Malays. Appl. Biol. (2020) 49(4): 141–148

ASSOCIATION BETWEEN ROOT COMPLEXITY OF *Rhizophora apiculata* AND SEDIMENTATION AT PANTAI KELANANG, SELANGOR

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Accepted 23 November 2020, Published online 25 December 2020

ABSTRACT

Roots play important roles in tree structural adaptation and accumulation of nutrients during growth. This is particularly critical for mangrove trees that facing strong current and weak based for implantation in the sand. However, how the complexity of mangrove roots contributes to structural adaptation and affect sedimentation remains unelucidated. In this study, the complexity of *Rhizophora apiculata'*s roots influence the sedimentation under the root structures and at the walkway area in Pantai Kelanang, Morib were investigated. The complexity of *R. apiculata* pneumatophores was computationally analyzed. The sediment composition was measured using a wet-sieve method and laser diffraction method. The correlative analysis shows that no definite pattern between angles and lengths of *R. apiculata* roots. Assessment of sediment composition shows significant differences between walkways and under the roots. There is a high accumulation of organic matter and sand in sediment samples from under the roots. While the walkway has a high accumulation of clays and silt than others. Mathematical scoring reveals a positive association between root complexities with the accumulation of organic matters and sand in both areas. While sand and clay accumulation are inversely associated.

Key words: Mangrove, sedimentation, silt, clay, pneumatophores, sand, root complexity

INTRODUCTION

Mangrove ecosystem is important to global biodiversity and also provide direct and indirect ecosystem resources to human (Chen *et al*., 2016). Mangrove ecosystems are preferable habitat for one of the faunal marine group known as macrobenthos. This is due to the ability of aerial roots structure and pneumatophores to trap sediments that provide nutrients and foods for the animals (Ellison *et al*., 1999). The sedimentation process is influenced by the type of mangrove trees. *Avicennia* sp. and *Rhizophora* sp. able to trap 30% and 20% of total suspended sediment, respectively (Kathiresan & Bingham, 2001). Malaysia's paleotropical zone is one of the hotspots of the mangrove forest. The forest consists of species from several genera including *Rhizophora*, *Avicennia*, *Sonneratia*, *Bruguiera*, and *Kandelia* (Craft *et al*., 2016).

The ability for mangroves to thrive in intertidal zones is due to their unique root structure, the pneumatophore and prop roots. Their roots adapted as specialized anchorage to support physical stability during high tide, strong current, and wind (Lee *et al*., 2014). At the same time play a role in trapping sediments to accumulate nutrient while filtering excessive salt during water and nutrient absorption to balance the osmotic pressure (Kathiresan & Bingham, 2001). How the type of roots of mangrove trees affect the sedimentation remains largely open for investigation.

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Mangroves aid soil formation by trapping the debris while the accumulation of sediments is aided by prop roots and pneumatophores. Grain size distribution plays a role in sediments characterization (Abdullah & Lee, 2016). The characteristics of surface sediments can be analyzed according to a particle size that can help to correlate the sediment organic matter content and the mangrove structure (Zhu *et al*., 2012). Although it is known that mangrove tree species could affect the rate of sedimentation, however, how the structure of the tree contributes to the sedimentation process remain unelucidated. It is known that the pneumatophore roots of mangroves are exposed to the tidal movement affect the type of accumulated sediment (Kathiresan & Bingham, 2001). Therefore, in this study, sediment composition between the roots area and walkway area was characterized and we hypothesized that the sedimentation process is correlated with the root complexity. This study aims to investigate the contribution of the mangrove root complexities to the sedimentation process, especially for *Rhizophora apiculata* at mangrove forest, Pantai Kelanang, Morib, Selangor, Malaysia.

MATERIALS AND METHODS

Sampling location

Sampling was conducted at the mangrove area in Pantai Kelanang, Morib, Selangor, Malaysia (2°45’42.0"N 101°26’06.1"E). It was located on the coast that fulfilled with the mangroves ecosystem and surrounded by coconut plantations, chilies, and oil palm plantations (Figure 1).

