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Specific Growth Rate of Mangrove Avicennia Marina Seedling Within Silviculture Pond Canals in Semarang Coastal Area

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Environment quality and its changes both play important role in the growth of mangrove plants, especially at seedling stage. This research aimed to study the effect of environment parameters and its changes on the specific growth rate of *Avicennia marina* seedlings. Research was conducted through field experiment by planting mangrove seedling of *A. marina* in the silvicultural pond canals involving 18 pond plots and 3 observation periods. Observations were conducted to measure environment parameters such as temperature, turbidity, salinity, pH, DO, OM, N, P and TSS and specific growth rate of *A. marina* including height and diameter growth. Analysis was conducted through regression with confidence interval of 90%. The observations resulted the environment dynamics in the silvicultural pond canals including decreasing and increasing value of defined parameters, except for salinity which consistently increased among periods. Regression analysis resulted only specific height growth rate was affected by environment parameters including temperature change, salinity and salinity change, and P concentration change. Positive effect was achieved from temperature and salinity indicating both parameters were optimum for seedling growth, while negative effect was showed by P change indicating P value had exceeded its optimum limit. Determination coefficient of the affecting parameters were low including 20.1% ($P = 0.093$) for temperature, 47.5% ($P = 0.021$) for salinity and 19.5 ($P = 0.100$) for P change. This research suggests that to achieve optimum growth of mangrove, potential change of environment parameters values should be considered.

Keywords: Environment Quality, Growth, Seedling, Silvofishery Pond.

1. INTRODUCTION

Appropriate utilization of coastal area is needed to achieve sustainable development. Application of silvofishery is important in rehabilitation/conservation programme in accordance with improvement of aquaculture activities.[1] Aquaculture development without considering the sustainability of the ecosystem had showed significant impact on coastal ecosystem degradation in the past, which further impacted the aquaculture activities. Aquaculture development was conducted by clearing mangrove plants followed by pond constructions.[2] Application of silvofishery was proposed to overcome the aquaculture problem in terms of feed, water and effluent management through the alteration of assimilative capacity, protection of resources and rehabilitation of habitat.[3]

Various silvofishery system had been proposed in the development of sustainable aquaculture. Empang parit model of silvofishery was mostly applied aquaculture model in Indonesia.[4] The silvofishery application in many countries had been developed and modified to achieve optimum water filtration for aquaculture such as the combination of mangroves, oysters and seaweeds.[5] The combination had showed significant effect on the nitrogen removal from the pond. The role of mangrove in nutrient removal showed that various mangrove species has different capability on nutrient removal.[6]

Agroforestry system had been proposed to maintain environmental stability to support the sustainability of farming activities.[7] The application of silvofishery in coastal farming (aquaculture) had been proved to increase the mangrove coverage significantly.[8] Mangrove ecosystem is related to another ecosystem, including coral reefs and seagrasses.[9] The rehabilitation of mangrove ecosystem is needed in order to protect linked ecosystem. Rehabilitation of mangrove forest as well as the application of silvofishery in aquaculture system is required to void the ecosystem stress caused by fish culture. Long term management plan is required to achieve optimum goal of mangrove reforestration in the coastal area.

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Mangrove ecosystem plays important role in as a resource nor as an environment service reserve. Mangrove ecosystem provide various ecosystem services such as fish nurseries, wildlife habitat, coastal protection, flood control, sediment trapping and water treatment.[3] The economic advantages resulted from ecosystem services of mangrove are usually uncalculated.[10] The economic valuation is needed to improve the conservation policy in making and participation of the communities.[11] Various economic valuation method of mangrove ecosystem had been proposed in several researches.[12,13] Mangrove as habitat provide various economic values including fisheries resources such as fish and crabs.[14] Plantation of mangrove instead of providing assimilation services for the pond can also provide additional economic value from fish/crab yield.

Ecosystem services provided by mangrove for aquaculture includes the food supply.[15] Litter decomposition by microorganism is the main nutrient sources for primary productivity which support the natural food variation and abundance for cultivated biota. The availability and abundance of decomposer microorganisms might vary due to the variation of mangrove structure.

Avicennia is known to be natural colonizers of mangrove ecosystem which grow in intertidal coastal area.[2] *Avicennia marina* is mostly found as an initiating mangrove species for ecosystem expansion.[16] The growth of mangrove vegetation is important for rehabilitation success. Mangrove ecosystems are the most dynamic ecosystem compared to any other ecosystem. Mangrove forests could expand rapidly on the coastal areas with active sedimentation. However, it could be degraded rapidly on the highly disturbed areas. Rapid stabilization of mangrove ecosystem would lead to more effective rehabilitation process.[2] The growth rate of mangrove define the productivity of mangrove stands and its contribution to the ecosystem. The plant growth affect the complexity of vegetation structure and production of litterfall of mangrove, which further effect the available services.[18] Hence, rapid growth of mangrove should provide more ecosystem services such ash carrying capacity and resilience capability.

