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Effect of peanut intercropping and mycorrhiza in increasing yield of sweet corn yield

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Abstract. Many researchers reported that mycorrhizal symbiosis could significantly increase crop yield. The objective of this research was to examine the effects of mycorrhiza and intercropping with two peanut varieties on growth and yield of sweet corn. The experiment was conducted following paddy rice crop in Dasan Tebu, West Lombok, Indonesia, in the dry season 2018 and designed according to Split Plot design with four replications and two treatment factors, i.e. application of mycorrhiza-based biofertilizer as the main plots (M0 = without and M1= with mycorrhiza) and intercropping with peanut as the subplots (T0 = without intercropping, T1 = intercropping with peanut var. “Kelinci”, and T2 = intercropping with peanut var. “Bison”). The sweet corn cobs were harvested at the dough maturity stage. Results indicated that application of biofertilizer significantly increased stover dry weight, cob fresh weight, and number of green leaves per plant at harvest. Intercropping with peanuts also affected those observation variables and the height of ear position in the stem, and the “Bison” peanut variety was better than “Kelinci”. Although showing no significant interaction, intercropping with “Bison” did show higher benefits of biofertilization on both dry stover and fresh sweet corn cob weights than those with “Kelinci” variety.

1. Introduction

Corn (*Zea mays* L.) is a cosmopolitan crop and the major staple food in several countries of Latin and Central America, Eastern Africa, and South-east Asia, including China, but in the North America, corn is grown as a food, feed and industrial crop [1]. In Indonesia, in terms of the total annual harvested areas published in the website of central bureau of statistic, maize is the second staple food crops after rice, which is mostly consumed in the form of processed or semi-finished products. Based on the results of study conducted by the Central Bureau of Statistics in 2017, the average domestic per capita consumption of corn was 20.84 kg year⁻¹ [2,3].

Sweet corn (*Zea mays saccharata* Sturt) is a type of specialty corn, which all parts of the plant are very useful, including the stems and leaves as animal feed and the fruit or cobs harvested when the seeds are still young for use as food ingredients [4]. The cobs are harvested when the seeds are in the “dough” maturity stage, about 18-21 days after pollination, when the sugar content is high (about 25-30%). Sweet corn is one of the most popular vegetables in the United States and Canada, generally used as a vegetable or consumed immediately after being boiled [4]. In addition to the high sugar content in sweet corn, as a food ingredient corn in general contains a lot of nutrients and crude fiber needed by the human body. The chemical or nutritional content of corn consists of 10.0% protein, 4.0% fat, 61.0% carbohydrate, 1.4% sugar, 6.0% pentosan, 2.3% crude fiber, 1.4% ash, and 0.4% other substances, such as several types of vitamins [5].



Corn cultivation is mostly carried out on dry land or paddy fields but cultivation in the dry season follows rice crops; therefore, in corn production, there are many obstacles faced by farmers. On dry land, the most important constraint is the limited availability of soil moisture. Meanwhile, as a very high nutrient consumption plant, maize needs high doses of fertilizer application to increase its yield closer to its yield potential. According to the model developed from 12 site-years of data each with 10 N rates, it was found that economic optimum rates of N fertilization ranged from 128 to 379 kg ha⁻¹ N [6]. In addition, Hammad *et al.* [7] reported from four N doses (150, 200, 250, and 300 kg ha⁻¹ N) applied under semi-arid conditions, corn produced highest dry matter with an average grain yield of 7.8 t ha⁻¹ by applying 300 kg ha⁻¹ N under eight irrigations. Thus, if 300 kg ha⁻¹ N converted to Urea (45% N) is equivalent to 667 kg ha⁻¹ Urea needed for fertilizing corn for high yield.

Due to the high fertilizer required to achieve a high corn productivity, intensive fertilization is needed, even though the low certainty of yields on dry land coupled with the limited financial capacity of dry land farmers. In addition, the frequent scarcity of fertilizers in market after the rice growing season, will make it very difficult to increase corn productivity through fertilization. In this condition, it is necessary to find and apply innovative production technology based on the management of beneficial cropping patterns and soil biota, such as the use of arbuscular mycorrhizal fungi (AMF) symbiotic with crop plants. The AMF are able to increase nutrient and water uptake for their host plants even under drought conditions [8]. Astiko *et al.* [9] also reported that AMF application to maize under maize-sorghum cropping sequence in the northern Lombok dry land areas significantly increased yield, as well as nutrient uptake by maize and the subsequent sorghum even with no fertilizer application on the sorghum crop.

