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P-Available Enhancement Mechanism through Combinations of Organic Matters and Incubation Period in Psammentic Paleudults Soil

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Abstract**—** *Understanding the mechanisms underlying the availability ofphosphorus (P) is important for improving soil productivity Psammentic Paleudults. This research aimed to determine the mechanism for increasing phosphorus availability due to the application of various organic matters and incubation period in the Psammentic Paleudults soil from Labuhan Batu Selatan District, Sumatera Utara Province. This research was conducted at the Research Laboratory of Faculty of Agriculture, Universitas Sumatera Utara, using Factorial Completely Random Design with 2 treatment factors and 3 replications. Factor 1 was organic matters (20 tons/ha) consisting of Control, Tithonia diversifolia Compost, Durian Skin Compost, Empty Fruit Bunches Compost, Chicken Manure, Tithonia diversifolia Compost + Chicken Manure, Durian Skin Compost + Chicken Manure and Empty Fruit Bunches + Chicken Manure. Factor 2 was the incubation period consisting of 1 week incubation, 2 weeks incubation, 3 weeks incubation and 4 weeks incubation. The results showed that the combination of Tithonia diversifolia compost with chicken manure was able to increase P-available soil higher and reduce Al-P and Fe-P content.Organic matters incubation for 3 weeks reduced soil Al-P and Fe-P content. The interaction of compost Tithonia diversifolia+ chicken manure with 3 weeks incubation was the best treatment increasing soil P-available and reducing Al-P and Fe-P content in Psammentic Paleudults soil.*

Keywords**— phosphorus; organic matter; incubation; Psammentic Paleudults.**

I. INTRODUCTION

Psammentic Paleudults soil is one of Ultisol soil sub-group formed by sand as its main material with base saturation (BS) <35%, cation exchange capacity (CEC) <16 me/100g and has a relatively low C-organic content [15]. Besides that, this soil has a texture of sandy clay to sand, causing a capacity to withstand nutrients and low water hence it is prone to drought.

The chemical characteristics of Psammentic Paleudults in Silankitang Subdistrict, Labuhan Batu Selatan District, Sumatera Utara Province are characterized by very acidic soil reactions (pH 4.31 - 4.49), low soil CEC (12-14 me/100 g) and poor in macro-nutrient, especially Phosphorus (low P-total) [11].In acidic mineral soils generally, the availability of dissolved Al and Fe elements were higher, causing these ions to react very rapidly with P to form Al and Fe phosphate minerals [1] hence the P availability of this soil is low [2] and will interferest with plant growth and productivity [19]

Efforts that can be done to improve the productivity of Psammentic Paleudults are through liming, fertilizing and applying organic matters. Liming is done to increase soil pH and also to suppress the saturation of Al ions hence they can maintain P supply.But in practice, these efforts face obstacles such as over liming (excessive use of limestone) causes P fixation by Ca and also the use of excessive or unbalanced P fertilizer causes eutrophication of water bodies such as rivers and lakes (not environmentally friendly).

The application of organic matters can be used to overcome nutrients problems and increase soil productivity. Organic matters in the decomposition process produce organic acids that can bind Al and Fe thereby reducing P fixation in the soil [18].It is generally assumed that phosphorus (P)

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availability for plant growth on highly weathered and P-deficient tropical soils may depend more on biologically mediated organic- P[15]

The application of organic amendments such as crop residues and manure, either singly or in combination will support increased soil fertility and low water holding capacity [13], further consistently enhanced maize crop growth and development[8]. Organic matters sourced from plant tissues such as empty fruit bunches,durian skin and *Tithonia diversifolia*is generally more difficult to decompose when compared to organic matters sourced from animal residues such as chicken manure. Hence the combination of some plant residues with chicken manure besides being able to enrich nutrients which will improve the quality of these organic matters also assists in accelerating the mineralization process.At the time of organic matter application in the soil, incubation is needed. Hence the mineralization process of organic matter occurred, which becomes the supplier in fulfilling the phosphorus nutrients for plant growth and yield. The effect of organic matter application on P availability in acid soils can be directly through the mineralization process and indirectly by assisting the release of P which is bound to Al and Fe [17].The mechanism for increasing P-available in the soil is the process of making P in the soil change from bound-solid phase form which does not dissolve into a form that can be absorbed by plants.

