Growth characteristics of mangrove seedling in silvofishery pond – the allometric relationship of height, diameter and leaf abundance

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Abstract. Dynamic environment condition of the silvofishery pond should provide an effect on the growth of mangrove seedling. This research aimed to observe the morphometric growth rate of mangrove seedling of *Avicennia marina* and *Rhizophora mucronata* planted in the silvofishery pond and to analyze the morphometric growth relationship of height, diameter and leaf number development of mangrove seedling. The research was conducted through field experiment involving mangrove species of *A. marina* and *R. mucronata* for 18 months during March 2015 to September 2016, both single structured and mixed structure. The observation was conducted every 13 weeks including seedling height, diameter and number of leaves. Data analysis was conducted by regression to provide the statistical relation between the growth of diameter – height, diameter – number of leaves and height – number of leaves. The result showed that the growth rate of *A. marina* in single structured pond was ranged from 0.38 – 3.00 cm.wk^{-1}, 0.0015 – 0.0969 cm.wk^{-1} and 0.1 – 13.7 leaves.wk^{-1} respectively for height, diameter and number of leaves, while in mixed structure was 0.23 – 1.69 cm.wk^{-1}, 0.0169 – 0.0731 cm.wk^{-1} and 0.5 – 14.0 leaves.wk-. The growth of *R. mucronata* respectively in single and mixed structure were 0.08 – 2.00 cm.wk^{-1} and 0.15 – 2.62 cm.wk^{-1}, 0.0031 – 0.1369 cm.wk^{-1} and 0.0008 – 0.0831 cm.wk^{-1} and 0.0 – 1.9 leaves.wk^{-1} and 0.0 – 1.6 leaves.wk^{-1} respectively for height, diameter and number of leaves. Data analysis showed that the growth of seedling height of Avicennia in the mixed structure was significantly affected by its diameter growth and the number of leaves of Avicennia in single structured was significantly affected by its diameter. While the height, diameter and number of leaves of *R. mucronata* both in mixed and single structured silvofishery ponds were independent to each other. This research concluded that mangrove seedling growth is varied among species and growth environment.

Keywords: growth, morphometry, seedling, silvofishery pond, variation

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1. Introduction

Silvofishery is an artificial ecosystem developed by the human to integrate mangrove replantation into aquaculture activities. It aims to provide better environmental quality along with rehabilitation purposes to support sustainable aquaculture activities through the maintenance of suitable water quality [1]. Silvofishery pond ecosystem environmental quality varied by its age which indicates ecosystem maturity and stabilization [2]. Thus, selection of suitable fish species is required to achieve optimum cultivation activities. Mostly, the silvofishery ponds occupy Milkfish and Crab as the recommended cultivars. Even though, certain treatment could be applied to improve its suitability for a more economically valuable cultivars.

Within a silvofishery pond, mangrove vegetation has important role in providing nutrient supply for the cultivated organisms. According to [3], mangrove plants are capable of hindering pond water from pollution. Unfortunately, the capability of mangrove is limited by its age. Young mangrove could not absorb nutrient effectively which might risk to nutrient eutrophication. Thus, mangrove require certain age or size to provide optimum benefit to pond ecosystem and aquaculture activities.

The growth of mangrove plant within a silvofishery pond is an important factor to support silvofishery ecosystem establishment. The condition of mangrove plants such as its density, height, canopy coverage, and species define the pond nutrient balance and productivity [4]. Seedling growth is an important aspect of plant development. Seedling is the most vulnerable phase of plant development. Thus, the risk of environmental stress and mortality is higher than the established plants. Mangrove vegetation might experience physiological stress due to environmental changes [5]. Coastal area land conversion had been occurred for various purposes which effect to the loss of mangrove ecosystem [6].

