



Decomposition of Oil Palm Frond and Leaflet Residues

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ABSTRACT

Frond and leaflet residues from pruning of oil palm which are applied as mulch on oil palm plantation will decompose and can be source of organic matter and some essential nutrients. Information about how much the released nutrients from the decomposition processes of frond and leaflet of oil palm is limited. The objective of this research was to study the period (two years) patterns of nutrient release and decomposition of frond and leaflet of oil palm at different burial depth (0 to 30 cm) in peat soil. Decomposition of frond and leaflet of oil palm did not have a different pattern in mass loss, chemical content changes of C/N, N content, P content, P released, however, it has different pattern in N released. During two years of decomposition, frond and leaflet lost 88% and 86% of its initial weight and released 51% and 83% of N, also it released P 87% and 93% respectively. Frond and leaflet from pruning of oil palm should be returned to plantation area for one source of nutrients beside fertilizer.

INTRODUCTION

Oil palm is one of plantation commodities that develops and has an important role in the current economic of Indonesia. According to the data from BPS (2018), the total area of oil palm plantations in Indonesia has reached 12.30 million ha in 2017 with an average productivity of 2.80 tons of CPO (crude palm oil) and 0.56 tons PKO (palm kernel oil)/ha/year. The export value of CPO and PKO in the period of 2012 to 2016 has reached US\$ 17.6 billion annually. The important role of oil palm plantations in Indonesia is not only related to the government and the private sector, but directly to the economy of the community. There are, however, many criticism of the oil palm plantations negative impacts on the global terrestrial carbon cycle compared to that of natural forests. The argument put forward is that oil palm plantations have far more carbon emission than carbon sequestration, especially on peatlands. However some researches showed oil palm has same capability as forests to absorb high amount of carbon (Henson, Betitis, Tomda, & Chase, 2012; Irsan, Anwar, Nugroho, & Indriyati, 2017; Tarigan & Sipayung, 2011).

Oil palm frond and trunk contribute the highest biomass availability compared with other

oil palm waste (Thaim, Rasid, & Wan Ismail, 2019). Pruning of frond and leaflet has become a necessity and routinely carry out in oil palm plantations to facilitate maintenance and harvesting. Gromikora, Yahya, & Suwanto (2014) suggested that pruning of frond provided an increase in palm oil production. By one or two fronds per tree pruning once a month in mature (more than four years old) oil palm plantation it can increase the productivity. The returned biomass from pruning activity will be higher by increasing the age of oil palm plantation. The pruning activity generates average dry weight of 9.8 to 14 t/ha/year in Malaysia for oil palm plantations on mineral soil and peatland (Aljuboori, 2013; Sung, 2016). The plantation of research site is a peatland area with the average of returned biomass from pruned frond is 4.58 to 6.59 ha/year (Irsan, Anwar, Nugroho, & Indriyati, 2017). Residue from pruning that stacked on the land has benefits as mulch, inhibited weed growth, and source of organic matter for soil. Besides that, during the process of decomposition the returned frond and leaflet residues will release essential nutrients needed by oil palm such as N, P, and K, adding to the nutrients from the soil and fertilizer application. Oil palm which planted on peatlands

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has high nutrient requirements and highly depend on fertilizer application.

Returning frond and leaflet residues is expected to reduce the fertilizer requirements that must be given yearly. The usage of oil palm residues as mulch is one of the best agriculture management practise in Indonesia. Frond and leaflet placed as mulch in inter row in oil palm plantation is a form of return nutrients and carbon for oil palm (Ariyanti, Maxiselly, Rosniawaty, & Indrawan, 2019). The frond and leaflet residues during decomposition, release some essential nutrients which are needed by oil palm and has potential to reduce the fertilizer uses (Singh, Sulaiman, Hashim, Peng, & Singh, 2013). The amount and degree of nutrients release depend on various factors such as: oil palm residue type, climate, soil microbial activities, and the nutrients concentrations of residue (Brady & Weil, 2001; Karberg, Scott, & Giardina, 2008; Oladoye, Ola-Adams, Adedire, & Agboola, 2008).

Unfortunately, study on frond and leaflet residues in Indonesia as palm oil producer is disproportionate compared to the studies in other countries such as Malaysia. Moradi, Teh, Goh, Husni, & Ishak (2014) mentioned that Malaysia has studied about decomposition rate and nutrient release process from some oil palm residues in short term research times (eight months). Hence, study long period (two years) patterns of nutrient release and decomposition of frond and leaflet of oil palm at different burial depth (0 to 30 cm) carried out in the same area to predict their natural phenomenon was the main objective of this research. There are some differences between the kind of residu among decomposition time and burial depth to the mass loss, nutrient concentration and nutrients release during decomposition time are the hypothesis of the research.

MATERIALS AND METHODS

The research was carried out from January 2015 to June 2017 in Oil Palm Plantation area at Pangkalan Pisang Village, Koto Gasib, Siak District, Riau Province, Indonesia (0°46'14" - 0°39'13" N and 101°40'36"-101°47'45" E). This research started with determination of research locations in January 2015. Sampling and analysis were carried out from August 2015 to August 2017. The analysis of plant samples was carried out at the Laboratory of Soil, Department of Soil Science and Land Resource, Faculty of Agriculture, Bogor Agricultural University (IPB).

Frond and leaflet residues from oil palm

pruning was separated, then sliced and cut, and air-dried. The frond was sliced and cut to about 10 x 3 x 0.5 cm, while leaves was cut to about 10 cm. It was exactly 20 g (equivalent to 65°C oven-dry) of the each frond or leaflet samples placed into a litter bag (20 x 10 cm). There were 576 litter bags for each frond and leaflet samples. The litter bags were buried at three depths (10, 20 and 30 cm in cas cading) in peat soil to see the influence of surrounding conditions that could affect the decomposition process. To prevent the samples at each depth interfering each other, the burial was carried out in 30 cm cascaded horizontally. The sampling of buried residues was done on every 2 months for 2 years with the total number of samples taken every 2 months was 48 samples.

