The Physicochemical Factors and Litter Dynamics (*Rhizophora mucronata* Lam. and *Rhizophora stylosa* Griff) of Replanted Mangroves, Rembang, Central Java, Indonesia

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ABSTRACT

Mangroves are a coastal habitat which contributes to the presence of biota through the litter they produce. The objective of the present study was to determine the physicochemical factors that influenced the dynamics of *Rhizophora mucronata* and *Rhizophora stylosa* mangrove litter on the Banggi Coast, Rembang, Central Java. The litter research used the 1×1 m method between September 2016 and August 2017. The results revealed that the factors influencing the litter dynamics were the sediment's organic matter and the salinity and substrate condition. Organic matter content is high relationship physicochemical factor which influences mangrove productivity.

1. INTRODUCTION

The Banggi coast in Rembang, Central Java is fringed by various species of mangrove such as *Rhizophora mucronata* Lam.*, Rhizophora apiculata* Blume*, Rhizophora stylosa* Griff.*, Avicennia marina* (Forssk.) Vierh., and *Sonneratia alba* Sm (Ariyanto et al., 2018a). The condition of the mangrove forest is restored with replanted mangrove by the community and the government in Banggi coast. Rhizophora is the most dominant mangrove species on the Banggi Coast, Rembang. The rhizophora inhabits the intermediate zone with sedimentation. The genus *Rhizophora* is the most common mangrove genus worldwide. Gulayan et al. (2015) reported that Rhizophora has a survival rate of 48.36% one year post planting and an average of 6.097 cm increase in height per month. *Rhizophora stylosa* Griff. is a widespread Indo-Pacific mangrove species (Ragavan et al., 2016). *Rhizophora mucronata* shows relatively high salt tolerance (Jayatissa et al., 2008; Reef and Lovelock, 2015) and the highest survival rate under all salinity conditions (Kodikara et al., 2017). Kamruzzaman et al. (2017, 2019) reported that *R. stylosa* was the most productive tree in the mangroves of dry matter production and *Rhizophora stylosa* Griff. is the most important family of true mangroves.

The mangrove forest is a very productive ecosystem (Donato et al., 2011, Ariyanto et al., 2018b; Carugati et al., 2018). Its high productivity was supported by the amount of litter, the recycling of nutrients (Morrisey et al., 2007; Ntyam et al., 2014; Alongi, 2018), and the contributions to the detritus-based food web (Komiyama et al., 2008; Lee et al., 2014; Thilagavathi et al., 2014). The mangove litter produced in the form of leaf plays the most important litter role compared to other organs as it was a source of nutrition for the organism. The mangrove ecosystem is a unique area because an integrated relationship between terrestrial and marine physical, biological, and chemical elements exists here. The combination results in a complex ecosystem between the terrestrial and marine

ecosystems which is supported by the production of litter. Litter is the main component of the net primary production (Kamruzzaman et al., 2017b), reflecting a phenological phenomenon (Duke, 1990; Clarke, 1994) which is also an important part of the energy and nutrient flux in the mangrove ecosystem (Wafar, 1997). Ellison (2000) added that criteria that could be used in assessing the success of a restoration effort include vegetation structure, secondary succession, and primary productivity.

Leaf litter was an important aspect in the study of the production and flux of organic materials in an ecosystem (Zalamea and Gonzalez, 2008; Dai et al., 2018). Mangroves on the Banggi Coast are mangroves planted by the government and the local community. The high secondary succession in benthic fauna in replanted mangrove forests was equal to the natural stands in Indonesia (Ariyanto et al., 2018c). Therefore, mangroves could provide a habitat for both marine and terrestrial fauna, play a role in the mangrove food web, and influence coastal fisheries in

a positive way (Nagelkerken et al., 2008; Kaiser et al., 2015; Ariyanto et al., 2018c; Nehemia et al., 2019). Mangroves are also an important contributor of nutrients for estuarine and coastal productivity through litter. The mangrove lifecycle refers to the period of intense leaf growth and shedding, flowering, and fruiting which are influenced by the sediment's physicochemical factors. Therefore, the objective of the present study was to determine the physicochemical factors that influenced the dynamics of mangrove litter *(R. mucronata* and *R. stylosa)* on the Banggi Coast, Rembang, Central Java.

