P-ISBN 978-602-8355-48-3
E-ISBN 978-602-8355-53-7
Buku 1 (Ilmu Pengetahuan Alam dan Teknologi)

FAKTOR BIOTIK DAN ABIOTIK YANG MEMPENGARUHI PERTUMBUHAN DAN KEMANDIRIAN BIBIT PEREPAT, *Sonneratia alba* DI HUTAN BAKAU

Khairul Adha A. Rahim[1]
[1]*Jabatan Sains Akuatik, Fakultas Sains & Teknologi Sumber, Universiti Malaysia Sarawak*

Email korespondensi : akhairul@unimas.my

Abstrak

Ulasan dilapangan dilakukan untuk mengetahui faktor abiotik dan biotik yang mempengaruhi pertumbuhan dan kemandirian bibit Perepat (*Sonneratia alba*) dihutan bakau. Pertumbuhan dan kemandirian bibit pohon *Soneratia alba* yang ditanam dan tumbuh secara alami di daerah bawah kanopi hutan dan daerah yang terkena sinar matahari pada tiga zona tikas pasang surut telah di monitor selama 12 bulan. Hasil penelitian menemukan tingkat kemandirian bibit yang ditanam dan tumbuh secara alami di daerah yang terkena dibawah cahaya matahari adalah lebih tinggi secara signifikan dibandingkan dengan yang hidup daerah yang terlindung dibawah kanopi hutan. Harga kemandirian bibit *Sonneratia alba* juga lebih tinggi secara signifikan di daerah zona tikas pasang surut yang lebih rendah dibandingkan dengan zona yang lebih tinggi. Perbedaan zona tikas pasang surut dan intensitas cahaya mempengaruhi laju pertumbuhan dan kemandirian bibit anak bakau. Ulasan dampak pemangsaan ke atas bibit Perepat yang hidup di tiga zona tikas pasang surut turut dilakukan di lapangan. Ada perbedaan yang signifikan terhadap efek pemangsaan keatas bibit Perepat di tiga zona tikas pasang surut dan dikawasan kanopi Perepat yang dominan. Studi yang dilakukan sebagian mendukung hipotesis penguasaan model predator.

Katakunci: *Sonneratia alba*, kemandirian, bibit, zon tikas pasang surut, pemangsaan

INTRODUCTION

The establishment and survival of seedlings directly affect species distribution and abundance patterns (Smith, 1987a; Krauss et al. 2008). Seedling establishment is a critical phase in the life cycle of all seed plants, but it is particularly crucial for mangroves due to the unstable stabstrate and the influence of tidal inundation within the mangrove (Tomlinson, 1986; Krauss et al. 2008). The processes before and after the establishment of mangroves, such as dispersal, predation, competition and other factors influence initial patterns of distribution and abundance across intertidal forest zone (Smith, 1987a; Mc Kee, 1995; McGuinness, 1997a; Allen et al. 2003).

Transplant and field experiments have been used to examine factors that influence survival and establishment of mangrove species and also to address questions about the cause of mangrove zonation patterns and the distribution and abundance of mangrove species across the intertidal zone (Rabinowitz, 1978; Smith et al. 1989; Ellison and Farnworth, 1993; Koch, 1997, Dahdouh-Guebas et al. 1988).

In Sarawak, only few studies have investigated the effect of abiotic and biotic factors on mangrove plants (Chai, 1975; Chai, 1982). Field study were conducted to acess the impact of several physical and biological factors on the establishment of *Sonneratia alba* seedling across the intertidal forest zone. *Sonneratia alba* is a pioneer mangrove tree which colonizes newly exposed mud and sandy area near the mouth of tidal rivers (Chai, 1982; Aksornkoae et al. 1992).

Although seedlings of *Sonneratia alba* are easily reared from seeds in nuseries, however detailed studies on the effect of biotic and abiotic factors on their establishment is currently lacking. Thus, the results of this study would provide information about abiotic versus biotic factors affecting mangrove regeneration patterns.

