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Effect of soil conditioner enriched with biofertilizers to improve soil fertility and maize (*Zea mays* L.) growth on andisols Sinabung area

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Abstract: Andisol soil contains a lot of heavy metals Al and Fe, which results in P being unavailable to plants and can cause low soil pH, this will inhibit plant growth. One effort that can be made to increase the availability of nutrients in the soil is by utilizing soil enhancing ingredients enriched with biological fertilizers. The research design used was factorial randomized block design (RBD) consisting of: Factor I: (biological fertilizers) M0 = without application, M1 = *Talaromyces pinophilus* (Hedgecock), M2 = *Azotobacter* sp, M3 = Mycorrhizae, M4 = *Talaromyces pinophilus* + mycorrhizae + *Azotobacter* sp. Factor II Soil enhancing ingredients, namely P0 = Without Soil Improvement, K1 = Zeolite 50 g, K2 = Humic acid 50 ml, K3 = compost / manure fertilizer for agriculture 50 g. From the results the combination of microbial treatment and soil conditioner can increase nitrogen in the soil by 2-40.81 %, cation exchange capacity by 1.7-44.29 % and P available by 1.3-49.36 %. Soil conditioner combined with biological fertilizers can improve soil quality in general, the best treatment is a combination treatment of *T. pinophilus* + mycorrhizae + *Azotobacter* sp. with coffee skin (M4P4).

Key words: andisol; biological fertilizers; maize; soil conditioner; soil fertility

Dodatek izboljševalcev tal obogatenih z biognojili izboljša rodovitnost tal in rast koruze (*Zea mays* L.) na andisolih na območju Sinabung, Indonezija

Izvleček: Andisoli vsebujejo veliko težkih kovin, Al in Fe, kar povzroča nedostopnost P rastlinam in lahko zniža pH tal in s tem zavira rast rastlin. Eden od načinov za povečanje razpoložljivosti hranil v takšnih tleh je uporaba talnih izboljševalcev obogatenih z biognojili. Poskus v raziskavi je bil popolni naključni bločni poskus, ki je obsegal naslednja obravnavanja: obravnavanje I: (biognojila) M0 = brez gnojil, M1 = *Talaromyces pinophilus* (Hedgecock), M2 = *Azotobacter* sp., M3 = mycorrhiza, M4 = *Talaromyces pinophilus* + mycorrhizae + *Azotobacter* sp. Obravnavnaje II- z dodatki izboljševalcev tal: P0 = brez izboljševalcev tal, K1 = zeolite 50 g, K2 = huminska kislina 50 ml, K3 = kompost / kurji gnoj 50 g. Rezultati so pokazali, da je kombinacija obravnavanja z mikrobi in talnimi izboljševalci povečala vsebnost dušika v tleh za 2 do 40,81 %, kationska izmenjevalna kapaciteta se je povečala za 1,7-44,29 % in vsebnost dostopnega fosforja za 1,3 do 49,36 %. Izboljševalci tal v kombinaciji z biognojili lahko na splošno izboljšajo kvaliteto tal. V poskusu je bilo najboljše obravnavanje *T. pinophilus* + mycorrhizae + *Azotobacter* sp. z dodatki ostankov iz pridelave kave (M4P4).

Ključne besede: andisol; biognojila; koruza; izboljševalci tal; rodovitnost tal

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1 INTRODUCTION

The accumulation of organic matter and the occurrence of organic matter complexes with Al are characteristic of some andisol soils. The research results of Ritonga et al (2015) and Sembiring et al. (2016), stated that the pH of andisol soil affected by the eruption of Mount Sinabung ranges from 3.7 to 4.7 which is in the very acidic category. The low pH of the soil affected by the eruption of Mount Sinabung results that the availability of P in the soil can be hampered. One effort that could be made to increase nutrient availability and andisol soil fertility is by applying soil conditioner enriched with biological agents, namely organisms that are useful in increasing the availability of nutrients for plants. According to Sembiring et al. (2016; 2017a; 2017b), application of phosphate solvent microbes (*Talaromyces pinophilus*) can increase the availability of P by 9.63 to 49.78 % in andisol soil. Observations of Marbun et al. (2015), shows that application of phosphate solvent fungi and organic matter can increase P uptake and potato plant growth on andisol soil affected by the eruption of Mount Sinabung. According to Sembiring et al. (2018), Hijikata et al. (2010), Kikuchi et al. (2014) application of mycorrhizae can improve plant growth. Application of *Azotobacter* can increase plant growth (Kizilkaya, 2009; Patil et al., 2011; Ponmurugan et al., 2012).