II. MATERIALS AND METHODS

Place and time of research

This research was conducted at the Research Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara - Medan and the Asean Agri Research and Development Laboratory - Tebing Tinggi. This research was conducted from February 2016 to July 2016.

The material used for this research was a sample of Psammentic Paleudults soil taken from Kampung Dalam Village, Silangkitang sub-district, Labuhan Batu Selatan District, Sumatera Utara Province at a depth of 0-20 cm compositely.The organic matters used were Tithonia diversifolia compost, oil palm empty fruit bunches, durian skin compost and chicken manure and other chemicals used for soil analysis in the laboratory.

The tools used for this research were GPS, clinometer, ground drill, pH meter, Spectrophotometer, Atomic Absorption Spectrophotometer (AAS) and other equipment for analysis needs.

Materials and methods

This research used a factorial Completely Randomized Design (CRD) with 2 (two) treatment factors and 2 replications, namely: Factor I: Organic Matter namely Without Organic Matters (0 tons Ha^{-1}), Compost of *Tithonia diversifolia* (20 tons Ha^{-1}), Compost of Durian Skin (20 tons Ha^{-1}), Compost ofEmpty Fruit Bunches (20 tons Ha^{-1}), Chicken Manure (20 tons Ha^{-1}), Compost of *Tithonia diversifolia* (10 tons Ha^{-1}) + Chicken Manure (10 tons Ha^{-1}), Compost of Durian Skin (10 tons Ha^{-1}) + Chicken Manure (10 tons Ha^{-1}), Compost of Empty Fruit Bunches (10 tons Ha^{-1}) + Chicken manure (10 tons Ha^{-1}).Factor II: Incubation Period: Incubation in 1 week, Incubation in 2 weeks, Incubation in 3 weeks, Incubation in 4 weeks. Based on the above combination, 64= (8x4x2) experimental units were obtained.

The sampling of Psammentic Paleudults soil from Kampung Dalam Village, Silangkitang Subdistrict, Labuhan Batu Selatan District, Sumatera Utara Province was carried out at a depth of 0-20 cm with a zigzag method and then composite. After that, the soil sample was air-dried and sieved with a 10 mesh sieve. Next, the soil sample was put into a plastic pot, equivalent to 2 kg of dry air.Initial soil analysis included pH H_2O and pH KCl using Electrometry method, Cation Exchange Capacity (CEC) NH_4Oac extraction pH 7 (me/100g), Al-exchangeable KCl 1N extraction (me/100g), Bases-exchangeable (Ca, Mg, K, Na) NH_4OAc extraction pH 7 (me/100g), Base Saturation (BS) (%), Aluminum Saturation (%), P-available using Bray II (ppm) method.Compost made from empty fruit bunches (EFB), durian skin and *Tithonia diversifolia* (T. *diversifolia*) plants before composting were chopped using a chopper. Next, each one was put in a separate open plastic bucket and applied the EM 4 (Effective Microorganism 4).To speed up the composting process each material was reversed every week and watered to maintain temperature and humidity. Furthermore, chicken manure before being applied was put into open plastic burlap for 1 week.

The application of compost and chicken manure according to the treatment with a dose equivalent to 20 tons H^{-1} was put into a pot that has been filled with soil as much as 2 kg and stirred evenly until homogeneous. Then each one was incubated according to the treatment for 1 to 4 weeks.The parameters measured for each incubation period included: pH H_2O Electrometry method, C-organic (%) Walkley & Black method, P-available contents (ppm) Bray II method, Al-P content (ppm), and Fe-P content (ppm) the method of Chang & Jackson [10]

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III. RESULTS AND DISCUSSION

Soil Reaction (pH H_2O)

General the effects of incubation interactions from 1 to 4 weeks, soil pH increased higher in the application of compost combinations with chicken manure compared to controls and by compost application without chicken manure (Table 1). The highest pH value was 7.07 (neutral) obtained in the combination treatment of chicken manure with an incubation period of 2 weeks followed by Compost *Tithonia diversifolia* + Chicken Manure with an incubation period of 1 weeks which was 7.07 (neutral) while the lowest pH of 4.73 (acid) was obtained in Control with an incubation period of 1 weeks.

