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Leaching Characteristics of Udipsamment Ameliored by Mineral Soil and Adhesive Polymer

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ABSTRACT

Udipsamment is characterized by sand fraction > 95%, loose, and very high leaching. This study aimed to determine the effect of mineral soil ameliorants and adhesive polymers on the character of nutrient leaching in Udipsamment. The leaching study in lysimeters used a completely randomized design with three replications. The treatments consist of bagasse (B), mineral soil included Inceptisol (I) and Vertisol (V), and adhesive polymers included tapioca 1% and 2% (T1 and T2), tapioca dregs 1% and 2 % (A1 and A2), Polyvinylalcohol 0.1% and 0.2% (P1 and P2). Combination of treatments are IB, VB, IBT1, IBT2, VBT1, VBT2, IBA1, IBA2, VBA1 , VBA2 , IBP1, I BP2, VBP1, and VBP2. Observations were made before and after leaching. The research showed that VBT2 increases moisture-holding capacity. Amelioration improved the ability of Udipsamment to hold nutrients, after leaching for six months, there was a decrease in organic C, total N, and available P compared to before leaching. Amelioration increased the soil CEC, even up to the sixth month leaching, the soil CEC showed a higher value than before leaching. The amount of clay fraction was relatively uniform between the surface and the bottom of the lysimeter, indicating that the adhesive polymer successfully bonding the clay-sand particles and prevented clay leaching.

Keywords: Ameliorant, clay, leaching, udipsamment

INTRODUCTION

The coast of Yogyakarta to the mainland has a dunes character at a distance of 20-500 m consisting of coarse sand, and *sand* ridges between 500-1,000 m composed of medium-coarse sand (Siradz and Kabirun 2007). The constituents material mainly come from sand deposits resulting from the eruption of Mount Merapi, which are transported and deposited at various speeds and mixed with various materials, both from the watershed and the sea. The soil on coastal sandy soil is a young soil which in the USDA classification belongs to the order Entisol/ Coastal Entisol and belongs to the sub-order Psamment and the Udipsamment group (Hardjowigeno 2003; Soil Survey Staff 2010). Udipsamment has a sand fraction of more than 90%, characteristic of coastal sandy soils (Sunarminto *et al*. 2014). This character is also shown by Udipsamment originating from Bugel beach (Kulon Progo), each containing a sand fraction of 94% (Rajiman 2010). The combination of limiting factors for organic matter content and low clay fractions, the structure of the grass, the loose consistency causes nutrient leaching to occur very quickly in Udipsamment. The meager clay fraction also causes the soil's cation exchange capacity to be meager and the soil to be nutrient-poor (Sunarminto *et al*. 2014).

Efforts to improve Udipsamment soil aggregation can be carried out by applying soil ameliorants. Amelioration is expected to improve Udipsamment aggregation, which impacts the ability to hold moisture and reduce leaching. Soil improvement materials can be divided into natural and synthetic (artificial). The constituent materials can be divided into two categories, namely organic soil enhancers (including biological soil enhancers) and inorganic (mineral) soil enhancers. Natural organic soil enhancers that have been extensively researched include starch and latex (Regar 2015), blotong (sugar factory waste) (Rajiman 2010), and bagas (bagasse waste). The use of *starch* as a soil enhancer in the sand was investigated by Regar (2015); gelatinized starch binds sand particles and increases mechanical contact between particles.

Clay particles can expand and retain water so that leaching can be reduced. Improved water-holding capacity is also expected to reduce the number of nutrients lost to leaching. Vertisol application in Udipsamment utilizes the ability of the dominant montmorillonite clay mineral contained in Vertisol. A distinctive characteristic of montmorillonite is that it is influenced by changes in water content reflected in the interlayer space of 9.6 when dry and expands to 21.4 when clay minerals are saturated with water (Sun *et al.* 2016).

Inceptisol soil, although its ability to store water is not as significant as Vertisol, like clay soils in general, it has a positive role in increasing aggregation, storing water, and reducing leaching. Inceptisols are undeveloped soils and _ generally quite fertile and contain slightly to moderate clay minerals of smectite and kaolinite (Hardjowigeno 2003; Nursyamsi *et al.* 2007).

The use of adhesive polymer as an ameliorant Udipsamment serves to glue the sand and clay particles to form a more structured soil and store water. Natural polymers such as tapioca starch and latex and synthetic polymers such as *Polyvinylalcohol* and *Polyacrylamide* are examples of polymers that can be used as adhesives for soil particles. Amylum (*starch*) or starch as a soil enhancer has been studied by Regar (2015) on Entisol soil originating from Mount Merapi. This study determined the character of nutrient leaching and water escape in Udipsamment soil, whose physical and chemical fertility was improved by using ameliorant and then leached in a particular time.