The growth scales among plant parts are defined by allometric relation. The relations are not limited to plant morphometry but also to its grain mass which could be used to estimate the harvest productivity of the plant [7]. Allometric relation of plants usually relate plant height or diamet or to its above ground nor below ground biomass. This model is expected to provide estimation on potential crops [8]. As for mangrove, leaf production is the most valuable product regarding its role as a source of organic matter for the ecosystem.

The allometric relation is considered as an important aspect of plant growth since it indicates the possible physiological response to particular disturbances. The growth pattern of plants are varied according to their growing environment. The allometric relation of a plant is also affected by its population. More plant density would result a thinner plant stands compared to less dense population [9]. Altering competition over nutrient affects the plant metabolism which causes reduced growth. Thus, to achieve an optimal plant growth, plantation density should be considered to hinder plant competition. According to [10], several woody species seems to have a nearly isometric growth pattern among its leaf and stem biomass to root biomass, while aboveground biomass was also nearly isometric to below ground biomass.

Environment condition is the main factors affecting the allometric model of plant's growth [11]. Plants which grow in a dynamic environment might have inconsistent allometric model such as post burned shrubs [12]. This condition might also occur in mangrove ecosystem which dynamically changes due to tidal activities [13]. Ecosystem aging seems to provide a better suitability for plant growth. Thus, changing environment suitability lead to the development of ecosystem structure. In a restored mangrove such as in the silvofishery ponds, mangrove plants could not achieve stable growth without human assistance. Thus, the impact of particular environmental condition should be understood to provide best management practice of mangrove replantation, especially in silvofihsery ponds.

The structural composition of mangrove ecosystem mainly affects the environment condition of mangrove floor. Species composition defines the enrichment of organic carbon, salinities and grain size which further affect litter decomposition rate and nutrient availability [14]. In the other hand, mangrove species distribution is also defined by its environment setting. Thus, mangrove ecosystem might have various species composition or growth performance due to its growing environment [15].

Within silvofishery pond, this would affect the advantages of mangrove community on the fish culture optimation.

Silvofishery pond is a unique ecosystem which represents mangrove development in a limited closed aquatic system differing its original habitat. However, there are the least understanding on how mangrove response this ecosystem and its impact on the growth pattern. Thus, research on mangrove growth is required to understand the right mangrove plantation model within silvofishery pond to achieve optimum allometric growth. This research aimed to observe the growth of mangrove seedling in the silvofishery ponds and to analyze the relationships of seedling height, diameter and number of leaves in the silvofishery ponds with different mangrove structures.

2. Methods

This research was conducted from March 2015 – September 2016 in Mangunharjo Village, Tugu, Semarang. There were two mangrove species occupied including *Avicennia marina* and *Rhizophora mucronata*. Research treatments involved single species and combined species of mangrove plantation in the silvofishery pond canals. Morphometric measurements were conducted to 27 samples of mangrove seedlings respectively from each treatment.

Data collections were conducted through field observation with three months intervals for five times. Observations included the measurements of the seedling height, seedling diameter and the number of leaves. Data was processed to calculate the growth of mangrove seedling between observations.

Data analysis was conducted through regression analysis to estimate the relation of seedling diameter on seedling height, seedling diameter and leaf abundance and seedling height and leaf abundance. Data analysis utilized 95% of confidence interval.

3. Results and Discussion

Field observation resulted in various numbers of mangrove stand survival of particular species and treatments. The survival rate of *A. marina* was low, but in the single structured treatment, the survival was better than in the mixed structure, while *R. mucronata* achieved better survival in the mix structured treatment although the difference was not noticeable. However, the survival of *R. mucronata* was noticeably higher than *A. marina*. It indicates that the silvofishery pond environment was more suitable for *R. mucronata* than *A. marina*.

Observation on mangrove seedling in the silvofishery ponds showed there were variations of the height, diameter and leaf growth. Collected data from 5 observations were combined into one. The observed growth of mangrove seedling was varied due to seedling mortality. Table 1 showed the range and average of observed mangrove seedling growth.

