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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 7 (10): 1801-1807, 2004
ISSN 1028-8880

A Preliminary Study of the Biological Aspects of an Intertidal Seagrass *Thalassia hemprichii* (Ehrenberg) Ascherson in Port Dickson, Malaysia

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Abstract: Seagrass is a valuable component contributing significantly to coastal productivity and stabilising sea floor sediments in the shallow coastal marine ecosystems. The present field case study was conducted in a monospecific patch in an intertidal seagrass bed in Port Dickson, Malaysia. Shoot density and biomass of *Thalassia hemprichii* were measured using 20x20 cm quadrats. Leaf growth and productivity of *T. hemprichii* were studied using leaf-marking method. During low tide period the habitat of this species was observed by snorkeling. The mean shoot density of *T. hemprichii* was 632.14±113.77 shoots/m^2, with mean above ground biomass measured at 13.87±1.17 g AFDW (ash free dry weight)/m^2 and mean below ground biomass 40.19±7.93 g AFDW/m^2. The mean leaf growth was 7.04±1.35 mm/shoot, where maximum leaf growth was recorded 11.45 mm/shoot. The mean leaf production was 0.56±0.17 g AFDW/m^2/day, where the maximum leaf production was measured at 1.00 g AFDW/m^2/day. Turnover rate and relative production rate (RPR) were measured at 3.68±0.79 percent/day and 0.07±0.03 g/g AFDW/day, respectively. Plastochrone interval of *T. hemprichii* leaf (PIL) during the study period was 12.03±1.01 days. Leaves of *T. hemprichii* beneath the shading of macro-algae (*Sargassum* sp.) were comparatively longer than those existing without such shading condition. There are 8-19 horizontal rhizome nodes within two shoots and this indication that two shoots of *T. hemprichii* were separated at this distance.

Key words: Seagrass, production, biology, *Thalassia hemprichii*, Malaysia

INTRODUCTION

Seagrasses are common in shallow marine water throughout the temperate, sub-tropical and tropical regions of the world[1]. Almost all seagrasses require an unconsolidated soil substratum in which they are able to secure by roots and rhizomes systems[2]. Unlike marine algae seagrasses have root systems to gain footholds in drifting sand, subsequently stabilizing the substrates. However, the roots and rhizomes of seagrasses penetrate into the soil substrate and deposit organic matter directly.

The meadows of seagrass have been recognised as one of the richest and most productive marine ecosystems, reaching large biomass and being relatively long live components of coastal and estuarine ecosystems[3,4]. Their role in the cycling of essential elements (i.e. nitrogen and phosphorus) is important owing to their ability to accumulate these elements, affecting the nutrient turnover in these systems. Seagrass beds are one of the most conspicuous and widely spread biotope types in the shallow marine environment throughout the world. A dense vegetation of seagrass produces a great quantity of organic material and also offers a good substrate for epiphytic smaller algae, diatoms and sessile fauna. This vegetation also acts as traps for sediment and minute suspended particles in its ambient environment[5].

The data on seagrasses in the marine environment of Malaysia is inadequate. So far studies have been conducted on ecology[6], photosysthesis[7,8], distribution[9] and penology[10] of seagrasses in Malaysian marine water. However, data on biomass, growth and productivity of seagrass is still meager in this region. Therefore, this study have been undertaken to investigate the shoot density and the shoot biomass of seagrass *T. hemprichii* (Ehrenberg) Ascherson in the seagrass bed of Port Dickson, Malaysia, and to measure the leaf growth, leaf production, turnover rate and other related factors of this seagrass in the existing natural habitat. The data gathered from this study were expected to be valuable in the understanding of the dynamics, habitat of a biological community and its contribution in a shallow marine coastal ecosystem of Port Dickson.

