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Growth of salt-secretor and non-salt secretor mangrove seedlings with varying salinity and their relations to habitat zonation

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Abstract. The growth of six mangrove seedlings under varying salinity was studied concerning the habitat zonation. Healthy and mature propagules and seeds of selected mangroves, *Rhizophora apiculata*, *R. stylosa*, *Ceriops tagal*, *Avicennia marina*, *A. alba*, and *Acanthus ilicifolius* were collected from North Sumatran mangroves. Mangrove seedlings were grown for three months in 0.0%, 0.5%, 1.5%, 2.0% and 3.0% salinity concentration. The growth of mangrove seedlings emerged to show variation among the species. The growth of two salt secretor species of *A. marina* and *A. alba* were increased in the occurrence of salt with maximum activation at 2.0%. This escalation was reduced once salt concentration was increased above 2.0%. By contrast, two non-salt secretor species of *R. apiculata* and *R. stylosa* significantly expanded to 1.5% salinity, at that moment decreasing by accumulative salts. A salt secretor species of Ac showed the less salt tolerant of mangrove species. *ilicifolius* and a nonsalt-secretor of *C. tagal*, which their optimum growth was at 0.5% salinity. The tolerance of mangrove species to salt concentration tracked the sequence of *Av. marina* and *Av. alba* (most foreshore species) >*R. stylosa* and *R. apiculata*>*C. tagal*>*Ac. ilicifolius* (most landward species), which is following the natural species distribution and habitat zones.

1. Introduction

Mangroves are woody plants that widespread at the boundary between land and sea in the tropical and subtropical area. One remarkable characteristic of mangroves is their capability to develop the innumerable level of salinity. The zonation pattern of mangrove species related to the extent and severity of soil waterlogging and salinity. Concerning their morphological features of salt, management revealed the presence of two significant groups of mangrove plants. The first group is the salt secretor species, including *Avicennia alba*, *A. marina*, and *Acanthus ilicifolius*, that have either salt secreting or salt hairs to eliminate the abundance of salt. The second group is non-secretor species, also known as ultrafiltration, exemplified by *Rhizophora apiculata, R. stylosa*, and *Ceriops tagal*, that do not possess such morphological characteristic for removal of extra salt [1]. These species are numerous mangrove plants in North Sumatran mangrove, Indonesia and are considered to be representative of each group.

Indonesia has the largest mangroves area in the world (22.6%); however, the mangrove area has been decreased from 4.2 million in 1980 to 3.1 million in 2011 [2]. This threat is continuing, for example in North Sumatran mangroves, is under considerable pressure from mangrove conversion to non-mangrove land-use such as aquaculture, oil palm plantation, agriculture and urban development [3]. Establishment of the economic value of these ecosystems is critical for their protection and the broader economic sustainability of the coastal communities within these areas. The deforestation rate of mangrove forest during 2000-2005 was the utmost in Indonesia (75%), primarily as a result of the expansion aquaculture (63%), agriculture (32%) and urban development (5%) [4]. Our previous study also demonstrated that aquaculture (50%) and oil palm plantation (29%) were found as a primary source of mangrove deforestation in North Sumatra [3]. Recently it has been reported that four majors converted primary mangrove in North Sumatra: secondary mangrove forest, swamp forest, barren land, and aquaculture; while in secondary mangrove have been deforested into aquaculture, barren land, swamp shrub, and oil palm plantation [4]

Although mangroves are salt tolerant plants, reports on the salt tolerance from Indonesian mangroves are scarce. This data is required for the achievement of reforestation and conservation efforts in North Sumatra, Indonesia and to deepen our knowledge of salt tolerance from mangroves. Our previous study has been reported that 0.5% salt concentration was the ideal growth for *Kandelia candel* and *Bruguiera gymnorrhiza* seedlings grown in a glass house [5]. Thus, to gain more understanding into the physiological function of mangrove to salinity, our present work aims to investigate the growth of salt secreting and non-secreting mangrove seedlings during long-term salinity and their relations to habitat zonation as well as implications for conservation is discussed.