Table 1. Growth of Mangrove Seedling Within Silvofishery Pond (Growth Period = 13 weeks)

No.	Mangrove Species	Observed Stands	Height (cm/period)	Diameter (cm/period)	Number of Leaves
A.	**Single Species**				
1.	*A. marina*	14	5 – 39 (19.86 + 11.38)	0.02 – 1.26 (0.37 + 0.35)	1 – 178 (56.08 + 53.43)
2.	*R. mucronata*	30	1 – 26 (11.77 + 6.90)	0.04 – 1.78 (0.43 + 0.35)	0 – 25 (4.78 + 7.15)
B.	**Mixed Species**				
1.	*A. marina*	8	3 – 22 (13.38 + 6.99)	0.22 – 0.95 (0.47 + 0.25)	7 – 182 (80.14 + 59.94)
2.	*R. mucronata*	35	2 – 34 (14.11 + 8.99)	0.01 – 1.08 (0.40 + 0.28)	0 – 21 (5.50 + 5.44)

According to Table 1, the growth of mangrove seedlings were not consistent among treatments. The height growth of *A. marina* was observed better in the single species treatment, while in the mixed

species treatment the diameter growth was better. Inversely, the height growth of *R. mucronata* in the single species treatment was lower, but it has better diameter growth performance compared to the mixed species treatment. Observation on the leaf number showed that the pattern was quite similar with the height growth, seedling with better height growth performance showed better leaf development.

Collected data were then analyzed with regression analysis to understand the growth relation among parameters. Regression analysis was grouped into three groups, including diameter growth to height growth, diameter growth to leaf number development and height growth to leaf number development. The detailed analysis result of each group is presented in Table 2 – Table 4.

Table 2. Linkage of diameter growth and height growth of mangrove seedling in silvofishery ponds

No.	Mangrove Species	Relationship	R^2 (Sig.)
A.	**Single Species**		
1.	*A. marina*	$Y = 1.4506.X^{0.030}$	0.002 (0.866)
2.	*R. mucronata*	$Y = 1.689 + 0.212 \ln(X)$	0.118 (0.063)
B.	**Mixed Species**		
1.	*A. marina*	$Y = 0.0131.X^{-1.215}$	0.595 (0.025)*
2.	*R. mucronata*	$Y = 0.3956.E^{7.113(X)}$	0.044 (0.225)

Note: * significant at confidence interval of 95%

Analysis result of the linkage of seedling growth of diameter and height of mangrove planted in silvofishery pond showed that only *A. marina* planted in the mixed species treatment was significantly related. It indicated that most of the observed growth of mangrove has no specific relationship. The determination coefficient was 59,5% indicated a fair linkage between the growth of seedling diameter and height. Analysis of other treatments showed no significant effect of the diameter and height growth relationship.

Table 3. Linkage of diameter growth and leaf number development of mangrove seedling in silvofishery ponds

No.	Mangrove Species	Relationship	R^2 (Sig.)
A.	**Single Species**		
1.	*A. marina*	$Y = 51.9873.X^{0.797}$	0.351 (0.033)*
2.	*R. mucronata*	-	-
B.	**Mixed Species**		
1.	*A. marina*	$Y = 0.5582.X^{-0.593}$	0.080 (0.539)
2.	*R. mucronata*	$Y = 0.3746.E^{0.662(X)}$	0.000 (0.920)

Note: * significant at confidence interval of 95%

The linkage between seedling diameter growth and leaf number development was significant on *A. marina* in single species treatment. The analysis resulted determination coefficient of 35.1% indicated a low relationship, while in the single structured *R. mucronata* was not analyzed since the data distribution of leaf number development was not normal. Analysis on the relationship of diameter growth and leaf number development in mixed mangrove structure showed no significant effects.