METHODOLOGY

Study species

Sonneratia alba is a pioneer mangrove tree which colonizes newly exposed mud and sandy areas near the mouth of tidal river in Sarawak. Aslo known as the mangrove apple, *S.alba* is usually found at lower elevations in the intertidal zone where inundation is frequent (Chai, 1982). As a pioneer species *S. alba* maintains its status by colonization rather than regeneration in mangrove forest (Chai, 1975).

Study Site

Fieldwork was carried out in the mangrove forest at Asajaya Laut Estuary (1^0 35’5”, 110^0 N 35’ 20” E) in Samarahan,Sarawak (Figure 1). The mangrove of Samarahan covers 1, 946 hectares. The common mangrove species in the area are *Sonneratia alba, Avicennia alba* and *A. marina* at lower intertidal zone. *Rhizophora apiculata, Bruguiera* species, *Ceriops tagal, Nypa fruticans, Aegiceras corniculatum, Acanthus ilicifolius* and *Acrostichum aurem* occur at the middle and higher intertidal zones.

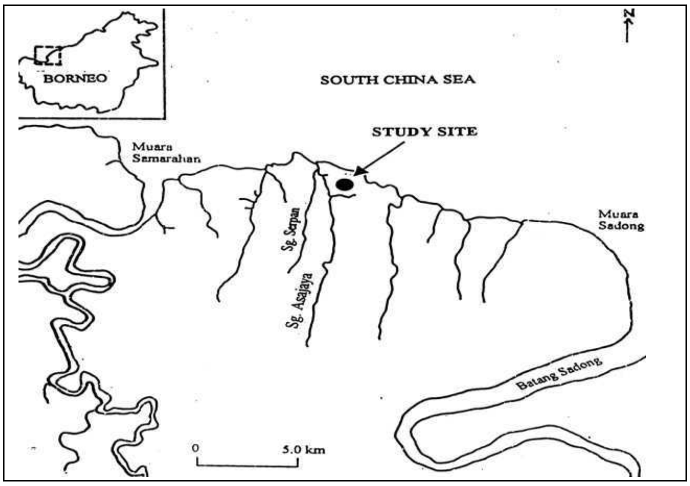

Figure 1: Map showing the location in Sg. Asajaya Mangrove Estuary.

Experimental design

Observation of seedling densities in the study area were determined from the three intertidal forest zone; lower middle and higher. The number of seedling were counted in four plots in 10 m^2 plots at each intertidal zones.

A transplant experiment was conducted to asscess *S. alba* seedling establishment and survival in three intertidal forest zone: lower, middle and higher. *Sonneratia alba* seedlings of 3-4 cm in height with 2-3 leaves were identified and collected from the study area. To remove the seedlings, methods as described by Osunkoya and Creese (1997) were followed. A core was used to dig hole to transplant the seedlings at the experimental plots. Twenty seedlings were planted in each of two experimental plot under forest gaps, and twenty seedlings were planted under two adjacent canopies in each of the three forest zones (Figure 2). The seedlings were numbered and tagged for studies of growth and survival. The seedling were allowed to established for one year. Seedling survival, height, stem diameter and number of leaves were monitered at two-month intervals for a year.

The effect of intertidal position and light availibility were also assessed for naturally regenerated *S. alba* seedlings. Seedling were tagged with nylon twine. Growth and survival of the seedlings were monitered by measuring the height, stem diameter and leaf numbers at 2 month interval for 12 months at two-month intervals for a year.