The research aimed to study the effect of mineral soil ameliorants and adhesive polymers on the character of nutrient leaching in Udipsamment.

MATERIALS AND METHODS

Study Sites

The research was carried out in January – October 2018 at the Soil Laboratory of the Yogyakarta Agricultural Technology Study Center. The soil used in this study consisted of Udipsamment from the Sanden sub-district, Bantul Regency, Daerah Istimewa (DI) Yogyakarta. Mineral soil ameliorant used Inceptisol soil (39% clay fraction , CEC (23 cmol(+) kg^{-1}) and Vertisol (59% clay fraction, CEC (43 cmol(+) kg^{-1}) which came from Sanden and Kretek sub-districts, Bantul district, DI Yogyakarta, respectively.

Research Design

Soil samples were taken at a depth of 0-20 cm. The soil was dried and sieved using a 2 mm diameter sieve. The study of leaching in lysimeters was arranged using a completely randomized design consisting of 14 treatments and three replications so that a total of 14 × 3 = 42 lysimeters. The treatments included Inceptisol + bagasse (IB), Vertisol + bagasse (VB), Inceptisol + bagasse + tapioca 1% (IBT1), Inceptisol + bagasse + tapioca 2% (IBT2), Vertisol + bagasse + tapioca 1% (VBT1), Vertisol + bagasse + tapioca 2% (VBT2), Inceptisol + bagasse + tapioca dregs 1% (IBA1), Inceptisol + bagasse + tapioca dregs 2% (IBA2), Vertisol + bagasse + tapioca dregs 1% (VBA1), Vertisol + bagasse + tapioca dregs 2% (VBA2), Inceptisol + bagasse + *Polyvinylalcohol* 0.1% (IBP1), Inceptisol + bagasse + *Polyvinylalcohol* 0.2% (IBP2), Vertisol+bagasse + *Polyvinylalcohol* 0.1% (VBP1), and Vertisol + bagasse + *Polyvinylalcohol* 0.2% (VBP2). The leaching used a mica-based lysimeter with the following dimensions (Figure 1).

Set-up of Ameliorants and Adhesive

Udipsamment soil as much as 2.5 kg was mixed with ameliorant according to each treatment. The bagasse and clay fractions were 1 and 5% of the

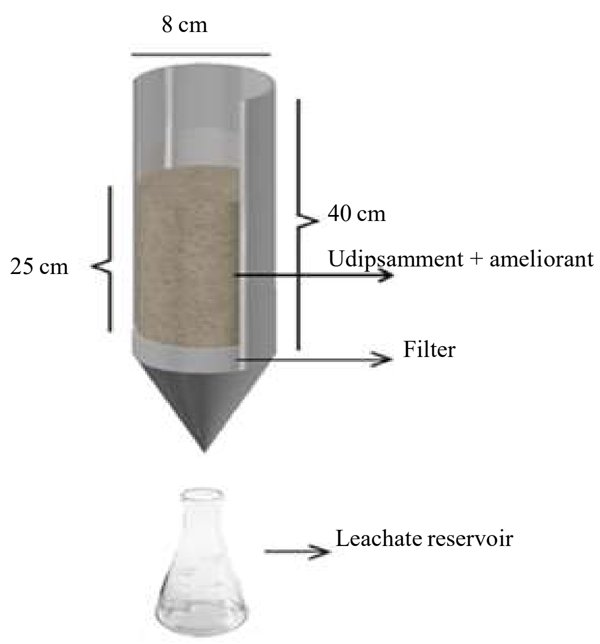

Figure 1. Illustration of a leaching experiment.

Table 1. Size distribution of sand, silt, and clay fractions of Udipsamment soil at Samas, Bantul.

Fraction Size Distribution (μ)	Udipsamment
Total Sand Fraction (%)	98.95
>1000	0.84
500 - 1000	15.22
200 - 500	49.53
100 - 200	28.15
50 - 100	5.21
Total Dust Fraction (%)	0.59
20 - 50	0.16
10 - 20	0.24
2.0 - 10	0.19
Total Clay Fraction (%)	0.46
0.05 - 2.0	0.11
0.0 - 0.05	0.35

dry weight of the soil, respectively. The weight of bagasse, Inceptisol, and Vertisol was 25 g, 321 g, and 212 g, respectively. Tapioca and tapioca dregs in variations of 1 and 2% (25 g and 50 tapioca/tapioca dregs per lysimeter), as well as 0.1 and 0.2% polyvinyl alcohol (PVA) (2.5 g and 5.0 g PVA per lysimeter). Tapioca and PVA were applied as a solution, while tapioca pulp was applied in a powder that had passed a 2 mm sieve. After mixing the soil, incubation was carried out for one month. In all treatments, 15 g of goat manure was applied, urea, SP-36, and KCl 0.11 g each, and 0.19 g of ZA and incubated again for two weeks to then be analyzed for changes in chemical properties after incubation.

