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Comparative relationship of specific gravity, diameter, and leaf size of two mangrove species at Masapelid Island, Philippines

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Abstract

Thirty individual trees composed of *Avicennia rumphiana* and *Sonneratia alba* belong to three diameter classes (5-8cm, 9-12cm, and 13-16cm) were sampled from the mangrove ecosystem located at Masapelid Island, Philippines. Wood samples, diameters and leaf sizes measurements were gathered in this study. Specific gravity was determined from the wood samples and correlated to species, diameter, and leaf sizes. Results showed that specific gravity has a significant difference in species (p= 0.0176) but no significant difference with its diameter and leaf sizes (leaf length and width). Between the two species, *A. rumphiana* had higher average specific gravity with 0.562 compared to *S. alba* with 0.487. The results showed that the species leaf length, width, and area vary in between diameter classes. In *A. rumphiana*, leaf length, width, and area increased consistently with the increase of the DBH in every diameter class. However, this was not observed in *S. alba*. Radial variations of specific gravity from the center of the stem to bark were also different between species.

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Introduction

Mangroves are an ecological group of tropical plants that inhabit coastal environments (Tomlinson, 1986) with majority of the species develops adaptation mechanism to exclude the absorb salt away from the cytoplasm of the cells for survival. Moreover, the mangrove ecosystem is a harsh habitat to support above-ground biomass due to waterlogged and high salinity conditions. However, surviving desiccation and water loss were overcome by developing leaves with the thick epidermis, waxy cuticle, and succulent leaves (Primavera *et al.,* 2004). The leaf area of a tree or stand of trees has important implications in the ecology of forests because it participates in biological processes (Fownes and Harrington, 1990; Kozlowski *et al.*, 1991).

In forest stands, the net primary production, *i.e.,* the sum of increases in biomass, is positively correlated with the leaf area index (Pallardy, 2008). Further, information on the wood-specific gravity of forest trees, an important factor influencing the amount of forest biomass (Detienne & Chanson, 1996). Wood-specific gravity is a convenient indicator of life history strategy in trees and direct importance for ecosystem studies. It is the single best descriptor of functional properties of wood and life-history traits of trees and the most important variable in estimating above and below-ground biomass and carbon stocks in forests (Ketterings *et al.*, 2001).

Nowadays, a growing number of studies have begun to report a negative relationship between wood-specific gravity and leaf area (Ackerly, 2004; Cavender-Bares *et al.*, 2004; Wright *et al.*, 2006, 2007). Though this relationship is reported, the correlation's mechanism has been less studied (Wright *et al.,* 2006). One possibility is that lower wood specific gravity is associated with higher stem conductance, which can, therefore, support larger leaves, but this hypothesis still needs to be broadly tested (Wright *et al.*, 2006). Also, there may be a direct morphological link; wood-specific gravity is higher in individual trees growing more slowly than it is in conspecific individuals that grow more quickly (Koubaa *et al.,* 2000).

Several factors contribute to the variations of specific gravity of wood species; location of the wood sample (i.e., juvenile or reaction wood), the geographic range of the tree species, site conditions where the tree grows, genetics, age of the tree and in the climatic life zone (Wiemann and Williamson, 1989, 2002; Woodcock, 2000; Baker *et al.*, 2004; Muller-Landau, 2004). Mangrove forests in Masapelid Island, Philippines, are less studied. In the study of Gamboa, Jr. *et al.*, 2019, on the Diversity and Vegetation Analysis of mangrove species in Condona Island, which is situated in the western part of Masapelid island, they mention that there were *Rhizophora* sp., *Sonneratia* sp., *Aegiceras* sp., *Bruguiera* sp. and *Avicennia* sp., exist in the area and must be considered in any reforestation program to increase its diversity and fish production. They also added that the community's illegal cutting activity, which is utilized for firewood, charcoal, and pen construction for lobster by the community, is observed and rampant within the mangrove area, resulting in low species richness and uneven distribution of mangroves.