Table 1. Effect of applying organic matter and incubation period on soil pH

Organic Matter	Incubation Period (Weeks)				mean
	1	2	3	4	
Control	4.73j	5.31hij	5.21ij	4.78j	5.01
Compost*T diversifolia*	5.77ghi	6.35c-g	6.03fg	6.04fg	6.05
CompostDurian Skin	5.87gh	5.92gh	6.55b-f	5.77ghi	6.03
CompostEFB	6.25efg	6.03fg	5.87gh	5.86gh	6.00
Chicken Manure	6.68a-e	7.17a	6.92abc	6.59b-f	6.84
Compost*T.diversifolia* + Chicken Manure	7.07ab	6.87a-d	6.90abc	6.31d-g	6.79
CompostDurian Skin+ Chicken Manure	6.93ab	6.60b-f	7.01ab	6.29d-g	6.71
Compost EFB+ Chicken Manure	6.37c-g	6.13efg	5.93gh	5.90gh	6.08
Mean	6.21	6.30	6.30	5.94	

Note: The numbers followed by the same letters in the same column and row were not significantly different from the DMRT test at the 5% level.

The average value of soil pH showed that the interaction without organic matter application with an incubation period of 1 to 4 weeks soil pH ranged from 4.73 - 5.31 with acidic criteria to slightly acidic but after being treated with organic matter the soil pH increased to 5.77 - 7.17 with criteria slightly acidic to neutral.The increasing of soil pH was caused by the decomposition of organic matter during incubation produces organic acids which can chelate Al ions to form complex compounds (chelate) hence Al is not hydrolyzed again. This was consistent with Suntoro's (2001) report which stated that the application of organic matter to acid soils such as Ultisol can increase soil pH and decrease Al-exchangeable [16].An increase in soil pH will also occur if the organic matter applied has been decomposed further because the mineralized organic matter will release the mineral in the form of basic cations.

Soil C-Organic (%)

The application of various organic matters can significantly increase the C-Organic content of Psammentic Paleudults soil compared to control (Table 2). Treatment compost Durian Skin produced the highest soil C-organic content, from 0.62% to 1.34%, hence an increase in soil C-organic content was 0.72%. This was because carbon content as the main constituent of the two organic matters itself is higher hence by adding organic matter in the form of durian skin and empty fruit bunches compost can increase the C-organic content in the very low Psammentic Paleudults soil.

Table 2. Effect of applying organic matter and incubation period on soil C-organic

Organic Matter	Incubation Period (Weeks)				Mean
	I1	I2	I3	I4	
	----------%----------				
Control	0.75	0.66	0.58	0.50	0.62d
Compost *T diversifolia*	1.16	1.13	1.02	1.07	1.10c
Compost Durian Skin	1.25	1.63	1.37	1.10	1.34a
Compost EFB	1.52	1.26	1.23	1.15	1.29ab

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Chicken Manure	0.96	1.03	1.02	1.00	1.00c
Compost *T.diversifolia* + Chicken Manure	1.16	1.17	1.17	1.11	1.15bc
Compost Durian Skin + Chicken Manure	1.19	1.20	1.13	1.08	1.15bc
Compost EFB + Chicken Manure	1.11	1.16	1.17	0.77	1.05c
Mean	1.14a	1.15a	1.09ab	0.97b	

Note: The numbers followed by the same letters in the same column and row were not significantly different from the DMRT test at the 5% level.

The incubation treatment for 4 weeks can reduce the soil C-organic content of Psammentic Paleudults. Starting from C-organic soil 1,14% fell to 0.97%.This was due to the mineralization of organic matter with the increasing of incubation period hence the residual mineralization of the plant will be further which at first the C-organic content of plant was higher will be lower because carbon was used by microbes as an energy source and some of the carbon was lost and become CO_2.In accordance with Jama **et. al**., statement, which stated that incubation, is carried out to be able to provide an opportunity for microorganisms to develop and metabolize to decompose organic matter into inorganic compounds [7].