Measured and Soil Analysis

The measured value will be the basis of reference before leaching. After the soil was incubated, the leaching phase was continued using aquadest at intervals of 1 month and observations for six months. The water escape ability was tested by adding 200 mL aqua dest to each treatment into a lysimeter that has been closed at the bottom. Then, the bottom cover of the lysimeter was opened, and the time of water escape was recorded in each leaching period. Before leaching, after incubation, and after leaching for six months, the analysis of soil texture, organic C, total N, available P, and cation exchange capacity were done. Analysis of soil texture using the Hydrometer method (Rowell 1994; Balittanah, 2005), organic C using the Kurmies method, N total by the Kjeldahl method (ACIAR 1990; Balittanah 2005), available P by the Olsen method (ISRIC 1993; Balittanah 2005), and CEC by extraction method with NH_4OAc 1 N pH 7.0 (Rowell 1994; USDA 2004; Balittanah 2005).

RESULTS AND DISCUSSION

Udipsamment Soil

The soil characteristics, which are dominated by 99% sand fraction, are in line with research by Rajiman (2010) and Faozi (2018) on the Udipsamment of Bugel Beach (Kulon Progo) and

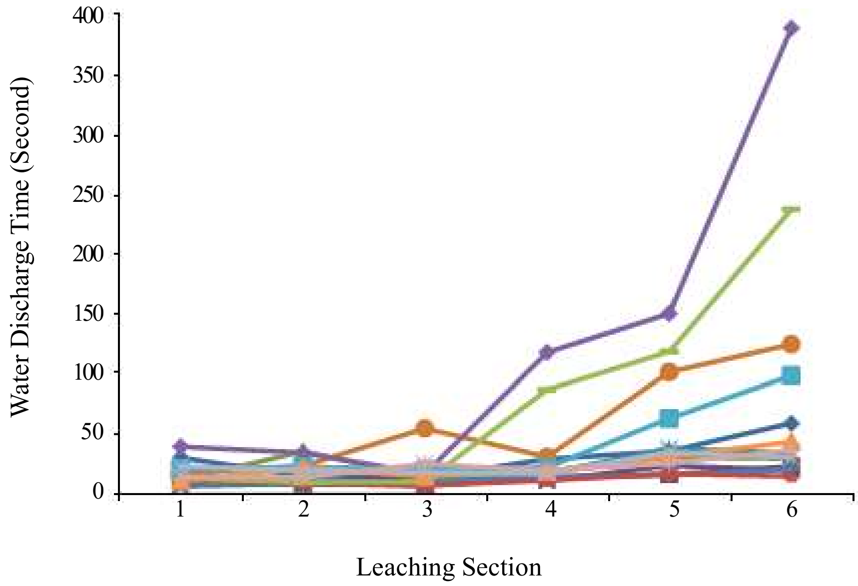

Figure 2. The discharge time of 200 mL of water in Udipsamment after amelioration. : IB, : VB, : IBT 1, : IBT 2, : IBA 1, : IBA 2, : IBP 1, : IBP 2, : VBT 1, : VBT 2, : VBA 1, : VBA 2, : VBP 1, : VBP 2.

Samas (Bantul), which found that the sand fraction reached more than 94%. The dominant coarse grain size (100-500 ì) causes the Udipsamment soil at the study site to have a small surface area, making it difficult to hold nutrients and moisture. Table 1 describes the grain size distribution of the Udipsamment soil.

Water Discharge Time

Ameliorant reduces the speed of water discharge in Udipsamment so that the soil is more able to hold moisture, as shown in Figure 2. Leaching in the first month shows that water discharge relatively quickly; amelioration takes time to establish contact between particles to retain more water. With the improvement in the between particles contact, the reduction of macro pores, and the increase in the water holding capacity, the water discharge time is getting longer, which indicates the soil has held some water.

In general, it could be seen that most of the treatments showed a better ability to hold moisture until the fifth month after leaching, and some treatments experienced a slight decrease in inability at the sixth month after leaching. This decreased inability may be caused by the decomposition of some soil-enhancing materials, which will reduce the ability to bond between particles and reduce the ability to hold moisture. Several treatments showed an increase in the ability to hold moisture until the sixth month after leaching. VBT 2 was the most prominent treatment, which showed an increase in the ability to hold moisture due to Vertisol's nature which was dominated by smectite (montmorillonite). Using Vertisol will increase the water holding capacity due to the swelling ability of smectite clay minerals (Kertonegoro 1993). The structure of the montmorillonite layer consists of one Al octahedral sheet flanked by two Si tetrahedral sheets, filled with the interlayer *space* that can be filled by cations or water (Sun *et al*. 2016). The effect of 2:1 clay minerals and the inter-particle adhesion by tapioca significantly increases the moisture-holding capacity of Udipsamment.

