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Durability of coconut fronds as attractors for fish aggregating devices (FADs): an observation based on leaf epidermis structure

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Abstract. Traditional fishermen use coconut fronds (*Cocos nucifera*) as attractors in Fish Aggregating Devices (FADs) to attract and aggregate fish in the sea. The attractors are commonly referred to as `natural attractors' for FADs. Durability of coconut frond attractor has become an important point to minimize the maintenance cost and also to protect amount of fish around FADs. This study was conducted to investigate the durability level of coconut frond attractors for FADs taken from different distances (500 m, 1,000 m and 1,500 m) from the coast and placed in 23-30 m depth of water. Scuba diving was conducted to take frond samples once every two weeks until the fronds totally rot. The durability of coconut fronds was also determined in a controlled system where the experiment was carried out in a water tank to mimic the natural conditions. A total of 252 samples were obtained and investigated using Scanning Electron Microscopy. Results of adaxial and the abaxial epidermis analysis showed that the periods of immersion in the sea influence the epidermis thickness, hence the durability of the attractors ($P < 0.05$). Descriptive analysis of epidermis thickness showed that coconut fronds taken from 500 m and 1,000 m from the coast are more durable than fronds taken from 1,500 m from the coast. This finding is very important in the production of durable FADs.
Key Words: Natural attractors, coconut tree habitat, leaf epidermis, FADs.

Introduction. Fish aggregating Devices (FADs) has three main components, i.e. float, attractor and anchor. Attractor's ability to attract and aggregate fish around FADs becomes a major component in FADs (Altinagac et al 2010). The existence of attractors in FADs produces new trophic areas for water organism in the sea (Ibrahim et al 1996).

Coconut fronds (*Cocos nucifera*) were used by traditional fishermen as attractor in FADs. The attractors are commonly referred to as 'natural attractors' for FADs (Ibrahim et al 1990; Ibrahim et al 1996; Yusfiandayani 2004; Ghazali et al 2013). The abundance of coconut frond and low price make coconut frond as the chosen materials for natural attractor.

The coconut trees is native to coastal areas of Southeast Asia (Malaysia, Indonesia, and Philippines), tropical Pacific islands (Melanesia, Polynesia, and Micronesia) and westward to coastal India, Sri Lanka, East Africa and tropical islands (e.g. Seychelles, Andaman, Mauritius) in the Indian Ocean (Reddy et al 2010). Coconut tree is a multiple use tree and considered as one of the ten most useful trees in the world. Coconut tree is a member of the family Arecaceae (palm family) and is tolerant to various environmental conditions such as salt spray, soil salinity, drought, wind, etc. (Selvam 2007).

In terms of durability coconut frond is considered as a better attractor than areca (*Areca catechu*) and nipa fronds (*Nypa fruticans*). This is based on the structure of anatomical leaves namely epidermis and cuticle (Yusfiandayani 2004). Coconut tree is a mesophyte plan type that has 2 epidermis layers, i.e. adaxial (upper) and abaxial (lower) epidermis. The epidermis is the tough outer cell layer of the leaf that helps to protect the inner tissues and provides structural support (Graham et al 2003). Therefore, the decay process can be measured by the thickness of leaf epidermis.

Although many studies have been carried out to assess the durability of coconut frond as attractor of FADs, however, a specify study on the effect of distance from seashore on its durability is still lacking. Therefore, the present study is important in addressing this issue in determining the distance factor affecting the anatomical structure of coconut frond. The main objective of the present study was to determine the level of endurance coconut frond (different distance of the coast) as attractor against immersion in the sea water with an indicator characteristic of leaf anatomy. In addition, to observe the effect of immersion location of natural attractor on leaves structure, this study was carried out by immerging coconut frond in the sea and in sea water tank.