Seedling is the most vulnerable stage of mangrove development. Mangrove seedlings are more sensitive to environment changes since its organs development are not completed. Hence, its adaptive mechanism doesn't work perfectly. The mortality of planted mangrove was up to 80%.[19]

Various research concerning the effect of environment dynamics on mangrove seedling development had been conducted. A research showed decreasing growth of *A. marina* over high salinity and low freshwater supply.[17] Various environment parameters particularly composition of nutrient in mangrove floor affected the growth rate of mangrove seedlings.[20]

Application of mangrove plantation in ponds regarding silvofishery system require appropriate information concerning the effectiveness for both aquaculture and rehabilitation purposes. Particularly, in order to achieve optimum services of the mangrove stands, the growth of mangrove seedlings should be optimised. To understand the dynamic growth of mangrove seedling, the interaction of environment parameters should be studied. This research aimed to study the influence of environment parameters on the specific growth rate of mangrove *A. marina* seedling planted in silvofishery canals.

2. EXPERIMENTAL DETAILS

This research was conducted through field experiment on silvo-fishery pond at Mangunharjo Village, Tugu District, Semarang City. Silvicultural ponds occupied in this research was embankment—canal system in which mangrove seedlings were planted in the inlet and outlet canals of the ponds which are functioned as biocontrol of environment parameters. The numbers of ponds utilized in this research was 18 plots. Observations were conducted at each plots, including 3 mangrove stands as the samples. Observations were conducted with 3 repetitions, including early plantation period and 2 following observations to monitor seedling growths.

Data collections was conducted to monitor the environment quality factors, including water quality such as temperature, turbidity, salinity, pH, dissolved oxygen (DO) and total suspended sediment (TSS), and sediment quality such as organic matters (OM), nitrogen (N) and phosphorus (P). Data processing for environment quality was conducted by calculating the difference of parameter values among observations. While data collection of seedling growth was conducted by monitoring the changes on stand height and diameter of mangrove seedlings. Mangrove growth was analyzed by calculating the specific growth rate of mangrove seedling of *A. marina*. Data processing for the growths of mangrove seedling were formulated with following equations:

$$\text{SGR } h = \frac{\ln(h_{t1}) - \ln(h_{t0})}{t} 100\% \quad (1)$$

Notations: SGR h = height specific growth rate, h_{t1} = stand height at $t1$ (cm), h_{t0} = stand height at $t0$ (cm), t = time period between observations (days).

$$\text{SGR } h = \frac{\ln(d_{t1}) - \ln(d_{t0})}{t} 100\% \quad (2)$$

Notations: SGR d = diameter specific growth rate, d_{t1} = stem diameter at $t1$ (cm), d_{t0} = stem diameter at $t0$ (cm), t = time period between observations (days).

Analysis on the effect of environment on the specific growth of *A. marina* seedling was conducted through regressions. Independent variables were environment parameters and the changes of environment parameter values, while dependent variables was the specific growth rate of mangrove seedling including both height and diameter. Analysis of regression occupied partial multiple regression analysis in which each parameter was analyzed separately. Data analysis was conducted with SPSS 19 software with 90% confidence interval.

3. RESULTS AND DISCUSSION

Observation result showed there were variations of environment quality among periods and treatments. The changes of parameters value showed both negative (decreasing) nor positive (increasing) pattern among observations. Processed observation data for respective environment parameters value and its changes is shown in Table I.

Table I shows there were significant differences on the values of the observed parameters. Negative value change indicated some parameters tended to decrease among observations, such as temperature, turbidity, pH, DO, OM, N, P and TSS. Water salinity was the only parameter with increasing value among observations. According to observation data as presented in Table I,

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Table I. **Environment quality parameters values and its changes in silvicultural pond canals (range [average ± std. dev).**