The analysis of frond and leaflet residue samples included dry weight, C, N, P, and lignin contents. The description of analysis in the laboratory is presented more complete in Table 1.

Mass loss (%) at each observation was calculated using the following equation:

$$\text{Mass loss (\%)} = \frac{DM_0 - DM_t}{DM_0} \times 100 \dots\dots\dots 1)$$

Where: DM_0 is the initial weight of frond or leaflet; DM_t is the weight residue at time t.

Nutrient release for C N and P (%) was calculated using the following equation:

$$\text{Nutrient release (\%)} = \frac{(DM_0 \times C_0) - (DM_t \times C_t)}{(DM_0 \times C_0)} \times 100 \dots\dots\dots 2)$$

Where: DM_0 is the initial weight of frond and leaflet; DM_t is the residue's weight at time t; C_0 is the original chemical content (C, N or P) of frond or leaflet; C_t is the chemical content (C, N, or P) at time t

Decomposition rate for the frond and leaflet were calculated using exponential decay funtion (Olson, 1963):

$$W = W_0 e^{-kt} \dots\dots\dots 3)$$

Where: W is the amount of dry matter remaining at time, t (month); W_0 is the initial amount of dry matter; k is the decomposition rate constant (per month), while the larger of k value, the higher the rate of the decomposition will be

The data on the decomposition rate, percentage of mass loss, nutrient concentration and percentage of nutrients release were subjected to analysis of variance (ANOVA). Tukey test was used to compare the significant means. Finally, all data was analysed using Minitab Version 16 statistical software package.

Table 1. Details of materials and tools used for analyzing the oil palm residues

Analysis	Material/ method	Tool	Method/reference
Dry weight	Frond or leaflet residues oven-dried at 60°C for 3 days.	Oven, ceramic cup and analytical scale	Gravimetric
Ash content/ Carbon content	Frond or leaflet residues burnt-furnace at 500°C for 6 hours.	Furnace, ceramic cup and analytical scale	Loss on ignition method (Page, Miller, & Keeney, 1982)
N content	Concentrated H ₂ SO ₄ pa, 1% boric acid, 0.05 N H ₂ SO ₄ standard solution, conway indicator, selenium mix, 40% NaOH.	Electric heater, Kjeldahl flasks	Wet digestion method (Page, Miller, & Keeney, 1982)
P content	60% HClO ₄ , Ammonium paramolybdate [(NH ₄) ₆ Mo ₇ O ₂₄ .4H ₂ O], (NH ₄ VO ₃), KH ₂ PO ₄ , NaHSO ₃ , H ₂ SO ₄ .	UV-Vis spectrophotometer (UV-1280, Shimadzu, Japan) with a wavelength of 490 nm.	Wet digestion method (Page, Miller, & Keeney, 1982)
Lignin content	H ₂ SO ₄ 70%, H ₂ SO ₄ I N, aquades	Furnace, Oven, ceramic cup and analytical scale	Modified lignin klason method (Dence, 1992)

RESULTS AND DISCUSSION

Mass Loss

The dry matter loss weight represents the rate of decomposition process. The decomposition process rate of oil palm frond and leaflet decreased exponentially. From the beginning to six months, the decomposition process is relatively faster and then followed by lower rate after six months (Fig. 1). The frond and leaflet weight lost at the beginning of six months was higher than 15%, and after six months or more was less than 15%. The frond and leaflet weight lost at the twelve months were 71.07% and 75.10% respectively whereas at the end of experiment the frond and leaflet weight lost were 88.86% and 86.37% respectively. The faster weight loss of dry matter at the beginning of six months decomposition process probably is caused by the loss of the materials which are more decomposable easily such as organic acids, amino acids, soluble sugars, celluloses and hemicelluloses that will decay rapidly than the more recalcitrant materials such as lignin and waxes (Foth, 1990; Green, Blackmer, & Horton, 1995; Moradi, Teh, Goh, Husni, & Ishak, 2014; Rosenani, Basran, Zaharah, & Zauyah, 1996; Swift, Heal, & Anderson, 1979). Reshi & Tyub (2007) reported, celluloses and hemicelluloses will decompose eight times faster than lignin, and organic acids, amino acids, soluble sugars, will decompose 20 times rapidly than lignin.

The leaflet and frond contain initial lignin were 52.16% and 60.76% respectively whereas after six months of decomposition the residues contain lignin were 41.20% and 55.54%. The materials which are more decomposable as confronted to the more recalcitrant materials would be consumed by microorganisms (Duong, Baumann, & Marschner, 2009). As a result, in the beginning stages of frond and leaflet decomposition, the materials which are more decomposable from the residue would loss rapidly, faster than the recalcitrant materials which decline slower. Moreover, many factors from outside of the residue can affect the decomposition rate including temperature, moisture and heat from soil surface (sunlight).

The mass loss of frond and leaflet is demonstrated in Fig. 1, between frond and leaflet is significantly different. The depth of burial from the soil surface and decomposition time also shows the differences significantly. Moradi, Teh, Goh, Husni, & Ishak (2014) said leaflet would decompose faster than frond, this experiment also found that the decomposition of leaflet decomposed faster than frond, in which the demposition was faster in the beginning six months, became slower afterwards. There were significant differences between frond and leaflet decomposition rate constant, which was the highest for the leaflet (0.058 per month) and the lowest for the frond (0.054 per month). Low decomposition rate of the

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frond was due to its high C/N ratio (234.24) and lignin (60.76 %) compared to the leaflet C/N ratio (41.84) and lignin (52.16%). Brady & Weil (2001) stated that higher C/N and lignin/N increase the difficulty of the organic material to decompose. The highest reduction occurred at two months for the leaflet (23.21%) and frond (21.51%) and the rate declined until 24 months of the decomposition experiment. The variation of burial depth showed different effect, and this probably due to different surrounding factors / conditions which derived from different phenomenon as seen as Fig. 1. Different

condition will make microorganism activity in the 10 cm, 20 cm and 30 cm of burial depths from the soil surface has unequal reaction. However, Tukey test showed that 10 cm and 20 cm of burial depths have no differences. It supposed to be caused by the similarity of physical environment such as peat moisture. Peat moisture content average of oil palm plantation in the research site for the depth of 0-20 and 20-40 cm are 230% and 358% (w/w) respectively. The easily decomposable materials of the frond or leaflet residues to be the main factor which affect the decomposition process.