Material and Method

Selected material and treatment. Dwarf coconut tree type (*C. nucifera*) was selected in the east coast of Malaysian Peninsula, with different distances from the sea, i.e. 500 m, 1,000 m and 1,500 m. Measurement of the distance was done by GPS and goggle earth application. The coconut fronds were used as natural attractors in FADs. Nine FADs were installed in 23-30 m of waters between latitude $05^{0}35'$ N and longitude $103^{0}00'$ E (Figure 1). Prior to the installation, samples of coconut fronds of three different distances from the coast were taken as control. This strategy was conducted to compare leaves structure before and after immersion in the sea as well as in sea water tank. Data were collected every two weeks after installation until the fronds totally rot (May-July 2013). At each occasion, part of the fronds on FADs at 15 m water depth was sampled and preserved in 10% formalin for later identification in the laboratory with scanning electron microscopy (SEM).

In addition to the *in-situ* assessment, the durability of coconut fronds was also determined in a controlled system where the experiment was carried out in a water tank to mimic the natural conditions. Samples were collected every two weeks and preserved in 10% formalin for SEM analyses.

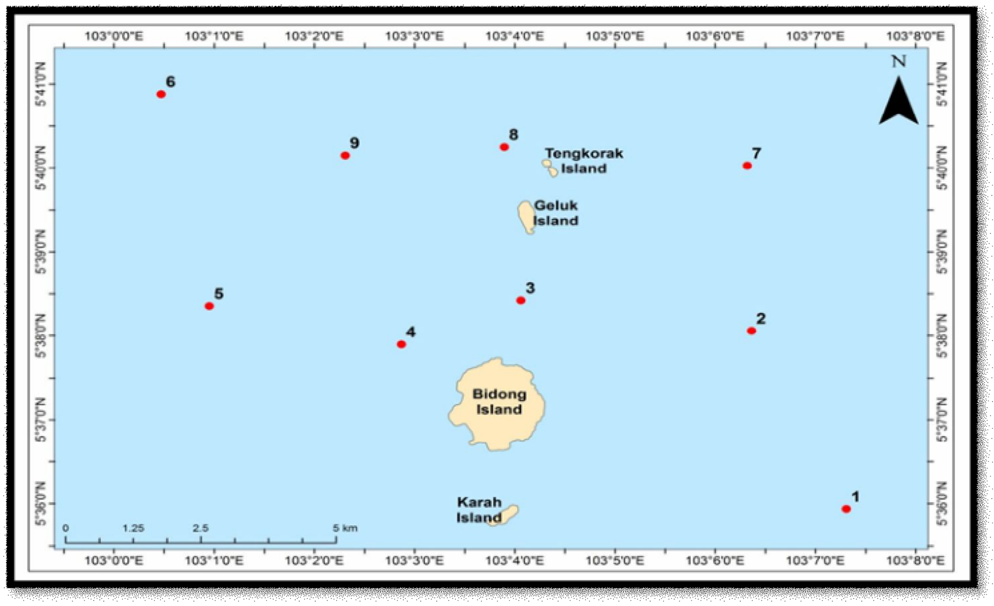

Figure 1. Location of sampling station for the FADs attractors.

Analysis of adaxial and abaxial epidermis by Scanning Electron Microscopy (SEM). Following the methods by Liu et al (2012), 6 sample sizes (n=6) were used to determine the cross-sectional area of different epidermis tissue. Six slices of different fronds were observed under Scanning Electron Microscope (TM-1000 Hitachi model).

Sample preparations were done according to the methods by Yang & Lin (2005), and Chen et al (2010). Samples were preserved in 10% formalin and washed with water until became clean. Approximately 4 cm of leaves were dried overnight at room temperature (28^{0}C). Dried specimens were cut cross-sectionally, mounted on stubs using double-sided "sellotape" and coated with platinum for 6 or 8 minutes in a Jeol JFC 1600 auto fine coater (JEOL Ltd., Tokyo, Japan). The specimens were then examined and photographed under a Hitachi Tabletop Microscope (Model: TM-1000). This method was used for leaves without treatment (fresh frond) and for leaves with submersion in the sea until 6 weeks.

