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Study of Tidal Inundation and Shade on Different Sediment Substrates on the Growth of Rizophora Mucronata Mangrove Saplings in the Management of Coastal Water Resources in Sinjai Regency

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Abstract: It is time for the urgency of mangrove vegetation for coastal water resources in Indonesia to become a serious concern in rehabilitating mangrove ecosystems which have been increasingly degraded due to heavy exploitation over the past three decades. In several densely populated coastal areas of Indonesia, mangrove vegetation and estuary areas have turned into residential and industrial locations, agricultural areas, recreational centers and harbor wharves. As a result of all this, it creates a negative impact that is no longer able to be offset by the natural growth of the mangrove itself. Based on these environmental problems, it is necessary to study the sediment substrate, the duration of inundation and shade, and their effects on budding and tiller height, as well as the survival of Rhizophora mucronata. From this study, using factorial group design analysis, the results showed that R. mucronata seedlings showed better germination, growth and survival rates on clay-clay substrate conditions with shading and flooding 7 hours/day, whereas on loamy sand substrates without shade with 3 hours/day of inundation showed a low rate of germination and growth and survival. The results of this study provide important information in the management of mangrove ecosystems, especially in the selection of mangrove seedlings in silvofishery ponds in the east coast of Sinjai Regency.

Key words: management, ecosystem, mangrove, Rhizophora, silvofishery.

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1. Introduction

1. Background

Mangrove ecosystems are very important for human life in coastal areas, especially in tropical areas. Indonesian people, especially those living in coastal areas, are very dependent on many needs produced from mangrove vegetation, such as wood for building materials, medicines, cosmetics, fodder, and tannins. For the life of aquatic biota (various types of fish, shrimp, crabs and molluscs), mangrove vegetation is very important as a habitat for growth, protection and a place to get food. In several coastal areas with densely populated populations, mangrove vegetation with estuary water conditions has turned into residential areas, agricultural and aquaculture areas, industrial sites, harbor piers, and recreation centers. The activity of utilizing the mangrove ecosystem ultimately (currently) has a negative impact, namely mangrove vegetation loses its homeostatic properties which are able to restore natural vegetation growth.

These environmental problems require the need for research, especially to determine the effect of sediment substrate, duration of inundation and presence or absence of shade on the growth of Rizophora mucronata saplings which can be a reference in the management of mangrove ecosystems in coastal areas.

2. Research objectives

This study aims to obtain information about the beach sediment substrate, the duration of inundation and the presence or absence of shade that affect budding and growth as well as the survival of Rizophora mucronata tillers that achieve optimal growth and life, and this as a basis for preparing reforestation efforts to restore homeostatic properties of the resource sustainable mangrove ecosystem in coastal areas.

2. Research methods

1. Research location

The research location is in the mangrove vegetation area of the east coast of Sinjai Regency with the consideration that this area is a silvofishery pond development area, namely an integrated pattern of pond management with mangrove plants in each management unit.

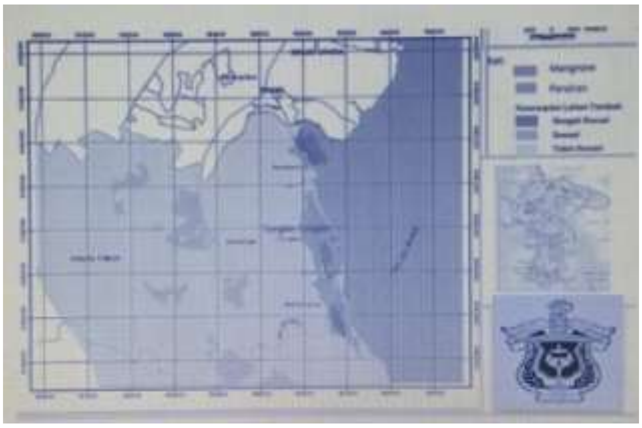

Fig 1. Map of the research location, east coast of Sinjai Regency

2. Sampling method

The method used in sampling was all R. mucronata fruit seedlings, both ripe on the tree and those that fell to the bottom, were taken, then placed under moist seagrass for 1-2 weeks so that the fruit did not dry out and shrink when sown. The fruit seeds to be sown are randomly selected from the stored fruit seeds. The treatments given were the substrate media, the duration of inundation, and the presence or absence of shade, and as a response to the treatment the stem height, germination percentage (number of leaf shoots) and survival percentage were measured as a response. Samples of sediment substrates were brought to the Laboratory of Soil Science, Faculty of Agricultural Sciences, Hasanuddin University to determine the texture or substrate fraction. There are 3 selected substrates, namely: clay loam (chewy mud), sandy loam, and muddy sand. For inundation, media plots were made surrounded by bund embankments whose height can be inundated by high tide according to research provisions.

