

Effect of termite activity on soil chemical properties using baiting systems at an arboretum area in Pontianak, West Kalimantan, Indonesia

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Abstract. Indrayani Y, Khasanah RU, Anwari S. 2021. *Effect of termite activity on soil chemical properties using baiting systems at an arboretum area in Pontianak, West Kalimantan, Indonesia. Biodiversitas 22: 2125-2130.* Termites play an essential and positive role as decomposers in nature, apart from being known as wood-destroying insects. These two varying characteristics led to the development of termite control technology, capable of digesting cellulose components and making soils rich in organic compounds. Therefore, this study examines the soil's biogenic structure due to termite activity using a control technology with a baiting system. The bait was made with various compositions of eucalyptus leaves, paper and cardboard, 60%: 40%: 0%, 60%: 20%: 20%, 60%: 0%: 40%, 0%: 100%: 0% and 0%: 0%: 100% with a size of 2cm x 2cm x 1cm and eucalyptus leaves as an attractant. In addition, a PVC tube measuring 10 cm diameter and 20 cm height with 25 holes consisting of 3 mm diameter on the side was used for field application. A total of 100 grams of bait for each composition was entered into the feed tube and placed in the Arboretum of Tanjungpura University, West Kalimantan, Indonesia with three replications and left for 21 days. At the end of the observation period, the soil's biogenic structures with termites were analyzed to determine their chemical properties. Furthermore, the same analysis was also carried out on the soil surrounding the test area without termite activity for comparison. The results showed that the pH, C/N ratio, C-Organic, Nitrogen, Phosphorus, and Potassium contents as well as Cation Exchange Capacity of the soil produced from the tube containing the bait with a composition of 60%: 0%: 40% was significantly higher. This means that the soil's biogenic structure produced by termite activity with a baiting system increases land productivity and chemical properties.

Keywords: Baiting system, organic waste, soil chemical properties, subterranean termites, termite control

INTRODUCTION

In tropical areas, termites are known as insects that destroy wooden structures (Perace 1997), as well as agricultural and plantation crops (Darlington 1987; Apori et al. 2020b). However, termites also play an important role in natural ecosystems (Darlington and Dransfield 1987; Black and Okwakol 1997). The level of soil fertility is caused by several factors, such as soil macrofauna, which determines the land productivity of plant growth. One of the macrofauna affecting the soil's physical, chemical, and biological characteristics is termites (Apori et al. 2020b).

Several studies have been carried out to determine the physical and chemical properties of termite nests. Li et al. (2017) reported the effect of termites on soil pH, while Afolabi et al. (2014) analyzed the chemical elements, such as organic carbon, total nitrogen, and phosphorus availability. Furthermore, Apori et al. (2020b) researched the chemical content of organic carbon, availability of phosphorus, total nitrogen, potassium, and magnesium (Mg^{2+}) contained in termite nests. Deke et al. (2016) also reported the chemical content of the soil in termite nests in the form of total nitrogen, with the availability of phosphorus and exchangeable cations and CEC. Although the soil chemical compounds reported in these studies were derived from termite nests, no research has been conducted

to determine their activity in increasing soil chemical compounds outside their nest. Therefore, it is necessary to observe the termites' activity in increasing soil chemical compounds outside their nests to determine their role in enhancing land productivity.

The technique used to collect soil from termite activity can be carried out using a baiting system. Indrayani et al. (2016) carried out research on collecting soil from termite activity using a baiting system made from newspaper with soybean boiled water as a nutritional enhancement. The research indicated an increase in bulk density, organic carbon, and C/N ratio in the soil. Indrayani et al. (2018) further improved the bait composition by adding natural attractants to attract termites, which were tested on a laboratory scale. However, bait application using this natural attractant has not been tested on a field scale. Therefore, this study determines the soil's chemical characteristics from termite activity through the baiting system from organic waste in the Arboretum of Tanjungpura University, West Kalimantan, Indonesia. Termites are expected to walk into the tube, eat the bait, and produce biogenic products capable of improving the soil's chemical properties. The results are expected to act as an essential part of providing necessary information regarding termite management.