No.	Parameter	Observation value	Value changes
1.	Temperature (°C)	29.3–39.7 [32.9 ± 1.9]	(−)7.5–(+) 0.9 [(−)1.8 ± 1.5]
2.	Turbidity (NTU)	80–933 [345.1 ± 227.4]	(−)772–(+) 429 [(−)26.3 ± 235.4]
3.	Salinity (‰)	19.7–32.2 [26.5 ± 4.6]	4.7–12.4 [8.9 ± 1.3]
4.	pH	4.7–11.0 [8.4 ± 1.4]	(−)5.8–(+) 4.2 [0.3 ± 2.6]
5.	DO (mg/l)	2.3–10.6 [6.7 ± 1.8]	(−)6.2–(+) 5.6 [(−)0.5 ± 2.7]
6.	OM (%)	0.89–2.82 [1.67 ± 0.48]	(−)0.29–(+) 0.56 [0.03 ± 0.22]
7.	N (%)	0.39–0.73 [0.54 ± 0.07]	(−)0.11–(+) 0.31 [0.03 ± 0.09]
8.	P (ppm)	18.34–64.87 [38.00 ± 12.24]	(−)12.47–(+) 21.76 [(−)2.64 ± 6.16]
9.	TSS (mg/l)	268.1–677.1 [451.9 ± 109.1]	(−)400.8–(+) 354.7 [(−)52.5 ± 180.4]

the value of parameters had large range which showed that there were significant variation among plots and observation period. It indicated that there were dynamic changes on the environment quality of silvicultural pond.

Mangrove ecosystem has dynamic water quality due to seasonal climatic changes. There were variations of environment parameters among season caused by ebb and flow during monsoon, post monsoon and pre monsoon periods.[21] Freshwater flow in monsoon affects the dynamic of several environment parameter such as salinity, total nitrogen and total phosphorus concentration.[22] Wet monsoon alters freshwater supply and decrease salinity, total nitrogen and phosphorus concentration within mangrove ecosystem. Inversely, total nitrogen and total phosphorus concentration were higher in monsoon period due to land run off.[23] Temperature, pH and TSS varied among seasons. pH was higher in the rainy season, while temperature was nearly at the same range, while TSS was higher in the dry season.[24]

Data processing on the growth of mangrove seedling showed low survival rate for both mangrove species planted in silvicultural canals. Based on the processed data, the survival rate of *Avicennia marina* seedling at first period was only 14.81% and 12.96% at second period. While the survival rate of *Rhizophora mucronata* seedling was 31.48% at first period and 38.89% at second period. It indicated that generally, the condition of environment in silvicultural pond canal was not suitable for the growth of mangrove seedling.

Analysis on the effect of environment parameters to the growth of mangrove seedling showed various effect pattern. The specific growth rate of mangrove *A. marina* seedling was affected by several environment parameters. Detailed regression analysis result is shown in Table II.

Regression analysis showed the effect of several environment factors as well as its changes to the specific growth rate of mangrove seedling. According to Table II, environment parameters with significant effect on the specific growth rate of mangrove seedling were temperature change (Temp_ch), salinity (including salinity value and salinity change [Salinity_ch]) and change of *P* concentration (P_ch). The three mentioned parameters only effect the height growth of mangrove seedling, while the diameter growth was not affected significantly. Temperature change had positive effect on the specific growth rate of *A. marina* seedlings. Salinity and salinity change had simultaneous positive effect on the specific growth rate of *A. marina* seedlings, while change of P concentration had negative effect on the specific growth rate of *A. marina* seedlings. Even though the effect of mentioned parameters were significant, but the determination coefficients were low. Respective determination coefficient of affecting parameters were 20.1% for temperature change, 47.5% for salinity and salinity change simultaneously and 19.5% for P concentration change.

The change of temperature affected specific growth rate of *A. marina* positively which means that higher increase of temperature would lead to better growth of mangroe seedling. Positive effect of temperature change on seedling specific growth rate indicated that the water temperature observed within three research periods were still in the optimum range for mangrove growth. Optimum temperature for mangrove photosynthetic activity is ranged from 28–32 °C.[25] This match the observation result which was ranged from 29.3–39.7 °C with average of 32.9 °C. This showed that the temperature dynamic of silvicultural pond water exceeded the suggested optimum value. The observation result concerning the temperature value indicated that mangrove seedling experienced temperature stresses, but the disturbance level was low, hence the effect was not noticed. Mangroves are tropical plant which require warm environment to grow appropriately.[26] Mangrove require minimum temperature of 20 °C to grow, while at temperature of 37 °C the growth would be inhibited.[27] Temperature effects the growth of mangrove plants through metabolism processes.[28]