3. Data analysis

This study was designed based on a factorial randomized block design (Steel and Torrie, 1980), so the data were analyzed statistically, namely; $Yijk = \mu + T_i + G_j + S_k + \varepsilon_{ijk}$ (Note: Y_{ijk} = results of observations of tidal inundation-i, sedimentary substrate-j, presence or absence of shading-k; μ = general average; T_i = tidal inundation-i; G_j = sedimentary substrate-j; S_k = presence or absence of shade-k; E_{ijk} = error T_i, G_j, S_k).

3. Results and Discussion

1. Tidal flooding

In natural coastal areas, especially with regard to mangrove ecosystems, the duration of inundation is a very determining factor for the growth of various types of mangroves, especially the level of mangrove seedlings. Statistical analysis showed that the effect of the three levels of inundation was very significant on the confidence interval (p=0.05), as well as the interaction between treatments showed a significant effect on the budding and growth of Rizophora mucronata (Table 3 and Table 4). Periods of inundation that fluctuate between high and low tides cause the accumulation and erosion of sediment so that it can form a level of sediment substrate which also affects the growth and presence of R. mucronata far from other mangroves (Carter, 1988).

Periods of inundation that fluctuate between high and low tides which cause the accumulation and erosion of sediments can form a level of sediment substrate which also affects the growth and presence of the far proximity of Rizophora mucronata to other fellow mangrove vegetation (Carter, 2008). Meadows and Campbell (2008) explain that the high and repeated frequency of inundation causes sedimentary soils to become softer and water is stored between the pores of the sedimentary soil. One of the most important aspects of the characteristics of the seedlings of R. mucronata is that they are vivipary as a respiratory adaptation behavior under the pressure of anaerobic conditions. In this anaerobic condition, there is a decrease in respiration activity in almost all types of estuary vegetation. However, the seedlings of R. mucronata showed better growth and sprouting under conditions of longer tidal inundation (Table 1 and Table 2).

If the length of tidal inundation is related to the condition of the sediment substrate which contains a high percentage of clay silt, the seedlings of R. mucronata mangroves will form a better aeration system than the sandy clay sediment substrate media. Table 2 shows the high percentage of R. mucronata seedling shoots on a relatively long inundation substrate media, so it is an indication that the longer an area is inundated by high tide, the better the R. mucronata seedling germination will be. This explains that with the process of forming good sedimentary soil aeration, it needs to be accompanied by relatively long inundation. So it can also be concluded that for the budding of R. mucronata seedlings, good soil aeration conditions are needed.

Table 1. Average Height Gain (cm) Seedlings of R. mucronata

Duration of inundation (hour)	Shade	Sedimentary substrate media			Average
		G_1	G_2	G_3	
3	Yes	11,75	10,50	10,45	10,73
	No	10	9	8,50	9,17
5	Yes	16	15,20	15,70	15,63
	No	11,50	11,20	11,15	11,40
7	Yes	20	15,60	19,70	18,46
	No	13	11,20	10,50	11,81
Average	Yes	15,92	13,77	15,28	
	No	11,5	10,47	10,05	

It can also be explained that on the other hand areas with long periods of inundation or high frequency of inundation allow for more groundwater supplies so that the deposition of macro-nutrient elements is also greater than with shorter inundation. The reduction of groundwater at a certain level will be a serious disturbing factor for photosynthesis, accumulation, metabolic processes and transpiration, and will increase the osmotic pressure of the soil solution. Water depth is a factor that determines the zoning of plants in coastal ecosystems. A decrease in the intensity of infrared light by 1.5%, blue light by 2.5%, and violet light by 6.4% at a depth of 5 m will show varied plant zoning (Choong, et al., 2009).