Agricultural development in Indonesia is faced with soil quality problems which are generally classified as low, characterized by problems with poor nutrients and organic matter, high soil acidity, and soil physical properties that do not support plant growth. High soil fertility shows high soil quality (Biswas and Kole, 2017; Doran and Parkin, 1994). Soil quality is the capacity of the soil which functions to maintain crop productivity. Good soil quality will support soil function, working as a medium for plant growth, regulate and divide water flow and support a good environment (Krener, 2013; Pal, 2016).

Soil conditioner is a material that can be used to accelerate the recovery / improvement of soil quality. Organic matter, besides being able to function as a source of nutrients, s functions as a soil conditioner has also been widely proven. In addition to organic soil conditioner, there are mineral soil conditioner that can be used to improve soil quality. Zeolite is a mineral material that can be used as a soil conditioner (Suwardi and Goto, 1996; Juarsah, 2016). Application of zeolite can increase the efficiency of fertilization, cation exchange capacity (CEC), soil potassium, P availability and plant growth (Juarsah, 2016; Balqies, et al., 2018). Cover crops that produce organic materials play an important role in improving soil quality because they protect the soil from erosion, and create suitable environmental conditions for microbial habitats that play a role in nutrient cycling (Marzaioli et al., 2010; Krener, 2013). Maize is a plant that can be used as an indicator because it requires fertile soil to produce properly. This is because maize plants need nutrients, especially nitrogen (N), phosphorus (P) and potassium (K) in large quantities. In general, maize plants require loose soil, fertile and rich in organic matter. Therefore this study aims to improve soil fertility and growth of maize using a soil conditioner and biofertilizers.

2 MATERIALS AND METHODS

Research was carried out in Kuta Rayat Village, Karo Regency. Indicator plant used was maize variety Super Sweet. The research was conducted for 3 months. The andisol soil characteristics used were: pH 4.56, 4.8 % organic C (Walkey and black titration method) P availability is at 67.28 ppm (Bray II method), soil N is at 0.55 % (Kjedahl-Titrimetry Method) and CEC 19.87 %me kg^{-1}. Materials used were: *T.pinophilus* (Hedgecock) Samson et al., *Azotobacter* sp. and mycorrhiza *(Glomus* sp.*)* used were obtained from the Laboratory of Soil Biology, Faculty of Agriculture, University of Sumatera Utara.

The research design used factorial randomized block design (RBD) with two factors and three replications. Factor I was biofertilizers consisting of treatments M0 = without application, M1 = 30 g *T.pinophilus* (18 x 10^9 CFU g^{-1}), M2 = 30 g mycorrhiza (*Glomus* sp.), M3 = 30 g *Azotobacter* sp. (18 x 10^9 CFU g^{-1}) and M4 = 10 %g *T. pinophilus* + 10 g mycorrhiza + 10 g *Azotobacter* sp.. Factor II: material for soil conditioner (application 50 %g/plant, equivalent to 1t ha^{-1}), P0 = without soil conditioner, P1 = zeolite, P2 = humic acid, P3 = chicken manure and P4 = coffee shell. Plot size 0.6 x 4.20 m, the distance between plots within a block was 30 cm and spacing between blocks was 50 cm. Soil conditioner application was carried out 2 weeks before the corn plant was planted by applying it to the planting hole and then mixed evenly. Application of biofertilizers was carried out after 1 week of plant growth by applying it around the plant roots. Basis fertilizers used were urea 3 g, super phosphat 36 (SP 36) and KCl 5 g/plant application was carried out 2 day before the corn plant was planted by applying it to the planting hole and then mixed evenly.

2.1 DATA COLLECTION

Phosphorus analysis (P) availability in soil with Bray II method, soil N nutrient content, soil K nutrient content in 25 % HCl, cation exchange capacity (CEC), soil pH, microbial population, nutrient content of N, P, K of plants and plant dry mass all parameters observed at the end of the vegetative period. Soil and plant samples were taken after plant growth for 45 days. By taking 1 sample/plot where the sample is randomly determined at the beginning of plant growth.