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MATERIALS AND METHODS

This study was conducted from August 1998 to July 1999 in the coastal area of Teluk Kemang in Port Dickson, Negeri Sembilan, Malaysia (2°27′N latitude and 101°51′E longitude). Mixed stands and monospecific forms of seagrass on sandy muddy bottom substrates and rubbles were found in this study area. The seagrass *T. hemprichii* was found in sandy coarse (90 - 92% sand) and sandy loamy (88.70% sand) substrates. There are 7 species of seagrass communities along with seaweeds were found in Teluk Kemang and they were *Halophila ovalis* (R. Br.) Hook. f., *Halophila decipiens* Ostenfeld, *Cymodocea serrulata* (R. Br.) Aschers. and Magnus, *Thalassia hemprichii* (Ehrenberg) Ascherson, *Halodule pinifolia* (Miki) den Hartog, *Enhalus acoroides* (L. F.) Royle and *Syringodium isoetifolium* (Aschers.) Dandy[9]. The most abundant seagrass species is *Halophila ovalis*, which was found living as monospecific communities and as mixed stands with other species. *H. ovalis* appeared to be less dominant as mixed stands in shallow water shoreward region [depth 0.2 m during high spring low period (HSLW)] but dominant in seaward region with greater depths of >0.2 m HSLW as mixed stands with *H. decipiens*.

Seagrass from different habitat: The area of seagrass bed is about 5000 m^2. Monthly sampling was not conducted since the methods used were destructive and the seagrass bed was small. *In situ* study of seagrasses from different habitats such as beneath the macro-algae and open stand were also carried out in the field. The leaf length (cm), rhizome internode length (cm) and shoot scars were measured and recorded from randomly selected seagrasses in every habitat. Rhizome length recorded was the distance between two seagrass shoots while the horizontal shoot scar numbers for *T. hemprichii* recorded was the interval of two shoots.

Seagrass parameters

Shoot density: At the study site, shoot density was measured using 20x20 cm quadrats. Ten quadrats were used to collect the samples. Seagrasses were sampled in a non-random fashion because of the patchy distribution of plants. Seagrass specimens were selected when available. All living plant materials within each quadrat were removed and analyzed in the laboratory. Shoot density was carefully counted for each quadrat. The shoot numbers recorded from the individual quadrat was expressed as density (shoot/m^2).

Seagrass biomass: For biomass study, seagrasses collected by quadrats were rinsed briefly under running tap water. Leaves and sheaths for above ground biomass were separated from roots and rhizomes for below ground biomass. Epiphytes or algal communities were removed carefully from the plants through scraping using a knife. These materials were then dried in the oven at 80°C for 48 h to obtain dry weight (DW) and then at 500°C for 4-5 h to obtain ash free dry weight (AFDW). The data obtained from this study were expressed in term of production per unit area (g/m^2).

Leaf growth and production: For leaves growth study, the making method by Zieman[11], which was modified by Kirkman and Reid[12] was used. All leaves of 10 shoots (≥3 leaves per shoot) within the 10x10 cm of 15 quadrats were marked at the base with a syringe needle. The reference quadrats were marked by PVC pipe. After 14 days all marked shoots were harvested and processed in the laboratory. Leaf biomass was measured and calculated using the formula described by Erftmeijer *et al.*[13]. To calculate leaf production and RPR (the amount of plant materials produced by every gram of plant material in a given time) the formula described by Dennison[14] was used. PIL (the time interval between the initiations of two successive leaves on one shoot) calculation was based on formula described by Jacobs[15].

RESULTS AND DISCUSSION

Seagrass from different habitat: Morphological variations were observed for *T. hemprichii* growing in different habitats in this study area. Comparatively, the leaves of *T. hemprichii* living shaded beneath the macro-algae were found to be longer than those without shading. The mean lengths of outer leaves number 1, 2 and 3 were measured at 8.508±0.234, 075±0.436 and 5.791±0.663 cm, respectively for plants growing in shading or beneath the canopy of macro-algae. Mean lengths were recorded as 6.975±0.743, 7.625±1.103 and 5.716±0.985 cm for outer leaves number 1, 2 and 3, respectively in unshaded areas. The leaf lengths in communities of *T. hemprichii* showed variation (t-test, $p > 0.05$) between those living within the macro-algae shaded and unshaded areas. This variation may be attributed to competition for light by plant growing under shading condition. Walker *et al.*[16] stated that the large seagrasses found in Australian water were due to shading. Their study also found that the plants showed a morphological change and increasing leaf dimensions in plants collected in the shade of over hanging rock and seagrass leaves were longer under the canopy than above bare sand.