In addition to the use of symbiosis with AMF, cropping patterns can also be used to increase the growth and yield of maize. The results of research reported by Wangiyana *et al.* [10] on intercropping waxy maize with mungbean and soybean (relay-planting of 1-3 rows of mungbean or soybean plants between rows of waxy maize), the maize plant significantly increased its yield even though the N fertilizer was reduced up to half the recommended dose. In the intercropping system, decreasing to 50% of the N dose for maize plants did not show any difference in the yield of corn kernels. However, in the monocropped, it was found a significant decrease in the maize grain yield due to the reduction of N fertilizer doses. This proves that grain yield of maize can be increased simply by relay-planting legume crops (additive intercropping), especially mungbean between rows of maize plants.

Increases in grain yield, dry weight, and/or N uptake of cereals when intercropped with legume crops compared to without intercropping were also reported by several other researchers for sorghum intercropped with soybean [11]; maize intercropped with soybeans [12,13]; and maize intercropped with peanuts [14]. By using radio-isotope techniques, several researchers have proven the transfer of N from legume to non-legume plants via AMF hyphae infecting the roots of both crop types in an intercropping system [12,13,15].

The objective of this research was to examine the effects of mycorrhiza and intercropping with two peanut varieties on growth and yield of sweet corn.

2. Materials and methods

The field experiment in this study was conducted in the farmers' rice field in South Kediri village (Dasan Tebu), West Lombok, Indonesia, from May to July 2018.

2.1. Design of the experiment

The experiment was arranged according to the Split Plot Design, with two treatment factors, namely: application of mycorrhiza biofertilizer (M) at planting time as the main plot factor (M0 = without mycorrhiza biofertilizer and M1 = application of the "Technofert" biofertilizer, containing mixed species of arbuscular mycorrhizal fungi (AMF) supplied by the BPPT Serpong, Indonesia); and additive intercropping (T) as the sub-plot factor (T0 = sweet corn in monocrop; T1 = sweet corn intercropped with peanut var. "Kelinci", and T2 = sweet corn intercropped with peanut var. "Bison"). Each treatment combination was made in 4 blocks (replications).

2.2. Implementation of the experiment

After the rice field with paddy stubbles being plowed and harrowed once using a hand tractor, the raised-beds for planting sweet corn were made with a dimension of 3 m x 1.2 m, each separated with a furrow of 30 cm wide and 20 cm deep and 50 cm wide between blocks. Sweet corn of “Bonanza F1” variety was planted at a planting distance of 75 x 20 cm, by putting only one plant seed per planting hole. Because this experiment was intended to show the contribution of peanut plants relay-planted between rows of sweet corn plants, sweet corn was supplied only with basal fertilizer using 320 kg ha⁻¹ Phonska (NPK 15-15-15) dibbled at 7 days after planting (DAP), and only once N fertilization using 100 kg ha⁻¹ Urea (45% N) dibbled at 30 DAP. Peanut of “Kelinci” and “Bison” varieties was relay-planted two rows between sweet corn rows and fertilized using 200 kg ha⁻¹ Phonska fertilizer only once at 7 DAP sweet corn.

The application of mycorrhiza biofertilizer (“Technofert”) was carried out by placing 5 g/hole the fertilizer in the bottom position and covering it with bokashi (EM4-fermented cattle manure) fertilizer equal to 5 t ha⁻¹, and then the sweet corn seeds were placed on top of the bokashi fertilizer and thinly covered with soil. For the treatment without mycorrhiza, there were only bokashi and sweet corn seeds put into the planting holes. Peanut planting holes were not supplied with the biofertilizer. Irrigation water was supplied by flooding the beds immediately after finishing planting sweet corn seeds and draining them after the soil was saturated. The subsequent irrigation was done after N fertilization and at anthesis of sweet corn, with the same technique as the first irrigation. Pest control was done using insecticides in accordance with pest conditions in the field.

Observation variables included growth and yield components of sweet corn, i.e. plant height, numbers of total and green leaves, height of ear position on the stem, dry stover and fresh cob weights per plant. Harvest of sweet corn cobs was done at the “dough” maturity stage. Data were analyzed with analysis of variance (ANOVA) and Tukey’s HSD at 5% level of significance using the CoStat for Windows ver. 6.303.