2.2 STATISTICAL ANALYSIS

Statistical analysis used to see the effect of treatment was carried out on F test at the level of 5 % and continued with LSD test at 5 % level (Gomez and Gomez, 1984).

3 RESULTS AND DISCUSSION

3.1 RESULTS

The results of observations and statistical analysis of soil conditioner applications and biological agents on all parameters of observation, can be seen in Table 1 and Table 2. Application of biological fertilizers had no significant effect on increasing soil pH, soil total N, soil K and soil CEC but had significant effect ($p \leq 0.05$) on available P in soil (Table 1). Application of biological agents (M) can increase the availability of phosphorus (P) in soil. Soil conditioner have a significant effect ($p \leq 0.05$) on the soil K content and plant dry mass, zeolite treatment (P1) increases soil K levels for 24.34 % when compared with no application (P0). The treatment combination of soil conditioner and biological fertilizers can increase cation exchange capacity for 44.29 % when compared with control (Figure 1), soil N content, the best treatment was *T.pinophilus* and coffee peels (M1P4) increased soil N content by 40.81 % (Figure 2) and available P for 49.36 % when compared to control (Figure 3).

Application of biofertilizers increases nutrient content of N, P, K in plants and plant dry mass (Table 2). The application of *T. pinophilus* + mycorrhizae + A*zotobacte*r sp. (M4) increases the nutrient P content in plants by 19.81 % and plant dry mass by 25.94 % when compared with the control. Application of mycorrhiza and zeolite (M3P1) can increase potassium (K) content in soil by 19.10 % (Figure 4). The treatment combination of soil conditioner and biological fertilizers can increase nutrient K content in plants (Figure 5), Treatment of *T. pinophilus* + mycorrhizae + *Azotobacter* sp. (M4) and coffee skin increase nutrient K content in plants by 28.83 % and plant dry mass by 25 % when compared to control.

Table 1: Average of soil pH, microbial population, levels of N, P, K soil and CEC treatment of soil conditioner enriched with biofertilizers

Treatment	Soil pH	Microbial Population (10^8 CFU g^{-1})	Soil N (%)	P-Available (mg kg^{-1})	Soil K (mg kg^{-1})	CEC (mol kg^{-1})
Biofertilizers (M)						
M0	5.46±0.24	33.53±11.48a	0.58±0.05	93.69±27.64a	601.19±54.07	19.38±2.34
M1	5.41±0.13	44.87±9.80bcd	0.56±0.08	118.07±15.26ab	581.46±52.72	19.81±2.39
M2	5.53±0.05	44.13±8.35ab	0.53±0.04	84.86±8.34a	563.24±110.07	18.12±1.60
M3	5.47±0.17	38.93±8.74a	0.56±0.06	101.99±19.16a	610.20±168.77	19.87±2.72
M4	5.61±0.10	44.47±13.24abc	0.55±0.03	100.63±26.02a	611.74±71.06	19.27±1.73
Soil conditioner (P)						
P0	5.5±0.17	39.53±10.93a	0.52±0.05	101.34±19.76	562.93±59.10a	18.44±1.22a
P1	5.46±0.18	41.80±7.78a	0.57±0.05	103.83±20.48	700.74±115.48b	21.16±2.84ab
P2	5.45±0.21	39.6±11.86a	0.56±0.05	103.84±17.26	567.23±73.34a	19.96±1.86a
P3	5.59±0.07	45.07±11.70ab	0.56±0.04	88.49±24.95	568.21±77.67a	18.76±2.01a
P4	5.47±0.15	39.93±13.59a	0.57±0.08	101.72±30.37	568.74±85.46a	19.13±2.20a
M	NS	*	NS	*	NS	NS
P	NS	*	NS	NS	*	*
MxP	NS	NS	*	*	*	*
CV%	6.38	27.67	10.34	27.8	10.17	11.89

Description: *significant at $p \leq 0.05$ and NS Not significance. Means in a column followed by a common letter are not significantly different at the level 0.05 level by LSD. M0 = without application, M1 = *Talaromyces pinophilus*, M2 = *Mycorrhizae*, M3 = *Azotobacter* sp., M4 = *T. pinophilus* + Mycorrhizae + *Azotobacter* sp., P0 = without soil conditioner, P1 = zeolite, P2 = humic acid, P3 = chicken manure and P4 = coffee skin.