Similar to the leaf dimensions, the uncovered rhizome internode lengths of *T. hemprichii* by sediments were

Table 1: Leaf growth rate (mm/shoot/day), leaf production (g AFDW/m^2/day), shoot biomass (mg AFDW/shoot), turnover rate (percent/day), relative production rate (g/g AFDW/day) and plastochrone interval of leaf (days) of *T. hemprichii* in Port Dickson seagrass bed

Study areas	Leaf growth	Leaf production	Shoot biomass	Turnover rate	Relative production rate	Plastochrone interval of leaf	Authors
Port Dickson, Malaysia	7.04±1.35	0.56±0.17	8.47±1.88	3.69±0.79	0.07±0.03	12.03±1.01	This study
South Sulawesi, Indonesia	15.7±0.21	3.5±0.6^a	ND	ND	0.039±0.101	10.1±1.06	Erftmeijer *et al.*[13]
WC Island, Micronesia	1.7-4.30	ND	ND	ND	ND	ND	Ogden and Ogden[33]
Bootless Bay, PN Guinea	8.4	2.90±0.37	17.8-36.7	2.97	ND	9.73	Brouns[27]
Bootless Bay, PN Guinea	ND	2.5	66	ND	0.043	101	Brouns[45]
Bootless Bay, PN Guinea	9.4±1.0	ND	ND	ND	ND	ND	Brouns[46]

a = mg AFDW/m^2/day, ND= Not detected

Table 2: Shoot density (shoots/m^2), above ground (AG) biomass and below ground (BG) biomass (g AFDW/m^2) of *Thalassia hemprichii* in Port Dickson seagrass bed

	Shoot density		AG biomass		BG biomass			
Study areas	Mean	Maximum	Mean	Maximum	Mean	Maximum	AG : BG	Author
Port Dickson, Malaysia	632.14±113.77	850	4.794±1.430	7.780	9.228±2.910	14.170	1: 2.07	This study
Urukthapel, Western Caroline Islands	610±165	ND	31±12^a	ND	145±35^a	ND	1: 4.68	Ogden and Ogden[33]
Bootless Inlet, PN Guinea	864	1040	56±10.45	81±15	336±83	ND	1: 6.0	Brouns[47]
South Sulawesi, Indonesia	2414±642	3700	71±23	ND	427±128	ND	1: 6.04	Erftemeijer[48]
P. Sipadan, Sabah, Malaysia	ND	ND	34.7±5.0	ND	111.5±16.2	ND	1: 3.20	Norhadi[26]
Banten Bay, Indonesis	342	464	47.35^a	67.7^a	143.2^a	194.3^a	1:3.02	Kiswara[18]
Loloata Island, PN Guinea	991.67	2060	102.67±11	103±12	417±39.33	ND	1: 4.08	Brouns[27]

a = g DW/m^2, ND = Not detected

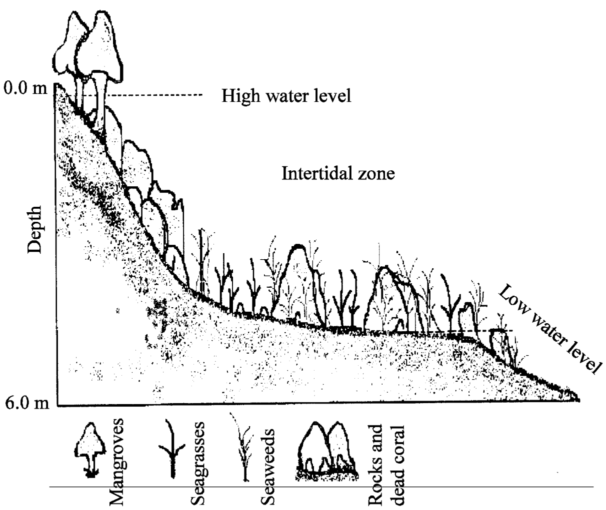

Fig 1: Schematic zonation pattern of seagrasses bed at Port Dickson, Malaysia (not in scale)

found to be longer than the covered rhizomes. The mean length of rhizome was 4.942±0.593 cm while the mean shoot scars number was 13.584±2.277. It is possible to say that uncovered rhizomes are able to grow more freely in the seagrass bed compared to the sediment-covered rhizomes. Coral rubbles in the seagrass bed could be another probable cause in restricting the free growth of seagrass rhizomes.