MATERIALS AND METHODS

Study area

This study was carried out at the Arboretum area of Tanjungpura University, Pontianak, West Kalimantan, as shown in Figure 1. The geographic location is $0^{\circ}03'07'' - 0^{\circ}03'0''$ S latitude and $109^{\circ}20'58'' - 109^{\circ}21'07''$ E longitude. The soil types used in the study area were organosol, gley, humus, and alluvial. Furthermore, the average rainfall, temperature, and humidity were 3000-4000 mm per year, 26.1- 27.4°C, and 86-92%, with a study height of 0.10 to 1.5 m above sea level (Development Planning Agency at Sub-National Level (BAPEDA) of Pontianak City 2018).

Procedures

Material preparation

This research was carried out using the old and young eucalyptus leaves. The leaves were air-dried for 5 days, then mashed using a hammer mill and filtered with a mesh size of 20. The middle part of the corrugated cardboard and paper was used to carry out this research. Furthermore, the paper and cardboard are cut or torn in small sizes, then dried under the sun for 24 hours before being mashed using a hammer mill and sieved with a mesh size of 20.

Bait making process

Paper and cardboard were soaked in distilled water for 20 minutes to make it easier to mix the material between the paper and eucalyptus leaf powder. Furthermore, the paper was squeezed using a croton cloth and mixed with mashed eucalyptus leaves before the bait was molded using a 2 cm x 2 cm x 1 cm zinc. The bait was made with various compositions of eucalyptus leaves, paper and cardboard, namely 60%: 40%: 0%, 60%: 20%: 20%, 60%: 0%: 40%, 0%: 100%: 0% and 0%: 0%: 100%.

The field test was carried out by inserting 100 grams of bait into a PVC pipe measuring 10.16 cm in diameter and a height of 20 cm. On the side of the tube, 25 holes were made with a diameter of 0.3 cm. Furthermore, PVC pipes or bait tubes are planted to a depth of 20 cm in the Arboretum of Tanjungpura University, Pontianak, Indonesia in areas with high termite attack activity, which was determined based on its presence under the litter or the nests found on the ground. The bait tube was randomly placed for each different composition and repeated three times. The test unit was left in the field for up to 21 days to allow termites to attack the bait. The soil in the tube caused by termite's activities was separated from the bait carefully then analyzing at the Laboratory of Chemistry and Soil Fertility, Tanjungpura University, to measure the organic C content, nitrogen, phosphorus, pH, and cation exchange capacity (CEC).

