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NUSANTARA BIOSCIENCE
Vol. 8, No. 1, pp. 66-70
May 2016

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n080112

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Manuscript received: 5 March 2016. Revision accepted: 23 April 2016.

Abstract. *Astiko W, Fauzi MT, Sukartono. 2016. Mycorrhizal population on various cropping systems on sandy soil in dryland area of North Lombok, Indonesia. Nusantara Bioscience 8: 66-70.* Inoculation of arbuscular mycorrhizal fungi (AMF) on maize in sandy soil is expected to have positive implications for the improvement of AMF population and nutrient uptake. However, how many increases in the AMF population and nutrient uptake in the second cycle of a certain cropping system commonly cultivated by the farmers after growing their corn crop have not been examined. Since different cropping systems would indicate different increases in the populations of AMF and nutrient uptake. This study aimed to determine the population AMF and nutrient uptake on the second cropping cycle of corn-based cropping systems which utilized indigenous mycorrhizal fungi on sandy soil in dryland area of North Lombok, West Nusa Tenggara, Indonesia. For that purpose, an experiment was conducted at the Akar-Akar Village in Bayan Sub-district of North Lombok, designed according to the Randomized Complete Block Design, with four replications and six treatments of cropping cycles (P0 = corn-soybean as a control, in which the corn plants were not inoculated with AMF; P1 = corn-soybean, P2 = corn-peanut, P3 = corn-upland rice, P4 = corn-sorghum, and P5 = corn-corn, in which the first cycle corn plants were inoculated with AMF). The results indicated that the mycorrhizal populations (spore number and infection percentage) were highest in the second cycle sorghum, achieving 335% and 226% respectively, which were significantly higher than those in the control. Increased uptake of N, P, K and Ca the sorghum plants at 60 DAS of the second cropping cycle reached 200%; 550%; 120% and 490% higher than in the control. The soil used in this experiment is rough-textured (sandy loam), so it is relatively low in water holding capacity and high porosity.

Keywords: Corn, cropping system, dryland, mycorrhiza

INTRODUCTION

The limiting factors such as water availability, poor nutrient, and low soil organic matter are the root of the problems in increasing maize yield on sandy soil in dryland area of North Lombok, Indonesia. Another constraint is the dependency of the implementation of agriculture intensification on the use of inorganic fertilizers. The practice of fertilization in this way is not efficient. Of the N fertilizer applied, at most only 50% is absorbed by the crop roots and the rest is left behind or lost from the soil. The most inefficient fertilizer is P fertilizer, which is absorbed by the roots only about 8-13% (Guswono 1996). Problem-solving can be done by studying the behavior of the limiting factors as well fixing them through land management actions for improvement of soil characteristics which support the improvement of the water system and adequate soil nutrients for plant growth (Suzuki and Noble 2007). One of the ways for solving the problems is to utilize arbuscular mycorrhizal fungi (AMF) for improving crop growth and yield.

Inoculation of AMF on maize in sandy soil is expected to have positive implications for the improvement of soil properties, nutrient uptake, and yield. This method is an alternative to bio-fertilizer that has high efficiency because it can catalyze the hydrolysis of adsorbed nutrients in the soil through enzymatic reaction by the AMF making them available to plants (Widiastuti et al. 2003). This has been proven from the results of previous studies that AMF inoculation management of cropping systems accompanied by manure application can increase P uptake, which results in higher crop yield than without AMF. Increased in nutrient uptake occurs as a result of AMF activities in increasing the availability of nutrients and improving root proliferation (Smith et al. 2010).

Management of the cropping systems by the arrangement of the sequences of different crop species planted in the period a year can lead to different levels of enrichment in AMF populations in the next cropping cycle. As an example, a maize crop planted in the first cycle of a corn-soybean cropping system can improve AMF sporulation and infection on the plant roots. This leads to the enrichment of AMF population in the soil, which is very favorable for growing the next crop cycle (Sylvia 2005; Muhibuddin 2006). Wangiyana et al. (2006) also reported different dynamics of AMF populations (AMF colonization and spore counts) between cropping systems on two dominant soil types in Lombok, Indonesia.

