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EFFECTS OF COMPOST ON SOIL PROPERTIES AND YIELD OF PINEAPPLE (*Ananas comusus* L. MERR.) ON RED ACID SOIL, LAMPUNG, INDONESIA

*Priyo Cahyono[1], Supriyono Loekito[1], Didin Wiharso[2], Afandi[2], Ali Rahmat[2], Naomasa Nishimura[3] and Masateru Senge[4]

[1]Research and Development Department, PT Great Giant Pineapple, Lampung, Indonesia;
[2]Faculty of Agriculture, Lampung University, Lampung, Indonesia;
[3]Faculty of Applied Biological Science, Gifu University;
[4] Ltd. Union Laboratory, Gifu University, Japan

*Corresponding Author, Received: 21 April 2020, Revised: 08 May 2020, Accepted: 21 May 2020

ABSTRACT: Compost is an organic matter commonly used to improve the chemical and physical properties of soil, especially of marginal soil, where the limiting factors of the soil fertility are the lack of organic matter and low soil pH. One aim of this study is to determine the effect of compost application on the improvement of the chemical and physical properties of acid soils planted with pineapple. Another aim of this study is to determine the effect of compost in reducing the foliar fertilizer and the influence of this reduction on the pineapple yield. A factorial experiment was arranged in a randomized block design with two factors and three replications. The first factor was the rate of compost application with the following treatments: K0: no compost, K25: compost 25 t ha^{-1} and K50: compost 50 t ha^{-1}, while the second factor was the reduction of foliar chemical fertilizer with the following treatments: P100: 100% of the standard fertilizer, P80: 80% of the standard fertilizer and P60: 60% of the standard fertilizer. The total combined treatments, i.e., nine treatments, consisted of K0P100, K0P80, K0P60, K25P100, K25P80, K25P60, K50P100, K50P80 and K50P60 with three replications. The results showed that the compost could improve the chemical and physical properties of acid soils, and the application of the compost dose of 25 t ha^{-1} enabled a reduction of foliar chemical fertilizer by 40% with no loss in yield.

Keywords: Compost, Foliar spray, Pineapple, Reduction of foliar fertilizers, Red soil

1. INTRODUCTION

Red soil is very widespread in tropical and sub-tropical regions throughout the world and occupies more than 45% of the total land area of the world [1]. Whereas in Indonesia, ultisol soil which is red soil has a distribution of up to 25% of the total land area [2]. The nutrient content in that soil is generally very low due to very intensive leaching, and the organic matter content is also low because the decomposition process occurs very quickly. Increasing productivity in this soil type can be done by liming or through the application of organic matter [2,3].

Compost is one type of organic matter; it can increase the nutrient availability and its effects can be direct or indirect. The direct effect is the addition of nutrients from the compost, while the indirect effect is the increase in microbial activity, an improvement in the soil structure and an increase in the water holding capacity [4,5]. Compost releases plant nutrients very slowly and indirectly, which are absorbed by the plant. Therefore, the plant cannot access the amount of nutrients needed in the critical yield period only by compost application. Hence, an approach for compost application in combination with inorganic fertilizer is a good strategy for increasing productivity [6,7]. On the other hand, a decrease in land quality, an increase in soil acidity and environmental pollution will occur due to the excessive and long-term use of chemical fertilizers [8].

A pineapple plantation of the Great Giant Pineapple Company (PT GGP) is located in Lampung, Indonesia where most of the soil consists of red-yellow podzolic [9-11]. The results of a soil analysis in the laboratory showed that the soil pH and the organic matter content at this plantation were very low and that the nutrient availability was also very low. With these poor soil characteristics, a large amount of foliar fertilizer tended to be applied.

One of the solutions for improving the soil properties and reducing the chemical fertilizer is to increase the amount of compost usage from cattle manure produced by the compost plant of PT GGP. Various studies on the role of compost and its soil properties have been done, but the researches associated with decreasing the usage of foliar chemical fertilizer are still very rare, especially for pineapple crops on red acid soil. The objectives of this research are to determine the effect of compost application on the chemical and physical properties of the soil, and to determine the effect of reducing the doses of foliar chemical fertilizers on the pineapple yield on red acid soil.