Leaves with immersion in the sea in 8 weeks, samples preparations were used with chemical fixation method, due to the flabby and thin texture of leaves. Based on method by Alberti & Nuzzaci (1996) and Karcz (2009), in order to observe the inner surface of the abaxial epidermis and adaxial epidermis, specimens were torn into pieces (approximately 4 cm), prepared with two fixation, washed, dehydrated, dried by evaporation of Hexamethyldisilaze (HDMS), mounted, coated and observed by Hitachi Tabletop Microscope (Model: TM-1000). To check the constancy of adaxial and abaxial epidermis thickness, scale bars of 50 µm were used.

Statistical analysis. Results were expressed as means ± standard deviations. For normality test was used Kolmogorov-Smirnov test. An analysis of variance (ANOVA) at significant level 95% ($p < 0.05$) was selected to assess the statistical significance of the treatment differences. All data was performed with SPSS 18.0.0 software.

Results and Discussion

Immersion in the sea water tank. Coconut fronds remained intact until 12 weeks of immersion and fronds became discolored to dark brown. Adaxial and abaxial thicknesses were still observed after 12 weeks immersion. Average adaxial thickness after 12 weeks immersion was 7.64–8.02 µm (Figure 2) while abaxial thickness was 6.98–8.01 µm (Figure 3).

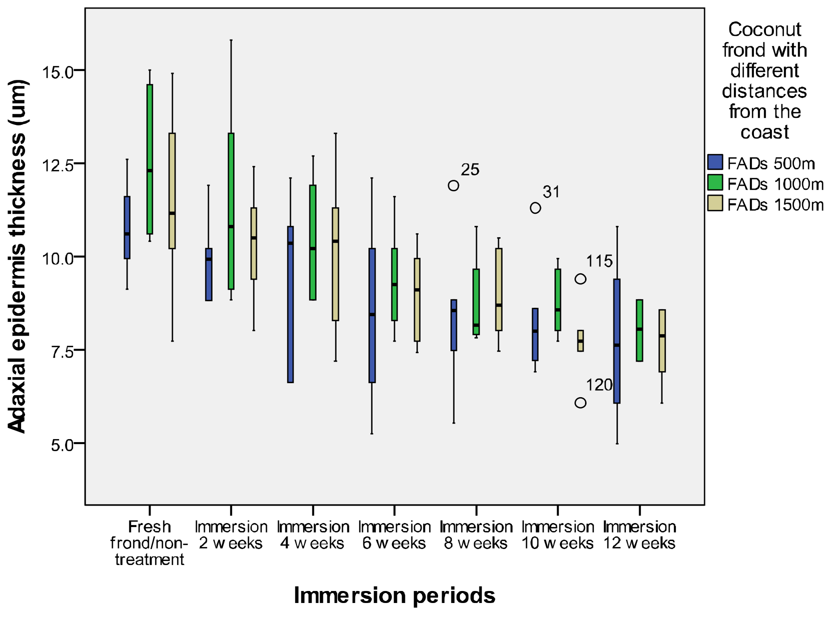

Figure 2. Adaxial epidermis thickness and immersion periods in the sea water tank.

Based on descriptive analysis, durability of coconut frond attractors based on adaxial and abaxial epidermis thickness until 6 weeks immersion in the sea showed that coconut tree with distances of 500 m and 1,000 m from the coast were better than for 1,500 m. Similar results were obtained with coconut fronds immersed in the sea water tank (Table 1).

