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The Effect of Arbuscular Mycorrhizae Fungi (AMF) *Glomus* sp. and Compost on Growth and Yield of Maize (*Zea mays* L.)

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Abstract: *Objectives of the research were to study the effect of Arbuscular Mycorrhizae Fungi could reduce the need of compost and increase the yield of maize. The research applied Split Plot Design by 3 replications. The main plot was AMF, which comprised of 2 levels: without AMF and AMF. Sub Plot was dosage of the compost, which comprised of 5 levels, such as: 0, 5, 10, 15 and 20 ton ha^{-1}. Result of the research showed significant interaction between AMF and compost on various observed parameters. On parameter of growth, AMF treatment and dosage of the compost 10 ton ha^{-1} have been able to increase leaf area, dry weight of root, dry weight of shoot and dry weight of cob, as well as reduce the need of compost for about 50%. On parameter of yield, AMF treatment and compost 15 ton ha^{-1} have been able to increase the weight of cob and weight of 100 seeds, as well as to reduce the need of compost for about 25%, while on weight of dry grains, the increasing dosage of compost up to 20 ton ha^{-1} has still been able to increase the yield. The application of AMF by dosage of compost 10 and 15 ton ha $^{-1}$ as better as in increasing weight of the corn grains.*
Keywords: *Arbuscular Mycorrhizae Fungi (AMF), compost fertilizer, maize (Zea mays* L.*)*

I. Introduction

Maize belongs to cereal crops, which is valuable as foodstuff, feed and biofuel. In Indonesia, the national production of maize in 2013 decreased 4.5% from 19.39 million ton in 2012 became 18.51 million ton (Ministry of Agriculture, 2014) [1]. Maize productivity decrease due to various problems in breeding, which frequently occur and one of them is nutrient availability in the soil. In general, the soil problem in tropical area relates to low level of organic materials content in the soil (Handayanto and Hairiah, 2007) [2].

Adding the organic fertilizer, which is derived from animal manure, does not only add the organic materials in the soil, but also contribute to nutrient availability, such as N, P, and K, as well as make the application of inorganic fertilizer become more efficient. In agricultural practices, full organic fertilization is highly difficult to be applied due to relative lesser amount of nutrient that contain in the organic material (Atmojo, 2010) [3]. Application of greater amount of organic fertilizers in the same time is difficult; therefore it requires an effort to reduce the organic fertilizer. Other effort that can be done to overcome condition of the soil as medium of the crop is the application of microbial-based technology. Arbuscular Mycorrhizae is an alternative that can be applied to increase the fertilization efficiency (Mosse, 1981) [4]. The role of AMF on roots would be able to increase ability of the root in absorbing P, efficient fertilization, assisting the growth and viability of the crop (Blal et al., 1997)[5].

II. Material And Method

The research was conducted at Dadaptulis Village – Junrejo, Batu – East Java, at the altitude of 560 m above sea level (asl) in Inceptisol soil, and temperature ranges 26^o – 29^o C. The research was started from September to December 2013. Materials of the research included: corn seed of BISI-18 variety, Arbuscular Mycorrhizae Fungi Glomus sp. using zeolite medium, cow manure, inorganic fertilizers of Urea, SP-36 and KCl. The research applied Split Plot Design by 3 replications, such as Main Plot: Arbuscular Mycorrhizae Fungi (M) that comprised of 2 levels, such as M0: without AMF and M1: AMF. Sub Plot: Compost (K) comprised of 5 levels, such as K0: 0 ton ha^{-1}, K1: 5 ton ha^{-1}, K2: 10 ton ha^{-1}, K3: 15 ton ha^{-1} and K4: 20 ton ha^{-1}. The application of AMF simultaneously with the seed planting for about 30 g plant^{-1} and application of compost fertilizer was given a week before planting. Urea fertilization was applied by dosage of 350 kg ha^{-1}, SP 36 by dosage of 300 kg ha^{-1} and KCl by dosage of 100 kg ha^{-1}. Observation on growth included: leaf area (cm^2), dry weight of root (g), dry weight of shoot (g) and dry weight of cob (g). Observation on harvest included: weight of cob (g), weight 100 seeds (g) and weight of grains (ton ha^{-1}). Chemical analysis on soil has been done before planting as presented in Table 1. Data of the observation was analyzed by analysis of variance (F-test) at the level 5% in order to find out the effect of treatment. If the result has non significant difference, it would be followed by LSD (Least Significant Difference) test by significant level of 5% to find out any difference among treatments.