However, how many increases in the AMF population and nutrient uptake in the second cycle of a certain cropping system commonly cultivated by the farmers after growing their corn crop has not been revealed. Since different cropping systems would indicate different increases in the AMF population and nutrient uptake, this study has revealed AMF population and nutrient uptake on some crops of the second cycle of cropping systems after

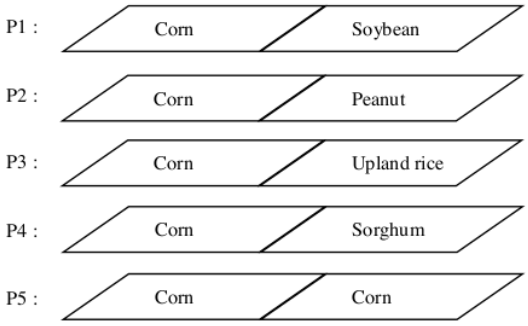
the first cycle of AMF inoculated and uninoculated corn crops had been harvested.

MATERIALS AND METHODS

Study site and design

This research based on a field experiment conducted on sandy soil in the dryland area of Akar-Akar Village of Bayan sub-District in North Lombok, West Nusa Tenggara, Indonesia, and the soil characteristics is presented in Table 1. Based on those results of soil analysis (Table 1), the soil used in this experiment is rough-textured (sandy loam), so it is relatively low in water holding capacity and high porosity (Soil Survey Staff 1988). Soil reaction (pH) is rather neutral, high levels of available P, medium available K, medium available Ca, and low organic C (Table 1).

The experiment tested five cropping systems and one control, and each pattern consisted of two cropping cycles. The corn plants in the first growing cycle were fertilized using the recommended fertilizer dosage while those in the second cycle were grown on the same land but without fertilizer. The experiments were designed using the Randomized Complete Block Design with four replications. The cropping system as the control treatment was corn-soybean without AMF inoculation (P_0). The other treatments of cropping systems in which corn in the first cycle was inoculated with AMF were as follows:



Implementation of the experiment and observation

The land was prepared using minimum soil tillage, cleared from weeds, and plots were subsequently created in blocks and in each block, smaller plots of 7 m x 5 m were created as the treatment plots.

An inoculum of indigenous AMF to be used in this experiment was the result of a personal collection of the mycorrhizal isolate M_{AA01} which was the best isolate of indigenous mycorrhiza of North Lombok. The final form of the inoculum is in the form of a mixture of growing medium containing infected root fragments, spores of the AMF species *Glomus fasciculatum*, and the growing medium of the host plants in pot culture, with propagule density of 10^7 colonies per unit. Inoculation with the mycorrhizal isolates M_{AA01} was done through seed-coating, i.e. by mixing the seeds thoroughly with the mycorrhizal inoculum with a help of glue made from tapioca flour, with a dose of 1 kg of inoculum for 20 kg of seeds (Astiko 1995; Feldmann et al. 2009). AMF inoculation was done only on corn in the first cycle, except for the control crops, and no inoculation was done on the second-cycle crops.

Seeding was done by burying 2 seeds of the 2nd cycle crops per planting hole of 2 cm made using a dibble. At 7 days after seeding (DAS), thinning was done by pulling out a seedling to leave only 1 healthy plant per planting hole. For crops in the cycle 2 (2nd cycle), direct seeding was done after harvest of the crops in the cycle 1, by firstly clearing the plots from the remains of plants from the cycle 1, followed by shallow harrowing the surface of the plots. Measurement on the plants was done on destructive plant samples, i.e. 10 plants sampled diagonally at 60 DAS on each treatment. Those plants were used to measure AMF population and nutrient uptake.

The planting distance for corn and sorghum was 70 cm between rows and 20 cm within a row, while for soybeans and peanuts was 30 cm between rows and 20 cm within a row, whereas for upland rice it was 20 cm within and between rows. The varieties used were Bisma for corn, Kaba for soybean, Bison for peanuts, Inpago Unram 1 for upland rice, and Numbu varieties for sorghum.

Fertilization for corn was performed twice, with the recommended dose of 300 kg/ha of urea and 200 kg/ha of Phonska (NPK 15-15-15). The first fertilization was done at 1 week after seeding (WAS) at a dose of 100 kg/ha of urea and 200 kg/ha of Phonska (NPK 15-15-15) fertilizer, and the second fertilization with the rest of the urea fertilizer at 1 month after seeding (MAS). Fertilizers were applied only to corn plants grown in the first cropping cycle while those in the second cycle were grown on the same land but without fertilizer application.

Maintenance of the plants includes several activities such as replanting, weeding, and soil-piling. Replanting for non-emerging maize and sorghum seedlings were done after 4-7 DAS, whereas for soybeans, peanuts, and upland rice it was done between 5-10 DAS. Weeding and soil-piling were done twice; first, at 15 DAS, while the second weeding was done at 30 DAS prior to subsequent fertilization. In the second weeding, soil-piling was also done by tilling and piling the soil around the stems. For soybeans and peanuts, the last soil-piling was done after flowering, i.e. at 40 DAS.