The relationship of incubation period with the content of soil C organic (Figure 1) was a linear line equation Y = -0.0557 X + 1.2267 and r2 = 0.88. From this relationship showed a negative tendency, namely the longer the incubation period, the soil C-organic will decrease. The incubation treatment can reduce soil C-organic by 1.22%. Every 1% of incubation period affects the decrease in soil C-organic content by 0.05%. This linear correlation equation model was strong enough to be accepted because it includes 88% of the effect of the incubation period on the soil C-organic content, while the other external influences were 12%.

The relationship of incubation period with the content of soil C- organic can be seen in Figure 1.

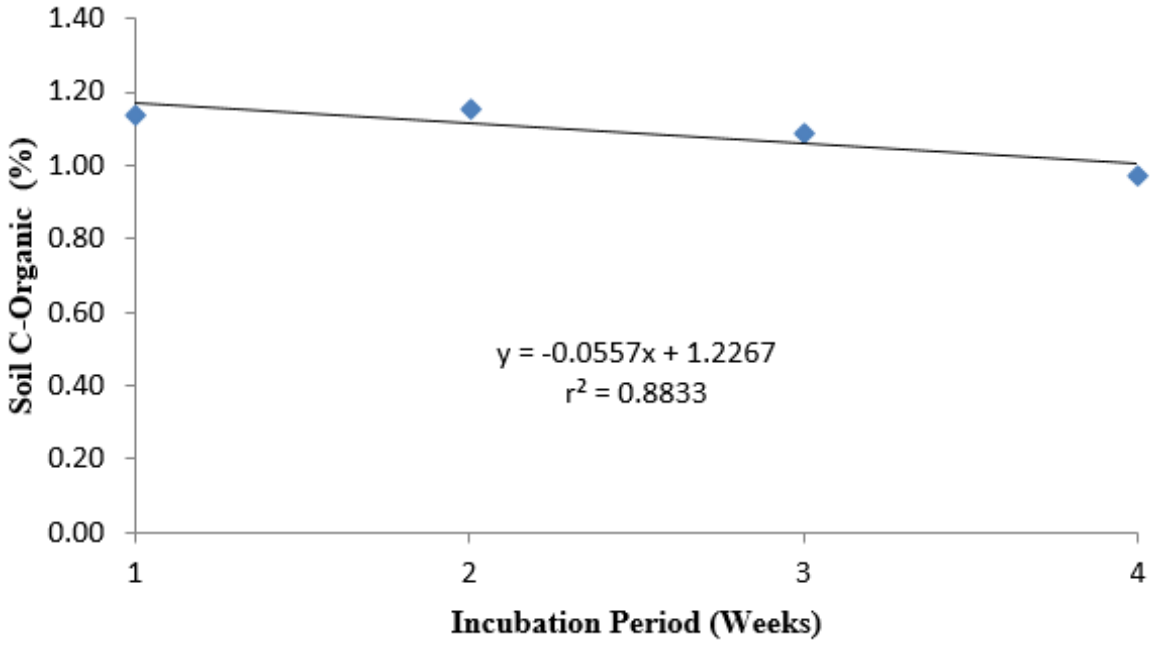

Fig.1: Relationship between incubation period and soil C-organic content

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Soil Al-P Content (ppm)

Table 3. Effect of applying organic matter and incubation period on soil Al-P

Organic Matter	Incubation Period (Weeks)			
	1	2	3	4
	---------- ppm ----------			
Control	182.32	173.41	170.56	169.42
Compost *Tithonia diversifolia*	141.88	136.38	133.49	132.33
Compost Durian Skin	149.27	147.39	144.81	143.77
Compost Empty Fruit Bunches	153.42	151.93	149.87	150.22
Chicken Manure	150.03	148.30	147.57	144.20
Compost *Tithonia diversifolia* + Chicken Manure	124.33	123.15	119.61	121.91
Compost Durian Skin + Chicken Manure	141.63	133.99	130.36	135.93
Compost EFB + Chicken Manure	149.28	148.43	139.47	145.04
Mean	149.02a	145.37b	141.98b	142.85bc

Note: The numbers followed by the same letters in the same column and row were not significantly different from the DMRT test at the 5% level.