3. Results and discussion

From the growth performance of corn plants in the field, it can be seen that AMF inoculation on intercropping with peanuts could improve the appearance of sweet corn plants. It can be seen from Figure 1, that the leaf colours of monocropped sweet corn plants without Technofert are more yellowish (plot F) than those of intercropped with peanuts (B, C, D, and E plots), and also growth appearances of the plants supplied with Technofert at planting are more fertile than those without application of Technofert (plot F). In this case, the performances of the sweet corn plants, especially in the field (plot C), are much greener than those in A and F plots. The average number of green leaves was also higher in C or D than in F plots (Table 1).

The results of the data analysis also showed a similar trend as seen in Figure 2. Based on the average dry stover weight, it appeared that the application of mycorrhiza biofertilizer on sweet corn plants at planting increased the dry weight of the plants harvested in the “dough” maturity stage, both in monocropping and intercropping with “Bison” and “Kelinci” peanut varieties (Figure 2). It can be seen that the application of mycorrhiza biofertilizer on sweet corn plants significantly increased plant dry weight, especially in intercropping with “Bison” variety showing the highest response of the plants to application of mycorrhiza biofertilizer (Figure 2).

Based on the measurement results on plant height, number of leaves (total and green leaves), dry stover and fresh cobs weights of sweet corn harvested at the “dough” maturity stage, the ANOVA results summarized in Table 1 indicating that there was no interaction between the two treatment factors on the observed variables. However, the application of mycorrhiza biofertilizer on sweet corn plants (M1) at planting significantly increased the number of green leaves and dry and cob fresh weights per plant, whereas intercropping significantly affected only on the number of green leaves, height of ear position on the stem, and dry and fresh cob weights per plant.

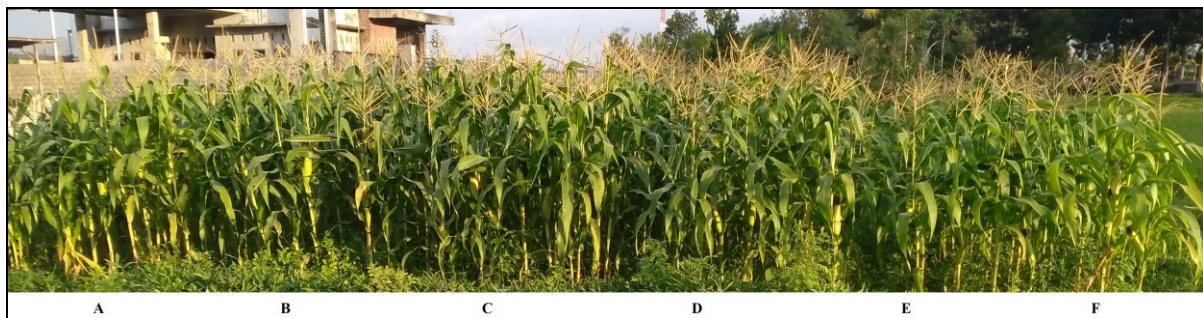


Figure 1. Growth performance of sweet corn plants in the field during the seed “dough” maturity stage: [A]. without peanut (monocrop) but with AMF; [B]. with peanut var. “Kelinci” and AMF; [C]. with peanut var. “Bison” and AMF; [D]. with peanuts var. Bison but without AMF; [E]. with peanuts var. “Kelinci” but without AMF; [F]. without peanut (monocrop) and without AMF.