Sediments sampling

Sediments were collected during low tides using tip fewer syringes that imitate the piston corer. Sediments were collected randomly, under the roots and a region of the walkway. The collected sediments were kept in the falcon tubes and stored in a chiller at 16°C before being analyzed.

Root mapping and complexity calculation

A wood palette that was marked at every 30 cm was used to measure the tree length. Images of mangrove roots were captured from several different angles (front view, lateral view, and back view). A total of five individual trees of *R. apiculata* were randomly chosen for sediment collection. Angles and length of roots from different views were recorded. Length and angles of the roots were measured using ImageJ software and recorded in Microsoft Excel.

Root complexity was determined by through sum of ranks. Complexities of trees were rank (between 1 and 5) based on the number of roots, variance in length, and angles. Trees with the highest number of roots, large variance in length and angle received the highest score. Ranks from each observation were total together to obtain the sum of ranks.

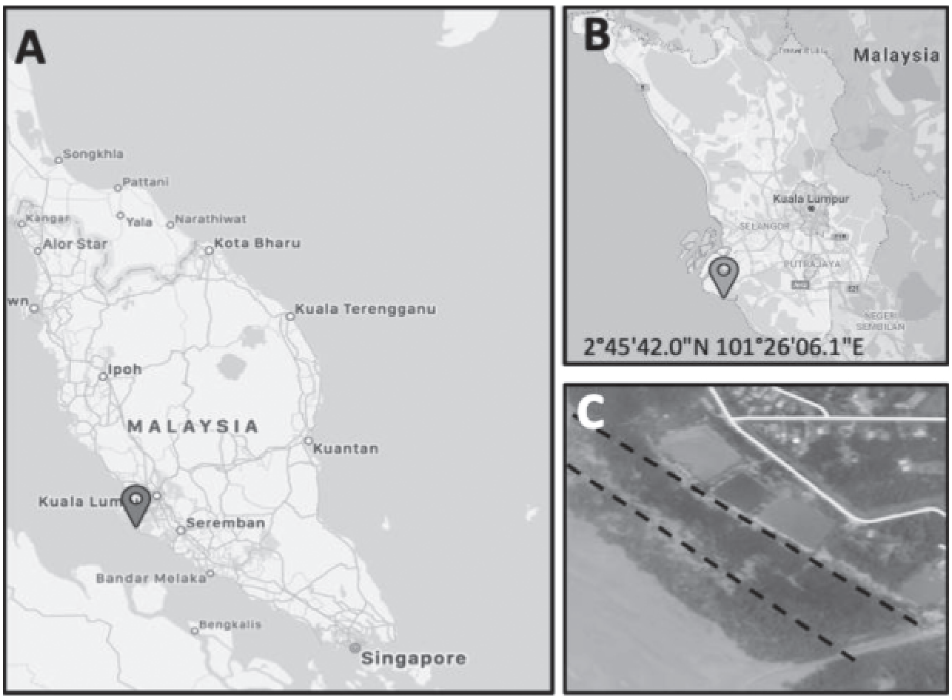

Fig. 1. Sampling location located at mangrove area, Pantai Kelanang, Morib, Selangor, Malaysia (2°45’42.0"N 101°26’06.1"E).

Sediment size analysis

The sediments being oven-dried at 80°C for 5 hr. Any wood fragments or roots fragments were removed from sediments. The sediments were grounded by using mortar and pastel then sieved using a 2 mm sieve. Hydrogen peroxide only used as mud sediments consist of more than 15% organic matter. After that, 3 g of sediments was weighed and mixed with 10 mL of Calgon solution that was composed of sodium hexametaphosphate, and 250 mL tap water was added. The solution was kept at room temperature for 24 hr to allow sediment dispersion. The mixed solution-sediments were then sieved by using a 63 mm sieve and rinsed well with tap water. The silt contents were removed and the remaining sand was weighted (Abdullah & Lee, 2016).