The application of all organic matter independently capable of significantly reducing the soil Al-P content compared to treatment Control (Table 3). Furthermore, the application of a combination of organic matter on Compost *Tithonia diversifolia*+ Chicken Manurewas able to reduce Al-P soil more than other treatments, from 173.93 ppm to 122.25 ppm. Thus a decrease in the content of Al-P soil Psammentic Paleudults due to the application of Compost *Tithonia diversifolia* + Chicken Manure amounted to 29.71%.The high ability of *Tithonia diversifolia* compost and chicken manure in reducing Al-P content was due to the fact that *Tithonia diversifolia* and chicken manure through decomposition have the ability to produce organic acids namely citric acid, acetate and malic acid which are higher than other organic matters, according to Magdoff and Ray, these acids produce ions which can break the bonds between P and Al hence P becomes available[9].Furthermore, by Winarso et al. added organic decomposition substances to release humic compounds, which can decompose metals including Al in acid so that they can release Al activity and P fixation on acidic soils[20]. The effect of incubation from 2 and 4 weeks significantly reduced the soil Al-P content compared with 1-week incubation and the lowest at 3 weeks incubation. The relationship of the incubation period of organic matter with the soil Al-P content can be seen in Figure 2.

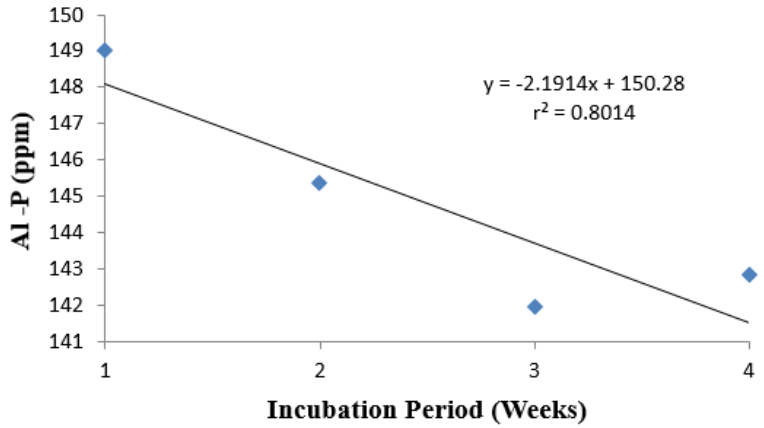

Fig.2: Relationship of Al-P soil with incubation period

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Based on Figure 2, it can be seen that the soil Al-P content decreases linearly with the equation Y = -2.1914X + 150.28 with the regression coefficient r^2 = 0.8014. From this relationship showed a negative tendency, namely the longer the incubation period, the Al-P content of Psammentic Paleudults will decrease. This linear regression equation model was strong enough to be accepted because it includes 80% of the influence of the incubation period on soil Al-P contents, while other external influences were 20%.

Soil Fe-P Content (ppm)

The application of all organic matter independently has significantly reduced the soil Fe-P content of Psammentic Paleudults soil compared to treatment Control (Table 4). Furthermore, the application of a mixture of organic matter in Compost *Tithonia diversifolia* + Chicken Manure was significantly reduced soil Fe-P compared to other treatments, from the initial Fe-P value of 138.79 ppm to 83.40 ppm. Hence, there was a decrease in the Fe-P content of Psammentic Paleudults soil by 39.90%. This was due to Tithonia diversifolia and chicken manure through decomposition capable of producing organic acids, namely citric acid, acetate and malic acid which have a higher concentration than other organic matters, these acids produce ions which can break the bonds between P and element of Fe thereby a decrease in Fe-P content in the soil occurred. In accordance with the opinion of Han and Jordan that organic acids released during the decomposition of organic matter can dissolve phosphate complexes by Fe and Al thereby increasing the solubility of P in the soil [5].Conversely, without the provision of organic matter, the Fe-P content in the soil is higher due to an increase in P content in the complex along with the increase of Fe molar, this is in accordance with Fahmi's that the presence of Fe is one of the limiting factors that greatly influences the P fixation process in the soil[3].