Avicennia rumphiana and Sonneratia alba were the dominant species found in Masapelid Island. Both species were classified as 'Least Concern' in the IUCN Red List of Threatened Species (IUCN 2011 & 2010). There is increasing interest in estimating the specific gravity of mangrove species in Masapelid Island and their relationship to leaf sizes and diameter. No studies have been carried out on the estimation of wood-specific gravity on the island. Thus, this study aims to determine the relationship of specific gravity and the leaf morphometric of the two mangrove species, such as *S. alba* and *A. rumphiana.* Specifically, it aims to determine its average length, width, leaf area of the leaves of the trees per diameter classes; determine the variation of specific gravity and the correlation of leaf morphometrics, and determine the radial variation of specific gravity.

Materials and methods

Study Site

This study was conducted in the mangrove forest located at Barangay Fabio, Tagana-an, Surigao del Norte, specifically in Masapelid Island, with geographic coordinates 9°42'33.98" N, 125°38'38" E. The Municipality of Tagan-an shares common boundaries with Surigao City, Placer and Sison in the mainland, Bucas Grande, and Siargao islands off the seawaters of Hinatuan Passage.

Based on the Corona system classification, the study site was classified as under climatic Type II characterized by no pronounced dry season with a very pronounced maximum rain period from November to January and received an average annual rainfall of 288.13mm.

Species Selection

Two mangrove species was studied such as *S. alba* and *A. rumphiana* both naturally grown in the middle of mangrove ecosystems.

DBH Measurement

Three diameter classes were measured per species as such: 1) 5-8cm, 2) 9-12cm and 3) 13-16cm. Five trees per diameter classes were measured at random using a diameter tape for a total of thirty sampled trees.

Leaf sizes Indices and Classification

The leaves of the first branch of the sampled trees were used in the measurement of leaf morphometric. The length and width of the leaves per diameter classes were determined using a ruler. Length was measured from the base to the tip while the width was measured at the widest portion of the leaves. The leaf area per diameter classes was determined using the formula of Cain and De Olivereira- Castro (1959):

Leaf area = 2/3 (L x W)

Where: L - full length of the leaf

W - Width of the leaf at its widest portion.

The average leaf area per species was classified using the classification according to Raunkiaer 1934 and Webb 1959 (Table 1).

Table 1. Leaf Size Classification.

Categories	Dimensions(cm^2)	Raunkiaer (1934)	Webb (1959)	Merged Categories
1	<0.25	Leptophyll	Leptophyll	Small leaves
2	0.25 - 2.25	Nanophyll	Nanophyll	
3	2.25 - 20.25	Microphyll	Microphyll	
4	20.25 – 45.00		Mesophyll	Large leaves
5	20.25 – 182.25	Mesophyll	Notophyll	
6	182.25 – 1640.25	Macrophyll	Macrophyll	
7	>1640.25	Megaphyll	Megaphyll	

Collection of Wood Samples

The wood samples per tree per diameter classes were taken at 1.3 meters above the ground using the increment borer. Two directions were observed, including parallel along the seaward and parallel along the landward to represent the radial samples. A total of 60 samples were collected and were placed immediately in a sealed container with seawater to maintain its moisture content. Wood samples were brought to the laboratory for weight measurements and oven-drying.

Green and Oven-dry Weight Measurements

The green weight of the wood samples was measured using a digital weighing balance. After the green weights were determined, the wood samples were subjected to oven-drying in ten days. In ten days, weight measurements were taken to represent the oven-dry weight.

Specific Gravity Determination

The specific gravity of the wood samples was determined using the formula:

$$G = \frac{1}{\frac{w_g - w_o}{w_o} + \frac{1}{1.53}}$$

Where: w_g = the Green weight of the wood sample

w_o = the Oven-dry weight of the sample

1.53 = density of pure cell wall substance

Radial Variation of Specific Gravity

One tree per diameter class per species was selected to determine the variation of the radial specific gravity. Due to smaller wood samples, only five equal segments were gathered instead of the standard ten equal segments.

Data Analysis

The data on the leaf length, leaf width, and specific gravity per species and diameter class was analyzed using a 2 x 3 factorial experiment in Completely Randomized Design. The comparative relationship of specific gravity, diameter class, leaf length, and leaf width was analyzed using correlation analysis.