Soil Texture

Application of 5% clay did not affect changes in the Udipsamment texture class, but there was a decrease in the sand fraction and an increase in clay by 1-2% in all treatments (Figure 3). The addition of 5% clay would not directly increase the amount of the same percentage of clay in the amelioration. The contact between sand, clay, and biopolymer is only a mechanical contact that still allows clay leaching during watering during the incubation period.

Udipsamment soil that has been incubated and then treated by leaching for six months shows the distribution of soil constituents as shown in Figure 4. Leaching affects the nutrient balance in the exchange complex and solution and affects the percentage of sand, silt, and clay fractions in layers 5 cm from the ground and 5 cm from the base of the lysimeter.

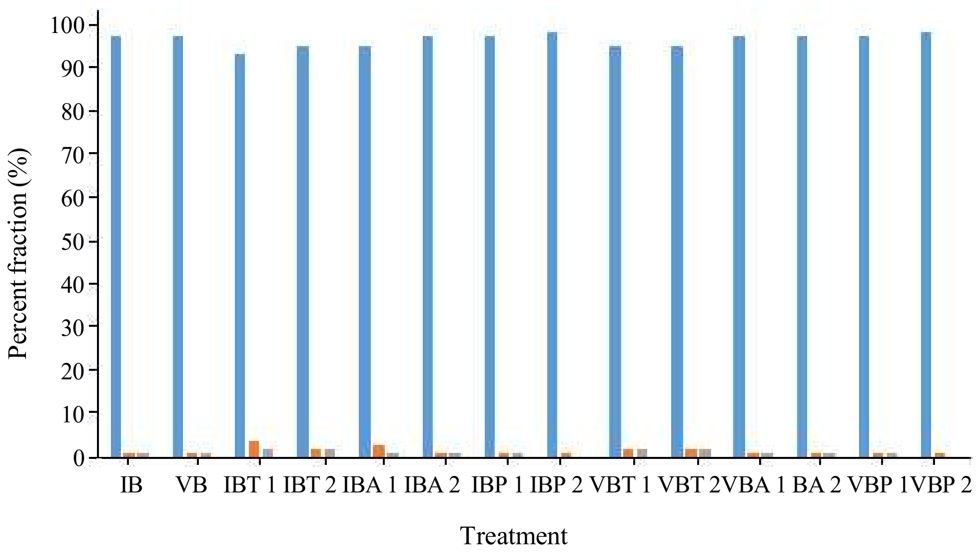

Figure 3. Udipsamment texture after incubation. ■ : sand, ■ : dust, ■ : clay.

