Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2021.v26i2.87

Effect of Biocompost and Arbuscular Mycorrhizal Fungi on Chemical Properties of Inceptisols and Mychorrizal Root Infection in Purple Corn Plant

Yusra*, Rosnina and Dewi Sartika Aryani

Department of Agroecotechnology, Faculty of Agriculture, University of Malikussaleh
Jl. Cot Tengku Nie Reuleut, Muara Batu, Aceh Utara 24355, Indonesia
**email: yusra@unimal.ac.id*

Received March 16, 2021; Revised April 22, 2021; Accepted 27 May 2021

ABSTRACT

Inceptisols soil is categorized as underdeveloped soil which dominates agricultural lands in Indonesia. This soil exhibits minimal horizon, low pH (4.5-6.5), organic matter, and macro and micronutrients. However, the use of proper technology is believed can overcome these scarcities. The purpose of this study was to evaluate the application of bio compost and arbuscular mycorrhizal fungi (AMF) on the chemical properties of Inceptisols and root mycorrhizal infection on the purple corn plant. This research was conducted at Experimental Garden, Faculty of Agriculture, the University of Malikussaleh in Reuleut Village, Muara Batu District, Aceh Utara. The research was conducted in a Randomized Block Design (RBD) with a 4x3 factorial treatment. The first factor was bio compost dose with four levels which were B0 (0 Mg ha^{-1}, 0 g plot^{-1}), B1 (5 Mg ha^{-1}, 1500 g plot^{-1}), B2 (10 Mg ha^{-1}, 3000 g plot^{-1}), and B3 (15 Mg ha^{-1}, 4500 g plot^{-1}). The second factor was AMF (mycorrhiza *Gigaspora* sp.) with three levels which were M0 (0 Mg ha^{-1}, 0 g plot^{-1}, 0 g plant^{-1}), M1 (0.25 Mg ha^{-1}, 75 g plot^{-1}, 5 g plant^{-1}) dan M2 (0.5 Mg ha^{-1}, 150 g plot^{-1}, 10 g plant^{-1}). The bio compost and AMF increased soil pH from 5.0 to 5.5; the bio compost application improved the organic C (from 1.58% to 2.98%); the application of AMF improved the root mycorrhizal infection by 90%. The application of 5 Mg ha^{-1} bio compost and 0.5 Mg ha^{-1} mycorrhizae was the best dose to improve the chemical properties of Inceptisols and mycorrhizal infection in purple corn plant root.

Keywords: Biocompost, inceptisols, mycorrhizal fungi, purple corn

INTRODUCTION

Marginal or suboptimal soils such as Inceptisols possess low pH and nutrient contents. The N uptake is reduced due to lower pH and drought. Drought stress in plants will physiologically affect photosynthesis activity, contributing to lower photosynthate production, leading to yield deterioration. Acidic pH, moderate organic C, and low nutrients (N, P, and K) are thought to be the cause of the yields loss (Mulyani *et al.* 2017; Aliyu *et al.* 2020; Patra *et al.* 2020) and also limiting factors related to chemical and biological properties of the soil. Therefore, the use of Arbuscular Mycorrhizal Fungi (AMF) is considered one of the best ways to improve the fertility of inceptisol soils (Nurbaity *et al.* 2019).

Inceptisol soils are usually considered arable with appropriate control of erosion or drainage and can be used for agricultural fields. They can be improved by applying soil reinforcement, adding some organic materials, enhancing nutrients, and stimulating the beneficial living microorganisms in the soil (Funderburg 2020). The application of biocompost is believed to enhance the nutrients in the soil and activate the microorganisms in the soils, contributing to the increase of marginal soil productivity. The presence of beneficial microorganisms, such as bacteria and fungi, in the soils helps to reinstate the degraded soils/lands (Kumar *et al.* 2017; Sinha *et al.* 2017; Cremeneac and Boclaci (2018); Barkha *et al.* 2020; Bertham *et al.* 2020).