Table 2: Average of N, P, K nutrient content in plants and plant dry mass in soil conditioner treatment enriched with biofertilizers

Treatment	N nutrient content in plant (%)	P nutrient content in plant (%)	K nutrient content in plant (%)	Plant dry mass (g)
Biofertilizers (M)				
M0	1.32±0.11	0.222±0.06a	2.42±0.23	206.46±41.69b
M1	1.52±0.23	0.256±0.03a	2.31±0.14	211.19±37.95c
M2	1.34±0.18	0.257±0.02b	2.44±0.28	236.53±45.45d
M3	1.32±0.13	0.261±0.02ab	2.22±0.34	200.02±33.20a
M4	1.42±0.21	0.266±0.02bc	2.34±0.33	260.02±28.06e
Soil conditioner (P)				
P0	1.35±0.22a	0.241±0.03a	2.21±0.39a	207.69±43.19a
P1	1.23±0.11a	0.251±0.02a	2.36±0.25ab	205.14±36.20a
P2	1.38±0.17a	0.266±0.03a	2.45±0.21bcd	230.77±49.94d
P3	1.49±0.19bc	0.273±0.01ab	2.28±0.17a	210.53±35.29bc
P4	1.47±0.13ab	0.231±0.05a	2.43±0.27abc	260.09±27.22e
M	NS	*	NS	*
P	*	*	*	*
MxP	NS	NS	*	NS
CV	18.4	15.9	9.74	22.09

Description: *significant at $p \leq 0.05$ and NS Not significance. Means in a column followed by a common letter are not significantly different at the level 0.05 level by LSD. M0 = without application, M1 = *Talaromyces pinophilus*, M2 = *Mycorrhizae*, M3 = *Azotobacter* sp, M4 = *T. pinophilus* + *Mycorrhizae* + *Azotobacter* sp, P0 = without soil conditioner, P1 = Zeolite, P2 = Humic acid, P3 = Chicken manure and P4 = Coffee skin.

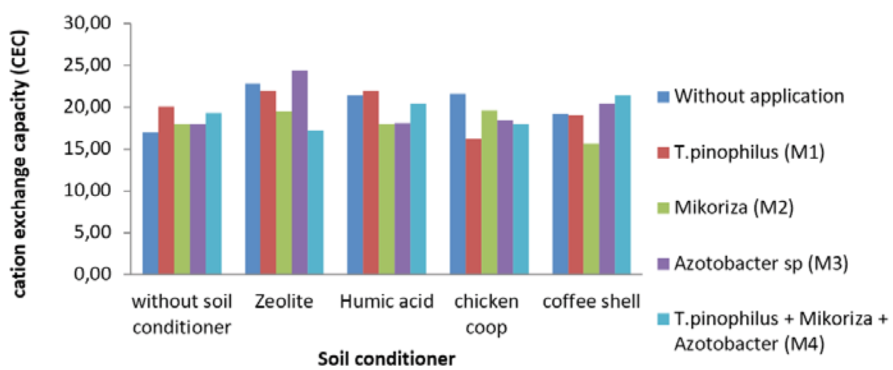

Figure 1: Interaction of soil conditioner and biofertilizers to CEC in the soil (mol kg $^{-1}$)

3.2 DISCUSSION

The application of *T. pinophilus* (M1) increases the P availability by 26.02 % when compared to without application (M0) and can increase the P available by 102.32 % when compared with the initial soil analysis (67.28 %). This is because *T.pinophilus* used is an environment-specific microbe isolated from areas affected by Mount Sinabung eruption (Sembiring and Fauzi, 2017). Rao (1999) argues that the mechanism of releasing P-bound from Al, Fe, Ca and Mg can be carried out in the presence of organic acids through chelating processes so that P becomes available and be absorbed by plants.