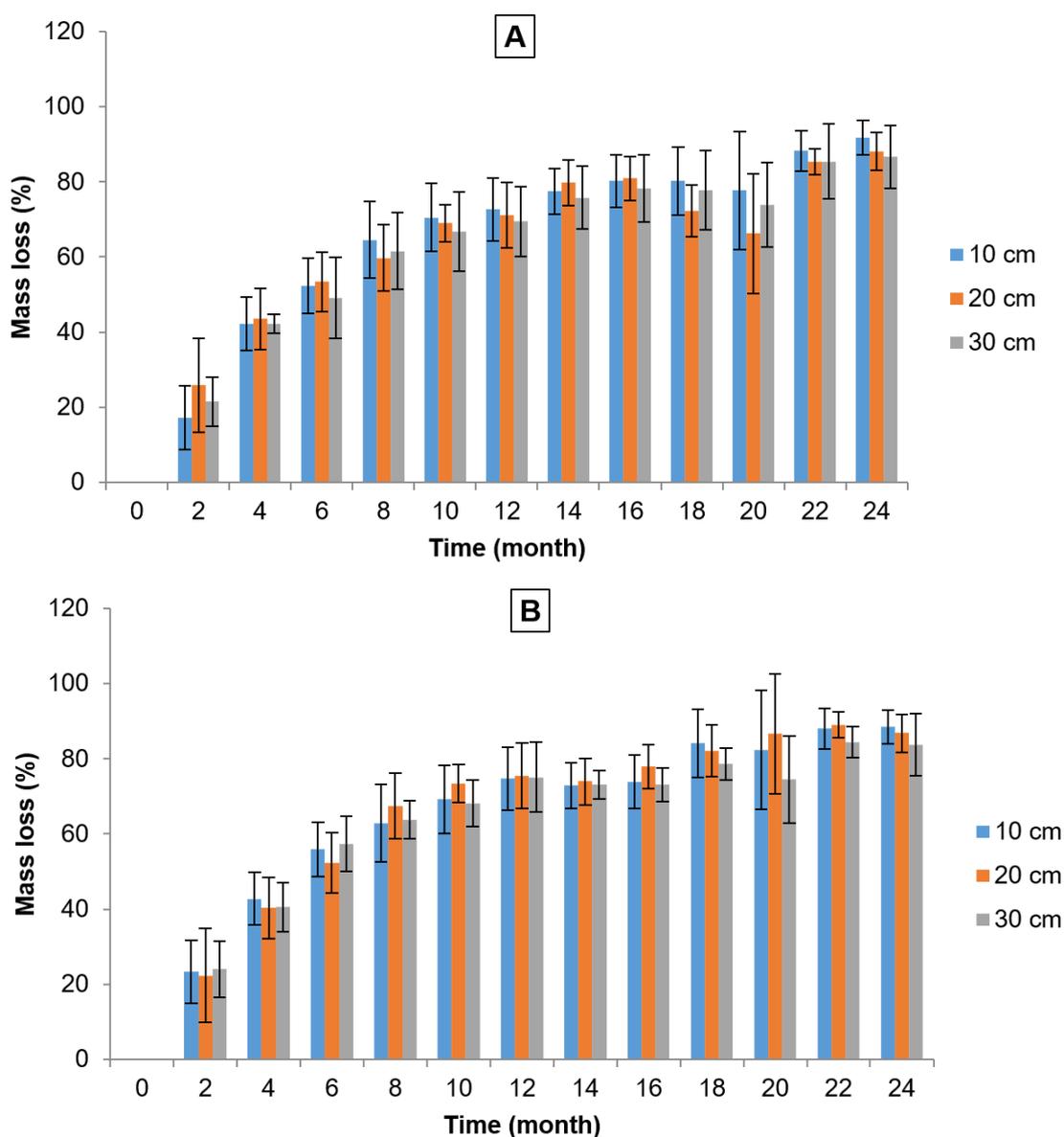


Fig. 1. Changes of dry matter mass loss for frond (A) and leaflet (B) due to their decomposition

Changes of Nutrient Concentrations

The organic carbon in the residues of frond and leaflet declines with time as seen in Fig. 2. The pattern of mass loss is like the remaining carbon (Fig. 1), i.e. a relatively more rapid decrease at the beginning of decomposition followed by a slower decrease after about six months of decomposition process until the finish of the experiment. The mass loss is in proportional to the of organic carbon in residues (Moore, Trofymow, Prescott, Fyles, & Titus, 2006). The loss of carbon also depends on the decomposable materials of residue, where the more decomposable materials will loss carbon faster. The materials which are more decomposable easily will drop quickly, and increase the proportion of the more recalcitrant materials which decompose slower.

In this research, the carbon remaining from frond and leaflet was significantly different, and leaflet would decompose faster than frond (Moradi, Teh, Goh, Husni, & Ishak, 2014). In this experiment the carbon remaining for frond and leaflet had similar trends and tensions. The organic carbon content of frond and leaflet did not change after two months of decomposition time, which ranged between 54.07–56.92%. The variation of burial depth was significantly different of the organic carbon remaining. Carbon remaining in the 10 cm burial depth had the smallest value because decomposition was the fastest. The 10 cm depth had the most suitable environment such as good aeration, suitable moisture and temperature for decomposer microbes to live.