2. METHODOLOGY
2.1 The study sites.

This research was conducted from September 2016 to August 2017 in Banggi Coast, Rembang, Central Java, Indonesia (Figure 1). Each station owns observing zones as: seaward zone, middle zone, and landward zone.
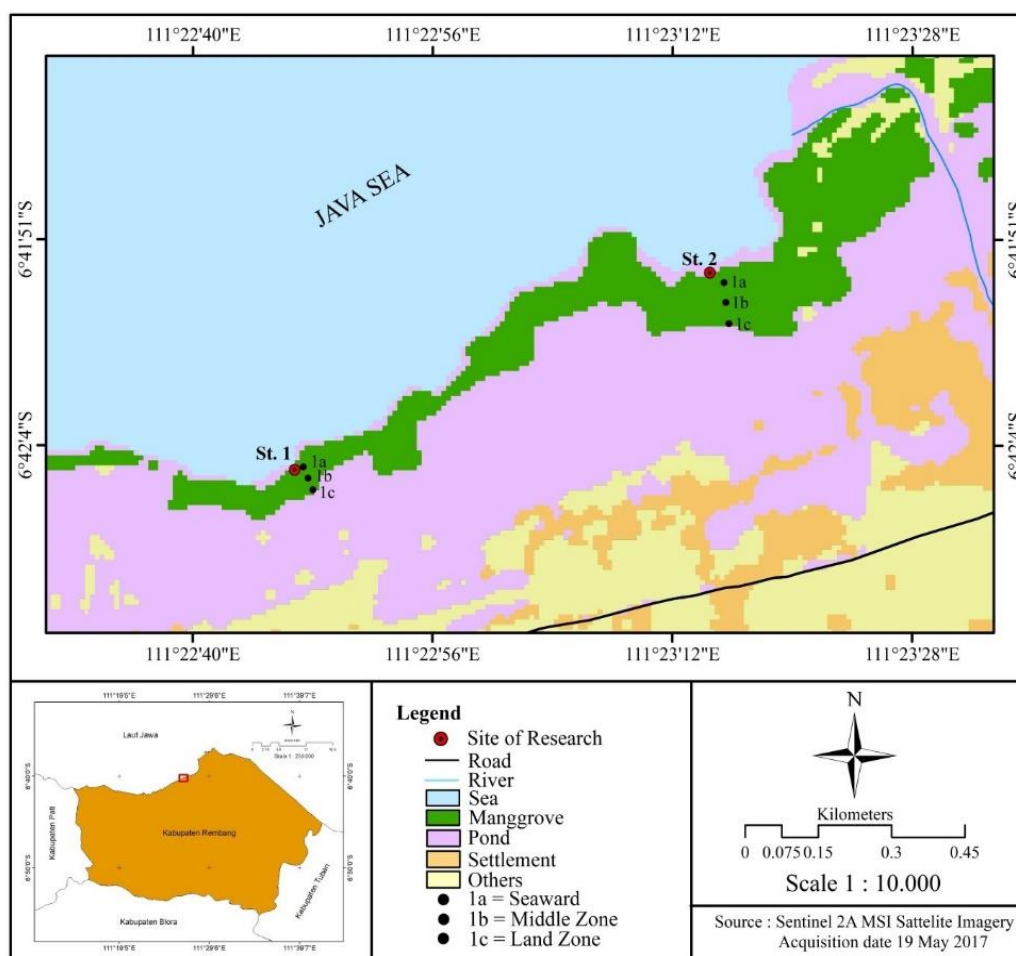

Figure 1. The location of research in Banggi Coast, Central Java, Indonesia.

2.2 Litter fall

Litter fall were trapped using litter traps with three repetitions at each station and were placed under the canopy of observation trees at 1.5 m above the soil surface in order to avoid the tidal range. Litter trap was made of nylon with a size of 1 x 1 m. The litter fall was collected and taken every 1 month during 1 year. The litter sample was dried, separated and weighed based on the type of mangroves and its components such as leaves, twigs, fruits and flowers.

2.3 Mangrove vegetation

This study employed 10 x 10 m mangrove transects. Line transects were placed in each station based on the mangrove vegetation type. The traps were placed beneath the tree canopy with the consideration that observations were made 1.5 m above the ground to avoid tides. Each station had three sub-transects that were perpendicular to the coastline, placed 50 m away for each transect.

2.4 Physico-chemical parameters.

The water quality measurements in each zone were: temperature, salinity, pH, DO, by using water quality meter. Each zone was measured six times: September and November 2016, January, March, May, and July 2017. Sediment samples were taken from 10 cm depth by using a pipe. Samples were taken from each transect, in September 2016, January 2017, and July 2017. Sediment sample analysis was conducted in Productivity Laboratory and Water Environment,

Bogor Agricultural University, comprised organic materials and sediment texture. Soil texture measurement was done by pipette method, and total nitrogen and total phosphorus used spectrophotometry (Pansu and Jacques, 2003).