The application of mycorrhizae also contributes to soil improvement. Its hyphae generate the physical properties of soil by loosening the soil. Previous research has found that this living organism helps plants expand the plant's room and absorption area, helping them reach farther into the soil to absorb the water and nutrients under drought stress (Zhang *et al.* 2018; Püschel *et al.* 2020; Hou *et al.* 2021). Wright and Upadhyaya (1998) also stated that mycorrhizal hyphae produce glomalin content, and organic acids composing micro aggregates become macro aggregates absorbed by plants.

Maize (*Zea mays* L.) is a promising food crop that can be grown in Inceptisol soil. However, maize productivity is influenced by a complex interaction between its plant characteristics and environment, such as soil. The low yield of maize planted in Inceptisol soil is contributed by lower soil fertility, where it possesses lower organic materials, pH, lower nutrients such as N, P, K, Mg, and Ca, and higher Fe and Al (Soepardi 1983). Therefore, the growth and yield of maize depend on the way we treat and manage the soil. Several maize varieties have been developed in Indonesia. One of the essential maize varieties is purple maize/corn (*Zea mays* var. *ceratina* Kulesh). Mahendradatta & Tawali (2008) informed that purple corn could be developed due to its high amylopectin, sweet taste, fluffy appearance, and exciting aroma.

Therefore, the research aimed to evaluate the practical application of biocompost and mycorrhizal fungi on the chemical properties of Inceptisols and the root mycorrhizal infection of purple corn plants in suboptimal soil.

MATERIALS AND METHODS

Study Site

The research was conducted at Experimental Garden, Faculty of Agriculture, the University of Malikussaleh in Reuleut Village, Muara Batu District, Aceh Utara Regency.

Experimental Design

A field experiment was conducted. The study employed a Randomized Block Design (RBD) with two factors. The first factor was biocompost (B) with 4 level dose: B0 (0 Mg ha^{-1}, 0 g plot^{-1}), B1 (5 Mg ha^{-1}, 1500 g plot^{-1}), B2 (10 Mg ha^{-1}, 3000 g plot^{-1}) and B3 (15 Mg ha^{-1}, 4500 g plot^{-1}). The second factor was mycorrhizal fungi *Gigaspora* sp. (M) with 3 three-level dose: M0 (0 Mg ha^{-1}, 0 g plot^{-1}, 0 g plant^{-1}), M1 (0.25 Mg ha^{-1}, 75 g plot^{-1}, 5 g plant^{-1}) and M2 (0.5 Mg ha^{-1}, 150 g plot^{-1}, 10 g plant^{-1}). There were 12 experimental units with three replications, which resulted in 36 experimental units in total.

At the beginning of the research, sample soils were taken for laboratory analysis to check the initial soil chemical properties. The field experiment was started by tilling the soil, incubated for one week, and then the soil was treated with 5 Mg manure ha^{-1} as a base treatment. Then, the maize was planted, and the biocompost and mycorrhizal fungi were applied. At 45 days after planting, the soils were analyzed for pH (H_2O), pH (KCl), Organic C (%), Total P (%), cations exchange capacity (me 100g^{-1}), exchangeable aluminum (me 100g^{-1}), exchangeable hydrogen (me 100g^{-1}) and root mycorrhizal infection (%).

Soil Chemical Analysis

The initial soil properties of Inceptisols are described in Table 1; the soil chemical properties are low. The Inceptisols soil in Reuleut Village, Aceh Utara, has acidic pH, low organic C, total P, and cation exchange capacity (CEC). These results indicated that this soil needed organic materials to increase its organic C and CEC to support the maize growth.

Table 1. Initial soil chemical properties of Inceptisols in Reuleut Village.

No.	Soil properties	Value	Category
1	pH (H_2O)	5.0	Acidic
2	pH (KCl)	4.3	Strongly acidic
3	Organic C (%)	1.58	Low
4	Total P (mg 100g^{-1})	12.17	Low
5	Cation exchange capacity (me 100g^{-1})	12.78	Low
6	Exchangeable aluminum (me 100g^{-1})	0.73	-
7	Exchangeable hydrogen (me 100g^{-1})	1.46	-

Source: Balai Penelitian Tanah (2009)

Statistical Analysis

The data collected were analyzed using the F test (Gomez and Gomez 1995). Then, significant differences were performed using Duncan Multiple Range Test (DMRT) at a 5% probability level.