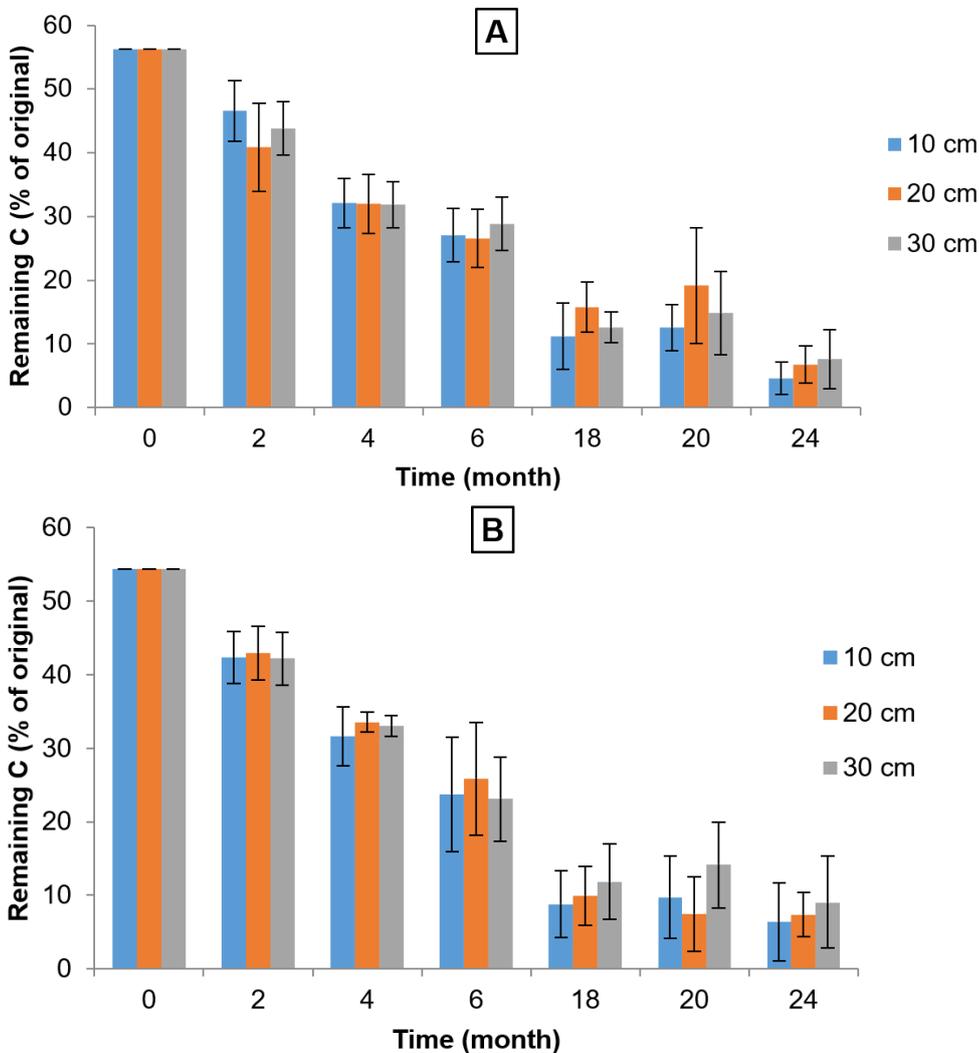


Fig. 2. The percentage of remaining C for frond (A) and leaflet (B) during two years experiment

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The oil palm residues (frond and leaflet) significantly decrease in their C/N ratio with time especially in the first six months of decomposition time and between frond and leaflet are also significantly different (Fig. 3). However Tukey test showed that leaflet was not significantly decrease in its C/N with decomposition time. The burial depth was not significantly different to the C/N. The increasing mass loss was followed by the reduction of C/N. The C/N of leaflet decreased at

lower rate than frond. The C/N of frond and leaflet decreased with time due to the N mineralization rate which was slower than the rate of C loss. Residue which more recalcitrant materials was released N after the C content in the residues became 60% (Moore, Trofymow, Prescott, Fyles, & Titus, 2006). Leaflet experienced a deliberate decay in its C/N because the residues contained materials having opposing qualities compared with frond. The leaflet is composed of lamina and midrib.