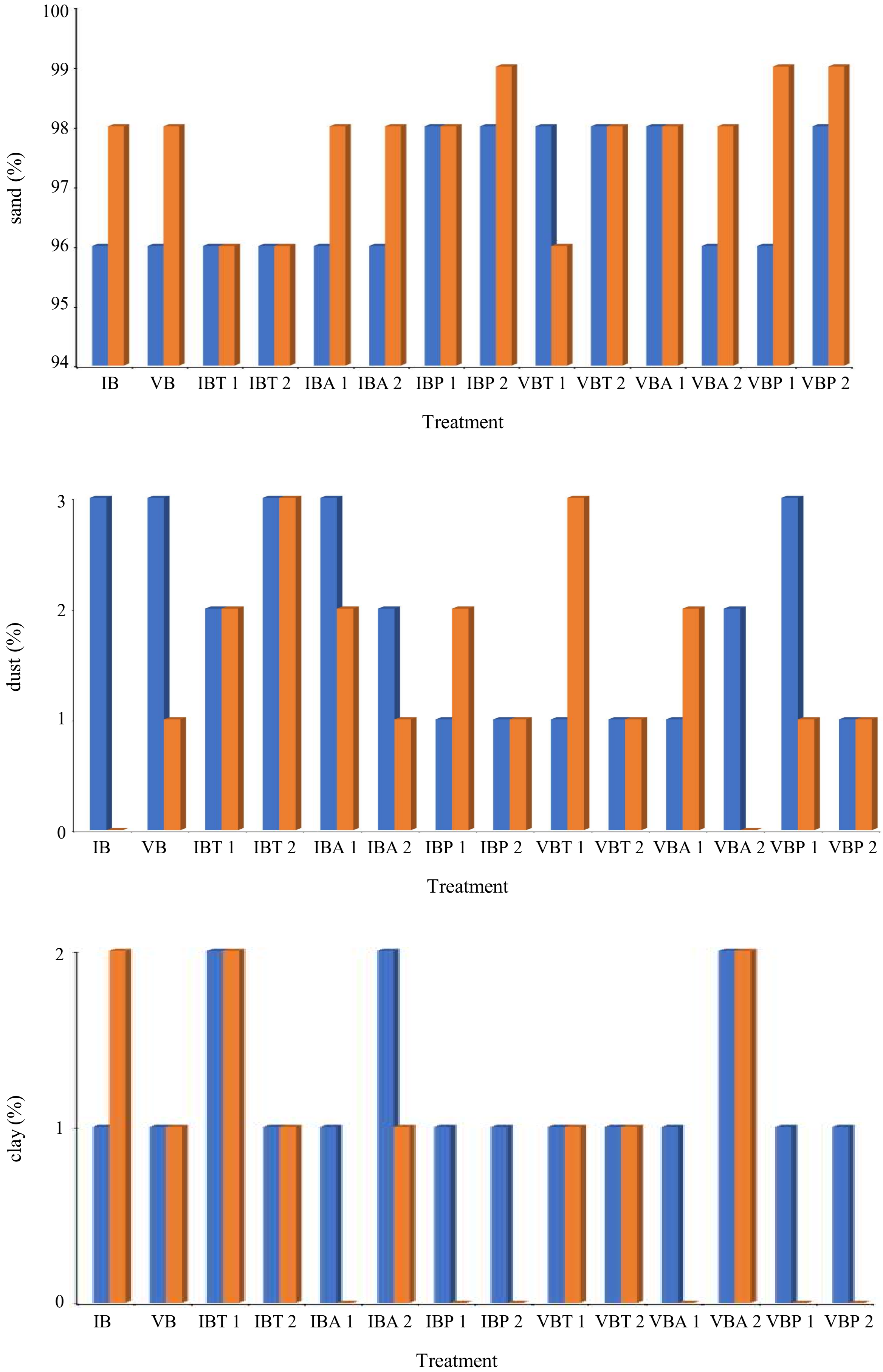

Figure 4. Distribution of Udipsamment sand, silt, and clay fractions at a depth of 5 cm from the surface vs. 5 cm from the base of the lysimeter. ■ : 5 cm upper, ■ : 5 cm bottom.

Leaching carries heavier particles to deeper soil layers so that in some treatments, it is seen that the sand fraction at a depth of 5 cm from the base of the lysimeter is in higher amounts than at the surface. According to the law of gravity, the sand fraction, which is heavier than silt and clay, will more easily leach to the bottom of the lysimeter.

The leaching of sand to the bottom layer was seen in the IBA1, IBA2, and IBP2 treatments and VBA2, VBP1, VBP2. An exception was seen in the VBT1 treatment where the lower sand fraction decreased in percentage compared to the top layer, possibly due to the leaching of the dust fraction. In the same treatment, it increases the amount of dust in the lower layer and reduces the percentage of the sand fraction, while the clay fraction remains relatively constant. The clay fraction in most treatments showed the same amount between the two layers, except that there was no detectable clay in some treatments because the amount was meager and probably due to the very fine clay fraction being carried along with the leachate. The amount of clay fraction that was relatively uniform between the top and bottom layers indicated that the soil enhancer successfully bided the sand-clay particles well and prevented the clay from leaching down. The positive effect of these results is that the Udipsamment fertility as deep as the treated layer is relatively homogeneous because the clay fraction as a component that plays a role in cation exchange reactions and moisture-holding capacity is inhomogeneous amounts throughout the depth.

Organic Carbon

All treatments experienced a decrease in organic C levels after six months leaching (Figure 5).

The process of wetting and drying that occurred during the experiment has stimulated the decomposition of organic matter, which is characterized by a decrease in the organic C content compared to the initial level during the incubation period. A significant difference occurred in amelioration using soil amendments derived from the organic matter because the decomposition continued until the end of the leaching experiment causing a significant decrease in organic C after leaching.

Total Nitrogen

Nitrogen is an easily leached element, so the total N content of the coastal sandy soil decreased after the leaching experiment (Figure 6). Organic matter is the primary source of N in the soil, decomposition of organic matter will initially increase the amount of N in coastal sandy soils, and there is an additional amount of N from Urea and ZA fertilizers applied during the incubation period.