Results and discussion

Leaf Length

Based on the results, A. *rumphiana* obtained the highest average leaf length for the diameter class 3 with 7.83cm, while the lowest was obtained by the diameter class 1 with 6.99cm. An increasing trend of leaf size concerning diameter classes was observed. For *S. alba*, diameter class 1 got the highest average leaf length of 7.80cm, while the lowest was obtained by diameter class 3 with 6.03cm. No observable trend of leaf size concerning diameter classes was observed. Moreover, the Analysis of Variance (Table 2) between the two species showed a significant difference. This variation of leaf length may be due to phenotypic plasticity (Siso *et al.*, 2001). Many previous studies have revealed that variations in leaf traits result from adapting to growth habitats (Pandey and Nagar, 2002). Differences in leaf size and shape can occur at several levels such as geographical origin, population, tree, and leaf (Viscosi and Cardini, 2011). Casilac, Jr. *et al.* (2018) also mentioned that different zones possess different exposures to tidal inundation, waterlogging, and salinity that may have contributed to the variations of Leaf Size Indices (LSI). The nutrient takes dynamics was found to affect the LSI, especially phosphorus and nitrogen content.

Table 2. Analysis of Variance for the Length.

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Species	1	344.0379	344.0379	6.99	0.0142*
Diameter	2	217.3437	108.6719	2.21	0.1319^{ns}
S x D	2	830.2240	415.1120	8.43	0.0017**
Error	24	1181.9300	49.2471		
Total	29	2573.5356			

Leaf Width

Based on the results, *A. rumphiana* obtained the highest average leaf width for the diameter class 3 with 3.78cm, while the lowest was obtained by the diameter class 1 with 3.17cm. An increasing trend of leaf width concerning diameter classes was observed. This trend was similar to the study of Peel *et al.* (2017), wherein leaf widths of *R. mangle* had a positive relationship with the stem diameter along salinity gradient. For *S. alba*, diameter class 1 obtained the highest average leaf width of 5.36cm, while the lowest was obtained by the diameter class 2 with 4.47cm. No observable trend of leaf width concerning diameter classes was observed. Moreover, Analysis of Variance (Table 3) between the two species showed significant differences. The variability of inter-species leaf morphology (e.g., leaf area, leaf length, leaf width) could be associated with faunal retention rates (Cannicci *et al.*, 2008), mangrove ecosystem seasonal dynamics (Berger *et al.*, 2008), and differences in canopy ecological habitat for faunal species (Nagelkerken *et al.*, 2008).

Table 3. Analysis of Variance for the Width.

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Species	1	1709.8334	1709.8334	77.52	0.0000**
Diameter	2	125.4990	62.7495	2.84	0.0779^{ns}
S x D	2	174.0580	87.0290	3.95	0.0330*
Error	24	529.3733	22.0572		
Total	29	2538.7638			

Leaf Area

A. rumphiana obtained the highest average leaf area for the diameter class 3 with 19.73cm2, while the lowest was obtained by the diameter class 1 with 14.75cm2. An increasing trend of leaf area concerning diameter classes was observed. The same result was mention by Xiang *et al.* (2009) that leaf size is positively correlated with the stem diameter, which may be due partly to the allometry between stem diameter and stem length. Liang *et al.* (2008) also mention that the leaf adaptation to drought stress, resulting from harsh osmotic relations, is commonly displayed as lower specific leaf area, thicker leaves and cuticles; hence, specific leaf area is a good indicator of environmental stress in mangroves. For *S. alba*, diameter class 1 obtained the highest average leaf area of 27.86cm2, while the lowest was obtained by the diameter class 2 with 17.96cm2. No observable trend of leaf area concerning diameter classes was observed. However, leaf area may be variable (Araujo, Jaramillo, & Snedaker, 1997) and reduced under suboptimal conditions and so can be an indicator of chronic environmental stress (Canoy, 1975; Snedaker & Brown, 1981). Leaf dimensions of the two species belong to both large leaves categories. Both *A. rumphiana* and *S. alba* leaf sizes belong to mesophyll classification (Raunkiaer 1934), with an average leaf area of 16.97cm2 and 22.24cm2 respectively.