Protection of the plants was done using the organic insecticide "Azadirachtin" under the trade name of OrgaNeem, which was sprayed every three days at a concentration of 5 ml per liter of water.

Harvesting of corn, sorghum, and upland rice was done about 100 DAS when the corn husks color turned to brownish yellow. Soybean and peanuts are also harvested at 100 DAS.

Observation of all parameters was done on the crops in the second cycle. Parameters related to AMF activities including fungal population and percentage of root infections at 60 DAS and nutrients uptake (N, P, K, and Ca) was measured at 60 DAS.

Mycorrhiza population was measured using wet sieving technique according to Brundrett et al. (1996). The supernatant caught at 38 μm-sieve was transferred to

centrifuge tubes and added with 60% of sucrose solution and subsequently centrifuged at 3000 rpm for 10 minutes (Daniel and Skipper 1982). The harvested spores were stored on the Whatman paper with permanent ink marked of 0.5 x 0.5 cm. Counting of mycorrhiza population was done using a stereomicroscope (40x magnification). Measurement of root infection percentage was conducted using a modification of clearing and staining method (Kormanik and McGraw 1982), followed by counting using the *Gridline Intersect* technique (Giovannetti and Mosse 1980) under stereo-microscope observation. Analyses for N, P, and organic-C were done by using Kjeldahl method, spectrophotometer, and colorimetric method according to Walkley and Black, respectively. K and Ca were analyzed by using Automatic Absorption Spectrophotometer (AAS).

Data analysis

Data were analyzed using analysis of variance (ANOVA), followed by means comparison using the Least Significant Difference test at 5% level of significance when the ANOVA showed a significant effect.

Table 1. Characteristics of the sandy soil in the Akar-Akar Village of Bayan District in North Lombok

Soil characteristic	Value	Category
pH (H_2O)	6.25	Rather acidic
N Total (%)	0.01	Very low
Available P (mg kg^{-1})	13.82	High
Available K (cmol kg^{-1})	0.57	Moderate
Available Ca (cmol kg^{-1})	7.38	Moderate
Organic C (%)	1.21	Low
Texture:		
-Sand (%)	69	-
-Silt (%)	29	-
-Clay (%)	2	-
Texture class		Sandy loam

RESULTS AND DISCUSSION

Soil characteristics

The N fertilizer applied to the land (generally in the form of urea) could be lost along the percolation water. It is marked by very low levels of N-total (<0.01%) (Table 1). Theoretically, high soil P content is potentially able to meet P requirements of the plants. However, P in the soil is easy to form complex compounds, making P unavailable to plants (Priyono 2005). The complex P compounds need to be transformed first into phosphate ions through the mineralization process catalyzed by the phosphatase enzyme (Sylvia et al. 2005).

Population of mycorrhiza

The number of spores and infection of the roots of sorghum in the corn-sorghum cropping system (P_4) were consistently and convincingly higher compared with those in other cropping systems. The increase in spore number and infection of the roots of sorghum in the second cycle at 60 DAS compared with control were up to 335% and 226%, respectively. In addition, soybean on the inoculated plot (P1), also increased spore population and root infection compared with soybean on the uninoculated (control) plot, although the increases were not as high as those on sorghum (Figure 1). This indication reveals that sorghum in the cropping system P4 can increase the population of AMF in the soil.

The accelerated increase in population of AMF on sorghum in the maize-sorghum cropping system (P_4) might be caused by environmental suitability and anatomical and physiological compatibility between the host plants and AMF (Kato and Miura 2008). Maize and sorghum crops are favored AM host plants, which may trigger AM sporulation. The phenomenon of increased AM sporulation around rhizosphere of maize and sorghum crops, as shown in the P4 treatment, is an indication of increased AM activity (Astiko et al. 2013a). With the increased AM sporulation, then enrichment of AM population in the soil will occur. Maize and sorghum are plants that have coarse roots with a low number of root hairs so that they are preferable AM host plants. This fact also reported by Van der Heijden et al. (2001), which suggests that plants having magnoloid type of roots (coarse roots with few or even no hairy roots), such as maize and sorghum crops, are more sensitive and responsive to the AM infection resulting in increased AM populations in the soil.