Table 1. Chemical analysis on soil at Dadaptulis Village, Junrejo-Batu

Parameter	Value	Status
pH H_2O	7.33	Medium
C-organic (%)	0.90	Low
N (%)	0.078	Very low
Ratio C/N	11.54	Medium
P_2O_5 Olsen (ppm)	9.97	Low
K (me)	0.10	Low

III. Result And Discussion

Result for analysis of variance showed significant interaction between AMF treatment and compost fertilizer on variable of leaf area, dry weight of root, dry weight of shoot and dry weight of cob at 70 DAP (days after planting) as presented in Table 2 below.

Table 2. Mean of leaf area (cm^2), dry weight of root (g), dry weight of shoot (g) and dry weight of cob (g) due to interaction between AMF treatment and compost fertilizer at 70 DAP

Treatment	Leaf area (cm2)	Dry weight of root (g)	Dry weight of shoot (g)	Dry weight of cob (g)
M0K0	1242.32 a	5.76 a	20.15 a	4.87 a
M0K1	1366.47 a	6.24 ab	21.87 a	5.68 ab
M0K2	1464.31 ab	6.60 ab	22.16 ab	6.12 abc
M0K3	1470.85 ab	7.23 ab	25.56 bc	6.41 abc
M0K4	1720.55 bc	7.95 bc	28.15 c	7.40 c
M1K0	1305.42 a	5.54 a	22.46 ab	4.98 a
M1K1	1459.44 ab	7.63 b	27.93 cd	6.71 bc
M1K2	1748.29 bc	8.44 c	30.27 de	7.72 cd
M1K3	1953.94 c	9.23 c	31.70 de	8.53 d
M1K4	2002.84 c	9.64 c	32.33 e	9.10 d
LSD 5%	286.73	1.99	3.53	1.67

Notes : numbers followed by the same letter show non significant difference on LSD test of 5%

1.1 Leaf area

AMF treatment by the application of compost fertilizer 10 ton ha^{-1} has been able to increase leaf area and the result has non significant difference with dosage of compost 20 ton/ha without AMF. AMF treatment by dosages of 10, 15 and 20 ton ha^{-1} have the same results and good in increasing leaf area. Therefore, the application of compost 10 ton ha^{-1} has been able to increase leaf area and reduce the need of compost for about 50%.

1.2 Dry weight of root

AMF treatment by dosage of compost 10 ton ha^{-1} has been able to increase leaf area and the result has non significant difference with dosage of compost 20 ton ha^{-1} without AMF. For AMF treatment by dosages of 10, 15 and 20 ton ha^{-1} have the same results and good in increasing dry weight root. This is similar to the leaf area, in which the application of compost 10 ton ha^{-1} has been able to increase dry weight of root and reduce the need of compost for about 50%.

1.3 Dry weight of shoot

AMF treatment by dosage of compost 5 ton ha^{-1} has been able to increase dry weight of shoot in comparison with treatment without AMF, which requires dosage of 20 ton ha^{-1}. AMF treatment by dosages of 10, 15 and 20 ton ha^{-1} have non significant results. The result was parallel with the research by Jan et al. (2014) [6] that applied 1/2 dosage (half compost) and 1 dosage of compost (full compost), and both of them were good in increasing growth and yield of wheat.