Laser diffraction methods were used to measure particle matters that are smaller than 0.002 mm, i.e. clay. PSA machine used was CILAS 1180, with processing software DSP. Clay particles were measured by using Fraunhofer or Mie theory.

Data analysis

Roots length and angles (from trunk to root) were measured using ImageJ software. The true length and true angle of each site with different views (front view, lateral view, and back view) were determined by choosing the maximum length and maximum angle. For the sediment composition analysis, the distribution of sediments was identified and recorded. Root complexity was determined by scoring and ranks based on the number of roots the trees possess, lengths, and angles variance. Student T-test was used to find significant differences across sediment samples. Regression and Pearson correlation was used to determine the relationship between root complexity and the type of sediment being accumulated.

RESULTS AND DISCUSSION

A weak association between length and angle of roots in *Rhizophora apiculata* at Pantai Kelanang, Selangor, Malaysia

The sampling area was protected from strong wave current by approximately 50 m wide of an area dominated by *Avicenna* sp. trees. Cumulative correlation analysis shows a very weak correlation between root length and angle (Figure 2a). Individual assessment on the sampled trees shows mixed between the mildly positive and negative correlation between angle and length (Figure 2b-f). These mixed and weak associations among *R. apiculata* may be due to the adaptation of the trees to the topographical depression and wave movement during high tidal (Lee *et al*., 2014).

Comparative assessment of sediment composition between under roots and walkway samples

The composition of sediments both the walkway and under the roots are dominated by sand, clay, and silt, respectively (Figure 3). Comparative assessment between collected samples shows that the ratio of sand percentage is significantly higher ($p<0.05$) under the roots compared to the walkway and vice versa for the clay percentages (Figure 3a). This is a contrast to the pristine mangrove forest of Apar Nature Reserve in Borneo island, where the soil ratio of sand:silt:clay is approximately 35%, 40%, and 45%, respectively (Sukardjo *et al*., 1994).

Assessment of the sediment composition of the individual tree shows a consistent result with a significantly higher average of sand percentage from samples collected under the roots than the walkway (Figure 3b). The sampling site has been considerably disturbed by agriculture activities which may contribute to the sand being accumulated more than the other smaller particles. The result of high sand percentage could be due to deposition of wind-blown sand as observed in mangrove forest Sipingo and Mgeni, South Africa (Naidoo & Raiman, 1982).

The silt percentage was inconsistent, but with a significant difference ($p<0.05$) across collected samples, in which only 4 trees have high average percentages on the walkway than under the roots (Figure 3c). However, 1 tree has significantly high percentages of silt under the roots (Figure 3c). Therefore, contributing almost equal average with insignificant differences in the cumulative observation (Figure 3a).

Interestingly, the presence of clay accumulation is high on the walkway area than under the roots and this result is consistent across five trees, even though only three trees exhibit significant differences ($p<0.05$) (Figure 3d). This could be contributed by the fact that clay composition is higher than silt due to the low energy of water that causing sedimentation of clay particles since mangrove forests are enclosed and protected (Eric *et al*., 2002). Assessment of the organic matter shows that significantly high accumulation ($p<0.05$) under the roots than walkway with an average of less than 10% (Figure 3e). This is equivalent to the organic matters (0.65-13.31%) recorded at mangrove forests in Sarawak, Malaysia (Rambok *et al*., 2010).

The proportion of sand:silt:clay in mangrove forest sediment of Pantai Kelanang, Morib has sandy clay loam soil properties. This is paralleled to the previous report that a common soil property in Asian mangrove forest which has approximately 53% of sand particles (Hossain & Nuruddin, 2016). High accumulation of organic matters under the roots is due to matters from degrading twigs, barks, leaves, roots, and even from macrobenthos animals such as polychaetes (Kamal *et al*., 2017).