Table 4. Linkage of height growth and leaf number development of mangrove seedling in silvofishery ponds

No.	Mangrove Species	Relationship	R^2 (Sig.)
A.	**Single Species**		
1.	*A. marina*	$Y = 1.8984.X^{0.833}$	0.134 (0.219)
2.	*R. mucronata*	-	-
B.	**Mixed Species**		
1.	*A. marina*	$Y = 5.1603.X^{0.765}$	0.301 (0.202)
2.	*R. mucronata*	$Y = 0.3856.X^{0.068}$	0.004 (0.743)

Analysis of the linkage between the growth of seedling height and leaf number development showed there were no any significant relationships among treatments. The height growth of mangrove was not related to the leaf development for all treatments. Analysis on single structured *R. mucronata* was not conducted since the data distribution of leaf number development did not have normal distribution.

The analysis resulted that the morphometric growth of particular plant parts was not always related to another plant parts. Only *A. marina* seedling showed the possibility of related plant developments. The absence of significant relation of seedling growth of *R. mucronata* might be caused by the variation of environmental factors which lead to various plant growth rate. Thus, the growth rate of diameter nor height were not consistent among stands.

The growth pattern of a plant is usually expressed in an allometric relationship. Allometric relations among plant parts such as height, diameter, and biomass indicated that plant has a proportional growth rate. According to the result, the various condition of growth linkage of mangrove seedling showed that the variation environment condition would lead to different growth patterns. Ecosystem and environment conditions were considered as the affecting factors for allometric measures and relations of mangrove trees [11].

The utilization of allometric relation of plant is considered to has a great potential for plant component estimation such as its measurements and biomass [11]. Estimation of the biomass of several plant parts such as the dry weight of leaf, branches, and trunks, nor total above ground dry weight had been conducted based on collar diameter, total height and canopy diameter [16]. High determination coefficients were achieved from the analysis indicating its capability on the estimation of tree productivity. Allometric relations is also utilized in the calculation of carbon stocks within mangrove forests [17].

The Plant growth is generaly proportional among parts such as height, diameter, above ground biomass and plant part biomasses [18]. Even though, the proportions might change as the plants grow. However, there is still limited information concerning the relation of growth rates among plant parts.

The relationship of mangrove growth showed that there was a significant linkage between diameter growth and height growth of *A. marina* in the single species treatment and between the diameter growth and leaf number development of *A. marina* in the mixed species treatment. Various factors might affect the growth performance of mangrove seedling which causes to inconsistent growth rate such as environment condition. Suitable environment condition should provide better growth performance of mangrove stands, inversely stressful environment conditions might decrease its growth performance [19].

The linkage of mangrove growth among parts should provide information concerning the development of the ecosystem. Faster mangrove ecosystem maturity is expected to provide better support for the environment [20]. The relation of growth rate among parts provided information concerning the optimum environment condition for best mangrove growth performance [21].

Various research has shown the significant role of environmental factors to the allometric growth of woody plants. According to [22], the consistent allometric pattern would only be achieved in an optimum growth environment. Even though, the change of plant size might also require different environment condition. The variation of environment condition also affected the biomass allocation of

plants. The certain growing environment might affect to smaller or larger organ size [23], which might be caused by physiological stress leading to organ malfunction or adaptation activities causing unbalanced nutrient distribution [24,25]. The adaptation capabilities of plants also play an important role in maintaining the optimum allometric pattern of plant growth. Thus, an inappropriate allometric growth of plants might indicate that plants are experiencing environmental stress or unsuitable environment condition.

The inconsistent plant growth rate resulted in this research indicated that silvofishery ponds in Semarang coastal area had low suitability for mangrove growth. It was supported by low survival of mangrove, especially for *A. marina* during the research. The inconsistent growth rate of *R. mucronata* also showed the variation of environment condition among sites. Thus, mangrove seedling experienced various stress level.