1.4 Dry weight of cob

AMF treatment by compost of 5 ton ha^{-1} has been able to increase dry weight of ear and the result has non significant difference with treatment without AMF by dosage of 20 ton ha^{-1}. AMF treatment by dosages of compost 10, 15, and 20 ton ha^{-1} have not significantly different results in increasing dry weight of cob.
At 14 and 42 DAP, there was not interaction between AMF treatment and compost fertilizer on variables of leaf area, dry weight of root and dry weight of shoot as presented in Table 3 below.

Table 3. Mean of leaf area (LA), dry weight of root (DWR) and dry weight of shoot (DWS) due to AMF treatment and compost treatment at 14 and 42 DAP

Treatment	14 DAP			42 DAP	
	LA	DWR	DWS	LA	DWR
Without AMF	214.94	0.19 a	0.91	621.11	1.38
AMF	228.38	0.23 b	1.01	651.57	1.89
LSD 5%	ns	0.02	ns	ns	ns
Compost					
0	207.56 a	0.17 a	0.83 a	608.31 a	1.30 a
5	211.33 a	0.18 b	0.87 ab	622.50 b	1.44 a
10	215.99 a	0.21 b	0.92 b	637.21 c	1.65 b
15	228.33 b	0.23 c	1.02 c	647.01 c	1.80 bc
20	245.09 c	0.26 d	1.16 d	666.67 d	1.98 c
LSD 5%	13.3	0.02	0.08	13.89	0.22

Notes : numbers followed by the same letter show non significant difference on LSD test of 5%
ns = non significant difference

Table 3 shows that during initial growth at 14 DAP, treatment without AMF and AMF have non significant differences in increasing leaf area, as well as at 42 DAP. On variable of dry weight of root at 14 DAP, AMF treatment has shown significant difference in increasing the yield, but it has shown non significant difference at 42 DAP. Treatment using compost at 14 DAP by dosage of 20 ton ha^{-1} could increase the leaf area, while for dosages of 0, 5 and 10 ton ha^{-1}, the results have non significant differences. At 42 DAP, leaf area has increased by the application of 20 ton ha^{-1} compost, but dosages of 10 and 15 ton ha^{-1} have better results. Dry weight of root has the highest yield by the application of 20 ton ha^{-1} compost, but at 42 DAP by dosages of 15 and 20 ton ha^{-1}, they have the better results in increasing dry weight of root.

Variable for dry weight of shoot at 14 DAP has shown non significant different result, but at 42 DAP, an interaction has occurred among treatments. Table 4 below shows an interaction between AMF treatment and compost fertilizer at 42 DAP. On the treatment without AMF by the increasing dosage of compost 20 ton ha^{-1}, the result has non significant difference in increasing dry weight of shoot. On AMF treatment by dosages of compost 15 and 20 ton ha^{-1}, the results have significant difference with the treatment without compost, but they have insignificant difference with dosages of 5 and 10 ton ha^{-1}.

Table 4. Mean for dry weight of shoot (g) due to interaction between AMF treatment and compost fertilizer at 42 DAP

Days (DAP)	Treatment	Compost (ton ha^{-1})				
		0	5	10	15	20
42	Without AMF	3.40a	4.22ab	4.26ab	4.36ab	4.62ab
	AMF	4.17a	4.26ab	4.83ab	5.65b	6.60b
LSD 5%				2.43		

Notes : numbers followed by the same letter show non significant difference on LSD test of 5%

Result of the regression analysis for relationship between AMF treatment and compost fertilizer by the equation of M_0 : Y = 0.107X + 5.68 and R^2 = 0.984. AMF treatment by the increasing dosage of compost from 0 to 20 ton ha^{-1} could increase dry weight of root by looking at trend of the inclining graphic, the equation on M_1: Y = 0.196X + 6.134 and R^2 = 0.912 as presented in Figure 1 below.