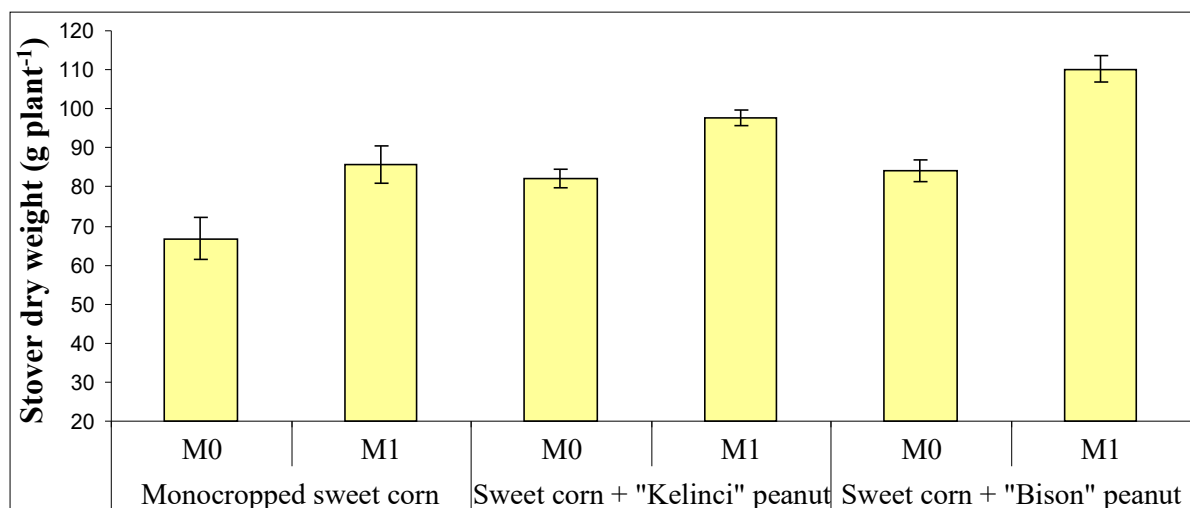


Figure 2. Average (Mean \pm SE) stover dry weight (g plant⁻¹) of sweet corn harvested at “dough” maturity stage as affected by application of mycorrhiza biofertilizer and additive intercropping with two peanut varieties (“Kelinci” and “Bison”).

The Tukey’s HSD test results for mean differences as presented in Table 1 inform that although the application of mycorrhiza biofertilizer on sweet corn plants did not significantly increase the total number of leaves at the “dough” maturity stage, it did increase mean values of the green leaf number. This phenomenon was probably related to the higher fresh weight of the sweet corn cobs on the plants supplied with mycorrhiza biofertilizer (M1) than those without biofertilizer application (M0). Higher value in dry stover weight also indicated that biomass production was higher in the M1 sweet corn plants compared to the M0 plants (Table 1). According to the findings of Sinclair and de Wit [16], seed plants re-mobilize the N contained in their leaves to seeds during the formation and seed filling stages, which in turn can accelerate leaf senescence, causing their color to change faster from green to yellow. In relation to the positive effect of applying mycorrhiza biofertilizer at planting in this study, previous research on application of AMF to corn plants also reported an increase in the nutrient uptake, including N and P, by the AMF inoculated corn plants. [9], especially in corn plants intercropped with legume crops, as reported by Inal *et al.* [14] and Meng *et al.* [17].

Table 1. Average plant height, total leaf and green leaf numbers, the height of ear position, and stover dry weight, and fresh cob weights at “dough” maturity stage, for each treatment combination of intercropping and application of mycorrhiza biofertilizer.

Treatments	Plant height (cm)	Total leaf number per plant	Green leaf number per plant	Height of ear position (cm)	Dry stover weight (g plant ⁻¹)	Fresh weight of sweet corn cobs (g plant ⁻¹)
T0: Corn monocrop	195.4 a	9.9 a	8.8 b	78.8 b	76.18 b	238.80 b ¹⁾
T1: Corn + “Kelinci”	203.7 a	10.3 a	8.9 b	84.4 ab	97.18 a	276.67 a
T2: Corn + “Bison”	206.0 a	10.2 a	9.5 a	91.3 a	89.92 a	267.54 a
HSD 0.05	14.1	0.5	0.6	9.5	9.55	20.22
M0: without AMF	201.6 a	10.1 a	8.9 b	86.1 a	77.63 b	249.05 b
M1: with AMF	201.8 a	10.3 a	9.3 a	83.5 a	97.89 a	272.95 a
HSD 0.05	12.0	0.5	0.3	12.6	13.79	18.56
Anova results:						
Mycorrhiza (AMF)	ns	ns	*	ns	*	*2)
Intercropping	ns	ns	*	*	***	***
Interaction	ns	ns	ns	ns	ns	ns
Coefficient of variation (%)	5.24	3.63	4.59	8.42	8.16	5.81

¹⁾ Same letters in each column indicate non-significant difference between levels of each treatment factor.

²⁾ ns= non-significant; *, **, *** = significant at p-value <0.05, p-value <0.01 and p-value <0.001.