2. Material and methods

2.1. Salt tolerance experiments

Viviparous healthy and mature propagules of three non-secretor mangrove plants, *Rhizophora apiculata* BL., *R. stylosa* Griff., and *Ceriops tagal* C.B. Rob. (Rhizophoraceae), were compiled from Pulau Sembilan, Langkat, North Sumatra, Indonesia. Crytoviviparous seeds of secretor species, namely *Avicennia marina* (Forssk.) Vierh,*A. alba* Blume and *Acanthus ilicifolius* L (Acanthaceae) were collected from Percut Sei Tuan, Deli Serdang, North Sumatra. These propagules and seeds were planted in bottle pots with sand under variable salinities for three months with a revelation to standard temperature and sunlight in a greenhouse of Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia.

Characteristic indicators of *R. apiculata* propagules maturity were red cotyledon and green to brown hypocotyls, 1.3-1.7 cm diameter, 20-25 cm long; mature *R. stylosa* propagules were yellowish green hypocotyls and greenish yellow cotyledon in color, 20-30 cm long and 1.5-2.0 cm diameter. While mature propagules of *C. tagal* were characterized by yellow cotyledon or brownish green hypocotyls, 0.8-1.2 cm diameter, up to 25 cm or more long. Mature seeds of *A. marina* were light green or yellowish green fruit husks, 1.5-2.5 cm long and 1.5-2.0 cm wide; *A. alba* seeds maturity were yellowish green pericarp, 1.5-2.0 cm wide, 2.5-4.0 long, while *A. ilicifolius* seeds maturity were 2.5-3 cm long and 10 mm in diameter. An artificial seawater solution was set by liquefying a commercial salt powder (Tropical Marine Salt, Thailand) to regulate the salt concentrations to 0.0%, 0.5%, 1.5%, 2.0% and 3.0% (equal to sea water level) in line with the company's procedure. Each bottle was waterlogged with 1000 mL artificial seawater solution.

The salinity in this experiment was denoted as the mass of salt powder of solution [6]. In each bottle pot, the treatment of salinity was checked every week during the research with an S/Mill-E salinity refractometer and adjusted accordingly. Thirteen to thirty-two seedlings per procedures were grown for three months. Subsequently, after three months of growth, the six mangrove seedlings were collected and sprayed with tap water to rinse out excess salts. Seedlings were separated into the leaves, stems, and roots were kept at 20 ºC for advanced investigation.

2.2. Growth measurements
The growth of *Av. marina, Av. alba, Ac. ilicifolius, C. tagal, R. apiculata,* and *R. stylosa* seedlings under varied salinity level was defined by the stem height and diameter of the plants at the end of experiments [6]. The height of individual shoots was measured from initiated shoot elongation (cotyledonary ring) to the apical bud. Stem diameter was measured using the digital caliper. Thus, the stem heights and diameters of six mangrove species (13-32 seedlings each treatment) after three months of planting were the indices of growth in this study.

2.3. Mangrove habitat zonation
To test consistently experimental observation in a greenhouse with field experiments, we measured salt concentrations when seeds and propagules were collected. Using a grouping of greenhouse and field experimentations, the functional responses to salinity is reflected by growth and habitat zonation. Zonation in this study is termed as the assembling species or group of species at a particular site concerning advancement being expectable [7]. We draw the schematic profile of mangrove distributed in Sembilan Island, Langkat, and Sei Percut Tuan, Deli Serdang, North Sumatra according to optimum growth along with salinity measurements in the field.

2.4. Data analysis
The data were evaluated by one-way analysis of variance (ANOVA) followed by Dunnett's test for assessments of all treatments (salt-treated) against the control. The values of $P< 0.01$and $P< 0.05$ were selected as standards of statistical significance. All statistical analyses were carried out using the SAS 9.1 statistical software program (SAS Institute Inc. Cary, NC, USA).