2. MATERIALS AND METHODS

2.1 Materials and Experimental Design

This experiment was conducted at the Research and Development Department (R&D Dept.), PT GGP, Lampung, Indonesia (about 46 meters above sea level with coordinates of 4°49'27''S and 105°13'55''E) for a period of 12 months, from January 2016 to January 2017. The nutrient contents of the soil and the compost are shown in Table 1. The compost was obtained from the compost plant at PT GGP; the raw materials originated from cow dung, bromelain waste and bamboo chopping through a composting process that lasted about one month.

The soil texture at this location is sandy clay with 56.4% sand, 6.6% silt and 37.0% clay. The physical properties of the initial soil are shown in Table 2. Seed materials were used from the suckers of pineapple which were taken from the pineapple plantation of PT GGP, Lampung, Indonesia. The seedlings were selected from the suckers picked from the slips of pineapple plants.

The compost was applied manually in a row, one week before planting. The rate of compost application was determined according to the treatment details shown in Table 3. Base fertilizer was applied one day before planting on the same row with the same amount for all treatments. The base fertilizer consisted of diammonium phosphate (DAP), potassium chloride (KCl) and kieserite ($MgSO_4.H_2O$). Another type of fertilizer was applied manually (by hand application) one month after planting; it consisted of ZA ($(NH_4)_2SO_4$) and K_2SO_4 for all treatments. The foliar fertilizer was applied two months after planting, and was continued every month following the details given in Table 4. The treatments of fertilizer reduction were started at this stage.

A factorial experiment was arranged in a randomized block design with two factors and three replications. The first factor was the rate of compost application which consisted of three doses: K0 (no compost), K25 (compost 25 t ha^{-1}) and K50 (compost 50 t ha^{-1}), and the second factor was the reduction of fertilizers which consisted of three steps of decrease: P100 (100% of the standard fertilizer or 0% reduction in fertilizer), P80 (80% of the standard fertilizer or 20% reduction in fertilizer) and P60 (60% of the standard fertilizer or 40% reduction in fertilizer). Details of the treatments are presented in Table 3. The plot area was ploughed to be 30 cm in depth and marked out to obtain individual plot sizes of 3×5.5 m.

Table 1 Characteristics of initial soil and compost

Properties	Initial soil	Compost
pH	4.76	7.20
Total C (wt %)	1.59	21.60
Total N (wt %)	0.16	1.68
C/N ratio	9.93	12.86
P (g kg^{-1})	0.01	2.60
K (g kg^{-1})	0.10	18.13
Ca (g kg^{-1})	0.22	21.50
Mg (g kg^{-1})	0.12	5.26

Table 2 Physical properties of initial soil

Properties		Initial soil
Bulk density (g cm^{-3})		1.24
Particle density (g cm^{-3})		2.31
Porosity (vol %)		46.30
Texture (wt %)	Sand	56.40
	Silt	6.60
	Clay	37.00

Table 3Details of each treatment

Treatment	Compost (t ha^{-1})	Standard fertilizer (%)	Reduction in fertilizer (%)
K0P100	0	100	0
K0P80	0	80	20
K0P60	0	60	40
K25P100	25	100	0
K25P80	25	80	20
K25P60	25	60	40
K50P100	50	100	0
K50P80	50	80	20
K50P60	50	60	40

Table 4Treatments for fertilizer reduction

Treat ment	Fertilizer	Reduction in fertilizer (%)				Total (kg ha^{-1})
		1st	2nd	3rd	4th	
P100	Urea	75	75	75	100	325
	K_2SO_4	50	50	75	100	275
P80	Urea	60	60	60	80	260
	K_2SO_4	40	40	60	80	220
P60	Urea	45	45	45	60	195
	K_2SO_4	30	30	45	60	165

2.2 Data Collection and Analysis

Soil sampling and an analysis were conducted once at the beginning and again four months after planting to understand the changes in the soil properties. Soil was sampled at a depth of 0-20 cm and a composite of three samples per treatment was made. The soil observation consisted of chemical properties, namely, (1) the pH was measured by a pH meter-mettler toledo, (2) the organic C-organic content was determined by the Walkley and Black method, (3) an N analysis was done by the Kjeldahl method, (4) a P analysis was done by the P Bray-1 method and (5) an analysis of K, Ca and Mg was performed by extraction with ammonium acetic pH 7 and a reading by Atomic Absorption Spectrofotometry (AAS)-GBC.