4. Conclusion

This research concluded that mangrove growth rate was varied among species and treatments. The growth rate of *A. marina* height was higher in the single structured community, while *R. mucronata* was higher in mixed structure community. The diameter growth rate both for *A. marina* and *R. mucronata* was higher in the single sturctured community. The leaf number development of both *A. marina* and *R. mucronata* were faster in the mixed structure community. The allometric growth of mangrove seedling was only significant for *A. marina*, including diameter to height growth in the mixed structure and diameter growth to leaf number development in single structured.

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References

[1] Hastuti ED, Budihastuti R (2016) Biotropia **23** (1): 58–63.
[2] Suwarto, Lahjie AM, Ruchaemi A, Simorangkir BDAS, Mulyadi F (2015) Global Journal of Agricultural Research **3** (1): 27–35.
[3] Purwiyanto AIS, Agustriani F (2014) Ilmu Kelautan **19** (2): 81–87.
[4] Gatune C, Vanreusel A, Troch M De (2017) Aquaculture Environment Interactions **9**: 73–85.
[5] Eddy S, Ridho MR, Iskandar I, Mulyana A (2016) *Jurnal Silvikultur Tropika* **7**(3): 42–47.
[6] Van TT, Wilson N, Thanh-Tung H, Quisthoudt K, Quang-Minh V, Xuan-Tuan L, Dahdouh-Guebas F, Koedam N (2015) Acta Oecologica **63:** 71–81.
[7] Qin X, Weiner J, Qi L, Xiong Y, Li F (2013) Field Crops Research **144:** 162–166.
[8] Deng J, Zuo W, Wang Z, Fan Z, Ji M, Wang G, Ran J, Zhao C, Liu J, Niklas KJ, Hammond ST, Brown JH (2012) PNAS **109**(22): 8600–8605.
[9] Li L, Weiner J, Zhou D, Huang Y, Sheng L (2013) Journal of Ecology **101:** 475–483.
[10] Cheng D, Ma Y, Zhong Q, Xu W (2014) Ecology and Evolution **20** (4): 3968–3977.
[11] Peters R, Vovides AG, Luna S, Gruters U, Berger U (2014) Ecological Modelling **283:** 53–61.
[12] Schafer JL, Mack MC (2014) Am. Midl. Nat. **172:** 266–284.
[13] Vovides AG, Vogt J, Kollert A, Berger U, Grueters U, Peters R, Lara-Dominguez AL, Lopez-Portillo J (2014) Trees **28:** 1413–1425.
[14] Kabir M, Abolfathi M, Hajimoradloo A, Zahedi S, Kathiresan K, Goli S (2014) AACL Bioflux **7**(4): 286–300.
[15] Satyanarayana B, Idris IF, Mohamad KA, Husain M-L, Shazili NAM, Dahdouh-guebas F (2010) Botanica Marina **53:** 79–88.
[16] Ghasemi A, Fallah A, Joibary SS (2016) İstanbul Üniversitesi Orman Fakültesi Dergisi **66**(2): 691–697.
[17] Sitoe AA, Júnior L, Mandlate C, Guedes BS (2014) 1967–1981.

[18] Medeiros TCC, Sampaio EVSB (2008) Wetlands Ecology and Management **16**(4): 323–330.
[19] Suwa R, Deshar R, Hagihara A (2009) Aquatic Botany **91**(2): 99–104.
[20] Salmo SG, Lovelock C, Duke NC (2013) Hydrobiologia **720**(1): 1–18.
[21] Su Y, Lin Y, Jing S, Hou PL (2011) Marine Pollution Bulletin **62**(7): 1455–1463.
[22] McCarthy MC, Enquist BJ (2007) Functional Ecology **21:** 713–720.
[23] Guo H, Weiner J, Mazer SJ, Zhao Z, Du G, Li B (2012) Journal of Ecology **100**: 452–458.
[24] Anfodillo T, Petit G, Sterck F, Lechthaler S, Olson ME (2016) Frontiers in Plant Science **7:** 1681
[25] Mao W, Zhang T, Li Y, Zhao X, Huang Y (2012) Journal of Arid Land **4**(2): 161–170