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Evaluation of Maize (Zea Mays L.) to Application of Arbuscular Mychorrizal Fungi in Coal Mining Tailings

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Abstract**—*The purpose of this study was to obtain The best dose of Arbuscular Mycorrhizal Fungi (FMA) and the best maize varieties for the growth and high yield of plants in coal mining tailings. This research was conducted using a completely randomized factorial design with 2 treatments. The first factor was the dose of arbuscular mycorrhizal fungal (6 treatments). The second factor was 4 varieties of corn. Data was analyzed statistically using the F-test at the 5% significance level. Significant differences were further tested using Duncan's Multiple Range Test also at the 5% level. Parameters measured were: percentage of roots infected with the Arbuscular mycorrizal fungi during growth and at the time of harvest, kernel with per plant. A dose 25 grams of FMA was the best dose for growth and yield of Bisi-2 with avarage production 179,8 gram per plant in coal mining tailings.*

Keywords—Application Doses, Maize Varieties, Arbuscular Mycorrhizal Fungi, Coal Mining Soil.

I. INTRODUCTION

Food needs continue to increase while the availability of agricultural land is getting smaller. This is due to the conversion of agricultural land to activities outside of agriculture. One of the critical lands that has the potential to be converted into potential agricultural land is coal mining tailings. Sawahlunto City is a city that has coal mining tailings. The total coal mining area in Sawahlunto City reaches 1,000.03 hectares which has turned into unproductive land (Subowo, 2011; Sari, 2012; Dinas Energi Sumber Mineral, 2013). The Problems in coal mining tailings used as agricultural areas are low fertility rates, damage to physical structures and nutrient degradation (Qomariah, 2003; Personal 2012). The problem is an obstacle if the land is used as agricultural land because it can inhibit plant growth.

In terms of technical aspects, coal mining areas can be used for agricultural cultivation if soil conditions have been improved by reclaiming the coal mining tailings (Subowo, 2011). So that it can minimize the negative impacts of mining that have been carried out (Sheoran et al., 2010).

Based on the results of experiments that have been carried out, plants with a dose of 0 gram AMF treatment were infected by FMA. This is presumably because the watering of plants does not use sterilized water so that mycorrhizal spores can be carried away by watering water from groundwater found around the trial area. Similar to Akmal's (2014) study that the effect of giving AMF and the frequency of watering on corn plants showed infection with a moderate category of 40.33%. Another factor that causes is the carrying of AMFspores by wind. In accordance with Coyne (1999) that AMF can be spread actively (growing with mycelium in the soil) and spread passively where AMF is spread through wind, water or microorganisms in the soil.

One of the coal mining tailings that has been reclaimed with the use of Arbuscular Mycorrhizal Fungi (AMF) is coal mining land in Nagari Sikalang, Sawahlunto City, West Sumatra Province. Simarmata (2004) mentions one strategy and effort that can be done to restore soil quality is by utilizing Arbuscular Mycorrhizal Fungi (AMF).

Mycorrhiza plays an important role in increasing plant tolerance to toxic metal elements, resistance to drought and can increase plant growth by releasing P which is fixed by Al and Fe so that P can be available to plants (Cho et al., 2006; Subramanian, 2006; Setiadi and Setiawan, 2015). In addition to the use of Arbuscular Mycorrhizal Fungi (AMF), a suitable type of plant is needed to be cultivated on coal mining tailings. One of the plants that can be used is maize.

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Maize are plants that have high phenotypic plasticity and are one of the most important world food crops besides wheat and rice. Maize production in Indonesia continues to increase every year. However, this production has not been able to keep up with market demand. Based on the Central Statistics Agency (2017), maize production in 2016 was 23.58 million tons, while in 2017 there were 26 million tons.

Several maize varieties have been produced in both free-range varieties and hybrid varieties. At present, only Sukmaraga free-range varieties are resistant to acidic land (Balitsereal, 2010). At present there are no commercial hybrid varieties that are reported to be resistant to acidic land conditions. Various varieties of corn have been produced by companies such as: Sygenta, Dupont, and Bisi International. But the resulting variety is still unknown in response to coal mining tailings. This present study was aimed to evaluate the accurate dose of AMF application that stimulated the best growth performance of coal mining tailings adaptive maize varieties.