2.5 Data analysis

The statistical analysis component (PCA) was used in order to determine the analysis of the relationship between gastropod distribution as an indicator of environmental conditions at various stations and time. The main component analysis displayed the data in graphical form, the data matrix, consisting of research zone as litter fall (line) and environmental variable as well (column). This analysis used Xlstat 2018 program.

3 RESULTS AND DISCUSSION
3.1 Mangrove litter

Every shift in time experiences fluctuating changes in leaf, twig, flower, and fruit production. Mangrove production, which consists of leaf, twig, flower, and fruit, demonstrate different patterns and the leaf production is usually higher than the production of other components (Figure 2). Figure 2 depicts the production of the components *R. mucronata* and *R. stylosa* mangrove components. *R. mucronata* had a leaf production of 49.51-99.78 g/m^2. An increased leaf production was observed in October-December 2016 and April-June 2017.
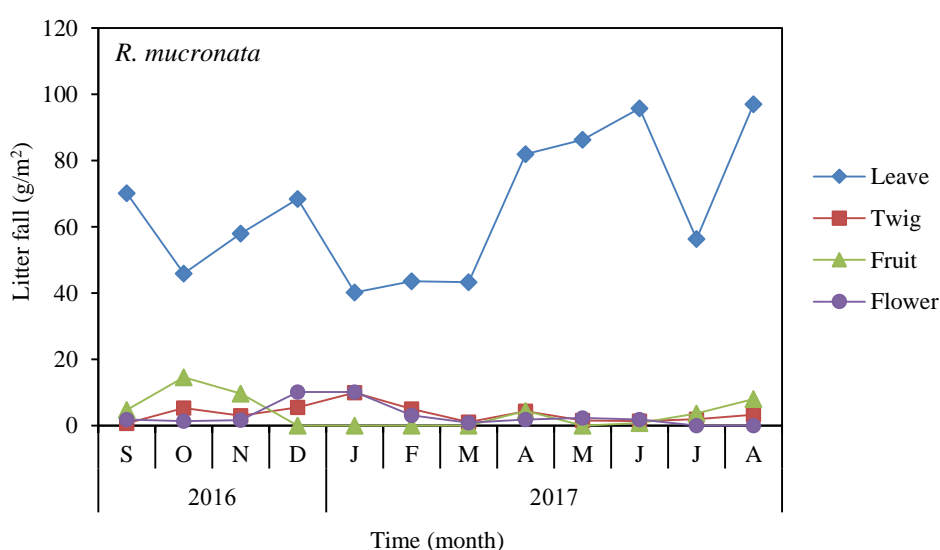

Figure 2. Litter fall of *R. mucronata* and *R. stylosa* in Banggi Coast, Rembang, Central Java (Leaves, twig, fruit and flower).
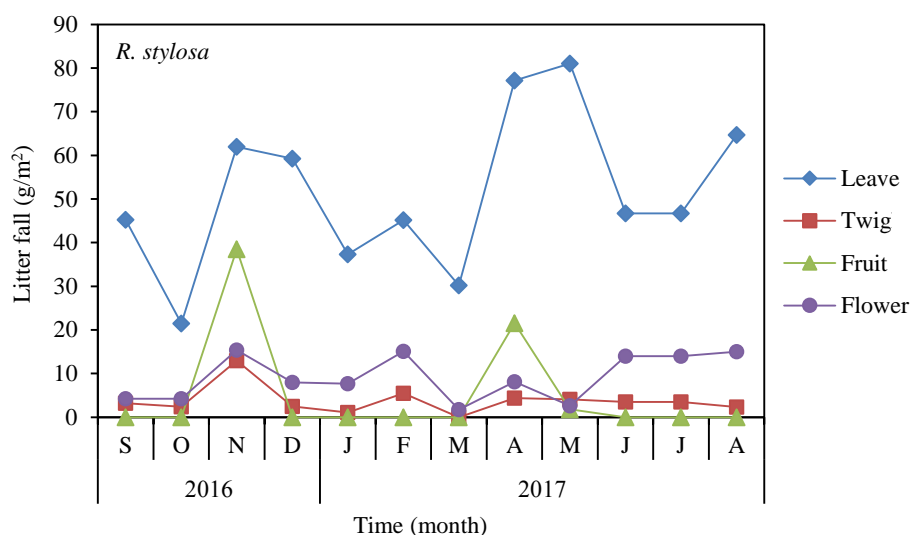
Figure 2. Litter fall of *R. mucronata* and *R. stylosa* in Banggi Coast, Rembang, Central Java (Leaves, twig, fruit and flower) (cont.).