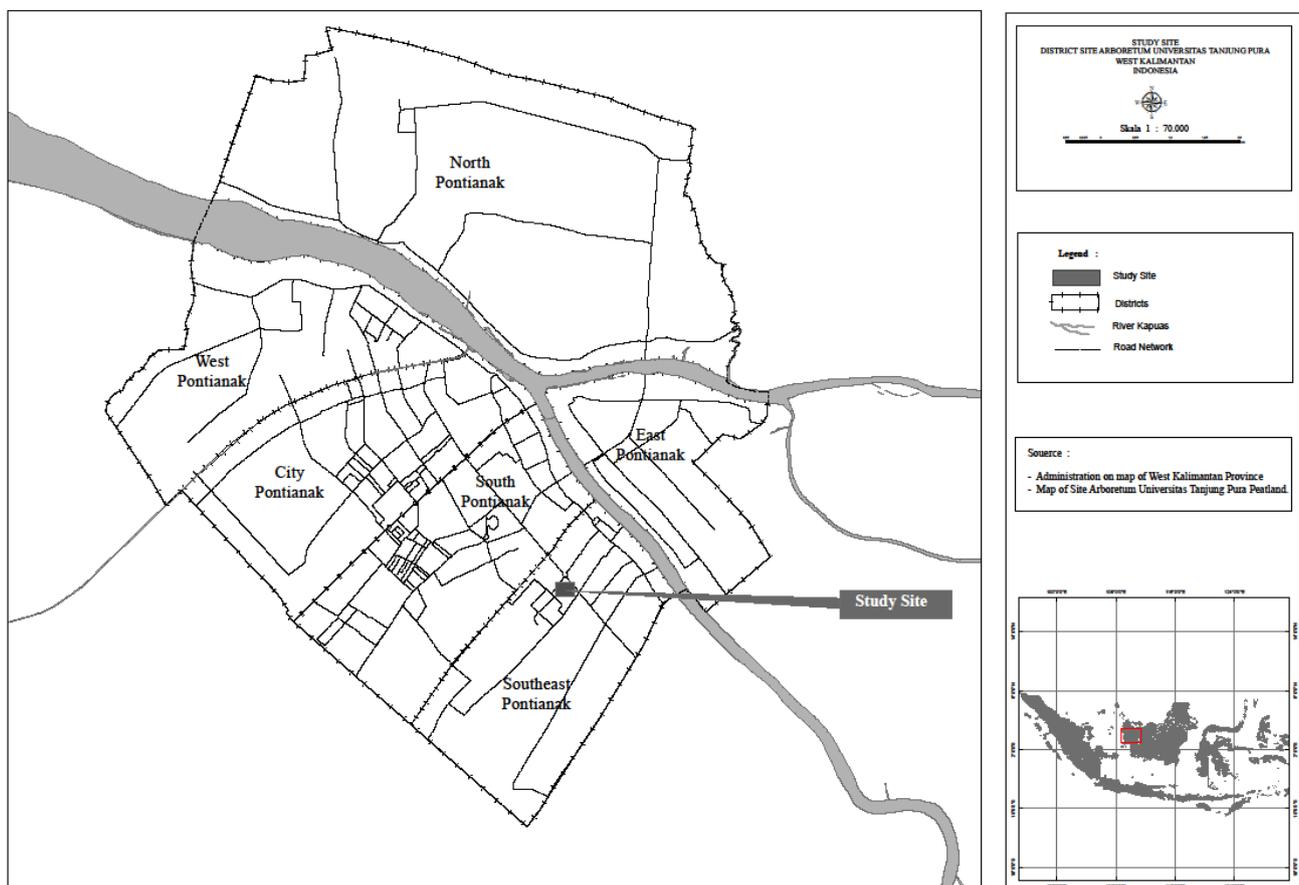


Figure 1. Map of the study area in Arboretum Tanjungpura University, West Kalimantan Province, Indonesia. Source: Administrative Boundary Map (2003)

Field testing and soil analysis

Organic C, N, and P were measured by using Spectrophotometer (Rayleigh UV – 1800). C-organic and N content were determined from a 0.5 g air-dry soil sample, while an amount of 2.5 g air-dry soil sample was used for K and P content quantified. Soil pH was determined from a 10 g of soil sample placed into a beaker with distilled water until 50 ml then stirred for 30 minutes, and measured with calibrated pH meter. The soil sample from surrounding the test unit within 1 m was taken using a soil ring measuring 5 cm in diameter as a control.

Data analysis

Data were statistically analyzed by Variable Analysis with factorial design by Dunnett's test, and Tukey's Analysis was used to compare the mean values.

RESULTS AND DISCUSSION

Soil acidity (pH)

Bait made of cardboard significantly increased soil pH (Tukey's test: $P < 0.01$) and significantly different than bait containing eucalyptus leaves and paper nor paper only and soil control (Tukey's test: $P < 0.01$) (Figure 1). According to Buckman and Brady (1960), several essential nutrients are closely related to soil pH, leading to a rise in absorbed nutrients. Low soil pH causes plants to be unable to utilize N, P, K, and other nutrients needed. It also leads to the availability of toxic elements such as aluminum, which poison plants and binds P, thereby making it impossible to absorb plants (Hardjowigeno 2007). There is a significant difference in the soil pH value between the soil collected in the bait tube from termite activity and the surrounding (Figure 1).

These results are in line with the studies carried out by Li et al. (2017) and Deke et al. (2016), which stated that termite nests' soil pH is higher than the surrounding. The bait compositions showed that those containing eucalyptus leaves and cardboard led to a higher soil pH compared to containing paper only nor paper and eucalyptus. This finding is supported by the research carried out by Indrayani et al. (2017b, 2018), which stated eucalyptus leaf extract can be used as an attractant for termites.

Organic carbon (C) content

The soil organic C content in the tube containing the bait made of cardboard and eucalyptus leaves was significantly higher (Tukey's test: $P < 0.01$) compare to the surrounding soil and the bait made from paper (Figure 2).