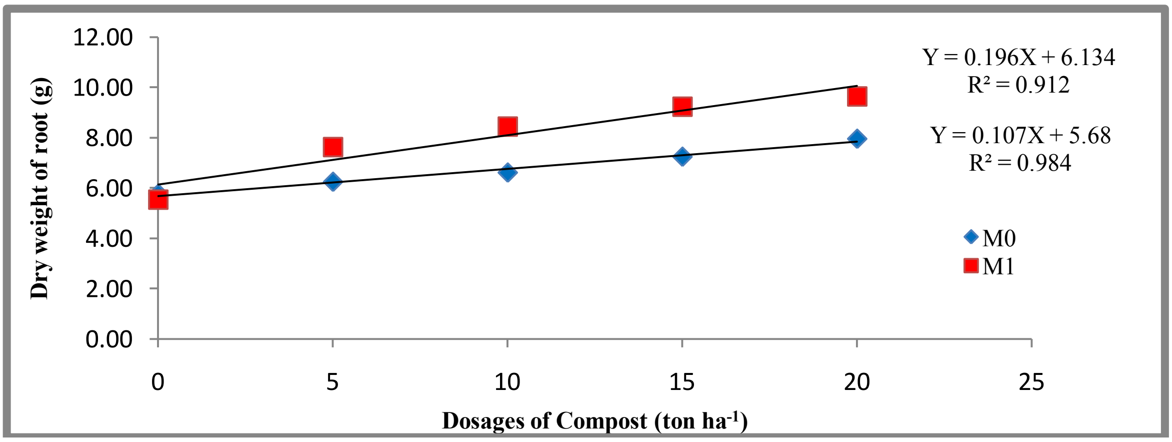

Figure 1. Relationship between dosages of compost and dry weight of root at 70 DAP on the treatment of M_0 (without AMF) and M_1 (AMF)

3.5 Weight of cob

AMF treatment by dosage of compost 0 ton ha^{-1} has resulted non significant difference with the treatment without AMF by dosage of compost 20 ton ha^{-1}. Dosages of compost 5, 10 and 15 ton ha^{-1} could increase weight of cob and resulted non significant difference. By dosage of 15 ton ha^{-1}, it has resulted non significant difference as dosage of 20 ton ha^{-1} with AMF treatment. By the application of 15 ton ha^{-1}, it has been able to increase weight of cob, so that it could reduce the need of compost for about 25%.

3.6 Weight of 100 seeds

AMF treatment by dosage of compost 0 ton ha^{-1} has resulted non significant difference as by the dosage of 10 ton ha^{-1} on treatment without AMF. As well as the dosage of 5 ton ha^{-1}, the result has non significant difference as the dosage of 15 ton ha^{-1} without AMF. For AMF treatment by dosage of compost 5 ton ha^{-1} has been able to increase weight of 100 seeds in comparison with the treatment without AMF that requires compost 15 ton ha^{-1}. By dosage of 15 ton ha^{-1}, the result has non significant difference as the dosage of 20 ton ha^{-1} by AMF treatment. By dosage of 15 ton ha^{-1}, it has been able to increase weight of 100 seeds and reduce the need of compost for about 25%.

3.7 Weight of grains

AMF treatment by dosage of compost 5 ton ha^{-1} has been able to increase weight of grains in comparison with treatment without AMF by dosage of 20 ton ha^{-1}. The increasing dosage of compost up to 20 ton ha^{-1} has still increased the yield. On AMF treatment by dosage of compost 10 ton ha^{-1} and 15 ton ha^{-1}, both of them have good results in increasing weight of grains (Figure 3).

Result for analysis of variance showed interaction between AMF treatment and the compost in observation on harvest at 106 DAP, which include : weight of cob, weight of 100 seeds and weight of grains (ton ha^{-1}) as presented in Table 5 below.