During the study, the leaf litter production of *R. tylosa* peaked in November-December and April-May (Figure 2). The leaf production in November-December was followed by the highest twig production (12.99 g/m^2). The flower production peaked twice during the study, in November (15.37 g/m^2) and February (15.07 g/m^2). The fruit production peaked twice during the study in November (38.47 g/m^2) and April (21.53 g/m^2). In general, the *R. stylosa* mangrove experienced minimum productivity in October (28 g/m^2) and maximum productivity in November (128 g/m^2).

Ragavan et al. (2011) showed that in *R. mucronata* the style is short and the ovary elongate and tapering and *R. stylosa* the style is long and ovary is

short. Seasonality can affect the adaptation of the mangrove environment for survival through litterfall in Indonesia (Sukardjo, 2010) and Kenya (Wang'ondu et al., 2014)

3.2   Litter part distribution percentage on the Banggi Coast, Rembang, Central Java, Indonesia

The entire mangrove production, which included leaves, twigs, flowers, and fruit, had a varied productivity contribution in various species of mangrove (Figure 3). In general, the leaf contribution of *R. mucronata* was higher than that of *R. stylosa*. The leaf productivity contribution was higher than those of the twigs and fruit in both *R. mucronata* (86%) and *R. stylosa* (74%).
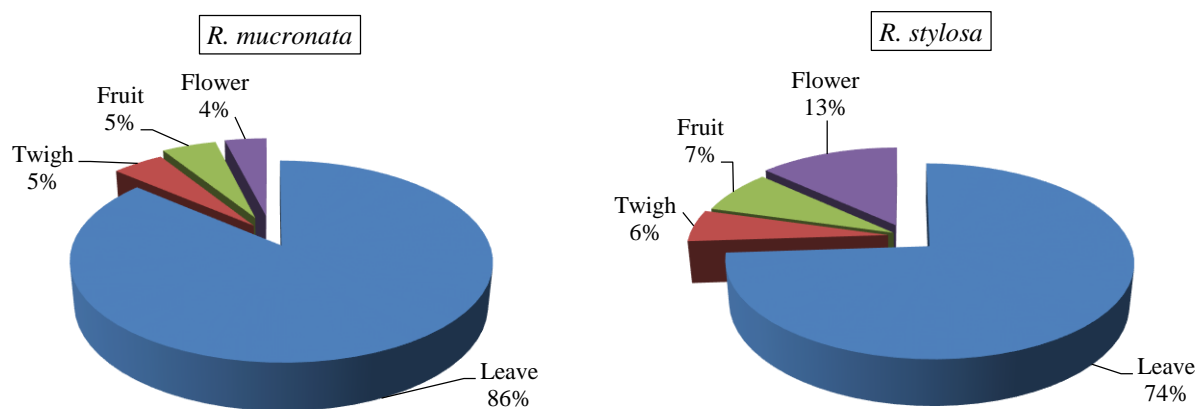

Figure 3. The part of litter fall in *R. mucronata* dan *R. stylosa* (leaves, flower, fruit, and twig).

The *R. mucronata* leaf production observed in this study was higher (86%) than the findings of other studies. The study by Steinke and Ward (1990) found that *R. mucronata* produced 52.3% leaf litter. The main component of mangrove litter is leaves (>50%) (Ake-Castillo et al., 2006; Mchenga and Ali, 2017) This is related to one form of plant adaptation in mangroves to reduce water loss in order to survive in high salinity. Kamruzzaman et al. (2013) found

78.7% conversion from fruit to propagules in *R. stylosa* on Okinawa. Rani et al. (2016) argued that each component had different seasonality in which leaf fall was highest.

Table 1 shows that *R. stylosa* had a higher density than *R. mucronata*. However, *R. stylosa* had lower litter productivity. This was because the *R. stylosa* trees were younger than the *R. mucronata* trees. A high density is not a guarantee for high productivity.