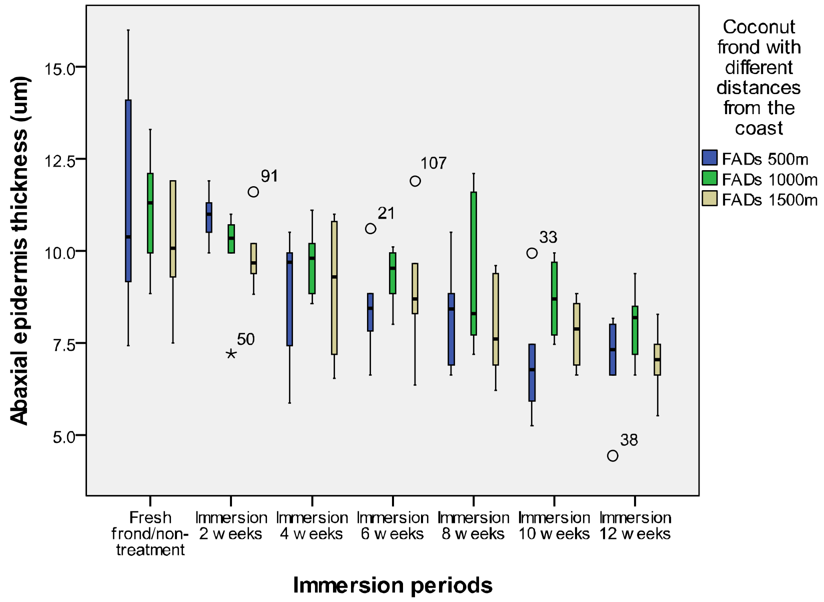

Figure 3. Abaxial epidermis thickness and immersion periods in the sea water tank.

Table 1

Epidermis thickness characteristics of coconut fronds with three different distances from the coast immersed in the sea water tank

Treatment	*Epidermis thickness (µm)*	*500 m*	*1000 m*	*1500 m*
No-treatment (fresh frond)	Adaxial epidermis thickness	10.74 ± 1.74	12.53 ± 2.04	11.41 ± 2.56
	Abaxial epidermis thickness	11. 24 ± 3.22	11.13 ± 1.58	10.12 ± 1.67
2 weeks immersion	Adaxial epidermis thickness	9.93 ± 1.15	11.44 ± 2.67	10.14 ± 2.18
	Abaxial epidermis thickness	10.94 ± 0.67	9.92 ± 1.39	9.89 ± 0.97
4 weeks immersion	Adaxial epidermis thickness	9.47 ± 2.30	10.44 ± 1.58	10.14 ± 2.18
	Abaxial epidermis thickness	8.85 ± 1.80	9.71 ± 0.96	9.02 ± 1.94
6 weeks immersion	Adaxial epidermis thickness	8.51 ± 2.53	9.38 ± 1.39	8.99 ± 1.24
	Abaxial epidermis thickness	8.46 ± 1.31	9.32 ± 0.78	8.93 ± 1.82
8 weeks immersion	Adaxial epidermis thickness	8.48 ± 2.09	8.75 ± 1.22	8.93 ± 1.23
	Abaxial epidermis thickness	8.28 ± 1.41	9.20 ± 2.11	7.88 ± 1.39
10 weeks immersion	Adaxial epidermis thickness	8.33 ± 1.59	8.74 ± 0.95	7.73 ± 1.06
	Abaxial epidermis thickness	7.01 ± 1.63	8.70 ± 1.04	7.78 ± 0.90
12 weeks immersion	Adaxial epidermis thickness	7.74 ± 2.21	8.02 ± 0.74	7.64 ± 1.02
	Abaxial epidermis thickness	6.98 ± 1.43	8.01 ± 0.98	6.99 ± 0.92

Data are mean ± standard deviation.

Based on Kolmogorov-Smirnov test was shown that data of adaxial epidermis thickness was normal (*KS*=0.951, *p*=0.327), also for abaxial epidermis thickness (*KS*=0.662, *p*=0.773). Statistic test showed that duration of immersion had influenced the decrease of adaxial and abaxial epidermis thickness in coconut frond ($p < 0.05$). And a two-way analysis of variance (ANOVA) showed that no significant differences was ffound between immersion in the sea water tank and different distances of coconut tree from the coast for the epidermis thickness (adaxial and abaxial epidermis) of coconut frond [$F_{(12,125)}=0.934$, $p > 0.05$ and $F_{(12,125)}=0.641$, $p > 0.05$].