Specific Gravity

A. rumphiana obtained the highest specific gravity in diameter class 2 with 0.664 while the lowest was obtained by the diameter class 1 with 0.560. No observable trend of specific gravity in relation to diameter classes was observed. For *S. alba*, the highest specific gravity was obtained in diameter class 2 with 0.526 while the lowest was obtained by the diameter class 1 with 0.443. No observable trend of specific gravity in relation to diameter classes was observed. Between the two species, *A. rumphiana* obtained the highest average specific gravity of 0.602 while the lowest was obtained by *S. alba* with 0.487. Location of the wood samples within a tree (i.e., juvenile or reaction wood), the geographic range of the tree species, site conditions where the tree grew, and tree genetics can cause specific gravity to vary (Muller 2004) given also that the stand was uneven-aged. According to Zobel and Talbert (1989), 70% of the overall specific gravity variation in species is due to genetic control and the remaining 30% is due to the differences among provenances and sites.

Correlation Analysis

Both *A. rumpiana* and *S. alba* showed no correlation between dependent and independent variables. But the overall correlations showed a significant correlation between specific gravity and leaf width ($n=15$, $r= -.438$, $p<0.05$). Since the value of Pearson correlation was negative, this implies that when the leaf width increases, the specific gravity will decrease and vice versa (Table 7). Nowadays, a growing number of studies have begun to report a negative relationship between wood-specific gravity and leaf sizes (Ackerly, 2004; Cavender-Bares *et al.*, 2004; Wright *et al.*, 2006, 2007). Though this relationship is reported, the correlation's mechanism has been less studied (Wright *et al.,* 2006). Lower wood specific gravity is associated with higher stem conductance, which can, therefore, support larger leaves, but this hypothesis still needs to be broadly tested (Wright *et al.*, 2006). Besides, there may be a direct morphological link; wood-specific gravity is higher in individual trees that are growing more slowly than in conspecific individuals that grow more quickly (Koubaa *et al.* 2000) expect higher wood densities on less fertile soils.

Radial Variation in Specific Gravity

Fig. 5 below showed the radial variation from pith to the bark of the two species. In *A. rumphiana,* diameter class 1 has an increasing trend in segments 1, and 2 then decreases in segment 3 and increases towards segments 4 and 5. Diameter class 2 also has an increasing trend in segments 1 and 2, then gradually decreases in segments 3, 4, and 5. For diameter class 3, it slightly reduced from segment 1 to 2, then increases in segment 3, decreases in segment 4, and again increases in segment 5.

Table 4. Analysis of variance for the specific gravity

Source	DF	SS	MS	F Value	Pr (> F)
Species	1	0.0426	0.0426	6.50	0.0176*
Diameter	2	0.0082	0.0041	0.63	0.5429
S x D	2	0.0132	0.0066	1.01	0.3796
Error	24	0.1572	0.0066		
Total	29	0.2212			

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. Correlation among variables of *A. rumphiana*

		specific gravity
specific gravity	Pearson Correlation	1
	Sig. (2-tailed)	
	N	15
Length	Pearson Correlation	0.417
	Sig. (2-tailed)	0.122
	N	15
Width	Pearson Correlation	0.402
	Sig. (2-tailed)	0.138
	N	15
Diameter	Pearson Correlation	0.402
	Sig. (2-tailed)	0.138
	N	15

Table 6. Correlation among variables of *S. alba*

		Specific gravity
Specific gravity	Pearson Correlation	1
	Sig. (2-tailed)	
	N	15
Length	Pearson Correlation	-0.197
	Sig. (2-tailed)	0.482
	N	15
Width	Pearson Correlation	-0.247
	Sig. (2-tailed)	0.374
	N	15
Diameter	Pearson Correlation	0.242
	Sig. (2-tailed)	0.384
	N	15

*.Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Correlation between the two species

		Specific gravity
Specific gravity	Pearson Correlation	1
	Sig. (2-tailed)	
	N	30
Length	Pearson Correlation	0.080
	Sig. (2-tailed)	0.674
	N	30
Width	Pearson Correlation	-.438*
	Sig. (2-tailed)	0.016
	N	30
Diameter	Pearson Correlation	0.218
	Sig. (2-tailed)	0.247
	N	30