Table 1. Density (tree/100 m^2), litter fall (kg/m^2/ year) and mangrove productivity (kg/m^2/year)

Mangrove	Density	This study	Others study	
R. mucronata	33±6	0.92	2.8	Mchenga et al. (2017)
R. stylosa	43±8	0.89	2.55	Duke et al. (1981)

The research study has trend of litter productivity of mangrove forest such as related to tree age, stand structure, and habitat characteristics. The other studies examined the self-thinning relationship, forest structure, and phenology in mangrove (Kamruzzaman et al., 2016).

3.3 The physico-chemical condition

Figure 4 shows the difference in the C, N, and P content in *R. mucronata* and *R. stylosa*. *R. stylosa* has a higher organic C content than *R. mucronata* at many times/seasons. This was also seen in the N and P content where *R. stylosa* had higher contents.
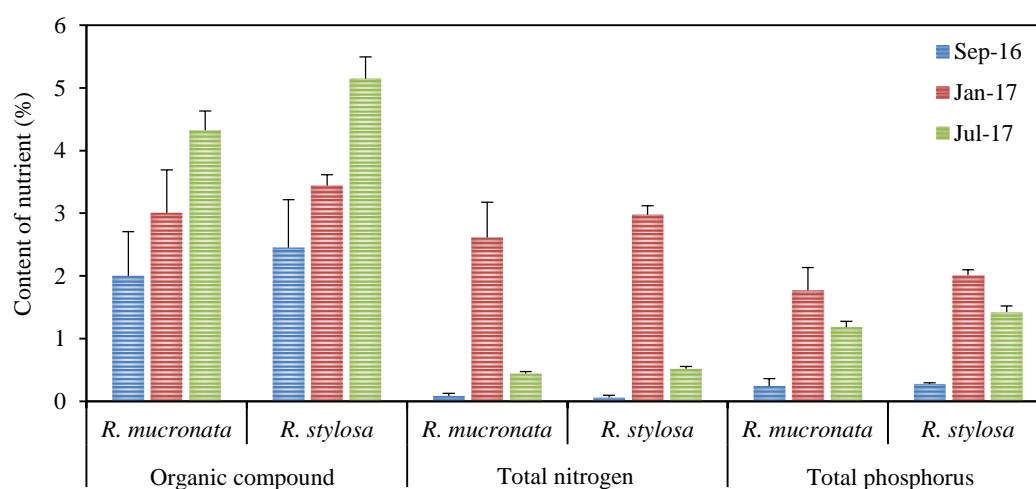

Figure 4. The CNP compound on *R. mucronata* and *R. stylosa* in Banggi Coast, Rembang, Central Java, Indonesia

Nitrogen (N) and phosphorous (P) are important nutrients which determine the quality of mangrove litter and their decomposition rate (Flindt et al., 1999; Keuskamp et al., 2015; Krishna and Mohan, 2017). The P content increased from the rainy season to the dry season during the observation period. The P content in the study location could be classified as high (0.24%-1.18% for *R. mucronata* and 0.27%-1.42% for *R. stylosa*). The factors which influenced the study were the effects of the tides; the increased nitrogen and phosphorous content were discovered

to be a long-term accumulation effect to the detritus by the decomposition process, and differences in the mangrove species ability to compete for external nutrients.

The composition of the substrate in *R. mucronata* and *R. stylosa* were no different in different seasons or sampling times (Table 2). The dominant substrate was dust. The dust in the substrate was due to the presence of a source of fresh water from inland which came in the form of a river which passed through the mangrove area headed to the sea.

Table 2. Sediment on *R. mucronata* and *R. stylosa* in Banggi Coast, Rembang, Central Java, Indonesia

Mangrove	Sand (%)	Silt (%)	Clay (%)
R. mucronata			
Sep-16	5.17±1.36	91.21±1.87	3.62±1.48
Jan-17	0.03±0.01	94.55±1.38	5.41±1.36
Jul-17	0.25±0.06	93.06±1.86	6.69±1.91
R. stylosa			
Sep-16	6.67±4.96	92.32±6.04	2.71±0.69
Jan-17	0.03±0.01	95.00±1.05	4.97±1.04
Jul-17	0.39±0.10	91.08±0.61	8.52±0.64

Table 3. Water quality parameters in Banggi Coast, Rembang, Central Java, Indonesia