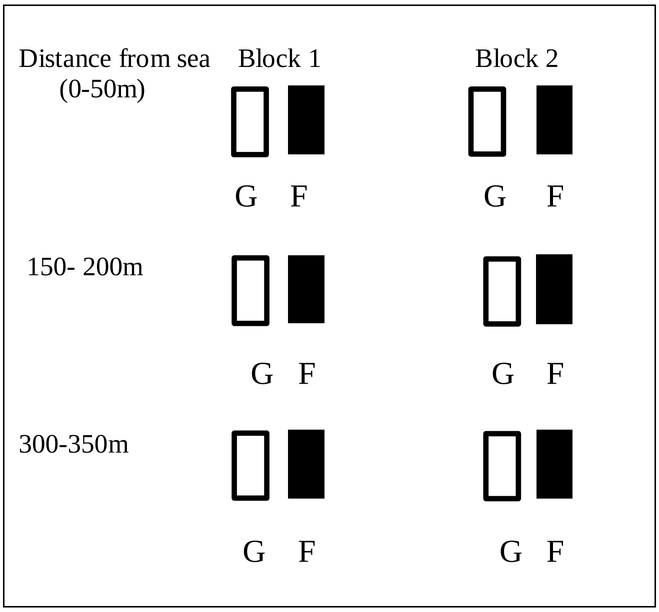

Figure 2: Schematic diagram showing the design of the transplanted seedling experiment. The treatment were: Canopy, light level and intertidal position. G = Canopy gap; F=Forest canopy.

Predation experiment

Experiments were conducted during the season when mature fruits drop from the parent trees. The experimental design followed Smith (1987a). Experimental plots of approximately 60 m^2 were established in each of three forest zones: lower, middle and higher zones. Twenty seedlings were tethered on 1 m nylon twine per plot in each intertidal forest zone. Four replicate plots with 20 seedlings in each plot were randomly established in each forest zone. Predation was measured by following the fate of seedlings tethered on 1 m

P-ISBN 978-602-8355-48-3
E-ISBN 978-602-8355-53-7

length of nylon twine. Predation was defined as any evidence of animals damage to seedlings, such as consumption of plant tissue. Experimental plots were checked as days 2, 4, 6, 8, 10 and 18 days after the start of experiment then each week for the two following month. Seedling were recorded and examined as intact, damaged or missing.

Statistical Analyses

SYSTAT Version 7 (1996) was used for all statistical analyses. The relationships between seedling density and intertidal gradients were analysed with regression analyses. Growth and survival of transplanted and naturally occurring seedlingss were analyzed with two factor ANOVAs. After analysis of variance, Turkey's post-hoc test were used to test the differences in seedling survival, height and diameter increment and leaf number in three intertidal zone.

Comparison of the amount of predation among the three forest zones were perfomed using the percentage of seedling consumed after 60 days. The effect of seedling predation was examined using a two factor ANOVAs, with intertidal position and forest dominance being the two factors.

RESULTS

Seedling distribution and abundance

Seedling of *S. alba* occurred throughout the three intertidal zones at the study site. There were no significant differences (P > 0.05) in seedling density among the three intertidal zone (Table 1). The overall mean seedling density in the three intertidal position ranged from 0 – 4/m^2.

Table 1: Analyses of variance for seedling density of naturally occuring of *S. alba* in three intertidal forest zone. P > 0.05. ns; not significant

Source of variation	df	MS	F	P
Intertidal (I)	2	896.3	0.43	ns
Transect (T)	1	2730.7	1.32	ns
I x T	2	3373.3	1.62	ns

The effect of intertidal position and light availability on seedling survival.

Survival of transplanted seedlings in canopy gaps was higher at a middle position and lowest in the higher zone. Survival of seedling under forest canopy was higher at lower and middle zone (22.5% and 20% respectively), and no seedling survived at higher zone at the end of the experiments. The ANOVA of survival after 12 months for transplanted seedlings showed a significant interaction between light and intertertidal zone, indicating that survival was higher in middle and lower intertidal positions but only for seedling in canopy gaps (Table 2).

