because the productivity of shallots in Indonesia is still very low, i.e. around 10 t/ha, while in other countries such as in the United States it can reach an average of 47.6 t/ha and in Korea it can reach an average of 58 t/ha [2].

4. Conclusion

It can be concluded that both fertilizer combinations containing organic and silicate fertilizers (P2 and P3) significantly increased yield of shallots, and more significantly with the addition of AMF biofertilizer (P3), when compared only with N-P-K-S fertilizers (P1), which indicates the importance of mycorrhiza for increasing the productivity of shallots. Although on average intercropping with peanut had no effect, there was a three-way interaction effects that showed differences in response between shallot varieties, where the Ketamonca variety did not show a difference in yield due to intercropping, but Bima Brebes variety decreased its yield due to intercropping, while that of Super Philip variety increased due to intercropping with peanuts, especially when inoculated with mycorrhiza biofertilizer (AMF).

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