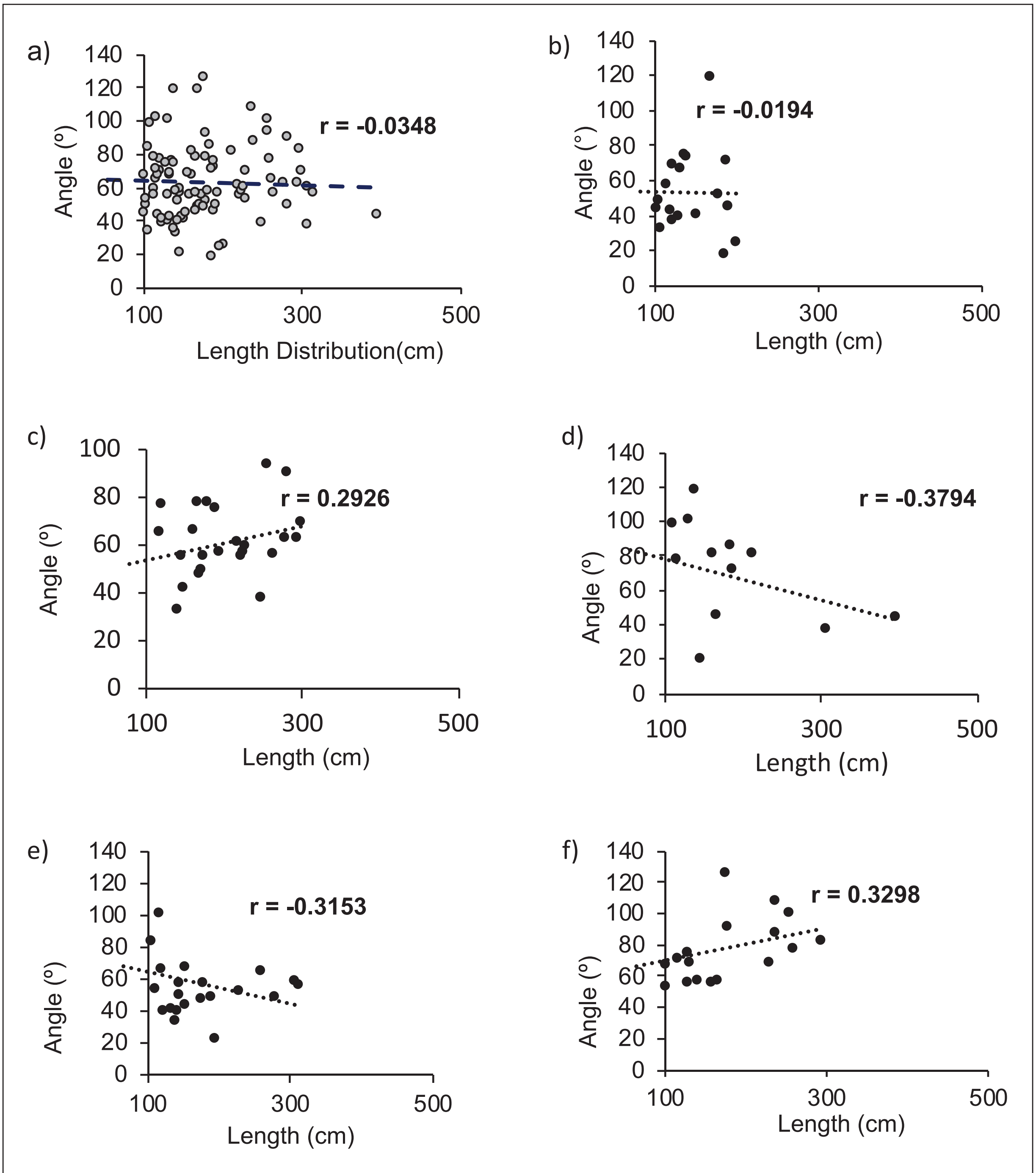

Fig. 2. Minimal association between root angle and length in *R.apiculata* (*n*=5) at mangrove area, Pantai Kelanang, Morib. a; Cumulative regression analysis on all five trees, b – f; association of angle vs root in individual trees; r = Pearson correlation between roots and angle.