RESULTS AND DISCUSSION

The result of ANOVA about the effect of biocompost and mycorrhizal fungi on soil chemical properties of Inceptisol is presented in Table 2. The results showed that the application of biocompost significantly affected soil pH (H_2O) and organic C. While, the application of mycorrhizal fungi significantly affected the mycorrhizal root infections. Furthermore, there was an interaction between the application of biocompost and mycorrhizal fungi on the increase of soil pH (H_2O); however, no interaction on other variables.

Effect of Biocompost and Mycorrhizal Fungi on Soil Chemical Properties of Inceptisols

The ANOVA results showed that the application of biocompost and mycorrhizal fungi had no significant effect on variables observed, except on soil pH (H_2O) (Table 2). Effect the application of biocompost and mycorrhizal fungi on pH (H_2O), pH (KCl), organic C, and total P of Inceptisol soil in Reuleut Village is presented in Table 3. There was a slight increase in the soil pH at 45 days compared to the initial pH value. The application of biocompost enormously increased the organic C (low to moderate), while total P slightly increased, although it did not change its category.

Table 2. The effect of application of biocompost and mycorrhizal fungi on soil chemical properties of inceptisols in Reuleut Village and mycorrhizal infection.

No	Soil properties	Bio compost	Mycorrhizal fungi	Interaction
1	pH (H_2O)	*	ns	*
2	pH (KCl)	ns	ns	ns
3	Organic C	**	ns	ns
4	Total P	ns	ns	ns
5	Cation exchange capacity (me $100g^{-1}$)	ns	ns	ns
6	Exchangeable aluminum (me $100g^{-1}$)	ns	ns	ns
7	Exchangeable hydrogen (me $100g^{-1}$)	ns	ns	ns
8	Mycorrhizal infection (%)	ns	**	ns

*significant, **highly significant, ns = non-significant

Table 3. The effect of biocompost and mycorrhizal fungi on pH (H_2O), pH (KCl), C-Organic, and P-total of inceptisol soils in Reuleut Village.

Treatment	pH (H_2O)	pH (KCl)	Organic C (%)	Total P (mg $100g^{-1}$)
B_0M_0	4.8 c	3.8	2.96	12.56
B_0M_1	4.9 c	4.0	2.30	13.70
B_0M_2	5.1 bc	3.8	2.99	18.87
B_1M_0	5.1 bc	3.9	2.60	18.87
B_1M_1	5.3 ab	3.9	2.41	15.91
B_1M_2	5.5 a	3.3	2.95	19.39
B_2M_0	5.2 abc	3.8	2.70	14.78
B_2M_1	5.0 bc	4.0	2.81	13.65
B_2M_2	5.2 abc	4.1	2.61	17.39
B_3M_0	5.2 abc	4.2	3.15	14.78
B_3M_1	5.3 ab	4.1	3.39	16.65
B_3M_2	5.2 abc	4.1	3.46	18.87

Note: B = Biocompost; M = Mycorrhizal fungi; B0 (0 Mg ha^{-1}); B1 (5 Mg ha^{-1}); B2 (10 Mg ha^{-1}); B3 (15 Mg ha^{-1}); M0 (0 Mg ha^{-1}); M1 (0.25 Mg ha^{-1}); M2 (0.5 Mg ha^{-1})

The application of biocompost and mycorrhizal fungi significantly increased the soil pH (H_2O). The best pH value (5.5) was revealed by applying biocompost 5 Mg ha^{-1} and mycorrhizal fungi 0.5 Mg ha^{-1}. The slow improvement of soil pH is linked to the characteristic of biocompost as a buffer to the soil. Organic matter is also a factor affecting the soil pH. With an increase in organic matter, the soil recovers its natural buffer capacity, increasing pH in acid soils. At low pH, aluminum becomes soluble, and organic matter forms together with aluminum, which is the primary soil pH buffering capacity. At high pH, the organic matter contributes to soil acidification by binding with non-acidic cations such as Ca^{2+} and Mg^{2+}, which they can be easily lost to leaching (Husson 2013). Stevenson (1994) confirmed that humus soils contain some functional groups (carboxyl, phenolic OH), which play a pivotal role in regulating cation exchange in soil, contributing to constant H^+ and unchanged acidic soil.