Immersion in the sea. The observation of the coconut frond specimens using scanning electron microscope (SEM) showed that coconut frond epidermis cells (adaxial and abaxial epidermis) were only observed in the specimens that had been immersed in no more than 6 weeks. Leaves structure only remained mesophyll, floem, xylem and bundle sheath after 8, 10 and 12 weeks of immersion (Figure 4). Based on figure 3, average adaxial thickness at the 6th week was 4.37–5.11 μm and abaxial thickness was 4.67–5.65 μm (Figure 5).

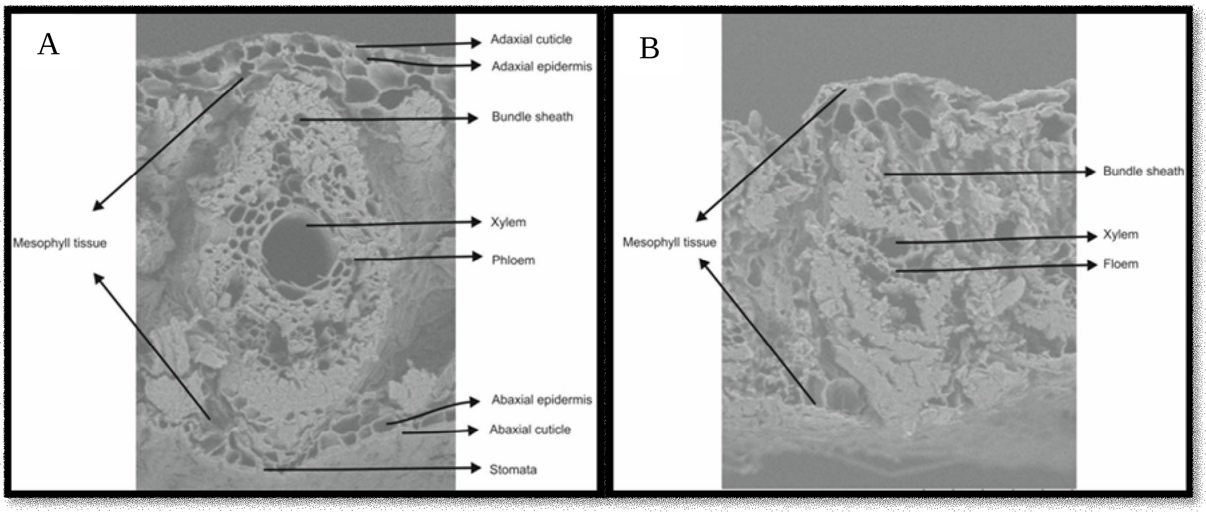

Figure 4. Structure of coconut frond cross-sections (non-treatment/fresh leaf) (A) and after immersion 12 weeks in the sea (B). Scale bar = 200 μm.