Effect of root complexity to sedimentation process under the roots umbrella

The presence of roots in the mangrove forest would affect the current movement that contributed to the sedimentation process. Linear regressive analysis between root complexity and sediment properties on the samples collected under the roots shows that heavy and large particles such as sand are not affected by root complexity (Figure 4a). Small and light particle accumulations such as silt are immensely influenced by roots complexity (r^2=0.832) (Figure 4b). The clay and organic matter accumulation under the roots are moderately influenced by the complexity of the roots (r^2~0.4) (Figure 4c-d). Interestingly, complex roots have a moderate negative influence on clay accumulation under the roots indicating a repelling effect of roots to floating clay during current and tidal movement.

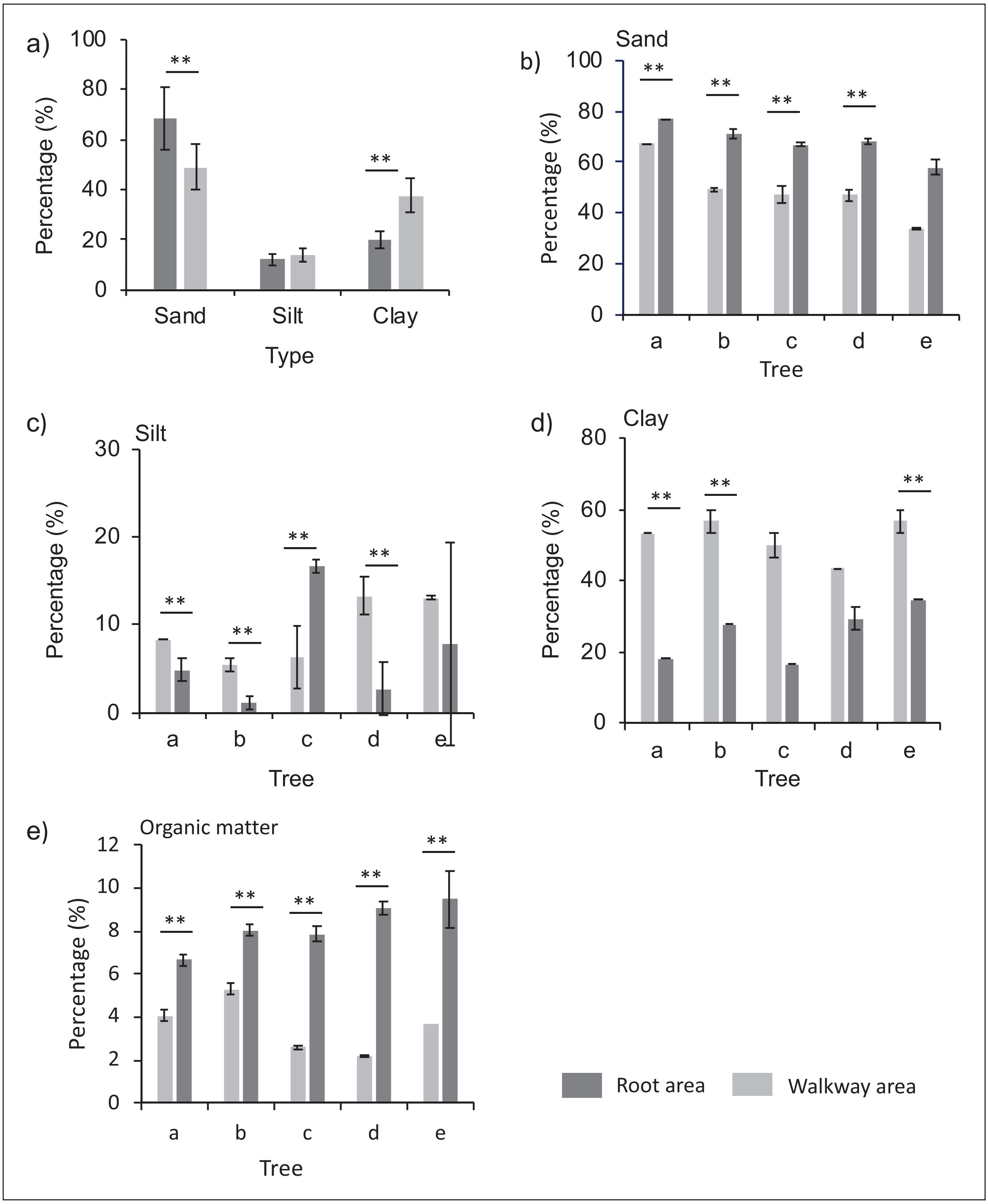

Fig. 3. Comparative assessment on sediment composition of sediments in the walkway and under the root. (a) Average cumulative composition of sediments for both areas at mangrove area Pantai Kelanang, Morib, (b) Sand Composition for both areas, (c) Silt composition for both areas, (d); Clay composition for both area and (e) organic matter content for both area. Mean ± SEM; n=5. **indicates p<0.05 two-tailed Student's T-test.

Rhizophora apiculata trees that have complex pneumatophore roots affect the type of sediments being accumulated under the roots during inundation (Amaliyah *et al.*, 2017). Complex roots caused waterlogging under the roots umbrella, which led to low aeration hence promoting the accumulation and degradation process of organic matters than the walkway (Hossain & Nuruddin, 2016).