II. MATERIALS AND METHODS

This research was conducted from February to Mei 2018 in the experimental garden and plant physiology laboratorium of Agriculture Faculty, Andalas University, Padang. Selection of several maize varieties with the application of various AMF doses in coal mining tailings was performed by observing the agronomical performances followed by root staining assay in the laboratorium (Philip and Heymen, 1979).

This study was conducted factorially with completely randomized design using two treatment factors, consisting of AMF doses and maize varieties. Six doses of AMF ranging from 0, 5, 10, 15, 20 and 25 g per polybag were evaluated to observe its effect on the growth performance of four marginal land-adaptive maize varieties (Bisi-2, NK-99, P3.2 and Sukmaraga). AMF inoculants used in this study were multispore type composed of *Glomus sp*., *Gigaspora sp*. and *Cytospora sp*. and collected from Laboratorium of Soil Biology, Faculty of Agriculture, Andalas University. Resulted data of this AMF application was further analyzed using regression and correlation analysis. Data were statistically analyzed using two way anova and significance among treatments was further evaluated using DMRT with a $p<0.05$.

III. RESULT AND DISCUSSION

3.1 Analysis of used soil coal pH after giving various doses of AMF

Based on the analysis of soil pH that has been done, there is an increase in soil pH value after administration of AMF treatment. The results of the statistical analysis with the F test at the level of 5% showed that the AMF dose had a significant effect on soil pH. The results of further tests with DMRT are shown in Table 1.

Can be seen in Table 1, giving AMF to each treatment has an effect on soil pH. The effect can be seen by doing a comparison between the pH value of the soil without the administration of AMF treatment and the pH value on AMF treated soil. The average pH value is 4.7 (tertolon. A dose of 25 grams of AMF is the best dose with an average pH value of 6.7 which is classified as neutral when compared to the dose of AMF 5 grams and 10 grams which results in a rather acidic soil pH value. However, AMF dosage of 15 grams and 20 grams also produces a soil pH that is classified as neutral, but not as high as the pH value produced by giving a dose of AMF 25 grams. One indicator of soil fertility is soil pH.

The higher the AMF dose given, the higher the pH on the soil. Y = 4.81 + 0.08x which shows a positive regression value. From the equation, it is explained that every addition of 10 grams of AMF dose can increase pH on the soil. Giving FMA can increase soil pH. This is because the presence of AMF activity and metabolism produces and releases organic compounds which play a role in increasing metal cations that cause acidity of the soil so that the soil pH increases.

Nature of soil pH has a direct or indirect relationship with other soil chemical properties. With increasing soil pH, nutrients such as N, P and K available in the soil will also increase. Plants need balanced nutrients for the growth process. N deficiency causes disruption of P and K absorption for plant growth phases. Nutrient P is needed in large quantities after nutrient N, because nutrient P plays a role for plant growth from the vegetative phase to the genarative phase (Sufardi, 2012).

3.2 Percentage of Root Infected by AMF (Arbuscular Mycorrhizal Fungi)

The results of the statistical analysis with the F test at the level of 5% showed that the interaction of AMF doses and varieties and single dose factors significantly affected the percentage of roots infected with AMF at 8 MST and at harvest.

The AMF 25 gram treatment is the best dose obtained (Table 2). This can be seen from the percentage of roots infected with AMF in the treatment of AMF 25 grams. The NK-99 variety is a variety that has the highest percentage of root infection, which is 92.5%. This is in line with the growth in the vegetative and generative period of each corn plant variety that the best growth is found in the treatment of AMF 25 grams. In contrast to the 0 gram AMF treatment the criteria for infection are low.

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Different responses in a plant to mycorrhizal infection are caused by differences in the dosage given and infection from spores, arbuscular and vesicular development, speed of spread of infection and growth of hyphae that emerge from the roots on a mycorrhiza with various hosts (Sastrahidayat, 2011). AMF will form spores in the soil and will develop well if associated with the host plant.