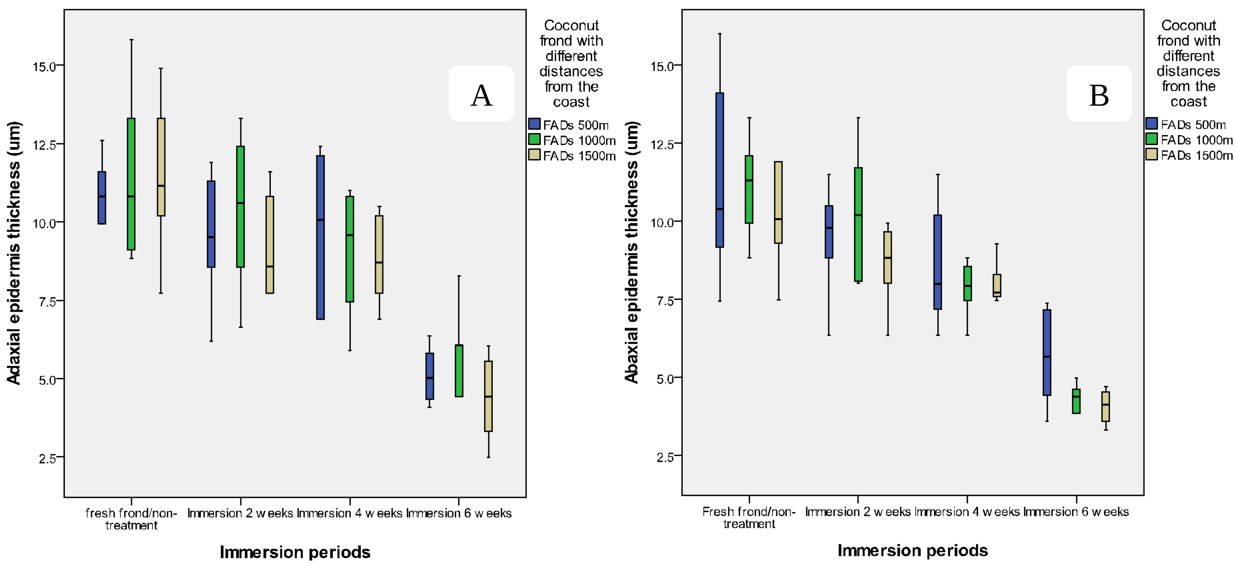

Figure 5. Adaxial (A) and abaxial (B) epidermis thickness characteristics after and before immersed in the sea.

Descriptive analysis of epidermis thickness showed that after 6 weeks immersion coconut frond with distances 500 m and 1,000 m from the coast have the greater thicknesses (adaxial and adaxial epidermis) than coconut frond at a distance 1,500 m from the coast (Table 2).

Table 2
Epidermis thickness characteristics of coconut frond (different distances from the coast) immersed in the sea

Treatment	*Epidermis thickness (μm)*	*500 m*	*1000 m*	*1500 m*
No-treatment (fresh frond)	Adaxial epidermis thickness	10.95 ± 1.03	11.44 ± 2.67	11.41 ± 2.56
	Abaxial epidermis thickness	11.24 ± 3.22	11.13 ± 1.58	10.12 ± 1.67
2 weeks immersion	Adaxial epidermis thickness	9.74 ± 2.41	10.35 ± 2.63	9.17 ± 1.64
	Abaxial epidermis thickness	9.46 ± 1.78	10.25 ± 2.09	8.60 ± 0.68
4 weeks immersion	Adaxial epidermis thickness	9.35 ± 2.04	9.05 ± 2.03	8.79 ± 1.39
	Abaxial epidermis thickness	8.54 ± 2.00	7.85 ± 0.89	8.01 ± 1.35
6 weeks immersion	Adaxial epidermis thickness	5.11 ± 0.86	5.89 ± 1.42	4.37 ± 1.35
	Abaxial epidermis thickness	5.65 ± 1.55	4.35 ± 0.46	4.07 ± 0.53

Data are mean ± standard deviation.

Based on Kolmogorov-Smirnov test, data of adaxial and abaxial epidermis thickness were normal (KS=0.682, p=0.741; KS=0.740, p=0.643). A one-way analysis of variance (ANOVA) followed by Bonferroni's multiple range test (significant level 95%) showed that immersion in the sea reduced adaxial and abaxial epidermis thickness in coconut frond attractors [F (3,71)=34.878, $p < 0.05$; F (3,71)=44.880, $p < 0.05$]. Meanwhile, a two-way ANOVA test showed no significant difference was observed for immersion in the sea and different distances of coconut tree from the coast for the durability of coconut frond attractors (adaxial and abaxial epidermis thickness) [F (6,71)=0.376, $p > 0.05$; F (6,71)=0.584, $p > 0.05$).