Karnilawati *et al*. (2013) stated that the mycorrhizal fungi applied in the soil could be associated with plant roots, improving soil structure and maintain better soil pH. The increase of soil pH due to mycorrhizal fungi application has proven to produce several compounds which can bind soil metals such as Al, Fe, dan Mn. The improvement of organic C due to biocompost application resulted from the release of organic C of biocompost itself. The result is in line with Arifiati *et al*. (2017) that an increase of organic C is caused by the release of organic C from the application of biocompost. The difference in organic matter value is attributed to biocompost application and its decomposition by microorganisms in the soil. Sutanto (2002) explained that organic matter produced by organic fertilizer has been using by living microorganisms in the soil as the source of energy and reproduction, and their population determines the amount of organic matter in the soil.

Total P in the soil has increased even though it was still considered low and insignificant, from 12.17 mg 100 g^{-1} to 19.39 mg 100 g^{-1} (B1M2 treatment). However, the addition of mycorrhizae was able to fix the roots of maize plants. In addition, a mycorrhizal fungus used in this study, *Gigaspora* sp., was able to exhibit a good effect on plant growth and root infection. The result follows the research of Chalimah *et al*. (2007), who stated that the application of mycorrhizal fungi *Gigaspora* sp. has increased plant biomass, the number of spores, and root infection. Research by Fitter and Hay (1991) and Lakitan (2000) stated that the fungus *Gigaspora* sp. hyphae penetrate the cells of the host plant's cortex from one cell to another so that they are strong enough to transfer the nutrients from the soil to plants and to free the carbon and phosphorus elements so that plants can utilize them to increase plant biomass, number of spores and also the degree of root infection. According to Bakhtiar (2002), mycorrhizal colonization is influenced by the type of spore. The ability of spores to infect, its effectiveness and compatibility with the host, and environmental factors, influence the root colonization.

Table 4. Effect of biocompost and mycorrhizal fungi on cation exchange capacity, exchangeable aluminum, exchangeable hydrogen of inceptisols, and mycorrhizal infection

Treatment	Cation exchange capacity (me 100g^{-1})	Exchangeable aluminium (me 100g^{-1})	Exchangeable hydrogen (me 100g^{-1})	Mycorrhizal colonization (%)
B_0M_0	14.55	0.96	0.39	20.00
B_0M_1	16.72	0.52	0.41	60.00
B_0M_2	16.54	0.46	0.46	73.33
B_1M_0	18.72	0.34	0.43	43.33
B_1M_1	20.02	0.34	0.34	63.33
B_1M_2	21.72	0.88	0.24	63.33
B_2M_0	18.11	0.36	0.36	16.67
B_2M_1	16.51	0.34	0.27	63.33
B_2M_2	15.81	0.68	0.44	53.33
B_3M_0	15.37	0.48	0.26	23.33
B_3M_1	13.48	0.66	0.66	56.67
B_3M_2	18.46	0.54	0.54	90.00

Note: B = Biocompost; M = Mycorrhizal fungi; B0 (0 Mg ha^{-1}); B1 (5 Mg ha^{-1}); B2 (10 Mg ha^{-1}); B3 (15 Mg ha^{-1}); M0 (0 Mg ha^{-1}); M1 (0.25 Mg ha^{-1}); M2 (0.5 Mg ha^{-1}).