Salinity and salinity change simultaneously effect the specific height growth of *A. marina* positively. This result indicated that increasing salinity and higher value change of salinity would increase the specific growth rate of *A. marina* seedling. Positive effect of both salinity value and changes suggested that the salinity within the observation was in the optimum range for mangrove growth. According to the observation result, the range of salinity was 19.7–32.2‰ with average of 26.5‰. Optimum salinity range for mangrove seedling growth is 5–30‰.[29] Mangrove had been known to be salt tolerant plant which could survive at salinity level of 90‰ even though it would experience such stress

Table II. **Effect of environment quality and its change on the growth of mangrove seedling.**

No.	Mangrove species	Independent variables	Dependent variable	Equation	*R*2 (Sig.)
1.	*A. marina*	Temp_ch(*X*1)	SGR *h*	$Y = 0,3769 + 0,0434(X1)$	0,201 (0,093)
2.	*A. marina*	Salinity(*X*1); Salinity_ch(*X*2)	SGR *h*	$Y = -1,0181 + 0,0137(X1) + 0,1095(X2)$	0,475 (0,021)
3.	*A. marina*	P_ch(*X*1)	SGR *h*	$Y = 0,2754 - 0,0139(X1)$	0,195 (0,100)

at certain level.[30] At salinity more than 30‰ the photosynthetic process of mangrove would be significantly inhibited.[31]

Salinity level influence the osmotic processes of mangrove plants. The growth of mangrove seedling is low on salinity stressed environment due to the increasing Na^+ amount.[32] Mangrove plants adapt salinity stressed environment through salt secretion. *A. marina* response sudden change of salinity by osmoregulation strategy.[33] Salt secretion of *A. marina* increase as the increase of water salinity.[34] *A. marina* is capable to maintain its salt concentration in leaf tissue at salinity level of 5–35‰. Hence, the mentioned salinity range is suggested to not effect the plant osmotic processes. It was proved by seedling establishment which was observed to 100% on all salinity ranges (5–35‰). Mangrove seedling grown in high salt concentration accumulate more nutrient in its tissue.[35] Even though, the tolerance of each mangrove species would be different.[36] Most of mangrove species has lower tolerance over salinity.

Change of P concentration affect the specific height growth rate of *A. marina* negatively. It showed that the rapid accumulation of P in the sediment would decrease the growth rate of *A. marina* height. This indicated that P observed P concentration caused to stress of *A. marina*seedling. This result is contrary,[37] that phosphorus fertilization increased the growth rate of *A. marina*. Application of 75 kgP/ha increased the plant height, number of leaves and number of branches significantly. The contrary result indicated that the concentration of P in this research was quite high. Suitability of environment for *A. marina* growth could be decreased by soil acidification processes caused by oversaturated nutrient concentration.[38] It is suggested that *A. marina* is sensitive over nutrient concentration dynamics.[39]

N and P availability could limit mangrove productivity and growth.[40] In a P—limited habitat, addition of P would increase the growth rate of mangrove stems. Eventhough, study on the effect of P—abundant habitat on the growth rate of mangrove is not well studied. High nutrient availability (especially P) effects to the decline of fine root biomass.[41] Nutrient enrichment reduce root accumulation and consequent contribution to soil volume by accelerating root decomposition. The negative effect of P concentration on the specific growth rate of *A. marina* seedling might be related to heavy metal uptake. P roles in the heavy metal binding such as Pb. Addition of P fertilizer had proven to increase Pb accumulation in mangrove organs.[42]

The result of this research indicate that the specific growth rate of mangrove *A. marina* seedling is affected significantly by several environment parameters, including temperature changes, salinity, salinity changes and P changes. It shows that the growth rate of mangrove seedling is not only influenced by parameters values, but also parameters values changes. This research also showed how mangrove seedling of *A. marina* response the changes of environment quality through its growth rate, especially the specific growth rate. Unfortunately, the effect of extreme environment changes on the growth could not be analyzed due to data limitation. Even though, this research suggest that consideration on the potential rate of environment changes instead of environment present condition are required in the mangrove reforestration and management plan. Further research is required to understand the response of various mangrove species over environment quality changes as well as their capability to response extreme environment changes in order to overcome future risk of mangrove ecosystem disturbances.

4. CONCLUSION

This research suggest that the specific height growth rate of mangrove *A. marina* seedling was affected dominantly by several parameter values changes. Environment factors which influenced the specific height growth rate of *A. marina* seedling were including temperature change, salinity change and P concentration change. Temperature (temperature change) and salinity (salinity and salinity change) effected the specific height growth rate of *A. marina* indicating both parameters are within optimum—tolerance range for mangrove seedling, while P (P change) showed negative effect on which indicate its oversaturated concentration. This research suggest the consideration of environment condition as well as its potential change in the rehabilitation plan of mangrove forest.

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