Table 2. Mean Number of Seedlings of R. mucronata Seedlings

Duration of inundation (hour)	Shade	Sedimentary substrate media			Average
		G_1	G_2	G_3	
3	Yes	5	3	4	4
	No	3	3	3	3
5	Yes	7	7	5	6,3
	No	4	3	3	3,3
7	Yes	8	7	5	6,33
	No	7	6	5	6
Average		6,67	5,67	4,6	
		6	4	3,67	

The results showed that the availability of sedimentary groundwater on the substrate media which was inundated by longer tides (7 hours of inundation) was a determining factor for the success of R. mucronata seedlings with increased height and more number of shoots compared to the other two types of flooding (3 and 5 hours of inundation), this was stated in the statistical analysis on the interaction between flooding and the substrate media on the growth of the height of the seedlings (Table 3). In relation to inundation and salinity, tides have a salinity value that always varies, depending on the tidal conditions associated with water from the river during the rainy season. The more often an area is inundated by high tides, the more salt will be deposited in the area, which means that the salt value of the sediment substrate will be high, but on the other hand macronutrients are deposited which can neutralize high salinity (Clough et al., 2002). Under these conditions the area where the fluctuating nature of salinity affects the salinity of sedimentary soils is still suitable for planting several types of mangrove plants along with other types of biota from the vertebrate (fish) and invertebrate (crustaceans and molluscs) group. Laboratory observations show that the salinity of the sedimentary soil in the seedling media ranges from 0.5 – 0.7 per mile. Likewise, reduced groundwater as a result of short tidal inundation times can cause serious disturbances to the formation of growth cells due to inhibition of nutrient accumulation, high osmotic pressure of soil solution, and disruption of plant transpiration processes (Sulia et al., 2010).

The effect of the sediment substrate did not show a significant effect on the growth and sprouting of R. mucronata, but its interaction with the duration of inundation and the presence of shade showed a significant effect, especially on the number of shoots of R. mucronata. Relatively long immersion (5 -7 hours) makes the clay-loam substrate have an open aerated soil structure for the mangrove plant root system, as well as exposure to growing media with shade under 100% intensity, showing perfect mangrove buds and leaves compared to when located in an open area that is directly hit by 100% intensity.

Table 3. Treatment Interaction on Seedling Growth of R. mucronata seedlings

Treatment interactions	dF	SS	MS	F	F_t
Substrate (G	2	7,79	3,89	3,21	6,94
Tidal inundation (T)	2	80,85	40,43	33,29**	6,94
Shade (S)	1	68,29	68,29	25,86**	5,99
G-T	4	24,85	36,06	11,37**	5,19
T-S	2	32,98	16,50	5,21	5,79
G-S	2	50,54	25,27	7,97**	5,79
Error	4	15,86	3,17		

**Significant at the p 0.05 confidence interval

2. Shade

Based on this study, statistical analysis showed that the substrate media under shade provided better growth of R. mucronata seedlings compared to the growth media exposed to 100% light intensity. Kathiresan and Bingham (2001) stated that with higher light intensity, the thickening and hardness of the stem cells is higher, but the number of buds and leaves is lower. It was also explained that the maximum value in general for plant species in the tropics is at a light intensity below 100%, even for some types of mangrove plants requiring far intensity under full light.

In the growth media for R. mucronata seedlings with relatively long soaking, light refraction will occur, so that less light tends to enter and this causes lower growth energy. Mangrove plants in this condition tend to look for sunlight as a result of which plant cells are formed that are elongated but have a soft and very thin posture.

Differences in growing media for shaded seedlings and growing media exposed to open intensity will cause differences in water content in plant tissue. Thus, in a growing medium that experiences a lack of water, it will inhibit the formation of carbohydrates, disrupt the distribution of food throughout all plant tissues, and delay cell development. Finally, the symptoms that arise are abnormal growth extending from the stem of the seedling, the leaf size is relatively small and the plant looks stunted, hard and stiff. Another abnormal symptom that appears is the absorption of chlorophyll and concentrated yellow pigment causing the green color of the leaves on the upper surface to contrast sharply with the yellow color on the lower surface.

In general, an optimal temperature is required for each plant for maximum growth rate. This growth rate will decrease at temperatures that are less or more than optimal temperatures. On growing media that is under shade, growth and root system will be better in terms of stem height and budding or branching. Within the optimal temperature range, the humidity of the media substrate is relatively normal and stable so that the process of transpiration and metabolic activity of plant tissues also takes place effectively.

4. Sediment substrate

Statistical analysis showed that the substrate media had a significant effect on the growth and germination of R. mucronata seedlings (Table 4). Lewis (2009) stated that the substantive meaning of sedimentary soils for mangrove plants is that there is a balance between the clay, silt and sand fractions whose configuration positions depend on the topography and coastal drainage.

In coastal topographical areas where tidal inundation levels are normal (not far from the mean sea level), will have a high clay-clay content compared to areas whose coastal topography is far from the average caudatum coastline. So that in this last condition the sedimentary substrate fraction will be dominated by the dusty sand fraction, and this makes the mangrove seedling substrate media less fertile and arid. Whereas in the relatively sloping topographical area, the clay fraction deposits that formed had joined together to form rather large clumps of particles, so that the substrate sediment from the clay fraction was difficult to carry away by shifting tidal currents.