The results of the application of biocompost and mycorrhizal fungi on cation exchange capacity (CEC), exchangeable aluminum, exchangeable hydrogen, and mycorrhizal colonization are presented in Table 4. The cation exchange capacity demonstrated an increase, even though it was not significant. In contrast, it has shown a decrease in exchangeable aluminum and exchangeable hydrogen generally. However, the application of mycorrhizal fungi alone has improved the purple corn, indicated by a high percentage of fungal colonization on its roots.

Total P and CEC possessed a non-significant increase. The highest total P (19.39 mg 100g^{-1}) was revealed by applying biocompost 5 Mg ha^{-1} and mycorrhizal fungi 0.5 Mg ha^{-1}. This improvement was considered low and insignificant due to different biocompost application doses and P in organic matter (Arifin *et al.* 2000). Furthermore, this organic matter is also able to influence the soil CEC by donating anions. Besides, organic matter can increase P availability, especially in soil with high hydroxide Al and Fe and colloidal properties (Yusra 2010).

Effect of Biocompost and Mycorrhizal Fungi on Mycorrhizal Root Infection of the Purple Corn Plant

The result of the application of biocompost and mycorrhizal fungi on mycorrhizal colonization is shown in Table 4. Mycorrhizal colonization on the treated roots of the purple corn plant was found to be high (90%) compared to control, demonstrated by the application of biocompost 15 Mg ha^{-1} and mycorhizal fungi 0.5 Mg ha^{-1} (Figures 1, 2 and 3). This finding corroborates with researches by Rajapakse and Miller (1992) and Ayu *et al.* (2015), where 76 % - 100% of mycorrhizal infection is considered a high percentage. Ningrum *et al.* (2013) also added that this high percentage caused by photosynthesis activity, where the photosynthate is distributed to the roots as a source of carbon to mycorrhizal fungi, enabling them to produce spores in a more tremendous amount. Therefore, it can be said that the symbiotic relationship between mycorrhizal fungi and purple

Figure 1. Untreated roots (AMF 0 Mg ha^{-1}).

Figure 2. Root treated with AMF 0.25 Mg ha^{-1}.

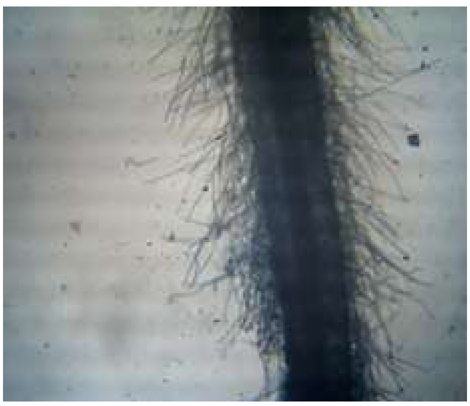

Figure 3. Root treated with AMF 0.5 Mg ha^{-1}.

corn roots is essential in producing high yields (Bi *et al.* 2018; Pinos *et al.* 2019).

Overall, several factors are affecting these insignificant and low results of organic C, total P, and CEC in the Inceptisol soil in Reuleut, Aceh Utara Regency, such as the delay soil response of treatment applied due to shallow soil, weak soil weathering, which just sufficient for mild development and they commonly found either with underlying weathering-resistant parent material, for example, opaque, quartzite and siliceous sands (Pinto *et al.* 2016; Muslim *et al.* 2020).

CONCLUSIONS

The application of biocompost and mycorrhizal fungi has increased soil pH (H_2O) from 5.0 to 5.5. On the other hand, the application of biocompost improved the organic C from 1.58% to 2.98%. *Gigaspora* sp. has been found to increase the root colonization up to 90% even though the total P was categorized low. The application of biocompost 5 Mg ha^{-1} and mycorrhizal fungi 0.5 Mg ha^{-1} was the best treatment to improve the chemical properties of inceptisols in Reuleut Village and enhance the roots mycorrhizal infection of the purple corn plant.

ACKNOWLEDGMENTS

We thank Universitas Malikussaleh for providing the research grant through PNBP funding with contract no. 246/PPK-2/SPK-JL/2020.

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