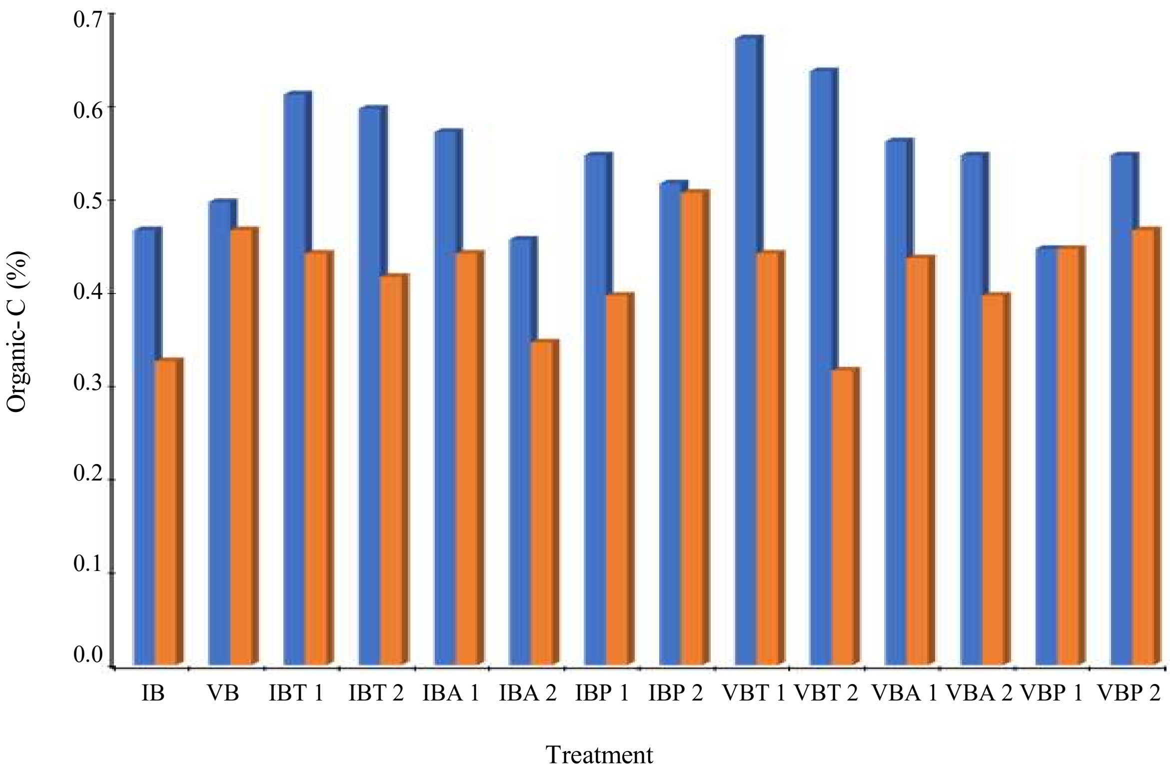

Figure 5. C-organic content (%) Udipsamment before and after leaching. ■ : Before, ■ ; After.

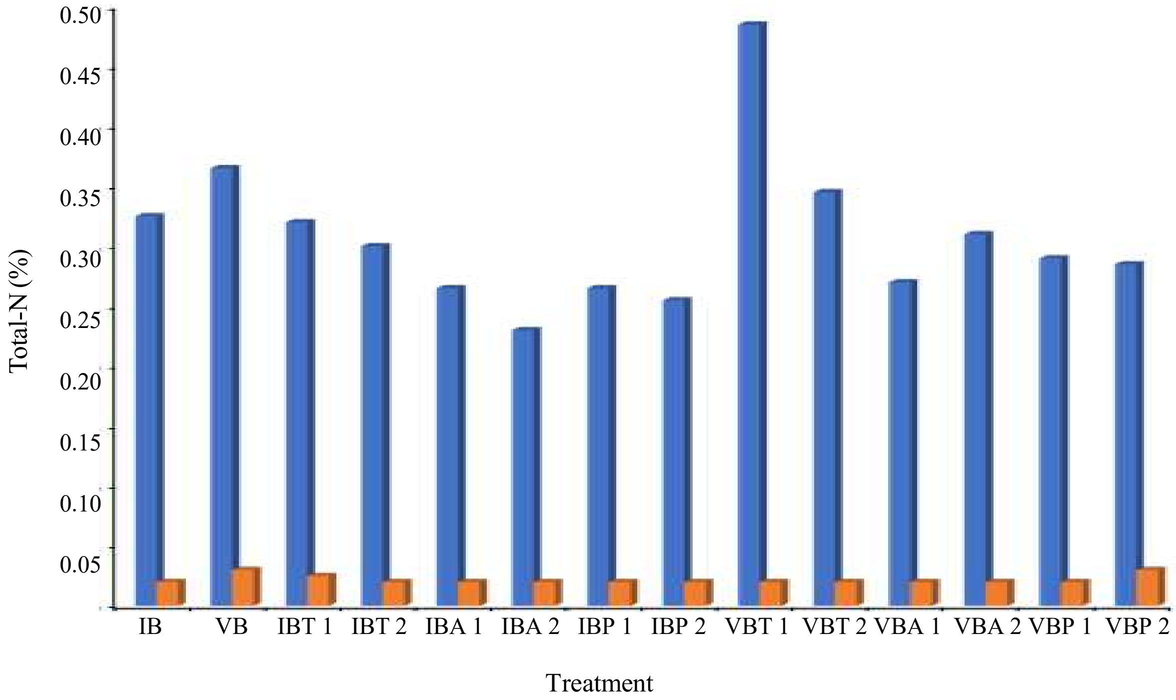

Figure 6. Total N-level (%) Udipsamment before and after leaching. ■ : Before, ■ ; After.