Table 4. Effect of applying organic matter and incubation period on soil Fe-P

Organic Matter	Incubation Period			
	1	2	3	4
	---------- ppm ----------			
Control	146.01	143.71	132.63	132.81
Compost *Tithonia diversifolia*	102.61	101.27	96.04	95.91
Compost Durian Skin	120.27	105.86	100.35	106.15
Compost Empty Fruit Bunches	126.52	123.08	120.73	122.28
Chicken Manure	118.93	114.03	106.85	111.59
Compost *Tithonia diversifolia* + Chicken Manure	86.14	83.42	80.02	84.04
Compost Durian Skin + Chicken Manure	105.31	99.94	99.52	98.71
Compost EFB + Chicken Manure	118.52	109.82	96.51	96.32
Mean	115.54a	110.14b	104.08c	105.97bc

Note: The numbers followed by the same letters in the same column and row were not significantly different from the DMRT test at the 5% level.

The incubation effect significantly reduced soil Fe-P contents from 1 to 4 weeks while the incubation effect of 4 weeks of soil Fe-P was not significantly different from 2 and 3 weeks. The relationship of the incubation period of organic matter with soil Fe-P can be seen in Figure 3.

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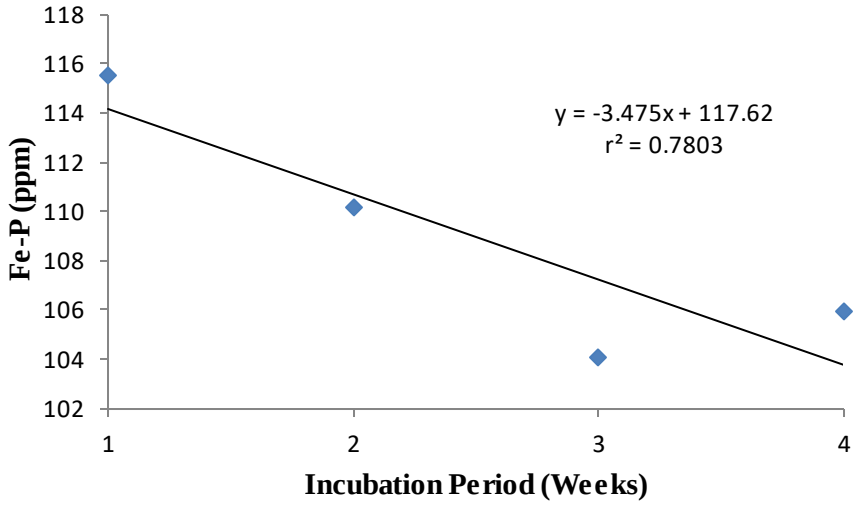

Fig.3: Relationship of Fe-P soil with incubation period.

Based on Figure 3, it can be seen that the soil Fe-P decreases linearly with the equation Y = -3.475X + 117.62 with the regression coefficient r2 = 0.7803. From this relationship it showed a negative tendency, namely the longer the incubation period then the soil Fe-P will decrease. This linear regression equation model was strong enough to be accepted because it includes 78% of the influence of the incubation period on soil Fe-P, while other external influences were 22%.

Soil P-available (ppm)

Table 5.Effect of applyingorganic matter and incubation period on soil P-available

Organic Matter	Incubation Time (Weeks)			
	1	2	3	4
	ppm			
Control	11.44k	11.93k	12.87jk	11.84k
Compost *Tithonia diversifolia*	25.78d-h	26.8c-g	27.14c-f	31.73bcd
Compost Durian Skin	21.62f-i	21.58f-i	26.34d-h	24.46e-h
Compost Empty Fruit Bunches	17.41ijk	20.06hi	22.63e-i	23.40e-i
Chicken Manure	20.16ghi	22.73e-i	28.72b-e	33.97ab
Compost *Tithonia diversifolia* + Chicken Manure	27.28c-f	28.75b-e	38.65a	31.79bcd
Compost Durian Skin + Chicken Manure	21.21f-i	19.67hij	32.99bc	34.01ab
Compost EFB + Chicken Manure	24.14e-i	24.66e-h	28.95b-e	25.09e-h
Mean	21.13	22.02	27.29	27.04

Note: The numbers followed by the same letters in the same column and row were not significantly different from the DMRT test at the 5% level.