Survival of naturally occuring seedling was significantly affected by both intertidal position and light availability (Table 3). Survival of naturally occuring seedlings was significantly higher a lower and middle than in the higher zone. At all intertidal positions, seedling survival was significantly greater in canopy gaps than under forest canopy. No seedlings survived under forest canopy treatment in higher zone after 12 months.

Table 2: Summary of two-factor ANOVAs for percentage survival of transplanted seedlings after 12 months in three intertidal zones and under forest canopy and canopy gap. Significant, *:P < 0.05, ns: not significant.

Source of variation	df	MS	F	P
Intertidal (I)	2	0.151	242.3	0.00
Light (L)	1	0.152	243.0	0.00
I x L	2	0.047	75	0.00

Table 3: Summary of two-factor ANOVAs for percentage survival of naturally occuring seedlings after 12 months in three intertidal zones and under forest canopy and canopy gap. Significant, *:P < 0.05, ns: not significant.

Source of variation	df	MS	F	P
Intertidal (I)	2	0.07	6	0.04
Light (L)	1	0.241	21.9	0.004
I x L	2	0.001	0.07	ns

The effect of intertidal position and light availability on seedling growth.

For transplanted seedlings, mean stem height growth was not significantly differed in three intertidal zone (P > 0.05). The height increment showed a significant interaction between light and intertidal position indicating that mean height was higher under light gaps than in the forest canopy in the highest intertidal zone. Mean stem diameter varied significantly (P < 0.05) under interactions of light and intertidal position, indicating the stem diameter was higher under canopy gaps for higher intertidal position. Mean leaf number was greater in the highest intertidal zone for canopy gap seedling only.

Despite lower survivorship of transplanted seedling in canopy gaps at higher intertidal zone, average seedling height was greater for the survival seedlings. Mean stem diameter increment was also greater in the higher zone in the canopy gaps, and seedling in this treatment also produced more leaves.

For naturally regenerated seedlings, mean height increament, mean diameter increment and mean leaf number of seedlings were significantly (P < 0.05) greater in gaps than in understorey microcites. There were no significant (P > 0.05) differences in diameter and height increment among the three intertidal positions. Leaf production was significantly greater for seedlings in gaps at lower position, seedling at the middle position did not differ between gaps and under the canopy.

Seedling predation

Significant differences (P < 0.05) in predation on *S. alba* seedlings existed among the three intertidal zones (Table 4).The propotion of seedlings consumed by predation was significantly greater at the higher intertidal position than in middle and lower position. There was significant differenc in predation between lower and middle zones (Turkey's test). The type of seedling damage was due to predation from snails and grapsid crabs, particularly the small gartropod and *Sesarma* species.

Table 4: Result of the analysis of variance examining the effect of predation on percent survival of *S.alba* seedlings in three intertidal zones. Percentage of seedling scored viable after 60 days. Lower and middle zones dominated by *S. alba* and higher zone dominated by *R. apiculata.* P < 0.05

Source of variation	df	MS	F	P
Intertidal position	2	52.33	45.9	0
R	9	1.14		

DISCUSSION

Seedling transplant experiments allowed examination of factors that influence establishment and survival in different microsites of mangrove forest (Smith, 1987a, b; McKee, 1995; Koch, 1997; Krauss et al. 2008). In the study, the overall proportion of seedling surviving to 12 months was 30.8% for transplanted seedling and 30% for naturally occuring seedlings. Studies on other mangrove species, such as on *Avicennia* species have shown a higher survival rate over 18 months compared with the present study (47% - 56%) (Burns and Ogden, 1985; Clarke and Allaway, 1993).

Seedling survival in *S. alba* was greater in lower and middle intertidal position than in the higher intertidal position for both transplanted and natural seedling. In addition, no seedling survival under forest canopy in higher intertidal zone compared with some survival under ligh gaps indicated that factors other than intertidal position significantly influence seedling survival of *Sonneratia alba*.