When compared with the AMF effect on the sweet corn plants, intercropping with peanuts in fact affected more significantly on the height of the ear position on the stem, the number of green leaves, and dry stover and fresh weights of corn cobs per plant at the dough maturity stage (Table 1). However, in relation to the effect of intercropping sweet corn with different peanuts, the intercropping with “Bison” variety affected more significantly positive than with “Kelinci”. Based on the description on both national superior peanut varieties by Balitkabi Malang, Indonesia, the “Bison” peanut variety was claimed to have shade tolerance of up to 25% and its better effects than “Kelinci” variety could be due to the different properties. From the plant growth performances in the field, it was found that establishment rates of the “Bison” variety were more uniform resulting in higher plant population of the “Bison” than the “Kelinci” variety. Whether it was caused by the differences in its tolerance to shading or different viability of their seeds, it needs to be further investigated.

However, if the average fresh weight of the sweet corn cobs were plotted on both treatment factors although there was no significant interaction effects on it, Figure 3 shows that application of mycorrhiza biofertilizer did not show significant effects on fresh weight of corn cobs, but intercropping with “Bison” peanut variety showed the highest effects of application of mycorrhiza biofertilizer on fresh weight of corn cobs. Figure 3 clearly shows that both intercropping with “Bison” variety peanut and application of mycorrhiza biofertilizer had significant positive effects on fresh weight of the sweet corn cobs of the “Bonanza F1” variety. Several researches have also reported that when mycorrhizal symbiosis is involved, intercropping with legume crops normally shows significant positive effects on growth and yield of cereal crops in intercropping systems, as has been reported by Meng *et al.* [17] in maize-soybean intercropping, and Wangiyana *et al.* [18,19] in rice-soybean intercropping. Inal *et al.* [14] also reported similar results of intercropping maize with peanut although without application of mycorrhiza biofertilizer. In addition, other researchers also reported significant transfer of fixed nitrogen from legume to non-legume plants under involvement of mycorrhizal hyphae infecting roots of the component crops in intercropping systems [12,13,15].

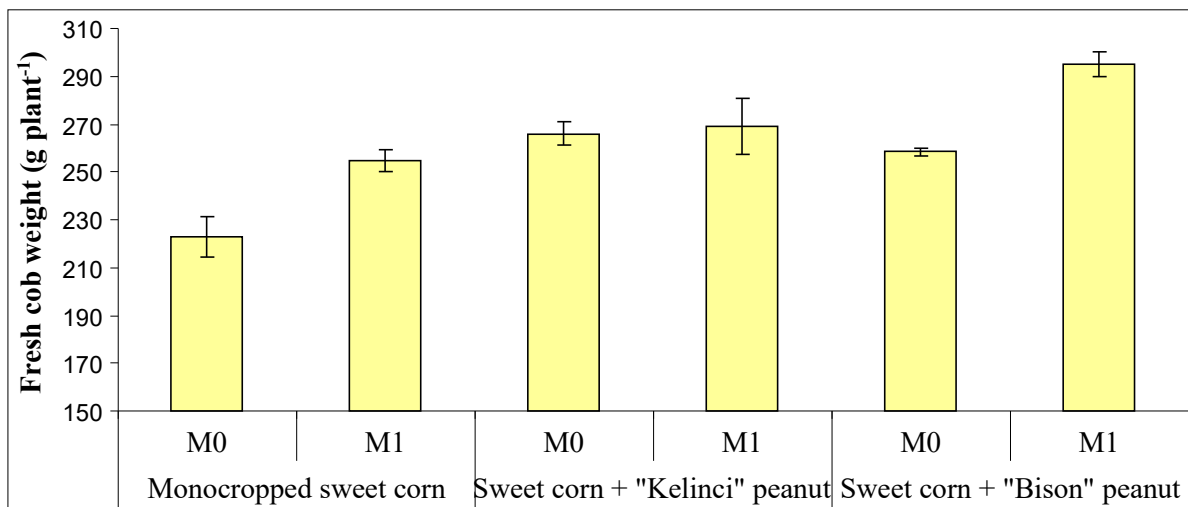


Figure 3. Average (Mean \pm SE) fresh weight of sweet corn cobs (g plant⁻¹) harvested at dough maturity stage as affected by application of mycorrhiza biofertilizer and additive intercropping with two peanut varieties ("Kelinci" and "Bison").

4. Conclusions

It can be concluded that application of both mycorrhiza biofertilizer and intercropping with peanut significantly increased plant dry weight and yield of sweet corn in the form of cob fresh weight. Although there were no interaction effects between the treatment factors, it was clear that intercropping sweet corn with "Bison" variety of peanut resulted in higher cob yield than intercropping with "Kelinci" variety, especially under application of mycorrhiza biofertilizer.

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