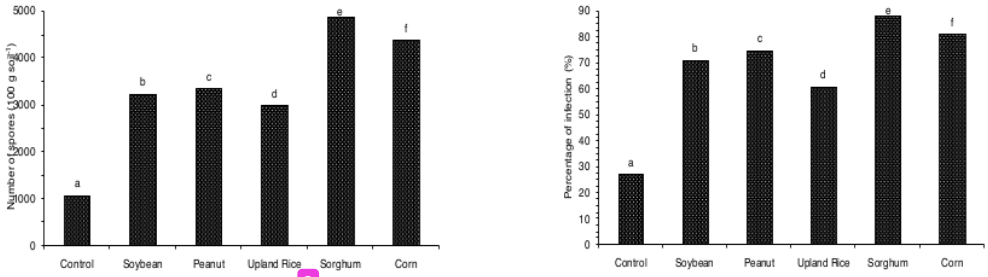


Figure 1. The population of mycorrhiza (number of spores and percentage of infections) in the second cropping cycle plants grown on sandy soil with various treatments. Bars with the same letters at the same category are not significantly different (at p=0.05)

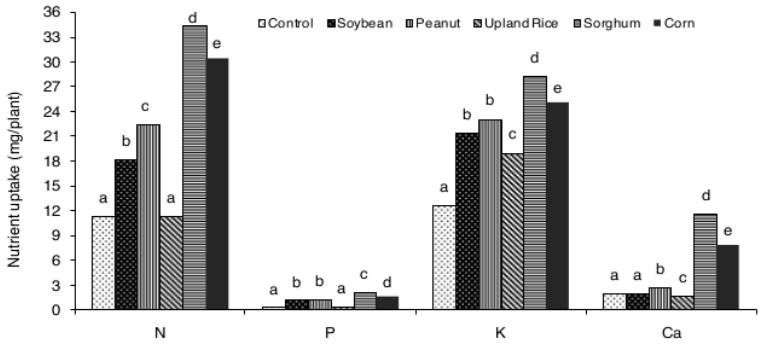


Figure 2. Nutrient uptake (N, P, K and Ca) in the second cropping cyle by the plants grown on sandy soil with various treatments. Bars with the same letters at the same category are not significantly different (at p=0.05)

Nutrient uptake

The highest nutrient uptake at 60 DAS was achieved by sorghum in the planting cycles two on the corn-sorghum pattern (P_4). Increased uptake of N, P, K and Ca in the sorghum crop at 60 DAS reached 200%; 550%; 120% and 490% higher when compared to the control. Soybean plants on the inoculated plot also increased uptake of those nutrients except for Ca, when compared with soybean on the uninoculated (control) plot (Figure 2).

The differences in nutrient uptake between plant species in the 2nd cycle of those cropping systems seem to be more influenced by the different responses between crops. These could be the main reason for the differences in nutrient uptake between crops in the 2nd cropping cycle. The facts that the sorghum crop nutrient uptake in the 2nd cycle of maize-sorghum cropping system was higher and significantly different from other crops in the 2nd cycle of the other cropping systems might be related to the suitability of the role of AM with the sorghum as a host plant in improving the absorption of nutrients. Angel et al. (2007) and Muchane et al. (2010) suggested that AM role can increase nutrient uptake of N and P as well as Cu and Zn in plant tissue of suitable hosts. Furthermore, Knapp et al. (2007) stated that the role of AM can enhance nutrient uptake when coupled with an appropriate fertilizer application to the soil. The increased nutrient uptake might be caused by the activities of the external hyphae that extend beyond the depletion zone that is not accessible for plant roots (Joner et al. 2000; Drew et al. 2003; Zhu et al. 2003). The AMF inoculation at the beginning of the growing season becomes a necessity in the systems of planting patterns practiced by the farmers in sandy soil (sandy loam) of North Lombok (Astiko et al. 2013b). However, in order for the AM inoculation to be highly successful, there should be a host plant suitability to AM species, the status of soil nutrients supporting plant growth, and adequate AM inoculum potential (Corkidi et al. 2008).

In conclusions, mycorrhizal populations (spore number and infection percentage) were the highest (335% and 226%) in sorghum of the second cropping cycle, which were significantly higher than those in the control treatment. Increased uptake of N, P, K and Ca at 60 DAS reached 200%; 550%; 120%, and 490% higher in the sorghum crop compared with controls. The soil used in this experiment is rough-textured (sandy loam), so it is relatively low in water holding capacity and high porosity.

ACKNOWLEDGEMENTS

The authors would like to convey special thanks to the Directorate General of Higher Education (DGHE) of Indonesian Government, and Rector of the University of Mataram, Indonesia for the research grant provided through the competitive grants scheme of 2015 budget year.

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