Table 5. Mean for weight of cob (g), weight of 100 seeds (g) and weight of grains (ton ha^{-1}) due to interaction between AMF treatment and compost at 70 DAP

Treatment	Weight of Cob (g)	Weight of 100 seeds (g)	Weight of Grains (ton ha^{-1})
M0K0	103.83a	22.37a	5.12a
M0K1	127.47a	22.66a	5.49a
M0K2	125.53ab	22.99ab	5.62a
M0K3	137.94ab	24.01bc	5.75ab
M0K4	155.06ab	24.63c	6.06b
M1K0	130.81ab	23.34ab	5.54a
M1K1	181.47bc	23.98bc	6.69c
M1K2	196.94c	24.83cd	7.78d
M1K3	233.69cd	25.68de	8.08d
M1K4	277.92d	26.009e	8.63e
LSD 5%	66.87	1.05	0.37

Notes : numbers followed by the same letter show non significant difference on LSD test of 5%

Result of the regression analysis on treatment without AMF by the equation : Y = 0.042X + 5.18 with R^2 = 0.960. AMF treatment by increasing dosage of compost from 0 to 20 ton ha^{-1} has been able to increase weight of grains for about three times in comparison with the treatment without AMF, by the equation Y = 0.146X + 5.938 with R^2 = 0.923 as presented in Figure 2 below.

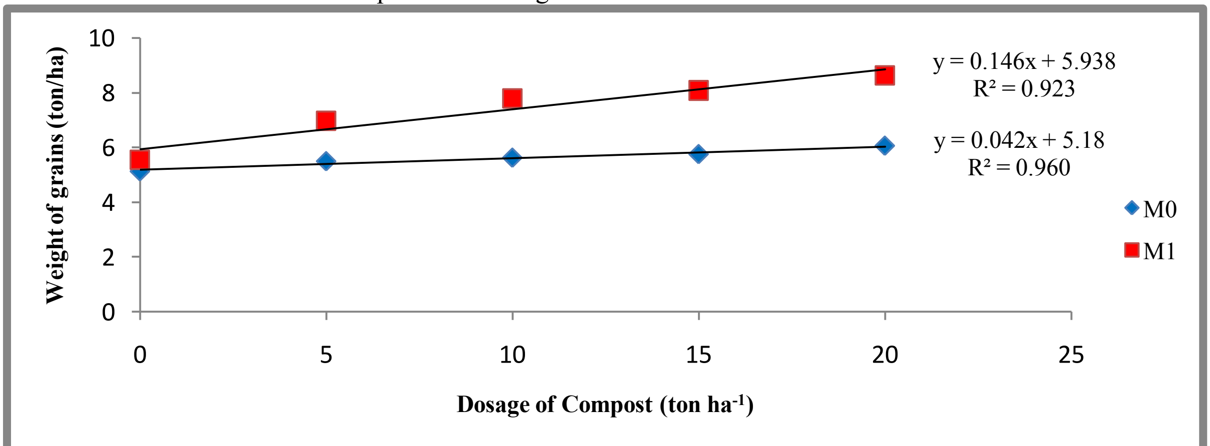

Figure 2 : Relationship between dosage of compost (ton ha^{-1}) and weight of grains (ton ha^{-1}) on treatment M0 (without AMF) and M1(AMF)