Figure 2 proves that eucalyptus leaves have attractive properties that attract termites to the bait (Indrayani et al. 2017, 2018; Noviansari et al. 2013). The difference in the amount of cellulose content in cardboard is 75% (Yanez et al. 2004), while 64.85% of paper is found in the dry weight (Sholikhah et al. 2018). The cellulose content in paper also makes termites more interested in eating the bait. Muin and Arif (2017) confirmed this analysis by stating that a mixture of degraded pine wood with paper, cardboard and newsprint are formulated into attractive baits for termites.

The high organic C content of termite nesting from the surrounding soil was also reported by Lavelle et al. (1997), Afolabi et al. (2014), and Apori et al. (2020a).

Soil nitrogen (N)

The total nitrogen content plays an essential role in improving soil chemistry. According to Sudaryono (2009), nitrogen is used to improve vegetative plant growth. The soil collected from the bait tube contains bait made of eucalyptus leaves and cardboard with the composition of 60:40 show a significantly higher content of total nitrogen and significantly different than the surrounding soil and other bait with other compositions (Tukey's test: $P < 0.05$), as shown in Figure 3. The rest bait with other compositions, as shown in Figure 3, were not significantly different at Tukey's test: $P < 0.05$.

An increase in the total amount of nitrogen was recorded in eucalyptus leaf bait and cardboard with the composition of 60:40 compared to the surrounding soil and other composition. The high value of total nitrogen in the bait containing eucalyptus leaves and cardboard (60:40) proves that subterranean termites prefer this composition. This phenomenon is understandable because the total nitrogen content in termite nests is higher than the surrounding soil (Jouquet et al. 2018; Apori et al. 2020b; Afolabi et al. 2014).

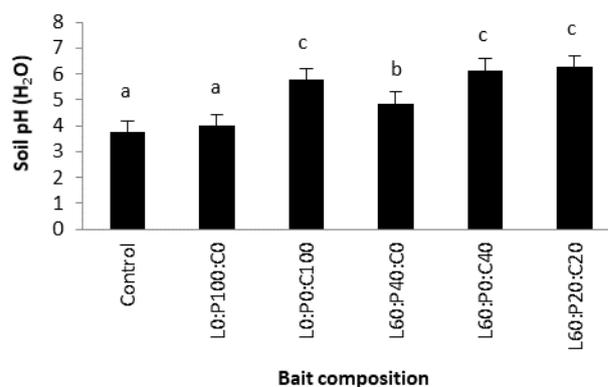


Figure 1. Soil acidity (pH H₂O) at various bait compositions. L: leaf; P: paper; C: cardboard. Columns with different letters differ significantly at a 99% confidence level.

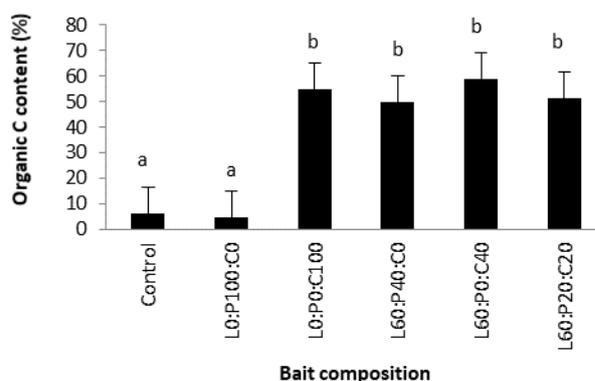


Figure 2. Soil organic C content (%) at various bait compositions. Caption see in Figure 1. Columns with a different letter differ significantly at a 99% confidence level.

C/N ratio

The C/N ratio is the ratio between the amounts of elemental carbon (C) content to the nitrogen (N) contained in organic material (Priya et al. 2017). The decrease in nitrogen content increased the C/N ratio in the study area. Furthermore, the C/N concentration ratio was significantly higher in the bait tube's soil with a 100% cardboard composition and showed significantly different than other compositions (Tukey's test: $P < 0.01$) (Figure 4.)