The interaction effect of incubation period from 1 to 4 weeks on the level of soil P-available of Psammentic Paleudults was not significant on without the application of organic matter Control treatment(Table 5). While the interaction effects of incubation period ranging from 3 to 4 weeks were higher in increasing the P- available content of the soil especially in the application of a mixture of organic matters namely Compost *Tithonia diversifolia* + Chicken Manure, Compost Durian Skin + Chicken Manureand Compost EFB + Chicken Manure compared to Compost

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Tithonia diversifolia, Compost Durian Skin, Compost Empty Fruit Bunches, Chicken Manureand Control.The effect of the combination of *Tithonia diversifolia* compost and chicken manure with 3 weeks incubation period was able to increase the highest soil P available compared to other combinations. Starting at combinationcontrol with an incubation period of 1 weeks, P-available was 11.44 ppm (low) increased to 38.65 ppm (very high) onCompost *Tithonia diversifolia* + Chicken Manurewith an incubation period of 3 weeks or an increase of 237.85%.This was due to the P content of *Tithonia diversifolia*compost and chicken manure classified as higher[15] than other organic matters and in the incubation for 3 weeks the mineralization process or P release into the soil will occur. Furthermore, through the organic acids produced namely citric acid, acetate and malic acid indirectly assist P released which is fixed by Al and Fe.The results stated in Tables 3 and 4 showed that a decrease in Al-P content from initially 182.32 ppm to 119.61 ppm and the Fe-P content from 146.01 ppm decreased to 80.02 ppm causing P release and increasing P availability in the soil [6].In line with Stevenson's (1982) statement that through organic acid the result of decomposition of phosphate release occurs which binds to Al and Fe which does not dissolve into a soluble form with the following reaction equation:

$$Al\ (Fe)(H_2O_3)(OH)_2H_2PO_4 + Chelate \longrightarrow PO_4^{2-}(soluble) + ComplexAl\text{-}Fe\text{-}\ Chelate$$

The relationship between the incubation period of organic matter and the P available content of soil can be seen in Figure 4.

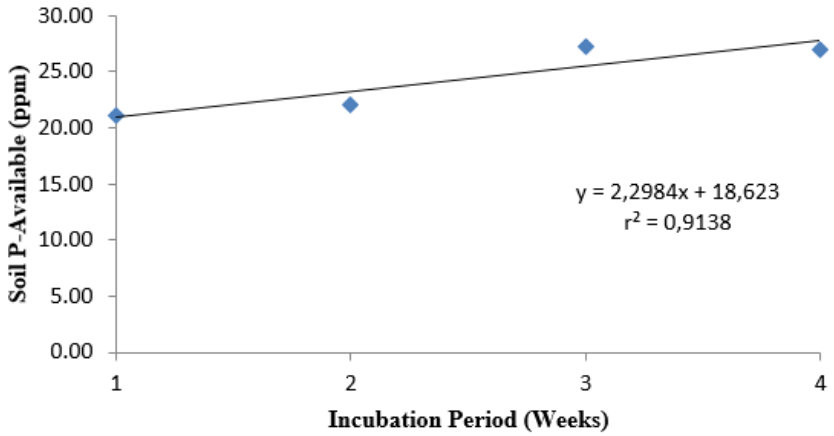

Fig.4: Relationship of Soil P-available with incubation period

Based on Figure 4, it can be seen that the soil P available content increases linearly with the equation Y = 2.2984X + 18,623 with the regression coefficient r2 = 0.9138. From this relationship showed a positive tendency, namely the longer the incubation period, the soil P available content will increase.With the treatment of incubation period can increase soil P-available content by 18.63%. Every 1% incubation period affected the increase in soil P available content by 2.29%. This linear equation model was strong enough to be accepted because it covered 91% of the influence of the incubation period on soil P available content, while other external influences were 9%.

IV. CONCLUSION

1. Application of various organic materials can increasing soil pH, C-organic and P-available soils as well as reduce the content of Al-P and Fe-P in the Psammentic Paleudults soils.
2. Incubation of organic matter for 3 weeks was able to reduce the content of Al-P and Fe-P on Psammentic Paleudults soils.
3. The interaction of compost *Tithonia diversifolia* with chicken manure with 3 weeks incubation was the best treatment in increasing soil P-available and decreasing Al-P and Fe-P on Psammentic Paleudults soil.

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