Table 4. Analysis of Interaction Treatment of Seed Seedlings of R. mucronata

Perlakuan	dF	SS	PS	F	F_t
Substrat-G	2	16,778	8,389	5,805	6,94
T. inund. (T)	2	24,116	12,056	8,343*	6,94
Shad (S)	1	2,98	2,98	15,935**	6,61
G-T	4	24,24	6,06	32,409**	5,19
T-S	2	8,889	4,45	23,797**	5,79
G-S	2	11,85	5,925	31,684**	5,79
Galat	4	1,122	0,187		

**Very significant at the p 0.05 confidence interval

Analysis of Table 4 shows that the effect of tidal inundation is significant on the sprouting of R. mucronata seedlings. On the interaction between the treatments, it shows the significance of the effect on the perfect budding and formation of mangrove leaves. The amount of clay fraction in sediments greatly determines the root system in penetrating sedimentary soil, and this depends on the humidity and shade of the growing media which does not saturate the sediment substrate with water and the clay fraction is porous.
Sedimentary soils with high and erratic tidal immersion levels will be supplied with sandy and dusty substrates so that the water saturation level is high which causes the clay-loam fraction to shift when the tide arrives. It is different in areas with high but sloping topography allowing relatively short and low tidal submergence as a result of which clumps of the clay fraction from sediments can survive, and this is very suitable for the roots and growth of the mangrove species Rizophora sp. So it can be stated that in the sloping coastal zone with clay and clay fractions, R. mucronata is often dominated as the main buffer species in coastal ecosystems.

4. Survival of R. mucronata

Of all the treatments and their interactions, they showed relatively the same effect on the survival rate of R. mucronata, meaning that during the seedling period (ready for replanting), both for budding, growth and survival showed a response to each treatment that was still feasible for the life of the seedlings. However, during the stand period (tancap), some of these mangrove stands died, especially on sandy loam sediment plots with short tidal inundation levels and exposure to 100% light intensity (Table 5). The loss of the sedimentary soil fraction in the replanting zone in the silvofishery pond development area, as well as the exposure of the stands under exposure to open light intensity caused the death of R. mucronata stands. As previously explained, exposure to short tidal inundation and direct exposure to open light allows for a more closed sediment aeration system and lower nutrient deposition from receding inundation periods (Choong, et al., 2009).

Table 5. Survival rate of Rizophora mucronata stands at different times and tidal inundation

Duration of inundation (hours)	Mortality (%)	Shoot survival rate (%)
3	9,75	90,25
5	5,70	94,30*
7	5,65	94,35*

* Significant at the p 0.05 confidence interval

4. Conclusions and Recommendations

1. Conclusion

Treatment of tidal flooding for 5-7 hours/day with shade on clay-clay substrate media had agood effect on budding, growth and survival of the seedlings of Rizophora mucronata,whereas on substrate media that was submerged by tides for 3 hours/day without shade showed low percentage of germination, growth and survival.

Interaction treatments showed a significant effect on germination and growth of R. mucronata seedlings.
Soaking the tides for 3 hours/day with shade on a sandy dust substrate media affects the elongated growth of the roots and stems of R. mucronata seedlings, accompanied by a soft posture of roots, stems and leaves, so that these conditions are very popular with herbivorous biota, especially crabs . This treatment case causes the survival rate of mangrove seedlings to be low.
In sediment substrates from silt-clay or sandy fractions with no shade it posture and root elongation, when compared to substrate media equipped with affectssoft shade, and these conditions are favored by predatory herbivorous biota such as crabs.

All treatments and their interactions showed relatively the same effect on the survival rate of R. mucronata, meaning that during the time limit of the seedling period, both the germination, growth and survival showed a response to each treatment that was still feasible for the life of the seedling.
During the stand period (tancap), some of the R. mucronata mangrove stands died, especially on sandy loam sediment plots with short tidal inundation levels and exposure to 100% light intensity. This is due to the porous fraction of the sedimentary soil in the replanting zone in the silvofishery pond development area, as well as the exposure of the stands to exposure to open light intensity.

2. Suggestion
For the management of silvofishery ponds, it is better to select ponds on a relatively sloping topography with a clay-clay sediment composition, and seek integration with the planting of R. mucronata mangroves in each management unit.
Need to maintain mangrove vegetation by reforestation planting in the main stand line as a buffer line in the coastal zone.

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