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

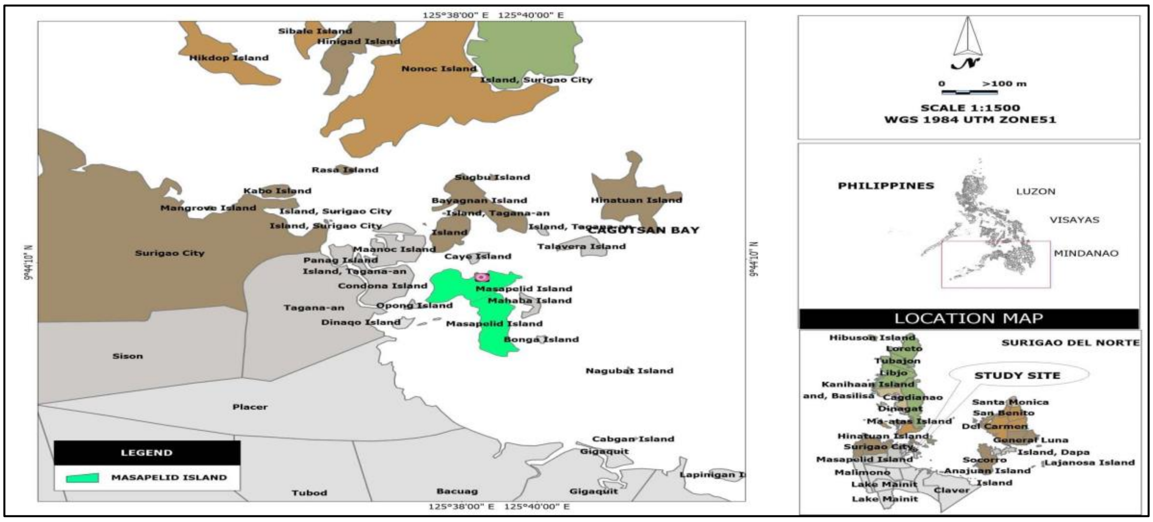

Fig. 1. Map of the study site.

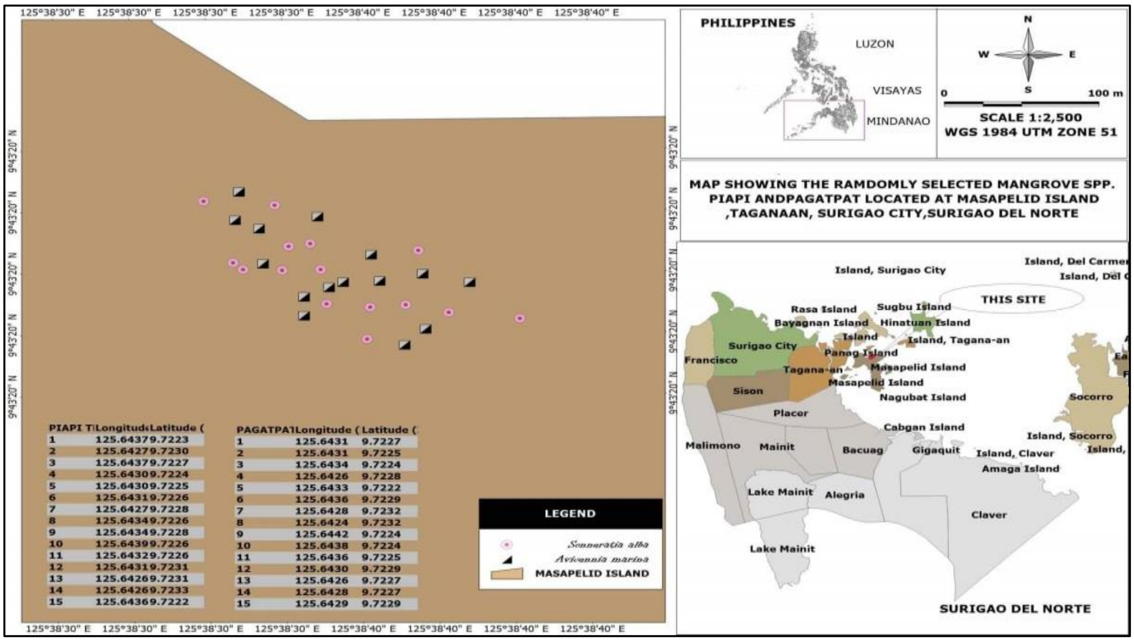

Fig. 2. Location of the sampled species.