The C/N ratio of the surrounding soil and the bait made of 100% paper is low, at 8.05 and 5.21, and significantly different from other bait compositions (Tukey's test: $P < 0.01$). This is because the bait made of 100% paper does not contain eucalyptus leaves which can attract termites came to the bait (Indrayani et al. 2016). In this research, bait without cardboard resulting in a low C/N ratio and C-organic content. This is in line with Muin et al. (2015), who found higher termite attract in bait with cardboard than bait without cardboard. According to Syahfitri (2008), organic matter cannot be used directly by plants because the C/N ratio does not match those in the soil, ranging from 10-12. However, when the organic matter has a C/N ratio close or equal to those in soil, plants can use the material. The C/N ratio of the soil collected in the bait tube in this study was high due to several factors, such as climate. According to Buckman and Brady (1960), temperature and rainfall significantly affect the soil's C/N content at the time of data collection. Conversely, the research carried out by Bera et al. (2020) in West Bengal, India, stated that the C/N ratio value in termite nests is smaller than the surrounding soil.

Available phosphorus (P)

The average value of P availability (P_2O_5) is shown in Figure 5. The use of 100% cardboard and the addition of eucalyptus leaves to cardboard in the making bait increases the P availability. However, the P concentration in the bait with the addition of eucalyptus leaves on cardboard is significantly higher than ambient soil and other compositions (Tukey's test: $P < 0.01$), as shown in Figure 5.

In general, the P soil in the bait tube was significantly higher than the surrounding (Tukey's test: $P < 0.01$). The P mean in the soil in the bait tube ranges from 60.67 mg Kg^{-1} - $194.48 \text{ mg Kg}^{-1}$ and considered in the high to a very high level in terms of soil fertility (Siswanto 2006). Buckman and Brady (1960) stated that P nutrients' need was absolute because plant growth depends on the amount of P availability in the soil with its role in root growth, stem, cell division, and seed ripening. The high P-value in the tube with a bait composition of 60%: 0%: 40%, 0%: 0%: 100%, and 60%: 20%: 20% is due to the higher values of soil pH in the surrounding and other compositions. According to Buckman and Brady (1960), P nutrients' availability is optimal at pH 6 to pH <8. The P-solubility is influenced by pH at 6-7 when it is <6, enabling it to bond with Fe and Al (Mallarino 2000). P is the second essential macro element needed by plants after nitrogen, which functions in cell division, albumin formation, flower, fruit, and seed formation, accelerates ripening and strengthens stems, therefore they do not collapse easily.

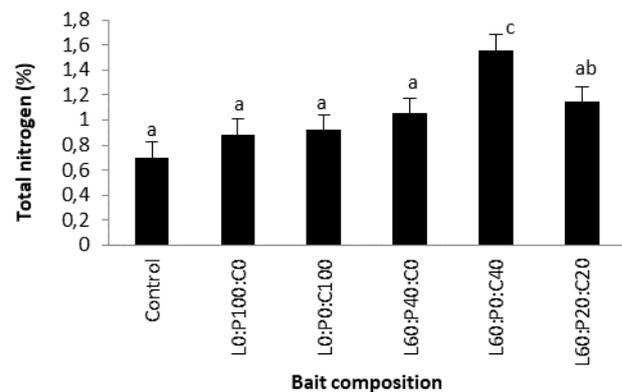


Figure 3. Total Nitrogen content at various bait compositions. Note: Caption see in Figure 1. Columns with a different letter differ significantly at a 95% confidence level

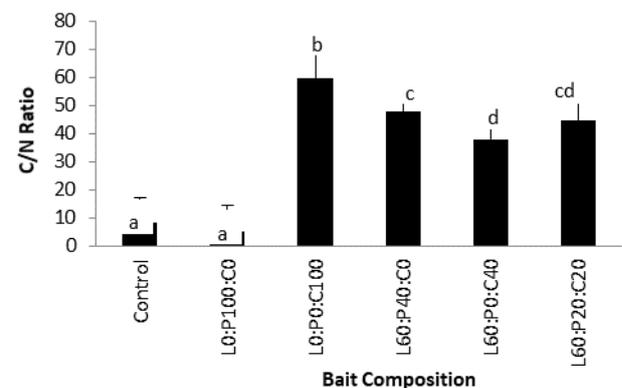


Figure 4. C/N Ratio at various bait compositions. Caption see in Figure 1. Columns with different letters differ significantly at a 99% confidence level