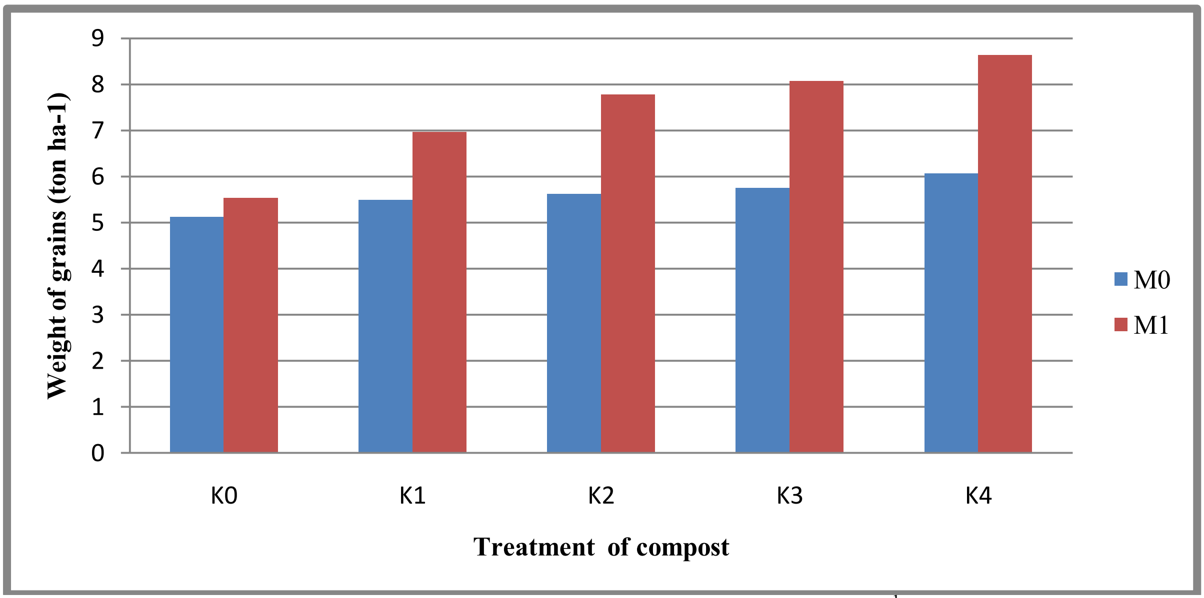

Figure 3 : Relationship between treatment of compost and weight of grains (ton ha^{-1}) on treatment M0 and M1

AMF and compost have significant effect on growth of plants, interactions occur in all variables of growth as observed on days of observation. AMF could provide positive effect that support growth of the plant because it could increase absorbability of water and nutrients, increase tolerance to nutrient deficiency in the soil that contain low organic materials and increase viability of the plant during early growth (Moelyohadi et al., 2012)[7]. AMF development is also affected by type of host and metabolism process that produces carbon from exudates of the plant's roots, which can be utilized for AMF development (Rungkat, 2009) [8]. Some positive effects, as a result of symbiosis with AMF, include: increasing absorbability of water and nutrients, particularly N, P, and K, resistance to pathogenic infection on root, tolerant to nutrient deficiency, increasing photosynthetic rate and increasing survivability during early growth (Widiastuti et al., 2003) [9].

Increasing yields for each dosage of compost with AMF are as follow: dosage 0 ton ha^{-1} is 8.20%, 5 ton ha^{-1} is 26.78%, 10 ton ha^{-1} is 38.43%, 15 ton ha^{-1} is 40.52% and 20 ton ha^{-1} is 42.41%. The increasing grain yield due to AMF and the organic acids would increase P availability in the soil and along with hypha AMF could increase the range of P adsorption per area unit. Increasing P availability in the soil and increasing adsorption would increase the yield because P is required in establishing and maturing the seeds during generative phase on maize. The increasing yield of corn's grains by AMF inoculation through external hypha has been able to extend the root's adsorption area, so that the plant would obtain sufficient nutrient supplies to increase the yield (De la Cruz, 1991) [10].

IV. Conclusion

AMF treatment and compost have significant effect on diverse parameters and days of observation. On parameter of growth, AMF treatment and compost by dosage of 10 ton ha^{-1} could increase leaf area, dry weight of root, dry weight of shoot and dry weight of cob, as well as reduce the need of compost for about 50%. On parameter of yield, AMF and compost 15 ton ha^{-1} have been able to increase weight of ear and weight of 100 seeds, as well as reduce the need of compost 25%, meanwhile for weight of grains, the increasing dosage 20 ton ha^{-1} has still increased the yield. The use of AMF by dosages of compost 10 ton ha^{-1} and 15 ton ha^{-1} show that both of them are good in increasing weight of grains on maize.