Condition of epidermis cell (adaxial and abaxial epidermis) of fresh frond has significantly decreased after 4 and 6 weeks immersion ($p < 0.05$) and no difference was recorded after 2 weeks immersion ($p > 0.05$). These results showed the process of decaying leaves which occur after 4 weeks of immersion (Figure 6).

Abaxial epidermis condition tended to be more easily decayed than adaxial epidermis. Based on statistical test, significant differences were observed for abaxial epidermis after 2 weeks of immersion ($P < 0.05$). However, there was no significant difference between the condition of abaxial epidermis thickness after 2 and 4 weeks immersion ($P > 0.05$).

The endurance of natural attractors made of coconut frond (*C. nucifera*), areca frond (*A. catechu*) and nipa frond (*Nypa fruticans*) as attractors are relatively short. Coconut fronds as attractors on FADs totally rot around three months (Ibrahim et al 1996; Ali 2000). It was probably because the process of immersion in the sea continuously causing fresh frond of becoming quick foul. Water current and the presence of organism on the leaves in the water sea allegedly accelerate the occurrence of decay.

Invertebrates such as *Membranipora membranacea* and *Electra Pilosa* of Bryozoa phylum were found attached on the surface of coconut frond attractors. Bryozoa is an invertebrate that live in colonies and makes plant (algae) as host. As *M. membranacea* colony grows, it forms a sheet across the surface of its host plant, making the algal body brittle (www.salemsound.org) and this has become one of the factors that accelerate the decay or loss of leaves of mid rib (rachis) of the coconut fronds.