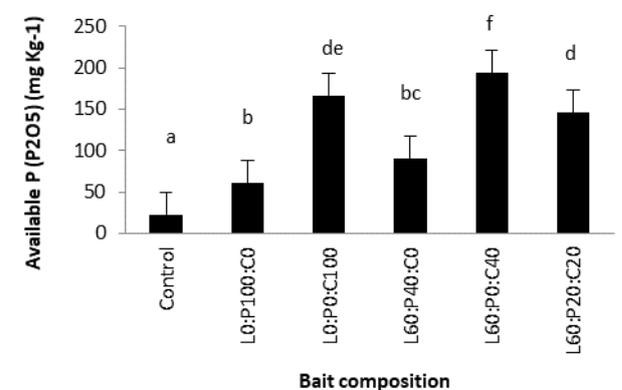


Figure 5. Available P (P_2O_5) at various bait compositions. Caption see in Figure 1. Columns with different letters differ significantly at the 99% confidence level

Cation Exchange Capacity (CEC)

The lowest CEC mean was recorded on the soil around the nest and bait without eucalyptus leaves and cardboard with a value of $19.88 \pm 1.63 \text{ cmol kg}^{-1}$ and $20.76 \pm 2.5 \text{ cmol kg}^{-1}$. Meanwhile, the highest CEC was on the soil in tubes with bait made from a mixture of eucalyptus leaves and cardboard with $126.32 \pm 15.28 \text{ cmol kg}^{-1}$ as shown in Figure 6.

There was a significant difference in CEC between the surrounding soil and those in the bait tube (Tukey's test: $P < 0.01$). The results of this study are similar to Deke et al. (2016) research using the same analysis of termite nests and surrounding soil. However, the CEC rate in cardboard baits or a mixture of eucalyptus leaves and cardboard is very high. This is related to the soil pH contained in each tube, with the High CEC due to the increase in soil pH in the tube. Meanwhile, according to Buckman and Brady (1960), the availability of CEC is optimal at soil pH 6 to < 8 . Soils with high CEC are able to absorb and provide nutrients better than those below.

Potassium (K) content

The average K content of $7.77 \pm 0.3 \text{ cmol kg}^{-1}$ in the soil of bait tube with eucalyptus and cardboard is significantly different from the surrounding soil at $0.44 \pm 0.08 \text{ cmol kg}^{-1}$ (Tukey's test: $P < 0.01$) as shown in Figure 7.

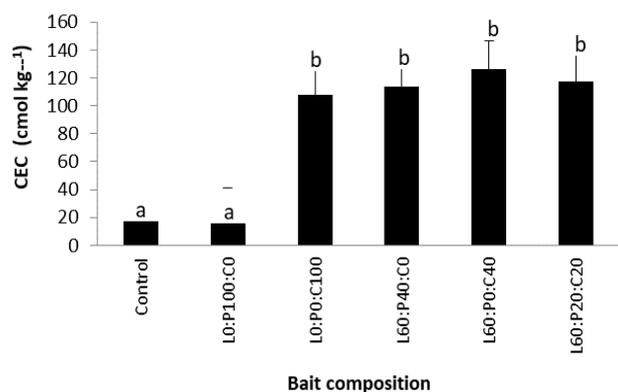


Figure 6. Cation exchange capacity (CEC) at various bait compositions. Note: Caption see in Figure 1. Columns with different letters differ significantly at 99% confidence level

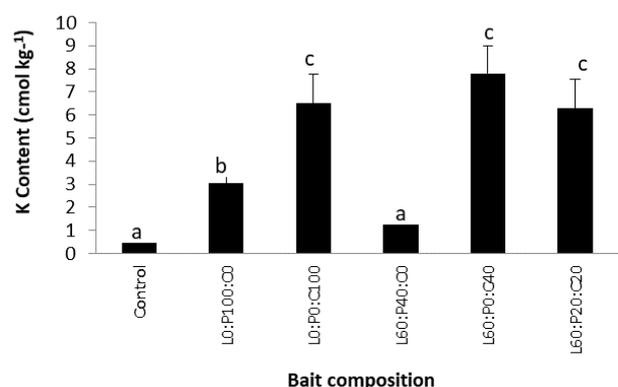


Figure 7. K Content at various bait compositions. Note: Caption see in Figure 1. Columns with different letters differ significantly at a 99% confidence level