Soil conditioner increases soil K content and plant dry mass, zeolite treatment (P1) can increases soil K nutrient levels by 24.34 %. According to Suwardi (2009), zeolite as an enhancer given to the soil with sufficient quantities can improve soil physical, chemical and bio-

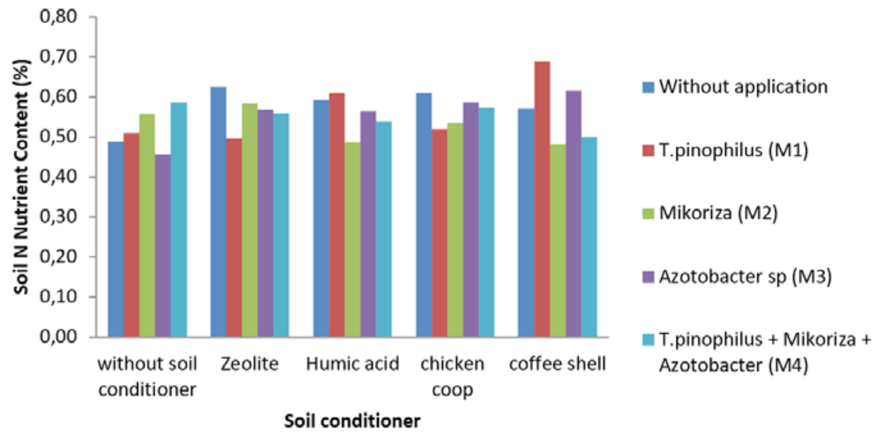

Figure 2: Interaction of soil conditioner and biofertilizers to soil N nutrient content (%)

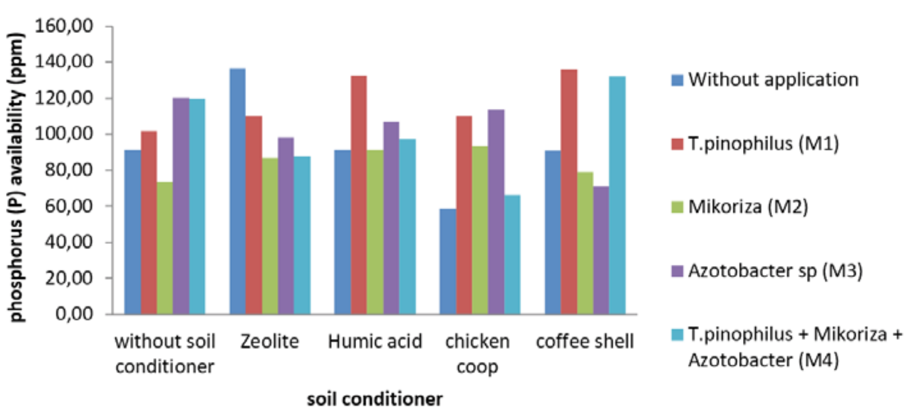

Figure 3: Interaction of soil conditioner and biofertilizers to P available in the soil (mg kg^{-1})

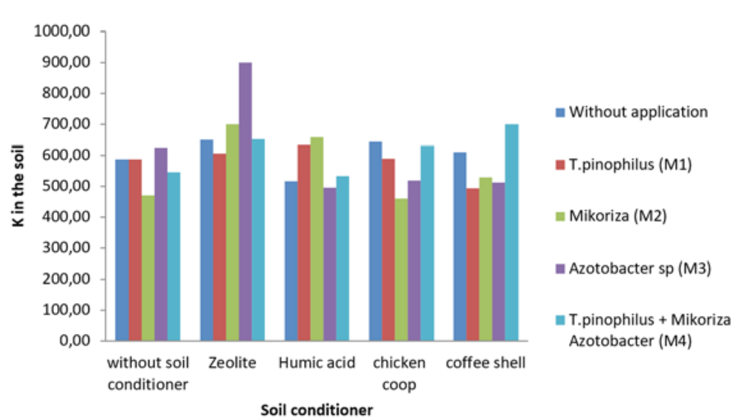

Figure 4: Interaction of soil conditioner and biofertilizers to K in the soil (mg kg^{-1})

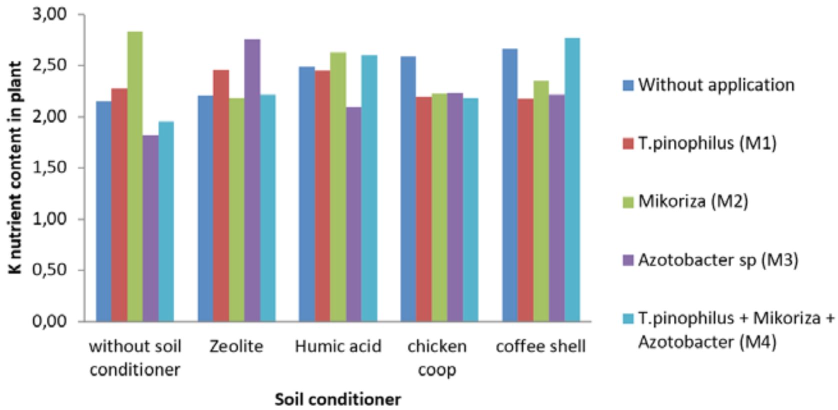

Figure 5: Interaction of soil conditioner and biofertilizers to nutrient K content in the plant (%)