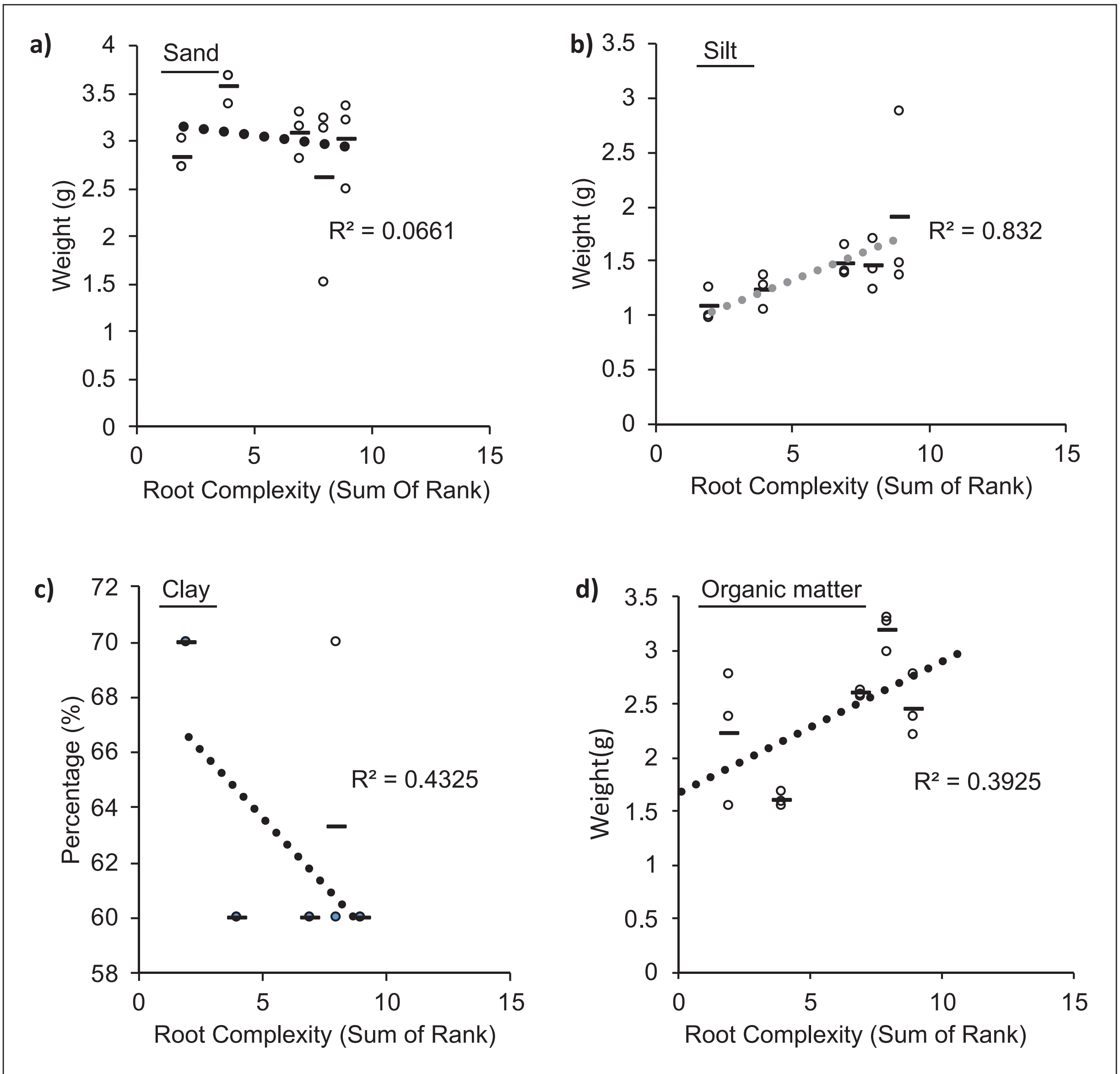

Fig 4. Effect of Root Complexity of *R.apiculata* to Sedimentation Process under Root Area at mangrove area, Pantai Kelanang, Morib. Accumulation of sand (a), silt (b), clay (c), and organic matter (d). Line and R^2 indicate linear regression; horizontal line indicates mean for root complexity, *n*=5.

Effect of root complexity to sedimentation at the walkway area

The complexity of *R. apiculata* roots also affects sedimentation on the walkway, areas that are not covered by the pneumatophores root or outside of root umbrella. A similar trend was observed in the sediment properties collected from the walkway (Figure 5). Root complexity has a weak to moderate influence on the sand and organic accumulation (Figure 5a and 5d). Interestingly, root complexity also has a strong influence (r^2=0.82) on silt accumulation on the walkway, outside the root umbrella (Figure 5b). While moderate negative influence on clay accumulation (r^2=0.43; Figure 5c).

A similar trend of sediment properties that were observed between samples collected under the roots and the walkway may be due to the effect of roots complexity to wave/current movement during high and ebbing tide. Roots complexity reduces the tide effect, disrupting the flow hence trapping finer particles such as silt and clay to the surrounding roots, not just under the roots but also the walkway. At the same time repelling the clay away from trapping under the roots umbrella. An increase in the complexity of the roots promote suspension of sediments particulate due to turbulence and fluctuation of water flow around the roots (Eric *et al*., 2002).