Potassium is the third nutrient needed by plants after N and P because it plays an important role during photosynthesis, as well as in the formation of carbohydrates and proteins (Sudaryono 2009). The results of this study are in line with the analysis of K content in termite nests and surrounding soil carried out in Minna, Nigeria (Afolabi et al. 2014), Central Uganda (Apori et al. 2020a), Miyo and Yabello District of Borana Zone, Southern Ethiopia (Deke et al. 2016).

This study demonstrated that characteristics of biogenic structure resulted from the bait by the activities of subterranean termite were varied according to the composition of bait ingredient. The activities of termites allow change in the biogenic structure such as higher pH, higher C-organic content, higher total nitrogen, higher available Phosphorus, higher CEC, and higher potassium content compared to the surrounding soil. The termite's biogenic product resulted from bait with the composition of 60 eucalyptus leaves, and 40 cardboard was observed to be the most favored composition by termites due to its high biogenic structure. The termite's biogenic product in bait composition of eucalyptus leaves 60 and cardboard 40 increased pH, C-organic content, total Nitrogen, available Phosphorus, CEC, and Potassium value more than 100%.

The characteristic of biogenic products in this study will support the increase of soil fertility since termite's activity on bait composition change the soil chemical properties. However, how this change to the soil on a real scale needs to be further investigated.

Termite species contributing in enhance soil chemical

Three species of subterranean termites contribute to enhancing soil chemicals at the study site, i.e., *Coptotermes* sp., *Schedorhinotermes* sp., and *Termes* sp. (Figure 8). Species of *Schedorhinotermes* sp. was the most frequently found in bait tubes. *Schedorhinotermes* sp. belongs to subfamily Rhinotermitinae widely distributed in the tropical region (Nandika et al. 2015). The rest species, *Coptotermes* sp. (subfamily Coptotermitinae) and *Termes* sp. (subfamily Termitinae) were found in several bait tubes. *Coptotermes* sp. and *Schedorhinotermes* sp. found in bait tube in this research were also find in tropical forest in West Kalimantan (Indrayani and Yoshimura 2011) nor in buildings in Pontianak, West Kalimantan (Indrayani et al. 2017a).

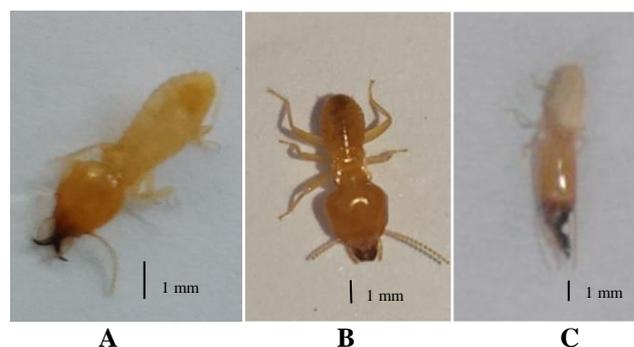


Figure 8. Subterranean termites contributing in enhance soil chemical: A. *Coptotermes* sp., B. *Schedorhinotermes* sp., C. *Pericapritermes* sp.

In conclusion, this study highlights the use of mixture formulation of eucalyptus leaves, cardboard, and paper potentially used as termites' bait. The activity of termites significantly affects soil chemical properties and potentially improves land productivity. Furthermore, their activities increase soil pH, C-Organic content, Potassium content, total Nitrogen, available Phosphorous, and Cation Exchange Capacity by more than 100%. Termite species contributing to enhancing soil chemicals in Arboretum of the Faculty of Forestry, Tanjungpura University were *Coptotermes* sp., *Schedorhinotermes* sp., and *Termes* sp. The most frequently found subterranean termite species in the study site was *Schedorhinotermes* sp. The composition of the bait favored by termites is 60% leaves and 40% cardboard.

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