Station	Sep 2016	Nov 2016	Jan 2017	Mar 2017	Mei 2017	July 2017
R. mucronata						
DO (mg/L)	5.98±1.51	4.36±0.11	5.41±0.87	8.00±0.00	7.30±1.90	4.13±0.12
Salinity (psu)	29.33±1.15	26.00±3.00	26.67±2.87	32.83±2.03	32.90±0.34	33.87±0.05
pH	7.43±0.10	8.02±0.24	7.96±0.03	5.51±2.86	8.37±0.38	6.33±2.94
Temperature (ºC)	28.66±0.25	29.50±0.36	29.43±0.32	27.63±2.56	27.73±1.10	26.87±0.06
R. stylosa						
DO (mg/L)	7.96±0.70	4.89±0.73	7.22±0.07	8.02±0.02	6.18±1.32	4.37±0.81
Salinity (psu)	26.33±1.52	29.33±2.31	28.33±2.88	33.26±0.65	32.93±0.25	34.46±0.78
pH	7.38±0.08	7.51±0.25	7.52±0.04	6.30±2.89	8.01±0.31	7.69±0.36
Temperature (ºC)	27.63±1.58	27.83±0.55	29.27±0.45	29.30±0.26	26.87±0.41	25.90±1.64

Table 3 shows the variation in water quality conditions. DO conditions ranged from 4.89-8.00 mg/L. The salinity and pH conditions were respectively (26.00-34.46 psu and 5.51-8.02). Temperature conditions experienced variations ranging from 25.90-29.27 ºC. The water quality fluctuated in value based on the season. Rani et al. (2016) reported the increase in temperature increases evapotranspiration and increases salinity and causes stressed condition which leads to litterfall.

3.4 The relationship of litter fall and environmental conditions

The relationship between mangrove litter of *R. mucronata* and *R. stylosa* with the environmental physicochemical factors was analyzed using PCA (Figure 4). The result was 3 eigenvalues. The analysis of the first main component had an eigenvalue of 5.41 (49.19% variance), the second 3.69 (33.57% variance), and the third 1.09 (9.93% variance). The three eigenvalues describe that the data variability was 82.77% (% cumulative/total variance). The relationship between the original variables and the new variables formed by the analysis of the main components is called the loading factor value. This showed that high mangrove litter productivity was influenced by organic matter, sand, and salinity.

The high organic matter content in the mangrove sediment originated from the mangrove leaf litter. Moreover, the mangrove forest is considered as the driving force for physiological and biochemical processes which actively influences the mobility and availability of nutrients (Bosire et al., 2005; Medina et al., 2015; Gao et al., 2019). This influence is affected by the tidal hydrology, litterfall production, leaf decomposition rate, and standing stock, and the physicochemical properties of the local sediment. Temperature was the limiting factor for mangrove forests which was consistent with the previous study (Wafar et al., 1997; Sanchez-Andres et al., 2010; Ward et al., 2016; Jacotot et al., 2019)
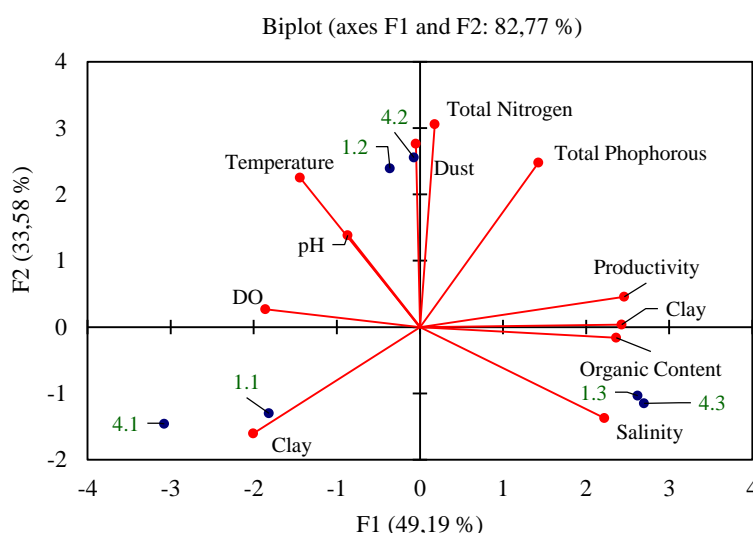
Figure 5. PCA for relationshio on physicochemical factors and litter dynamics *R. mucronata* and *R. stylosa* in Banggi Coast, Rembang, Central Java, Indonesia.

4. CONCLUSION

The leaf productivity contribution was higher than those of the twigs and fruit in both *R. mucronata* (86%) and *R. stylosa* (74%). The factors that influenced the litter dynamics on *R. mucronata* and *R. stylosa* were sediment organic matter, the salinity condition at 26.00-34.46 PSU. Higher organic matter caused higher productivity in mangrove *R. mucronata* and *R. stylosa.*

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