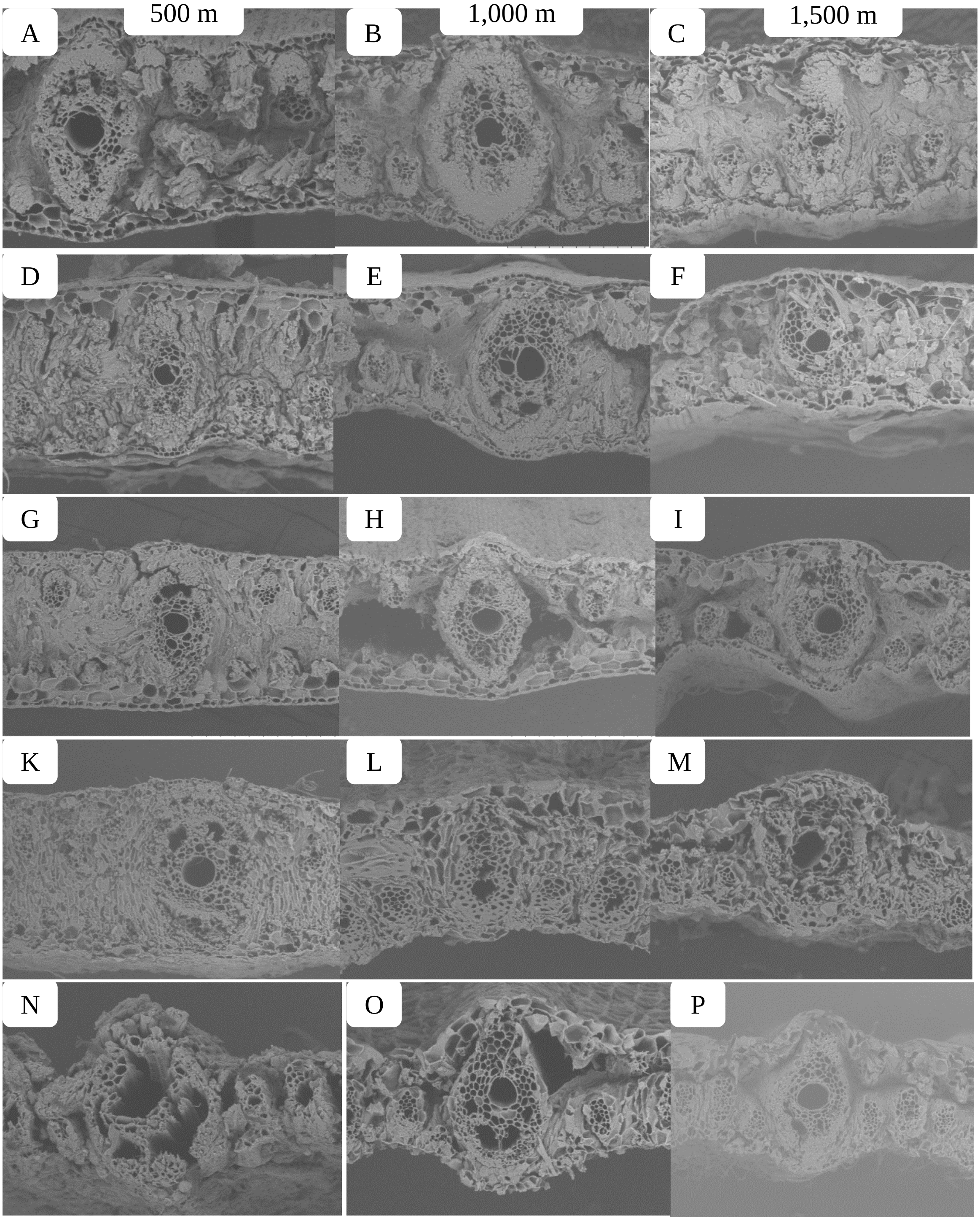

Figure 6. Scanning electron microscopy micrograph showing leaf cross-sections for non-treatment (A-C), immersion of two weeks (D-F), immersion of four weeks (G-I), immersion of six weeks (K-M) and immersion of eight weeks in the sea (N-P). Scale bar = 200 (μm).

This study showed no correlation between distances of coconut tree from the sea with durability of the coconut frond as attractors (epidermis thickness) in FADs. But endurance of the coconut frond is closely related to the length of immersion in the sea. Samples taken during the first sampling (15 days after the first immersion) showed that the leaves were still green and undamaged, but some characters had changed to brown in color. For the second sampling (28 days after the first immersion), leaves were found stained in brown color and the leaves were coming loose of petiole. Similar results were observed for the third, fourth and fifth sampling where many leaves were found coming loose of mid ribs (rachis). For the final sampling (three months immersion), only rachis were found remained on the fronds.

The decay process of attractor on FADs could cause a decrease in the amount of fish assembled around the FADs. Therefore, the production of fish catches decline. To protect amount of fish catch around the FADs, study by Ali (2000) suggested that any renewal of attractor (coconut fronds) should be done every two months. This is in conformity with the condition of the leaf epidermis that is depleting after 6 weeks in the sea and coconut fronds would lose its epidermis cell after 8 weeks (two months) in the water.

At the same time, the long immersion of attractors affects the presence of organisms around the FADs. Ibrahim et al (1996) suggested that ability of organisms to settle on FADs varied with species, immersion periods of FADs and textural conditions of the substrate. The density of organism on the FADs is closely related to the endurance of the substrates in the sea. The density of encrusted organism increases with the immersion period until the quality of the substrate diminishes and can no longer sustain a high density of the organisms. Natural attractor durability and long immersion of attractor is very important in FADs fishery. The long endurance of attractor would cause the cost incurred by fishermen to become smaller and the presence of organisms (phytoplankton and zooplankton) would be more abundant.

The present study indicates that the leaf epidermis can be one of the indicators for measuring the endurance of natural attractor on FADs. This study provides opportunities for knowledge collaboration in the fields of plant biology, material science and fish catching (FADs fishery) to attain better durability of natural attractors.

Conclusions. Statistical analysis shows that fronds of coconut trees taken from different distances from the coast did not show significant differences in terms of durability as FADs. Analysis of adaxial and abaxial epidermis thicknesses in coconut frond attractors also indicate that natural attractor made of coconut fronds could be more durable if placed in relatively low current areas such as bays.

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