The physical properties of the soil consisted of the following: (1) the bulk density was measured by the core method, and the soil sampling technique was carried out by taking one soil sample per treatment and three replications, thus, a total of 27 samples (9 treatments×3 replications), (2) the particle density was analyzed by the pycnometer method, (3) the porosity was calculated using the formula for bulk density and particle density and (4) the soil hardness was measured by a penetrograph.

Leaf sampling and an analysis were done seven months after planting to determine the effect of the treatment on the nutrient uptake in the leaves of the pineapple. Leaves were sampled by taking one leaf (the longest leaf) per plant and a composite of nine leaves per treatment (no replications). An analysis of (1) nitrogen (N) was done by the Kjeldahl method and (2) potassium (K) was done by the wet ashing method and a reading by AAS. The fruit yield was obtained by multiplying the average fruit weight by the population at harvest time.

2.3 Statistical Analysis

All data collected from the three replications were subjected to an analysis of variance (ANOVA) using the Tukey Test and 95.0% confidence to determine the differences among the treatments.

3. RESULTS AND DISCUSSION

Almost 90% of the fertilizer was given through foliar spray and only basic fertilizers and the first fertilization were supplied through the soil. The purpose of the application of compost in the soil was to reduce the frequency and the amount of fertilizer given through the leaves.

This experiment was to determine not only the effect of the compost application on the chemical and physical properties of the soil, but also its effect on the use of foliar fertilizer which is the most commonly applied fertilizer for pineapple plants.

3.1 Effects of Compost on Soil Chemical Properties

The chemical properties of the soil in the compost treatments four months after planting are presented in Table 5. There were significant differences between the soil pH of the compost plots (K25 and K50) and the plot with no compost (K0).

Table 5 Chemical properties of soil four months after compost application

Chemical	Dose of compost (t ha^{-1})		
Properties	0 (K0)	25 (K25)	50 (K50)
pH H2O	4.93a	5.68b	5.88b
C (wt %)	1.50a	2.02b	2.25b
N (wt %)	0.14a	0.18b	0.22b
P (g kg-1)	0.024a	0.028a	0.032a
K (g kg^{-1})	0.05a	0.10b	0.13b
Ca (g kg^{-1})	0.26a	0.62b	0.84b
Mg (g kg^{-1})	0.17a	0.27b	0.32b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test and 95.0% Confidence

The soil pH increased significantly in the plots applied with compost (K25 and K50), at doses of 25 t ha^{-1} and 50 t ha^{-1}, compared to the control (K0) and the initial condition (Table 1), because the pH value of the compost itself tended to be around neutral (pH 7.2), higher than that of the initial soil. The mineralization of compost releases basic cations, which are alkalines, so that the application of a large amount of compost, even done continuously, increase the soil pH [4]. The application of the compost dose of 50 t ha^{-1} caused the soil pH to increase 0.20 more than the compost dose of 25 t ha^{-1}, but the difference was not significant (Table 5).

The C-organic contents of the soil also increased with the compost application. The application of compost at doses of 25 t ha^{-1} and 50 t ha^{-1} (K25 and K50) significantly increased the C-organic contents compared to the control (K0), whereas that of the control plot slightly decreased in comparison with the initial condition (1.59 wt %). Furthermore, the C-organic content of the compost plot with the dose of 50 t ha^{-1} (K50) was higher than that of the compost plot with the dose of 25 t ha^{-1} (K25). However, no significant difference was seen between these two compost plots. In Table 1, it could be seen that the C-organic content in the compost was already high (21.60 wt %), so that when the compost was applied to the soil, the soil organic carbon increased. Bouajila and Sanaa [12] reported that the application of compost from manure and household waste resulted in a significant increase in organic carbon with the compost treatment being the most efficient. Their results showed that the application of 120 t ha^{-1} of household waste compost and manure improved the organic carbon (1.74% and 1.09%, respectively) compared with the control (0.69%).