The percentage of maize infection at the time of harvesting the best FMA dose was also found in the 25 gram AMF treatment (Table 3). The administration of various AMF doses was significantly different from the percentage of root infections by AMF in all tested varieties. All varieties showed a greater percentage of infections during harvesting compared to the percentage of infections during vegetative growth. However, the highest percentage of roots infected by AMF at harvest was found in Bisi-2 and NK-99 varieties.

In the Bisi-2 variety the percentage of roots infected by AMF was 96.0% while in the NK-99 variety it was 94.6%. Unlike the case with varieties P 3.2 and Sukmaraga which have a lower percentage of infections compared to the Bisi-2 and NK-99 varieties but still belong to the percentage of root infection by high AMF which is 92.3% in varieties P 3.2 and 92.5% on the Sukmaraga variety. The highest percentage of infections when the corn plant is 8 MST and when harvesting is the same, it is found at 25 grams of AMF.

In each variety the percentage of infections was greater than the percentage of roots infected with AMF during vegetative growth. This is in line with the very strong correlation value between the AMF percentage at the vegetative growth of corn plants and the FMA percentage at harvest time, ie $r = 0.97$. There is a very strong correlation between the two observed variables indicating that the more and the longer the mycorrhizae applied to the roots of the maize plant, the higher the root association level and the higher colonization between the mycorrhizae and the roots of the corn plants.

The linear regression results of the percentage of root infected by FMA during the vegetative growth period yielded an equation $Y = 21.58x + 2.89x$ whereas at harvest yielded the equation $Y = 23.41 + 3.00x$ this showed a positive regression value. From the equation, it can be explained that each addition of 10 grams of AMF dose can increase the percentage of roots infected with AMF both when the corn plant is 8 MST and at the time of harvest. Correlation analysis also shows that there is a strong correlation value $r = 0.97$ between the AMF dose and the percentage of roots infected with FMA. This is caused by the presence of mycorrhizal infectivity. Effectiveness is the ability of the fungus to infect and colonize plant roots. Mycorrhizae used are derived from the rhizosphere of maize plants so that there is compatibility between the maize plants evaluated with the given mycorrhizae.

3.3 Kernel weight per plant

In Table 4 we can see the kernel weight per corn plant of each variety. Giving various doses of AMF has a significant influence on seed weight in the varieties tested. Can be seen in Table 4 the higher the dose of AMF given the higher the kernel weight per plant produced. However, the lowest kernel weight per plant was found in the treatment without administration of AMF (0 grams).

The highest kernel weight per maize plant was found in the Bisi-2 variety, 179.8 grams per plant significantly different from the varieties NK-99, P 3.2 and Sukmaraga. The Bisi-2 variety has the highest kernel weight per plant compared to other varieties due to the higher number of cobs per plant than other varieties, the longest cob length compared to other varieties, and a large cob diameter compared to other varieties. This indicates that the more the number of cobs per plant, the longer the cobs and the bigger the cobs they have, the higher the weight of the beans produced.

Kernel weight in non-treated varieties is lower when compared with kernel weight in varieties given AMF. This is presumably because AMF can help plants absorb nutrients such as nutrient P, which plays a role in replenishing seeds. This is in line with what was said by Napitupulu et al., (2013) which states that the role of phosphorus for plants is to accelerate and strengthen the growth of young plants in general, can accelerate flowering and ripening of fruit, kernel or grain, and can increase grain production.

The linear regression results of kernel weight per maize in each variety with the equation of value $Y = 9.22 + 3.22$ with a correlation between AMF doses and corn varieties is very strong at 0.97. This is due to the dose of AMF given to the growing media of each variety capable of increasing nutrient absorption such as P which can increase seed production per maize plant. While the value of determination obtained is equal to $R2 = 0.95$.