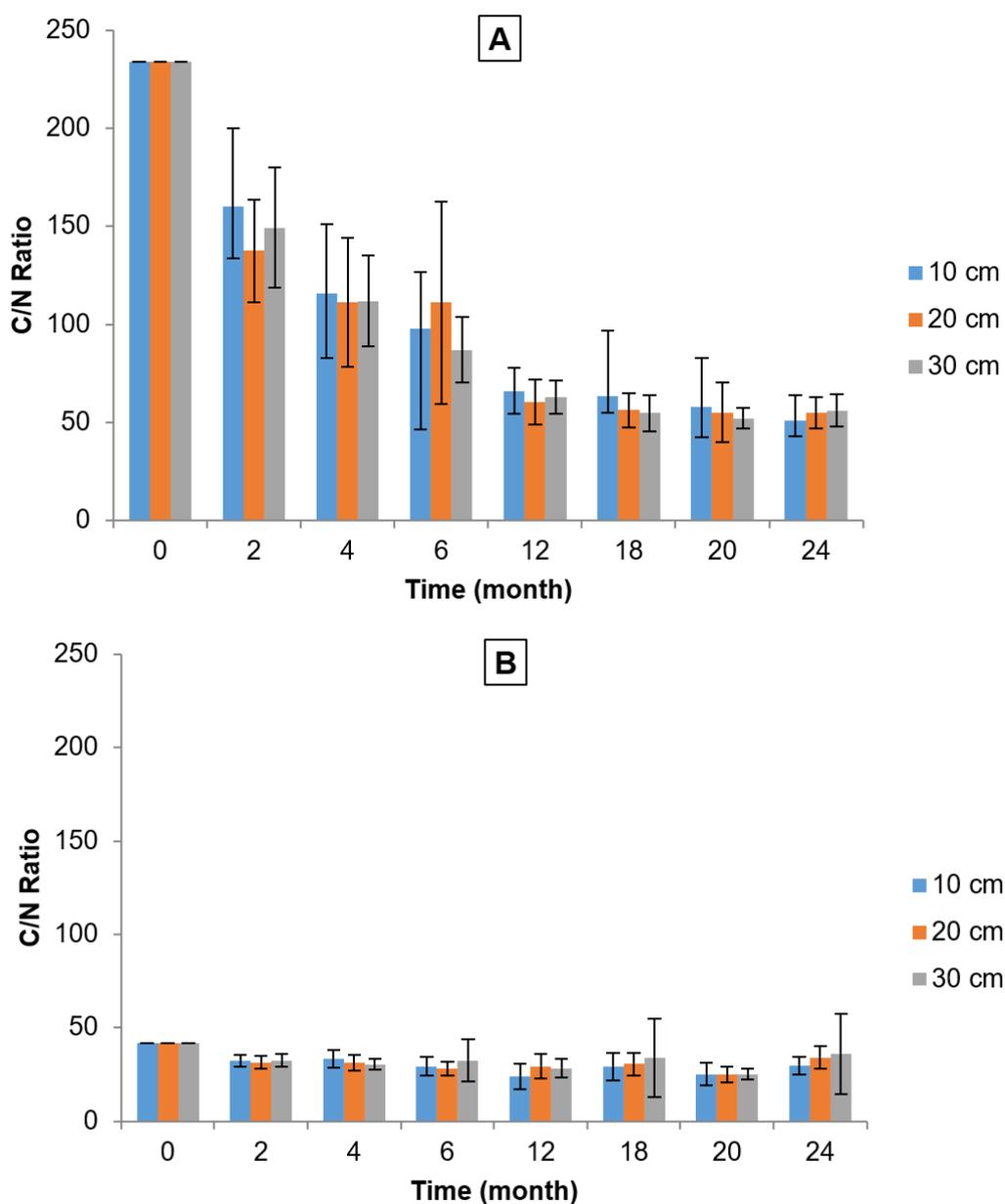


Fig. 3. C/N of frond (A) and leaflet (B) based on depth of buried and decomposition time

The frond's C/N is differently higher than leaflet's C/N at any time of observation (Fig. 3). C/N of frond had range between 234 at the initial decomposition to 54 at the end of decomposition time whereas C/N of leaflet had range between 42 at the initial decomposition to 25 at the end of decomposition time. The changes in the frond's C/N were represented by soluble sugars, amino acids, organic acids, cellulose and hemicelluloses which degraded rapidly than lignin. In the initial stage of leaflet decomposition, the reduction of C/N was because of the lamina and midrib, but as the decaying proceed, the leaflet's C/N was more reflected by the midrib and less by the lamina properties, like for the frond decaying. The reduction of frond's C/N showed a much faster all the time as likened to leaflet's C/N, because frond and leaflet have contrasting qualities of decomposable materials. The C/N for the low quality residues decreased at a faster rate than the high quality residues (Moradi, Teh, Goh, Husni, & Ishak, 2014). Quality of organic residue characterized by some parameters such as N, P, C/N, lignin and polyphenol content (Dux, Norgrove, Hauser, Wick, & Kühne, 2006). However, the most important and usually used parameters are C/N and lignin/N (Brady & Weil, 2001). Based on the parameters mentioned before the frond has lower quality than the leaflet (Table 2).

Table 2. Initial composition nutrients of frond and leaflet

Nutrients	Frond	Leaflet
C (%)	56.22	54.42
N ppm	2400.00	13008.20
P ppm	644.24	1850.82
K ppm	8105.84	5247.16
Ca ppm	2128.33	5464.10
Mg ppm	1037.06	2994.83
C/N	234.24	41.84
Lignin (%)	60.76	52.16

The changes of N and P concentrations in frond and leaflet residues showed at Fig. 4 and Fig. 5. The N concentration in frond and leaflet residues increased significantly whereas P concentration decreased remarkably along with decomposition time. The N concentration in frond and leaflet residues was not significantly decreased whereas P concentration notably decreased along with the burial depth. The N concentration of leaflet

increased at the initially stage of decomposition, then decreased in the end of decomposition periods. But for P of leaflet, the concentration reduced with time. Meanwhile, the N and P concentration of oil palm frond always increased with increasing time of decomposition. This phenomenon can be seen in Fig. 4 and Fig. 5. The increasing concentration of N along with time because the releasing N through mineralization was slower than mass or carbon loss.

As stated earlier, the increasing of leaflet's N concentration occurred in the beginning and then decreased. Decomposition of leaflet is strongly influenced by lamina and midrib, where midrib decays more difficult than lamina (Khalid, Zin, & Anderson, 2000). As a result, at the initial decomposition stage, leaflet has mass loss rate which is faster than mineralization rate due to decomposition of lamina from the increase of nutrients concentrations in the leaflet. But as more lamina lost during decomposition, the speed of mass loss would decrease slowly because more intensive decomposition occurred on the recalcitrant midrib. Therefore, N concentration of leaflet decreased instead of midrib decomposition derive rate of mineralization rate as similar as mass loss rate at the final stage of decomposition.

The nitrogen and phosphorus concentration in the frond increased with time. This is caused by frond has high C/N materials, thus more difficult to decompose. In the beginning stage of decomposition, the frond's nutrient concentrations will continue to decrease because more decomposable materials will lost, going before more recalcitrant to decompose.