The nitrogen (N) in the soil also increased with the compost application. The application of compost with the dose of 25 t ha^{-1} (K25) increased the nitrogen content in the soil significantly compared with the control. The nitrogen in the compost plot with the dose of 50 t ha^{-1} (K50) was higher than that with the dose of 25 t ha^{-1} (K25). However, no significant difference was seen between these two compost plots. Bouajila and Sanaa [12] reported that the application of compost concentrations (40 and 120 t ha^{-1}) resulted in a significant increase in the nitrogen in the soil. Hernández etc. [13] reported that the application of compost could increase the nutrients required by plant, including nitrogen, after the planting of a lettuce crop in the second cycle. Composts increased soil phosphorus, potassium and some micro-elements [14].

The available P increased slightly in all the compost treatments with the compost doses of 25 t ha^{-1} (K25) and 50 t ha^{-1} (K50) compared to the control (K0).

All the parameters of the exchangeable cations, such as potassium (K), calcium (Ca) and magnesium (Mg), significantly increased with the compost applications of 25 t ha^{-1} (K25) and 50 t ha^{-1} (K50) compared to the control (K0). Furthermore, these exchangeable cations of compost plot K50 were higher than those of compost plot K25. However, no significant difference was seen between these two compost plots. This means that compost was very useful for plants as a source of exchangeable cations. Adugna [7] expressed that the mineralization of compost would release many nutrients into the soil, such as potassium, calcium and magnesium, so that the nutrients would be greatly increased. Sarwar [15] Reported, the application of green compost revealed that increased soil pH and EC. Moreover, Mineral nutrients (Ca, Mg, K, P, Cl) of the soil also increased by the addition of green compost.

3.2 Effects of Compost on Physical Properties of Soil

The parameters for the physical properties of the soil are shown in Table 6. There was no influence on the physical properties of the soil among the treatments of foliar fertilizer reduction because only the fertilizer applied by the foliar spray was reduced.

The bulk density has an apparent tendency to decrease with an increase in the dose of the compost application. The lowest bulk density appeared with the treatment of the highest compost application with a dose of 50 t ha^{-1} (K50), which was significantly higher than the control (no compost) (K0), but not significantly different from the lower compost application with a dose of 25 t ha^{-1} (K25).

On the other hand, the particle density were not significantly different among all the treatments, because it takes too long time for the added compost to change to humus which is a constituent of soil. The parameter of porosity is obtained by calculating the bulk density and the particle density. This

Table 6 Physical properties of soil four months after planting

Dose of Compost (t ha^{-1})	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (vol%)
0 (K0)	1.14a	2.40a	52.50a
25 (K25)	1.05ab	2.39a	56.10ab
50 (K50)	0.97b	2.38a	59.20b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test and 95.0% Confidence

Table 7 Soil hardness four months after planting

Rate of compost (t ha^{-1})	Soil hardness (psi)
0	1.63a
25	0.64b
50	0.66b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test and 95.0% Confidence

parameter also clearly shows that compost treatment can increase soil porosity. The highest porosity was obtained by the treatment of the highest compost application with a dose of 50 t ha^{-1}(K50), which was significantly higher than the control, but not significantly different from the lower dose of 25 t ha^{-1} (K25). Brown and Cotton [9] observed that an increasing rate of compost decreased the bulk density. The bulk density indicates an increase in pore space and is indicative of improved soil tilth. In this respect, compost increases the portions of meso- and macro-pores because an improved aggregation and stabilization of the soil are significantly initiated by various soil organisms [16]. The application of compost could also decrease the soil hardness in the root zone (at a depth 0-20 cm from the soil surface) (Table 7). The applications of the compost doses of 25 t ha^{-1} (K25) and 50 t ha^{-1} (K50) showed significantly different levels of soil hardness compared with the control, but they were not significantly different. This means that compost application can improve the physical properties of the soil.