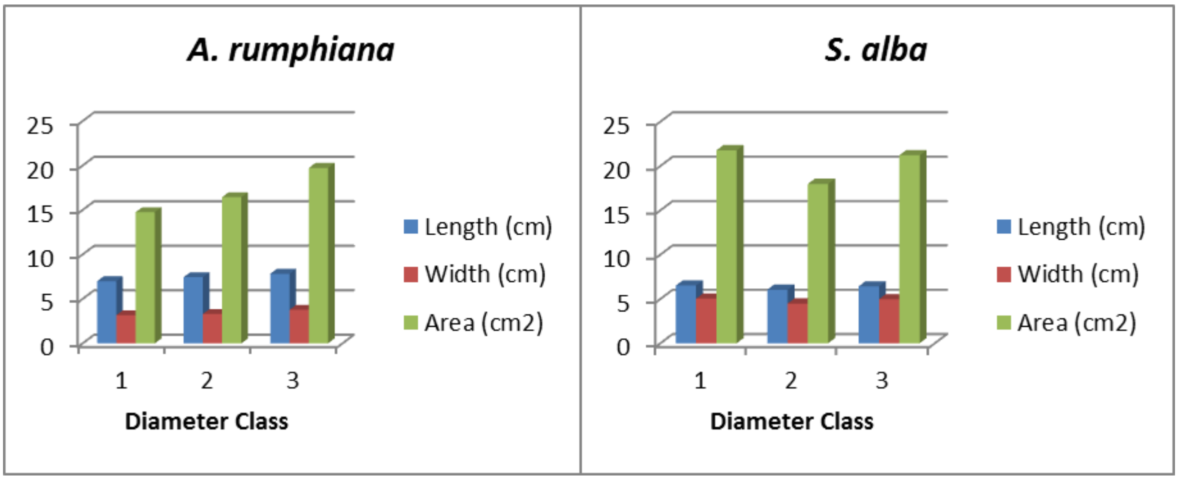

Fig. 3. Average leaf length, width, and area per diameter class.

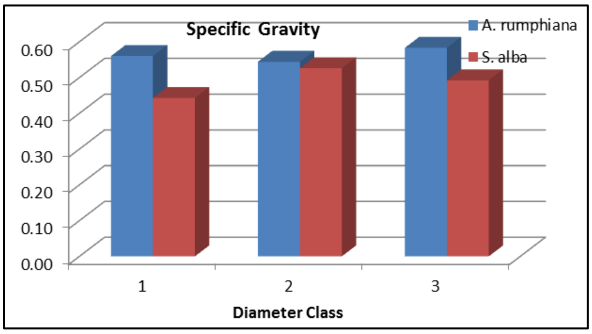

Fig. 4. Average Specific Gravity of two mangrove species.

In *S. alba,* diameter class 1 has a constant slight decreasing trend from segment 1 until the segment 5. Diameter class 2 has an increasing trend in segments 1, and 2 then decreases in segment 3 and increases in segments 4 and 5. Diameter class 3 has a decreasing trend from segment 1 towards segment 5. For the combined diameter classes per species, for *A. rumphiana,* it has an increasing trend from segment 1 to 2, then stable in segment 3 and gradually decreases in segments 4 and 5. For *A. alba,* a decreasing trend was observed from the segment 1 until segment 3, then increases in segment 4 and decreases again in segment 5. The average direction of the *A. rumphiana* from the center of the stem towards the bark was similar to the results of Schimleck *et al.* (2018) wherein loblolly pine had an increasing trend observed for ring-specific gravity variance from pith to bark. The observed variation in wood properties among and within trees is mainly attributed to tree genetics, environmental conditions in which the tree grows, and their interactions (Zobel *et al.*, 1995).