The leaflet released N faster and higher than frond at the stage of decomposition (Fig. 6). The leaflet released around 83% of its initial nitrogen while the frond released around 51% at the end of decomposition time (24 months). In the beginning stage of decomposition, N release had negative value indicating that the transfer of nitrogen from soil into the oil palm residues by the soil microorganisms. When residues with high C/N are appended to the soil, microorganisms will be N-restricted, thus N from soil will alternatively used by the microorganisms to decompose the residues. The nitrogen net immobilisation from the decomposing residues will be produced. Melillo, Aber, & Muratore (1982) and Mun (2009) found identical results. Fig. 6 also shows that it is about 51% N of frond is originated from the recalcitrant materials and around 83% of N which is used to decompose frond material comes from the outside source or the soil.

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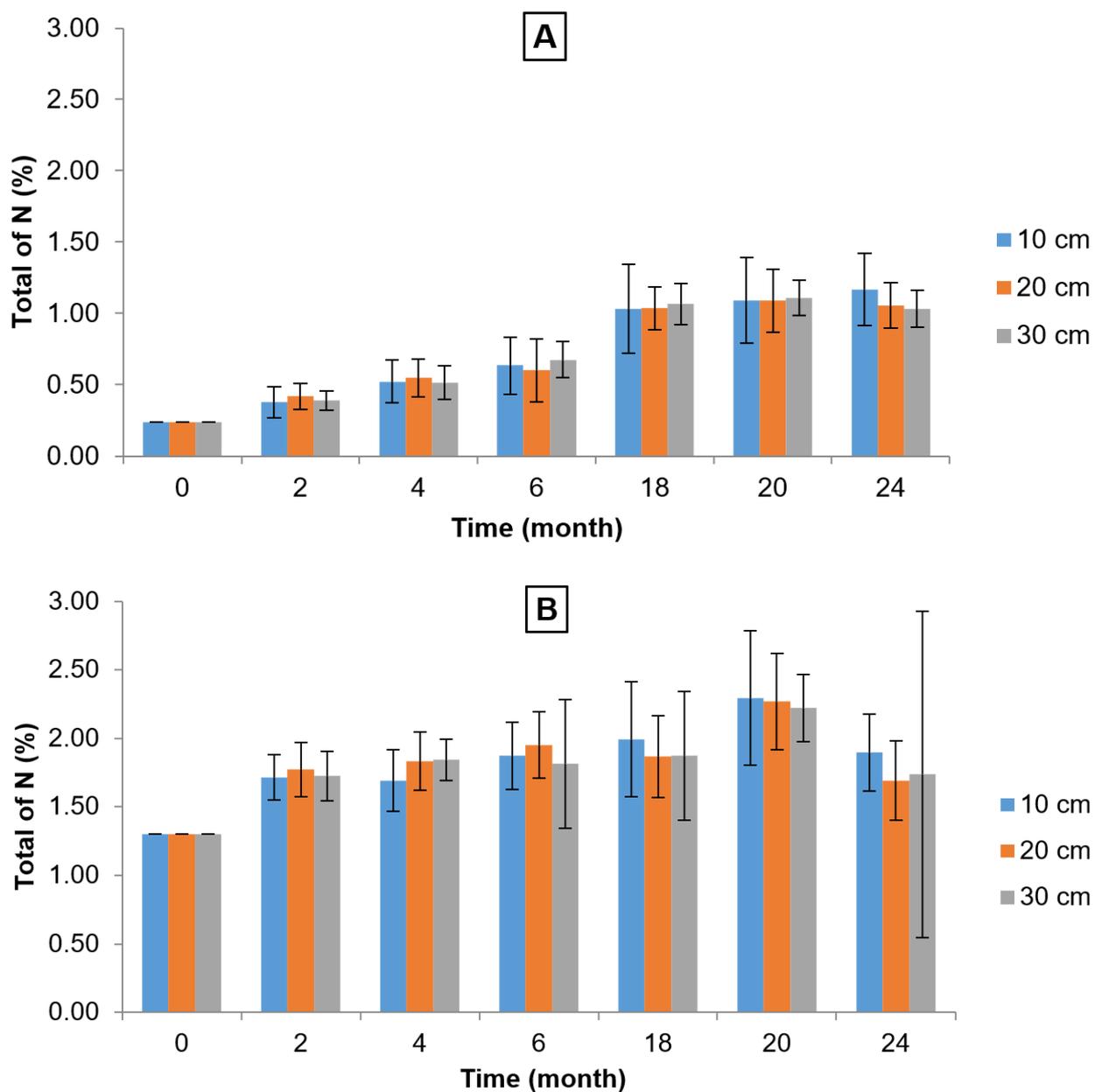


Fig. 4. N-content of frond (A) and B (right) based on depth of buried and decomposition time