logical properties so that agricultural production can be increased. According to Ahmed et al. (2010), zeolite is able to increase the availability of nutrients in the soil and soil nutrient uptake from fertilizers that are used to improve the efficiency of the availability of nutrients in the soil and reduce soil bleaching so that nutrients can be used for corn plant growth.

The treatment combination of soil conditioner and biological agents can increase soil N content for 40.81 % and P available for 49.36 %. The research results of Sembiring et al., 2017b; Masdariah et al., 2019; Siswana et al., 2019 stated that the application of phosphate solubilizing microbes and organic matter can increase the P availability in andisol. Phosphate solubilizing microbes and organic matter are able to produce organic acids so that the availability of nutrient elements in the soil increases (Richardson, 2001; Gyaneshwar et al., 2002). Application of mycorrhiza and zeolite (M3P1) can increase potassium (K) content in soil and cation exchange capacity. The ability of zeolites which can improve the physical, chemical and biological properties of soil combined with mycorrhiza applications is expected to increase the cation exchange capacity of the soil as observed from the results of Suwardi and Wijaya (2013).

The application of *T. pinophilu*s + mycorrhizae + A*zotobacte*r sp. (M4) increases the nutrient P content in plants and plant dry mass. The application of *T.* p*inophilu*s (M1) can increase the P available for 26.02 % when compared to without application (M0) and can increase the P available for 102.32 when compared with the initial soil analysis (67.28 %). This is because T.*pinophilus* used is an environment-specific microbe isolated from areas affected by Mount Sinabung eruption (Sembiring and Fauzi, 2017). According to Al-Karaki (2000; 2006); Gamper et al., 2004; Chiou et al., 2001) application of mycorrhizae can increase nutrient P uptake of plant. The research results of Sembiring et al, (2018); Farzaneh et al. (2011) stated that the application of mycorrhizae could increase nutrient P uptake for 67.83 % and plant growth for 59.45 %. According to Redman et al., 2002; Lewis 2004, the presence of mycorrhizae in plant roots can improve the ability to absorb nutrients so that plant growth becomes elevated.

Soil conditioner can increase soil nutrient content. Chicken manure treatment (P3) increases the nutrient N content in plants for 10.37 % and the nutrient P content in plants for 13.27 % when compared to control (P0). Sembiring and Fauzi (2017) stated that the application of chicken manure could increase the P uptake of plant for 6 % when compared to without application. Application of humic acid (P2) can increase the nutrient K content in plants for 28.83 % when compared to control. The treatment combination of soil conditioner and biological agents can increase nutrient K content in plants, treatment of *T. pinophilus* + mycorrhizae + *Azotobacter* sp. (M4) and coffee skin can increase nutrient K content in plants, plant dry mass. This is because the ability of each microbial is different and so if put together will expected to increase plant growth. This finding is in consistence with the findings of Sembiring et al. (2016).

Soil conditioner and biological agents can improve soil quality, namely pH 4.56 to 5.61 in this case ΔpH is 1.05. The effect of the increasing P available in the soil, the initial soil was 67.28 ppm to 118.07 ppm the increase in p available was at Δ50.76 ppm. The soil N parameters observed increased with the treatment, the initial soil analysis of soil N content was 0.55 % to 0.57 increase in soil N by ΔN 0.02 and CEC 20.87 increased to 21.16 me kg^{-1} so that ΔCEC 0.29 was obtained. From the results of this research we observe that the treatment applications improve soil quality which is in line with the findings of according to Kirener (2013); Marzioli (2010).

4 CONCLUSIONS

This study found superior soil repairers and microbes that can increase soil fertility and plant growth. This research will help researchers and farmers to overcome the low soil fertility in andisols. Thus the new theory found that the interaction of coffee skin with *T. pinophilus* + mycorrhiza + *Azotobacter* sp. was best for increasing plant growth in andisol soil which had an impact on Sinabung eruptions.

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