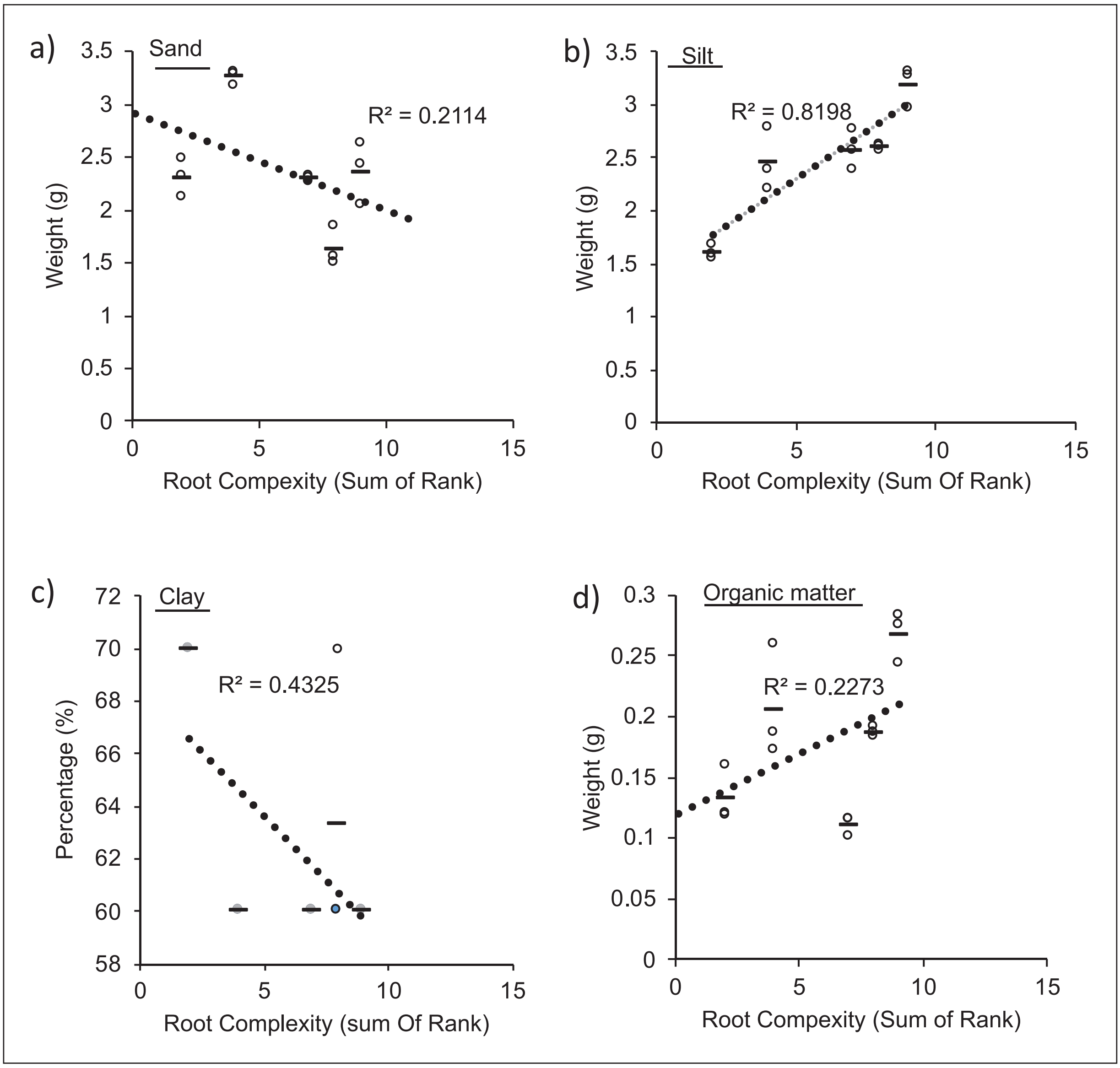

Fig. 5. Effect of Root Complexity of *R.apiculata* to Sedimentation Process at Walkway Area of mangrove, Pantai Kelanang, Morib. Accumulation of sand (a), silt (b), clay (c), and organic matter (d). Line and R^2 indicate linear regression, horizontal line indicates mean for root complexity, *n*=5.

CONCLUSION

This study shows that sediments in the mangrove area inhabited by *R. apiculata* at Pantai Kelanang Morib, Selangor, is sandy clay loam due to high total composition of sand and clay for both walkway area and under the roots. Sediment composition under the root and the walkway consist of a high composition of sand, followed by clay and silt. The high percentage of sand in the sediment composition is due to a location closer to land and retarded wave current by zone dominated by *Avicenna* sp. trees. Root complexity of *R. apiculata* affects the sedimentation process not just under the roots but also in the walkway area. Root complexity has a strong influence on silt accumulation. Moderate influence of organic matter and clay accumulation.

ACKNOWLEDGEMENTS

This project was fully funded by Centre of Talent and Academic Innovation, Universiti Malaysia Terengganu under Industrial Attachment - Academic scheme vot: 64943.

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