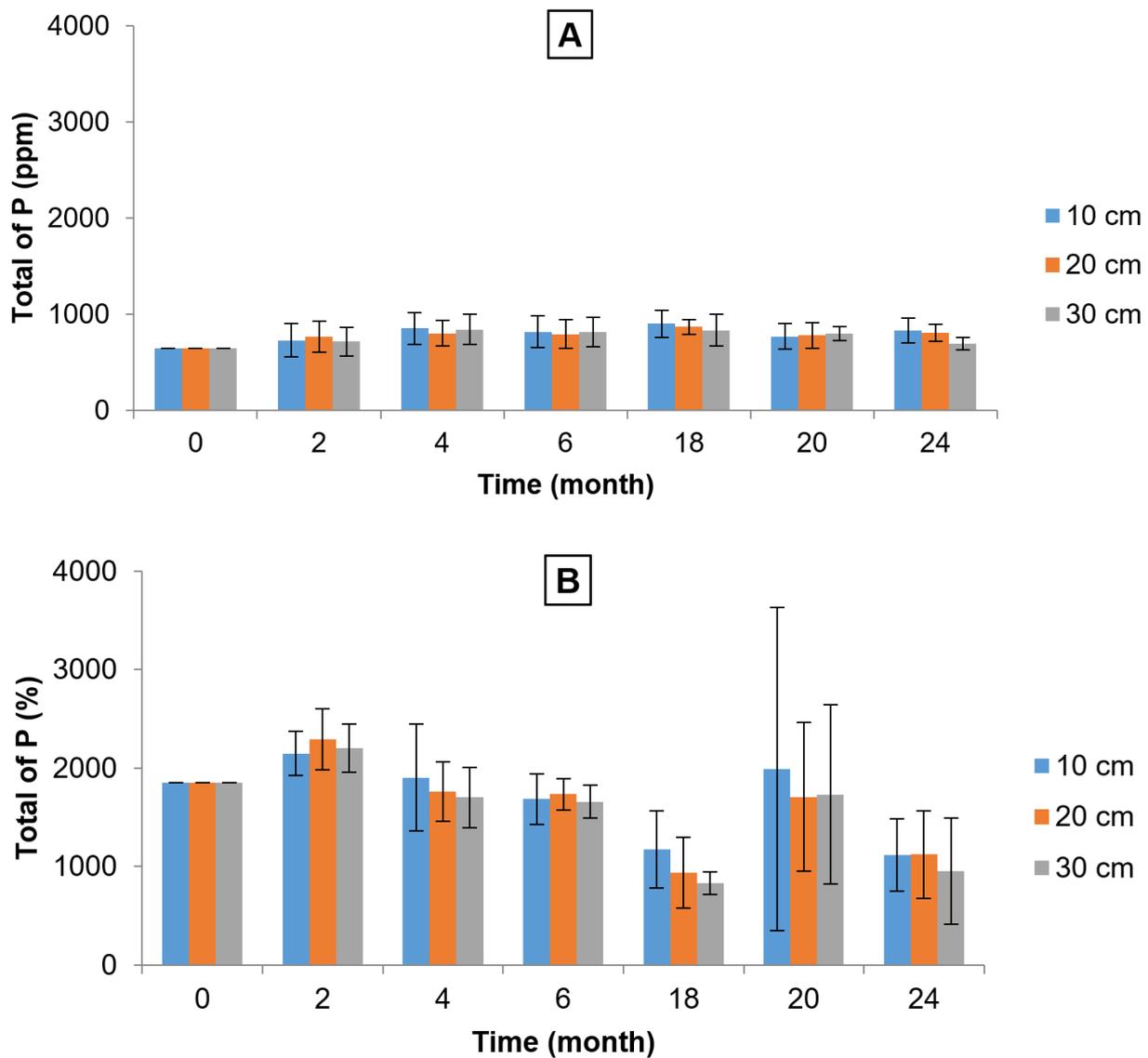


Fig. 5. P-content of frond (A) and leaflet (B) based on depth of buried and decomposition time

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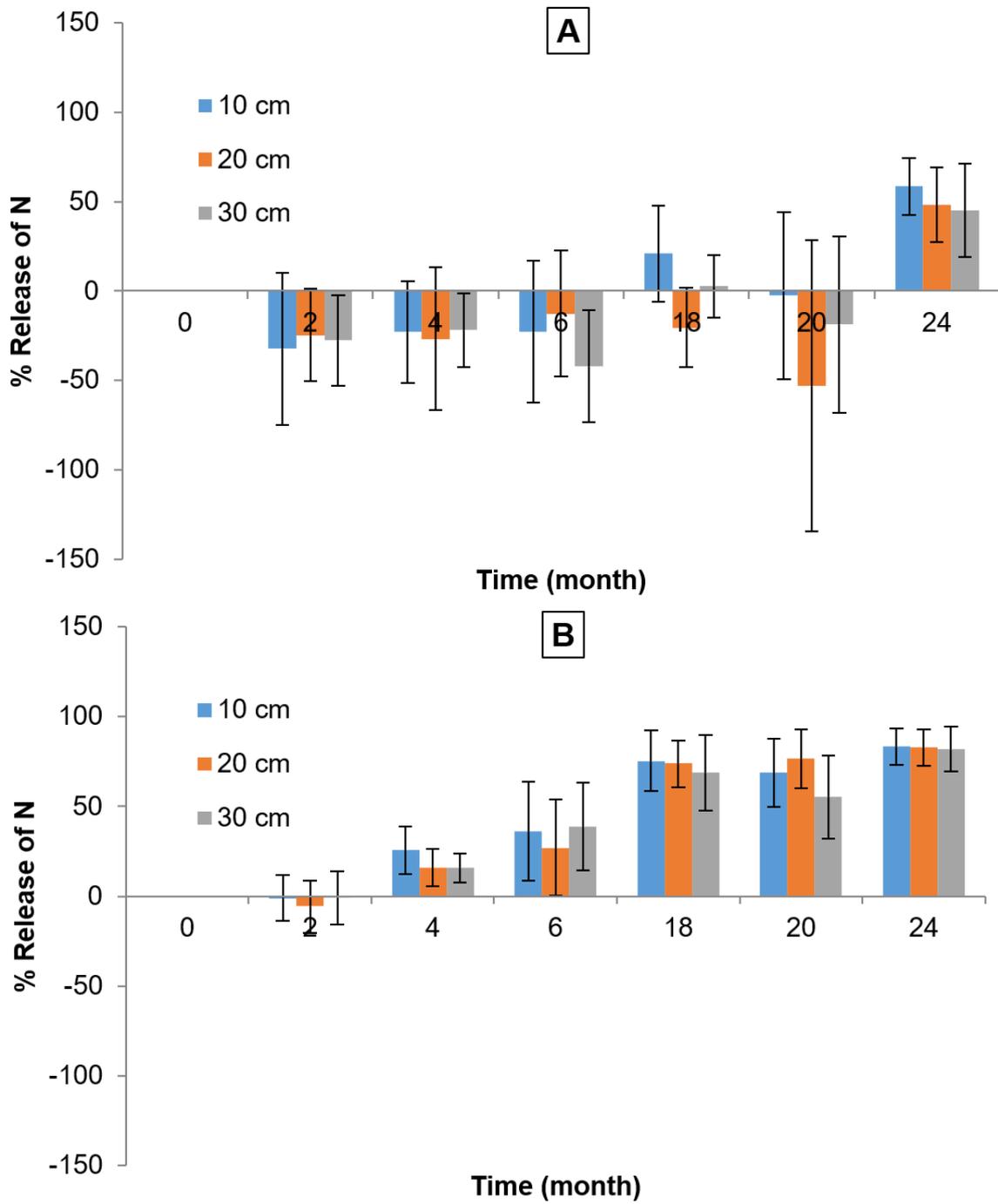