3. Results and discussion
The results were discussed in three subsections: the effect of salinity on seedlings growth, natural distribution and habitat zones, and conservation consideration.

3.1. Effect of salinity on seedling growth
Seedling growth was quantified by the height and diameter of the plants as shown in Materials and Methods. As depicted in Figure 1, the growth of mangrove seedlings appeared to show variation among species. The plant height and diameter of two salt secretor species of *A. marina* and *A. alba* were elevated in the occurrence of salt with the highest stimulus at 2.0%. This escalation was reduced when salt concentration was increased above 2.0% (Figure 1 A and B).

In contrast with this observation, the growth of two non-salt secretor species of *R. apiculata* and *R. Stylosa* expressively grew up 1.5% salinity, then decreasing with enhancing salinity (Figure 1). On the other hand, the less salt tolerant of mangrove species was shown by a salt secretor species of *Ac. ilicifolius* and a non-salt-secretor of *C. tagal*, which their optimum growth of plant height and diameter was at 0.5% salinity (Figure 1).

Overall, the growth responses changed among the species, signifying interspecific morphological elasticity for six mangrove species among the salinity treatments. Mangrove species frequently display growth prompt at low salinity (25% seawater/0.5% salinity concentration) and midway salinity (50% seawater/1.5% salinity) and at that moment a weakening in growth with advance increasing in salinity levels [8-9]. Nevertheless, the variety of salinity in which the mangrove plant can survive varies in relation to the species [9]. This work proposed that mangrove seedlings endured adjusting either in saline or freshwater condition.

Our existing work also well supported the previous studies on the best growth at 0.5% salt concentration in *K. candel* and *B. gymnorrhiza,* correspondingly [5]. The growth of both species faintly enhanced elimination subsequently elimination to salinity [10]. Likewise, the prime germination at 1.5% salinity concentration found in *A. marina* and *R. stylosa* seedlings developed in a greenhouse [6]. Seedling growth and establishing would extend mangrove spreading and upsurge reforested mangrove as well as the land facility.

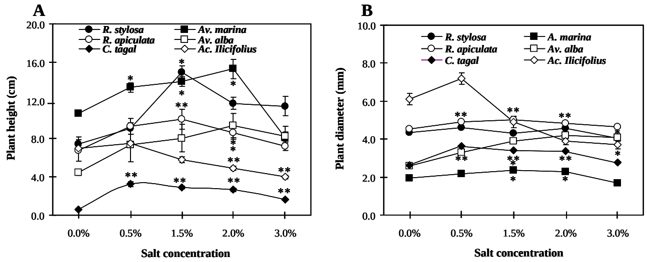

Figure 1. Effect of salinity on plant height (A) and plant diameter (B) in *Av. marina* (■), *Av. alba* (□), *R. apiculata* (○), *R. stylosa* (●), *C. tagal* (♦) and *Ac. ilicifolius* (◊) seedlings. The data are expressed as the means ± SE (*n*= 13-32); ***P*< 0.01, **P*< 0.05 compared with the control group (0%) by Dunnett's test.

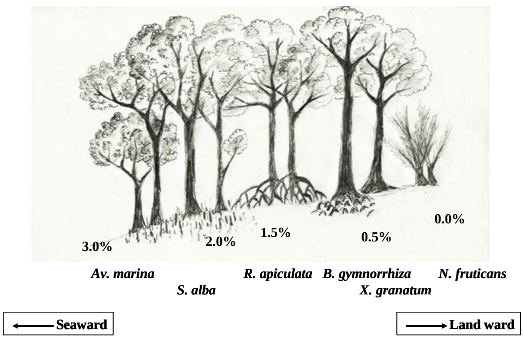

Figure 2. Schematic and generalized profile of mangrove plants distributed naturally in Sembilan Island, Langkat, North Sumatra, Indonesia. The coastal zone is usually *Avicennia* or *Sonneratia.*

3.2. Natural distribution and habitat zones

Figures 2 and 3 show schematic and generalized profile of mangrove plants in Sembilan Island, Langkat, and Sei Percut Tuan, Deli Serdang North Sumatra, Indonesia. Mangrove communities regularly reveal a discrete pattern of species dispersal. However, the reality in the field is often not as simple as stylized diagrams (Figures 2 and 3), and instead of flora composition typically, depicts some overlay between zones [11]. It has been proposed by [7] that the causes of species zonation have emerged based on the concept of plant succession, geomorphology, physiological ecology, and population dynamics.