The importance of light availability for survival and establishment of mangrove seedlings has received comparatively little attention compared to other environmental factors (Smith, 1987b; Ellison and Farnworth, 1993; Clarke and Allaway, 1993). Light
is an important factor for mangrove seedlings to develop to sapling stage (Koch, 1995; Lopez' Hoffman et al. 2007). The present study showed that light significantly influenced seedling survival rates in the three intertidal zones.

Seedling survival of both transplanted and naturally occurring seedlings was significantly higher in canopy gaps than under the forest canopy. The data from the experiments are consistent with studies by Burn and Ogen (1985) and Clarke (2004), that light is a limiting factors of *S. alba* seedling survival. This indicates that seedling establishment is dependent on light.

Clarke and Allaway (1993) and Koch (1997) found that canopy gaps stimulated *Rhizophora* and *Avicennia marina* growth rate. The present study showed that light significantly stimulated height and stem diameter increment, and leaf number production of seedling for both transplanted and naturally occuring seedlings.

Predation on seedlings is likely to account for higher initial mortality rate and the overall the lower survival in the present study compared with sudies by Burns and Odgen (1985) and Clarke and Allaway (1993). Predator consume mangrove propagules at Asajaya as been observed in

P-ISBN 978-602-8355-48-3
E-ISBN 978-602-8355-53-7

numerous other areas of mangrove forest (Smith, 1987a,b; Smith et al. 1989; Dahdouh-Guebas et al, 1998; Allen et al. 2003). Smith (1987a,b) showed that crab feed on propagules of several mangrove species and affect seedling establishment and influence mangrove community structure. Snail feed by scraping into a propagule with the radula, whereas most grapsid crabs have strong claws capable of ripping apart propagules larger then themselves (Smith et al. 1989; Clarke, 2004).

In the present study, predation level varied significantly across the Asajaya mangrove. Predation level was significantly lower in forest plot where adults of *Sonneratia alba* were dominant, and the predation rate was significantly higher in forest plots weas less dominant. Although studies by McKee (1995b) and Dahdouh-Guebas el al (1998) showed that there was no correlation between the amount of predation on a species' propagules and the abundance of conspecific species in canopy, the dominance-predation hypothesis is partially suppored by the present study. Smith (1987a) found an inverse relationship between conspecific species dominance with predation on mangrove seedling.

The significant differences in predation from lower to higher zones in the present study may be explained by the dominance of *S. alba*, the density of crab burrows and light penetration on the forest floor. There was no difference in seedling predation between lower and middle zones, and this was correlated with a lack of difference in dominance of *S. alba* between and middle zone. The abundance of seed predators appears to be related to the rate of predation on *S. alba* seedlings in the three intertidal zones as shown by positive correlation of crab burrow density and mortality of seedlings. The observation is similar with the conclusion of Smith et al (1989) and McGuinness (1997b). They found the higher rate of predation on mangrove propagules was attributed to the abundance, activity and the number of crab burrows across intertidal zone.

CONCLUSIONS

The present study indicated that light is a significant factors influencing survival and growth of *Sonneratia alba* seedlings. The study also supported the hypothesis that differences in intertidal position influence seedling survival of *S. alba*. Biotic factors such as the predation on mangrove propagules significantly affect the survivorship of seedlings.

The present study showed that competition for both light and regulation of predation limits seedling survival and recruitment of *S. alba* to the sapling stage.

ACKNOWLEDGMENT

The author thank Penghulu and the local community of Kg. Asajaya Laut for their field assistance. The authors would like also to thank Faculty of Resource Science & Technology, Universiti Malaysia Sarawak for supporting this work.

LITERATURE CITED

Aksornkoae, S., G. S. Maxwell, S. Havanond and S. Panichsuko. (1992). *Plant in mangrove.* Chalongrat Co. Ltd. Bangkok, Thailand.

Allen, J. A., K. W. Krauss and R. D. Hauff.(2003).Factors limiting the intertidal distribution of the mangrove species *Xylocarpus granatum Oceologia*, 135:110-121.