Fig. 6. Percentage release of N of frond (A) and leaflet (B) based on depth of buried and decomposition time

Meanwhile, most of N from leaflet is originated from decomposable materials from the released of N in higher amount.

The release patterns of P (Fig. 7) in general look like to that of nitrogen (Fig. 6), as also found by Berg & Staaf (1980) and Khalid, Zin, & Anderson (2000) except N release from frond. The frond released phosphor higher than the leaflet in the first two months of decomposition stages and then lower than the leaflet in the remaining decomposition stage. Around 40% of original phosphor content released within 6 months of

the decomposition period, but it continued rapidly released till 18 month. At the 24th months of the decomposition period, frond released about 87% of the initial P, and leaflet released about 93% of the initial P. The N release significantly decreased along with the burial depth of oil palm residues, however Tukey test showed that the N release at 10 cm depth was significantly different than at 20 cm and 30 cm depth. But there was no difference between N release at 20 cm and 30 cm depth. The variation of burial depth did not show any effect to the release P of oil palm residues.

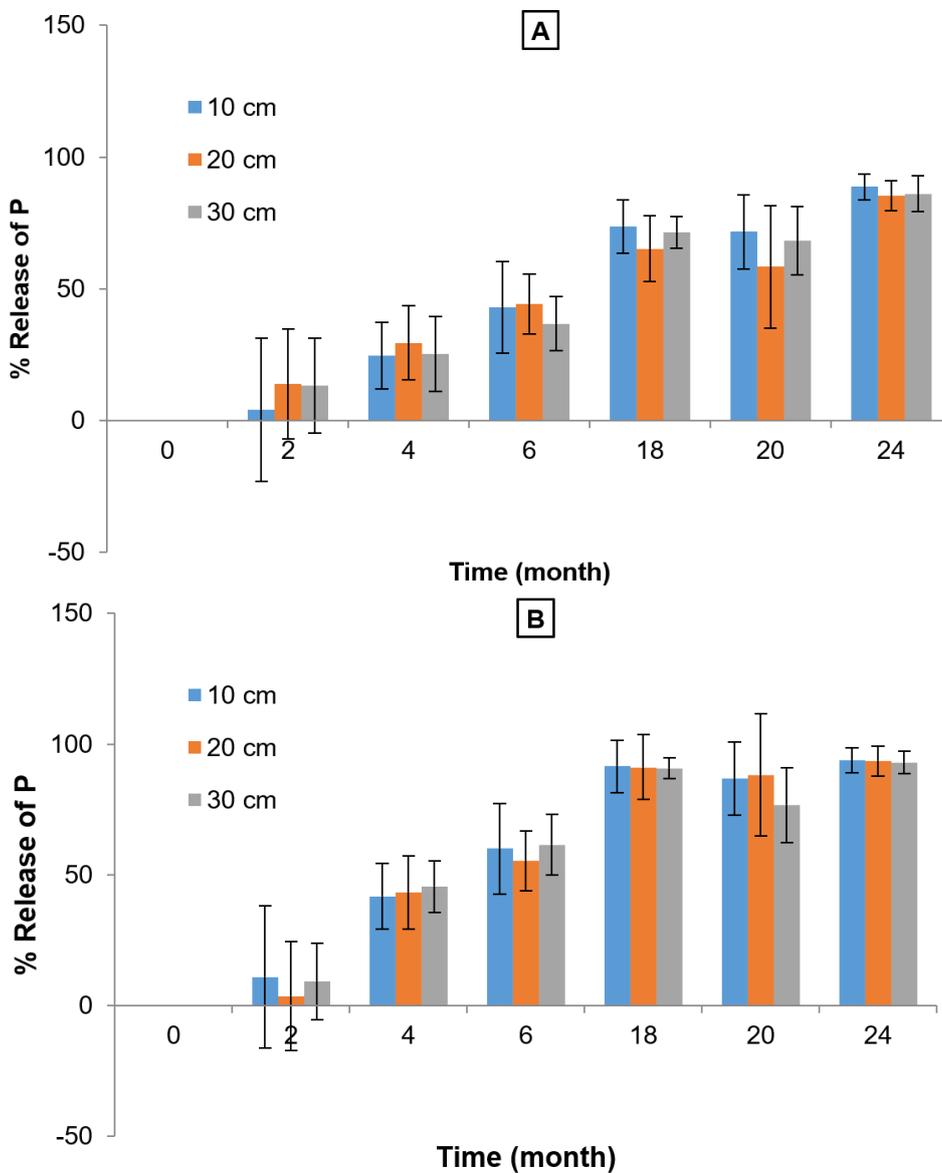


Fig. 7. Percentage release of P of frond (A) and leaflet (B) based on depth of buried and decomposition time

CONCLUSION

Decomposition of frond and leaflet of oil palm did not have different pattern in mass loss, chemical content changes of C/N, N content, P content and P released. However, it has different pattern in N release. During the two years of decomposition, frond and leaflet lost were 88% and 86% of its initial weight and released 51% and 83% of N, also it released 87% and 93% of P respectively. Frond and leaflet from pruning of oil palm should be returned to plantation area for one source of nutrients beside fertilizer.

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