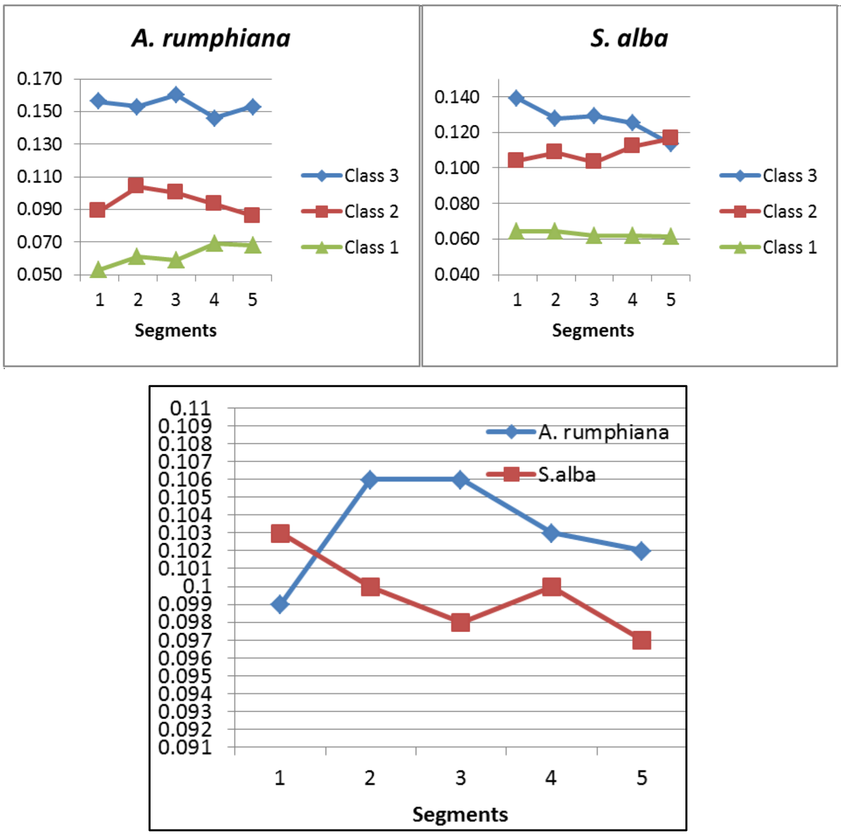

Fig. 5. (A). Individual and combined radial variation of specific between the two species.

Conclusion

Based on the results, the following conclusions are drawn:

A. rumphiana obtained the highest average leaf length and width in diameter class 3 and lowest in diameter class 1. An increasing trend of the average leaf length and width concerning diameter classes was observed. For *S. alba,* diameter class 1 obtained the highest average leaf length and width, while the lowest was obtained by the diameter class 2.

No observable trend of the leaf length and width concerning diameter classes was observed. Analysis of variance (Table 2) showed that leaf length and leaf width has a significant difference between *A. rumphiana* & *S. alba*. Moreover, the interaction between species and diameter showed to have a significant effect on species leaf length and width.

Leaf dimensions of the two species belong to both large leaves categories. Both *A. rumphiana* and *S. alba* leaf size belong to mesophyll classification with an average leaf area of 16.97cm² and 22.24cm² respectively. *A. rumphiana* obtained the highest specific gravity in diameter class 2 while the lowest was obtained by diameter class 1.

No observable trend of specific gravity concerning diameter classes was observed. For *S. alba*, the highest specific gravity was obtained in diameter class 2, while the lowest was obtained by diameter class 1. No observable trend of specific gravity concerning diameter classes was observed. Between the two species, *A. rumphiana* obtained the highest average specific gravity and followed by *S. alba*.

For the radial variation of species from pith to bark, for *A. rumphiana,* it has an increasing trend from segment 1 to 2, then stable in segment 3 and gradually decreases in segments 4 and 5. For *A. alba,* a decreasing trend was observed from segment 1 until segment 3, then increases in segment 4 and decreases again in segment 5.

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