Applying compost can increase in organic matter, and furthermore can improve aggregation, water-holding capacity, hydraulic conductivity, total porosity, resistance to water and wind erosion and lowers bulk density and the degree of compaction [17,18].

3.3 Effects of Compost and Fertilizer Reduction on Leaf Uptake

Nutrient uptake in the leaves of the pineapple was different among treatments. The application of compost on the soil and the foliar fertilizer will improve the nutrient contents in the leaves. Fig.1

shows that the highest levels of nitrogen uptake in the leaves were attained with treatment K50P100, followed by K0P100 (no compost, no chemical fertilizer reduction), and then K25P100 (compost 25 t ha^{-1}, no chemical fertilizer reduction). On the other hand, the lowest levels of nitrogen uptake in the leaves were attained with treatment K0P60 (no compost, chemical fertilizer reduction 40%), followed by K50P60 (compost 50 t ha^{-1}, chemical fertilizer reduction 40%), and then K0P80 (no compost, chemical fertilizer reduction 20%). Figure 2 shows that the highest levels of potassium uptake in the leaves were attained with the treatments with higher chemical fertilizer doses, namely, K50P80, followed by K50P100, K25P100, and then K0P100. They were all higher than the treatments with the other foliar fertilizer doses. At reduced foliar fertilizer doses by 20% or 40%, the lowest leaf uptake was observed. An increase in the compost dose did not increase the nutrient uptake in the leaf. This shows that the application of foliar fertilizer through the leaves is still effective for increasing the nutrient uptake in the leaves compared to compost applications. This means that foliar fertilizer supplied through the leaves can effectively increase the nutrient uptake, while compost application does not affect the increase in nutrient uptake. The leaves of the pineapple plant can absorb nutrients through the cuticles, and nutrients such as nitrogen, potassium, iron, zinc and boron are readily translocated to the whole plant [19].

3.4 Effects of Treatment on Plant Growth and Yield of Pineapple

The treatment effect on root weight was shown in Table 8, where there were no significant differences in root weight among the treatments of compost doses of 25 t ha^{-1} and 50 t ha^{-1} under all foliar fertilizer reduction treatments (P60, P80, and P100). While, it was also seen that the root weights of the treatments without compost (K0) were not significantly different from the treatments of compost 25 and 50 tons ha^{-1} (K25, K50) under the treatments with reducing foliar fertilizer less than 40% (P80 or P100). However, under the reduction of fertilizer 40%, the root weight of the treatment (K0P60) under no compost application was significantly lower than those of the treatments of compost doses of 25 t ha^{-1} and 50 t ha^{-1} (K25P60 and K50P60). These results could conclude that application of 25 t ha^{-1} was able to provide a good root and also reduce 40% foliar fertilizer. It has become a general consensus that low organic matter in the soil will cause growth and root health to be disrupted [20].

The treatment effect on plant weight was also shown in Table 9, where in the treatment of K0P60,