Over time the decomposition decreased because the source of organic matter was decreasing, which was also indicated by the decrease in organic C content; the total N also decreased. Several possible causes for the decrease in total N levels after leaching include immobilization when microbes that decompose organic matter require N in the form of NH_4^+, intensive leaching carries N in the form of NO_3^- carried with water (Foth 1990; Hardjowigeno 2003); Havlin *et al*. 2006), and the organic matter of the N source undergoes intensive decomposition so that it decreases over time.

Available Phosphorus

Most of the treatments had decreased levels of available P after leaching (Figure 7). Availability

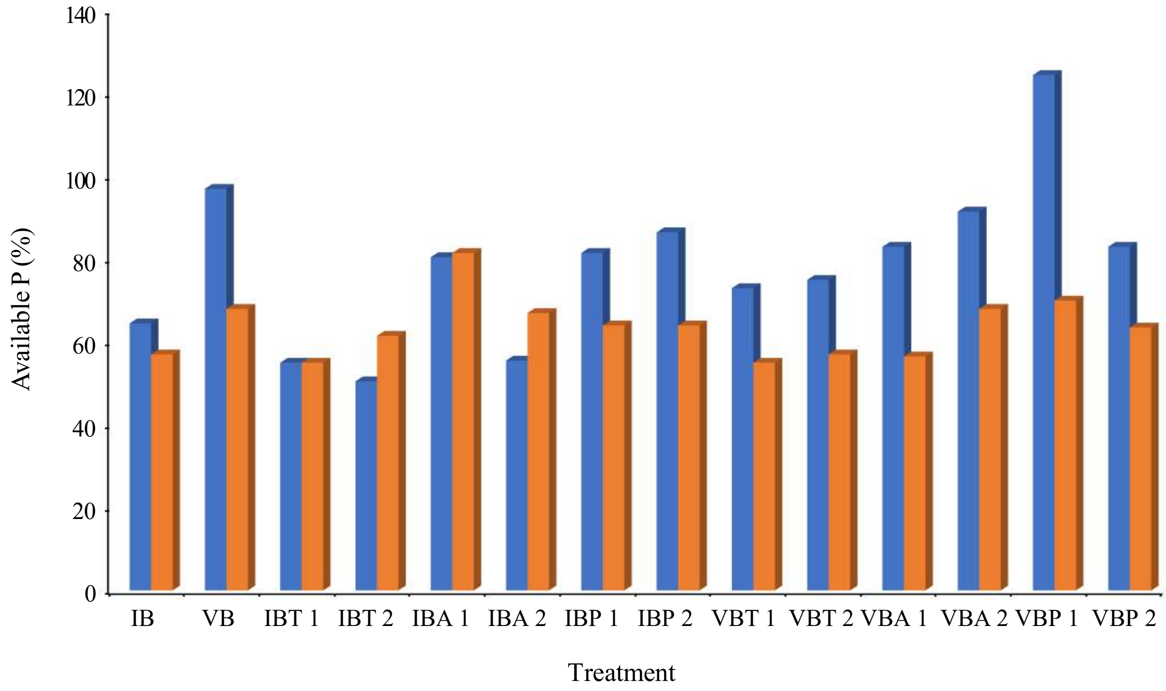

Figure 7. Soil available P (ìg g^{-1}) of Udipsamment before and after leaching. ■ : Before, ■ ; After.

of P in soil is strongly influenced by pH and is maximum at a pH value of around 6.5 (Foth 1990; Hardjowigeno 2003; Havlin *et al*. 2006). The pH of the coastal sandy soil after leaching has decreased but is still above 7; under these conditions, the solubility of P is reduced because Ca^{2+} has precipitation with P in the form of insoluble Ca-P (Havlin *et al*. 2006).

Cation Exchange Capacity (CEC)

Soil CEC after leaching increased in most treatments (Figure 8). The results are in line with Chaganti and Crohn (2015), who reported that the application of compost increased the soil CEC value compared to the soil CEC value before leaching.

Amelioration using clay can increase the ability of the soil to exchange cations. The wet-dry period between the two leaching times encouraged the decomposition of organic matter from the treatment using tapioca and tapioca dregs. Tapioca and tapioca dregs are sources of organic matter that produce humic substances containing functional groups and play a role in increasing soil CEC (Adani *et al*. 2006). The decrease in CEC in applying several treatments is thought to be related to the amount of organic matter, which is increasingly limited after a long period of intensive decomposition. A six-month leaching trial showed that ameliorant increased Udipsamment's ability to hold moisture. Ameliorant binds sand-clay particles well and reduces nutrient leaching in Udipsamment.