Burns, J. S. and J. Ogden. (1985). The demographyof the temperate mangrove [*Avicennia marina* (Forsk.) Vierh.] at is southern limit in New Zealand, *Australian Journal of Ecology*. 10: 125-133.

Chai, P. P. K. (1975). Mangrove forest of Sarawak.*The Malaysian Forester*, 38:108-134.

Chai, P. P. K. (1982). *Ecological studies of mangrove in Sarawak*. Ph.D Thesis. Universiti Malaya, Malaysia . Unpublished.

Clarke, P. J and W. G. Allaway, (1993). The regeneration niche of the grey mangrove (*Avicennia marina*): effect of salinity, light and sediments factors on establishment, growth and survival in the field. *Oceologia* 93:548-556.

Clarke, P. J. (2004). Effect of experimental canopy gaps on mangrove recruitment: lack of habitat partioniong may explain stand dominance. *Journal of Ecology*, 92:203-213

Dahdouh-Guebas, F., M. Verniert, J. F. Tack, D. V.Speybroeck and N. Koedam (1998). Propagule predators in Kenyan mangrove and their possible effect on regeneration. *Marine Freshwater Research*, 49:345-350.

Ellison, A. M and E. J. Farnworth (1993). Seedling survivorship, growth and response to disturbance in Belizean Mangal. *American Journal of Botany*, 80: 1137-1145.

Koch, M. S. (1997). *Rhizophora mangle* L. Seedling development into the sapling stage across resource and stress gradients in subtropical Florida. *Biotropica*, 29:427-439.

Krauss, K. W., C. E. Lovelock., K. L. McKee, L. Lopez-Hoffman, S. M. L. Ewe and W. P. Sousa. (2009). Environmental drivers in mangrove establishment and early development: A review. *Aquatic Botany*, 89:105-127.

Lopez- Hoffman, L., N. P. R. Anten, M. Martinez-Ramos and D. Ackerly. (2007). Salinity and light interactively affect neotropical mangrove seedlings at the leaf and whole plant levels, *Oceologia*, 150: 545-556.

McGuinness, K. A. (1997a). Dispersal, establishment and survival of *Ceriops tagal* propagules in a north Australia mangrove forest. *Oceologica*, 109:80-87.

McGuinness, K. A. (1997b). Seed predation in a tropical mangrove forest: a test of the dominance-predation model in northern Australia. *Journal of Tropical Botany*, 75: 1352-1359.

Mc Kee, K. L. (1995). Seedling recruitments patterns in a Belizean mangrove forest: effects of establishment ability and physicochemical factors. *Oceologia*, 10:448-460.

Osunkoya, O. O., and R. G. Creese. (1997). Population structure, spatial pattern and seedling establishment of the grey mangrove, *Avicennia marina var. Australasia*, in New Zealand. *Australian Journal Botany*, 45:707-725.

Rabinowitz, D. (1978). Dispersal properties of mangrove propagules. *Biotropica*, 10:47-57.

Smith, T. J. III. (1987a). Seed predation in relation to tree dominance and distribution in mangrove forest. *Ecology* 68: 266-273.

Smith, T. J. III (1987b). Effect of seed predators and light lecvel on the distribution of *Avicennia marina* (Forsk.) Vierh. In tropical tidal forest. *Estuarine Coastal Shelf Science* 25:43-51.

Smith, T. J. III (1987c). Effect of light and intertidal position on seedling survival and growth in
tropical, tidal forest. *Journal of Experimental Marine Biology and Ecology* 110:133-146

Smith, T. J., H.T. Chan, C.C. Mcivor and M.B. Robblee. (1989). Comparison of seed predation in tropical, tidal forest from three continents. *Ecology*.70:146-151.

Tomlinson, P.B. (1986). *The botany of mangrove*. Cambridge University Press. Cambridge, UK.