However, several studies have been reported that zonation in mangrove forests regularly have been recognized to the reactions of individual species to the difference in the grade of local tidal inundation or salinity that diverge certainly through the intertidal [11-12]. Therefore, in this form the efficacy in which each mangrove species bears salinity circumstances mostly defines its intertidal situation and the nature of morphological altered [12]. In case of North Sumatran mangrove (Figures 2-3), estuarine regions are predisposed by the open-coastal environment devouring the similar salinity states as that of the sea and certain species of *Avicennia, Sonneratia*, with their adaptive mechanism to resist the high salinity levels [12]. In contrast to this observation, the innermost riverine site improves a stage of salinity concentrations because of amplified freshwater current. This area exists many mangrove species, such as *Rhizophora*, *Bruguiera*, *Ceriops*, *Kandelia*, *Xylocarpus*, and others, displaying diverse adaptive mechanisms for tolerating salinity levels, form a different zone on this shielded part of the riverine scheme [12].

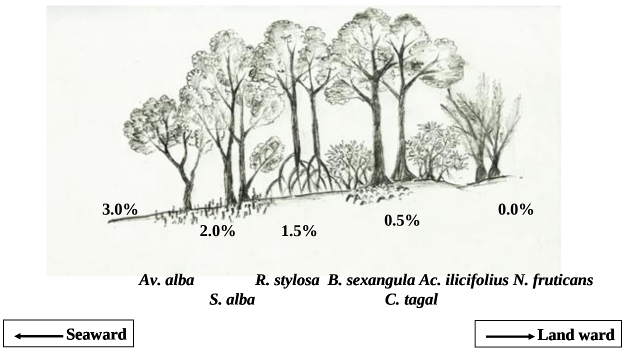

Figure 3. Profile diagram of mangrove plant represents species distribution in Sei Percut Tuan, Deli Serdang, North Sumatra.

3.3. Conservation consideration

Mangroves are disappearing all over the world nowadays attributable to direct and indirect utilization. In North Sumatra, mangroves have been degraded by human activities such as illegal logging, conversion to aquaculture pond, oil palm plantation and urban development [3-4]. The conversion of mangrove forest to aquaculture and oil palm estate significantly reduced forest biodiversity and carbon storage of mangrove forest biomass [3-4,13]. Therefore conservation determinations of mangrove resources are done not only to prevent extinction but also to confirm the readiness of resources for the following practice over alteration to environmental changes.

In this context, the replanting and restoration should be employed positively using the suggested species for degraded parts based on salinity adapted, habitat zones, and the availability of mangrove propagules or seeds in the area. In the forest area, land-uses were endorsed in the procedure of a green belt, while in the non-forest regions; alternate land uses might also reflect the character of land effectiveness and objective of the local community that has dynamic persistence, as well as protection purposes, such as directing the activities of silvofishery and ecotourism in mangrove forests [15,16].

4. Conclusion

The current findings supported the previous results on the salt tolerance of mangrove species in Okinawa, Japan [6]. In the case of North Sumatran mangrove, within the range salinity treatments, the tolerance of mangrove species to salinity followed the sequence of *Av. Alba* and *Av. marina*>*R. apiculata* and *R. stylosa*>*C. tagal*>*Ac. ilicifolius*, which is supporting their natural species distribution and habitat zones. This study also suggested the relevant data for the restoration effort in North Sumatra.

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