The polymer binds the sand-clay particles, that improve the soil structure of Udipsamment. Amelioration using clay and adhesive polymers increases the stability of the sandy soil structure, increases buffer capacity and reduces nutrient leaching (Buchman *et al*. 2015; Minhal *et al*. 2020). Process of wetting and drying that occurred during the experiment has stimulated the decomposition of organic matter, which is characterized by a decrease in organic C content compared to before leaching. The same thing happened to the decrease in total N and available P values compared to before leaching. On the other hand, amelioration increased the soil CEC after six months leaching. The wet-dry period between the two leaching times encourages the decomposition of organic matter, which produces humic substances containing functional groups and plays a role in increasing soil CEC.

CONCLUSIONS

Most of the treatments showed a better ability to hold moisture until leaching at the fifth month, and some treatments experienced a slight decrease in inability at the sixth month. The decreased inability was caused by the decomposition of some

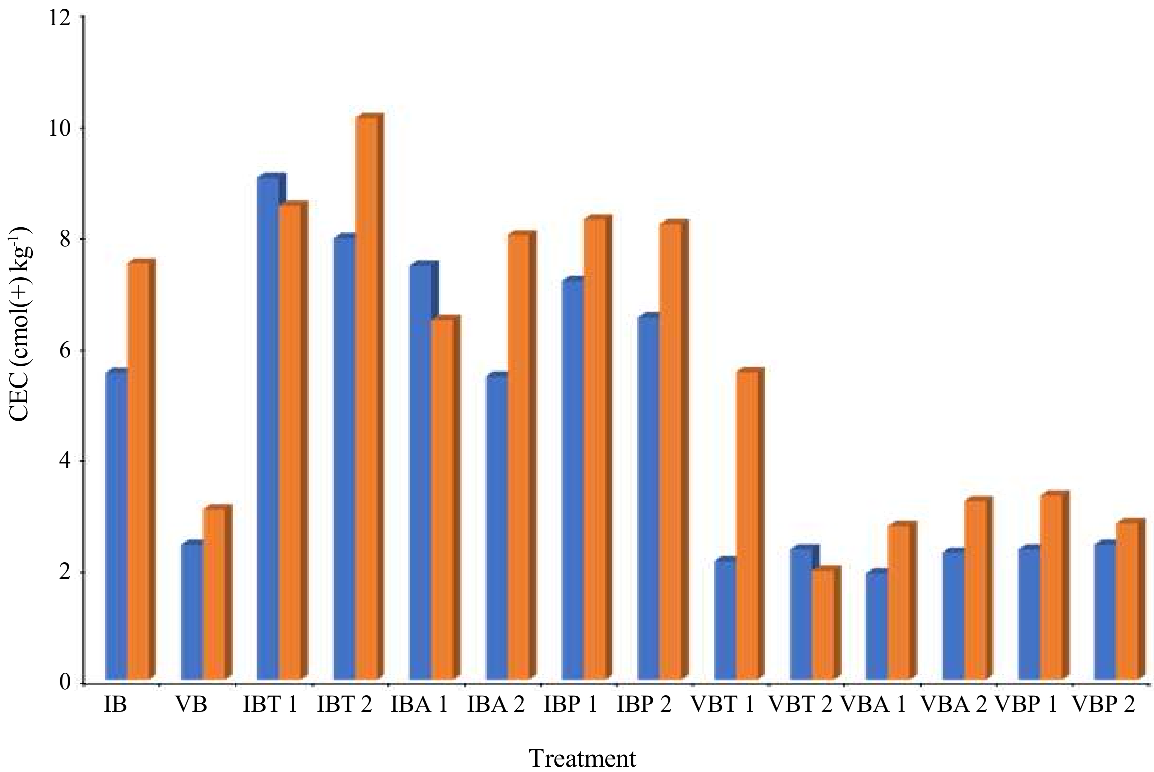

Figure 8. Udipsamment cation exchange capacity before and after leaching. ■ : Before, ■ ; After.

of the soil enhancer materials, reducing the bonding ability between particles and reducing the moisture-holding capacity. The amount of clay fraction is relatively uniform between the surface and the base of the lysimeter. This matter showed that the adhesive polymer combined with clay-sand particle s prevented clay leachi ng. Applying ameliorant improved the ability of Udipsamment to hold nutrients, although, after six months of leaching, there was a decrease in organic C, total N, and available P levels compared to before leaching. Amelioration increased the soil CEC, and up to the sixth month leaching, it turned out to show a higher CEC value than before leaching.

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