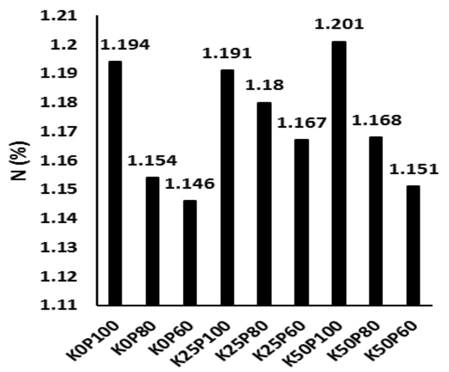

Fig.1 Effect of compost and fertilizer reduction on nitrogen in the leaves

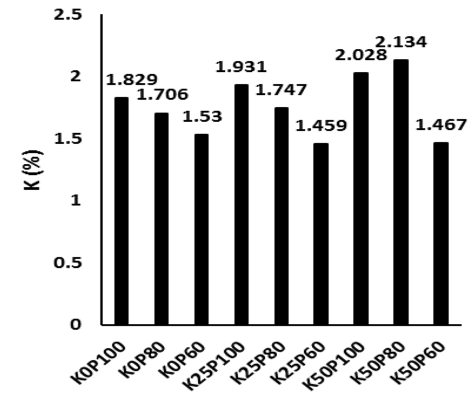

Fig.2 Effect of compost and fertilizer reduction on potassium in the leaves

Table 8 The effect of treatment on root weight

Treatment	Root weight (g)
K50P100	64.4a
K25P60	63.3a
K50P80	62.7a
K50P60	61.5a
K0P80	60.9a
K25P80	60.4a
K0P100	58.6a
K25P100	57.1a
K0P60	46.5b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test and 95.0% Confidence

Table 9 The effect of treatment on plant weight

Treatment	plant weight (g)
K50P100	2917a
K25P80	2680ab
K50P60	2627ab
K0P100	2627ab
K25P100	2610ab
K50P80	2540ab
K25P60	2353ab
K0P80	2300ab
K0P60	2100b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test the plant weight was the least and was significantly different from the treatment of K50P100. Increase of foliar fertilizer application to 80% and 100% of standard could improve plant weight of treatments (K0P80, K0P100) under no compost application, but not significantly. Likewise, the application of compost doses of 25 and 50 t ha^{-1} also increased plant weight, but not significantly.

However, it could be concluded at least that application of compost 25 t ha^{-1} was able to provide a good plant growth and also reduce 40% foliar fertilizer.

Beside, compost application can release nutrients; compost can stimulate root growth by the presence of humic substances released by the decomposing organic matter. These substances exhibit a beneficial effect on root proliferation and plant growth [21]. Adding cow dung compost on soil significantly increased by 33.09 - 48.54 %, the number of leaves, and the stem diameter of Moringa oleifera [22].

Table 10 The effect of treatment on yield

Treatment	Fruit weight (kg)	Yield (t ha^{-1})
K50P100	1.7a	110.5a
K25P80	1.67ab	108.5ab
K50P60	1.64ab	106.9ab
K0P100	1.64ab	106.9ab
K25P100	1.62ab	105.2ab
K50P80	1.54ab	100.1ab
K25P60	1.51b	98.0b
K0P80	1.47b	95.8b
K0P60	1.44b	93.7b

Note: Means that do not share same letter are significantly different, Grouping Information Using Tukey Test and 95.0% Confidence

All treatments of compost application could increase the yield compared to no compost treatments (Table 10). In particular, the treatment of compost application of 25 t ha^{-1} and a fertilizer reduction of 40% (K25P60) attained the highest yield among all treatments, and showed a significantly higher yield of more than 10% compared to all treatments of no compost application (K0P100, K0P80 and K0P60). Furthermore, the other treatments of compost application, except for K25P60, showed a higher yield compared to all treatments of no compost application, but not significantly. From Table 10 it can be seen that all compost treatments combined with foliar fertilizer treatments produce higher production compared to without compost. Increasing the dose of foliar fertilizer in non-compost treatment (K0P60, K0P80 and K0P100) did not significantly affect production. This is due to the condition of pineapple plant roots that are not good so that the effect of fertilizer does not look real.

4. CONCLUSION

Compost could improve the chemical and physical properties of soil, which were significantly different from those of the control. The application of compost could not increase the nutrient uptake in the leaves of pineapples, but the foliar fertilizer application was effective enough. The pineapple yield was seen to increase with the application of a compost dose of 50 t ha^{-1} compared with the control, but the yield was no different from that with a compost dose of 25 t ha^{-1}. However, the application of a compost dose of 50 t ha^{-1} consistently produced a higher yield compared to the other treatments except for K25P60 treatment. The application of the compost dose of 25 t ha^{-1} enabled a reduction in the use of chemical fertilizer applied by foliar spray by 40% with no loss in yield.

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