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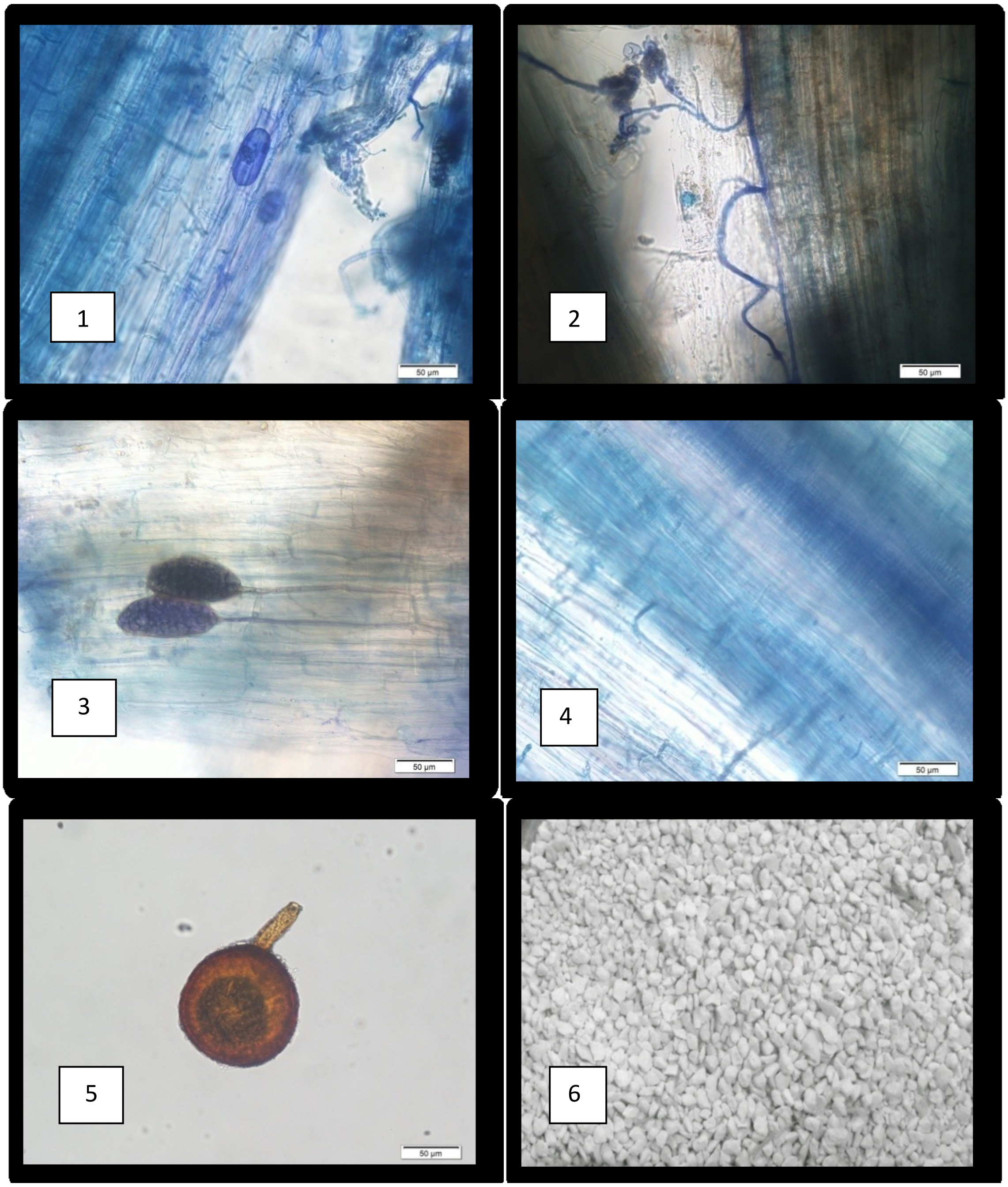
APPENDIX



Notes :

Fig. 1-3 : Arbuscular Mycorrhizae Fungi infection in maize roots
Fig. 4 : Maize roots uninfected of Arbuscular Mycorrhizae Fungi
Fig. 5 : Spores of Arbuscular Mycorrhizae Fungi Glomus sp.
Fig. 6 : Arbuscular Mycorrhizae Fungi using zeolith medium