These results indicate that for seed weight per corn plant 95% is influenced by the AMF dose given while 5% is influenced by other factors such as abiotic factors. In addition to these factors, the most influential environmental conditions are temperature at the time of growth. Temperature can affect the maximum seed size so that later it can affect seed weight per plant. The maximum seed size can be reached at an average temperature of 25 °C.

Table.1: Analysis of Used Soil Coal Coal pH after Giving Various AMF Doses

AMF Doses (g)	Maize Varieties				
	Bisi-2	NK-99	P 3.2	Sukmaraga	Rata-rata
0	4,7	4,7	4,7	4,7	4,7 a
5	5,4	5,2	5,4	5,2	5,2 b
10	5,6	5,5	5,7	5,5	5,5 c
15	6,1	6,2	6,2	6,1	6,1 d
20	6,4	6,4	6,4	6,4	6,4 e
25	6,8	6,6	6,6	6,8	6,7 f
CV = 2,4 %					

Numbers followed by the same in the same lowercases column were insignificantly different according to DMRT with a p<0.05.

Table.2: Percentage of Root Infected Arbuscular Mycorrhizal Fungi (AMF) at the time of Corn Plant Aged 8 MST

AMF Doses (g)	Maize Varieties			
	Bisi-2	NK-99	P 3.2	Sukmaraga
		-----------(%)----------		
0	21,3a	20,5 a	20,5 a	21,6 a
	A	A	A	A
5	37,3 b	34,5 b	36,6 b	39,3 b
	A	A	A	A
10	44,5 c	50,5 c	44,0 c	42,5 b
	A	B	A	A
15	61,8 d	67,0 d	60,6 d	70,6 c
	A	B	A	B
20	78,8 e	79,0 e	80,0 e	81,1 d
	A	A	A	B
25	89,0 f	92,5 f	88,6 f	88,8 e
	A	B	A	A
CV = 5,1 %				

Numbers followed by the same in the same lowercases column and the same uppercases in the same row were insignificantly different according to DMRT with a p<0.05.

Table.3: Percentage of Infected Root Arbuscular Mycorrhizal Fungi (AMF) After Harvesting

AMF Doses (g)	Maize Varieties			
	Bisi-2	NK-99	P 3.2	Sukmaraga
		-------------(%)-------------		
0	26,3 a	21,6 a	21,0 a	19,8 a
	B	A	A	A
5	38,0 b	42,0 b	48,8 b	46,3 b
	A	A	B	B
10	46,8 c	49,0 c	43,8 c	43,3 c
	B	B	A	A
15	72,1 d	72,0 d	72,0 d	67,6 d
	B	B	B	A
20	89,8 e	92,3 e	91,6 e	87,6 e
	B	B	B	A
25	96,0 f	94,6 e	92,3 e	92,5 f
	B	B	A	A
CV = 3,3 %				

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Numbers followed by the same in the same lowercases column and the same uppercases in the same row were insignificantly different according to DMRT with a p<0.05.

Table 4. Effect of various doses of AMF application on kernel weight of four maize varieties grown in coal mining tailings.

AMF Doses (g)	Maize Varieties			
	Bisi-2	NK-99	P 3.2	Sukmaraga
		------------(%)-----------		
0	99,9 a	92,4 a	93,2 a	93,03 a
	B	A	A	A
5	125,7 b	118,2 a	117,4 b	113,6 a
	B	A	A	A
10	128,0 b	135,9 b	136,2 c	128,6 b
	A	B	B	A
15	143,6 c	150,3 c	152,7 d	152,9 c
	A	B	B	B
20	167,6 d	169,8 d	158,3 d	167,4 d
	B	B	A	B
25	179,8 e	175,0 e	174,5 e	173,2 e
	B	A	A	A
CV = 2,6 %				

Numbers followed by the same in the same lowercases column and the same uppercases in the same row were insignificantly different according to DMRT with a p<0.05.

IV. CONCLUSION

Giving mycorrhizae at a dose of 25 grams per plant is the best dose to increase the growth and yield of corn plants in coal mining tailings. Bisi-2 varieties is a that has high growth and yield with an average production of 179.8 per plant to be planted in coal mining tailings.

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