Seagrass parameters

Shoot density: *T. hemprichii* was found to grow as monospecific patches in Teluk Kemang inner intertidal and subtidal area where there was sandy coarse and sandy loamy soil substrates (Fig. 1). The mean shoot density of *T. hemprichii* was 632.14±113.77 shoots/m^2 (Table 2) and this value was higher than the recorded value from tropical seagrass bed at Seribu Island and Banten Bay, Indonesia[17,18]. Nienhuis *et al.*[19] stated that the shoot number per surface area is species dependent and the range of the shoot numbers is extremely variable. This statement was found to be consistent with the results obtained in this study.

Shoot density is a parameter of the community structure, which is often used as a rough estimation for standing stock[20]. It was found that above ground biomass (AGB) increases with shoot density for *T. hemprichii* ($r=0.431$, $p<0.05$). Below ground biomass (BGB) also showed positive correlation ($r=0.730$, $p<0.05$) with shoot density. This relationship revealed that any natural stresses on these parameters may affects on the biomass and productivity of *T. hempricii* in this marine ecosystem. Backman and Barilotti[21] found a linear relation between dry biomass and shoot density in the seagrass *Zostera marina* bed of Southern California. With experiments in shading and unshaded areas, they showed that shoot density was a function of light irradiance the plants received and the same relationship existed with increasing depth[15]. Giraud[22] also observed the same phenomenon in the beds of seagrass, *Posidonia oceanica* (L.) Delile, in the Mediterranean and where an increasing depth resulted in a decreasing number of shoots. In the Philippines, seagrass shoot density was found to be directly associated with water temperature and *Thalassia* has the widest range of temperature tolerance i.e. 35°C[23].

The shoot numbers and biomass (AGB plus BGB) was positively correlated for *T. hemprichii* ($r=0.882$, $p<0.05$), indicating that the species biomass is dependent on the production of shoot numbers.

Seagrass biomass: The AGB of *T. hemprichii* was measured from *in situ* collected samples by quadrats and by the multiplication of shoot density with the mean biomass of 150 marked shoots. The AGB for *T. hemprichii* calculated from marked shoots is higher (20.86±3.69 g DW/m^2) than the biomass derived from quadrats. This variation may be due to the differences between marked mature (more than 3 leaves) shoots and immature shoots biomass collected from the quadrat samples.

During the study period, the AGB was recorded as 13.878±1.173 g AFDW/m^2, which is equivalent to 26% of ash free total dry weight biomass of this species. In comparison with reported studies of seagrass beds of other tropical areas, the AGB of *T. hemprichii* in this study was lower than the value reported for the same species in Sabah, Malaysia; South Sulawesi, Indonesia; Loloata Island, Papua New Guinea (Table 1). In Caribbean seagrass bed, the mean AGB for the pure stand of *T. testudinum* was ranged between 126 and 450 g DW/m^2, which is higher than the present study (19.05±2.58 g DW/m^2)[11,24]. This difference may be due to the morphological variation (i.e. leaf length, leaf width and leaf thickness), which was directly or indirectly affected by bottom substrates and also environmental factors within the habitat. Perhaps, the sandy coral rubble substrate may not be very suitable for vegetative propagation of seagrass resulting in the patchiness appearance of seagrass in the study area.

The mean value of BGB (rhizome and roots) of *T. hemprichii* was 49.43±8.83 g DW/m^2 (40.199±7.937 g AFDW/m^2) in the Teluk Kemang seagrass bed. In contrast, a higher total biomass of 68.47±10.72 g DW/m^2 (54.077±8.917 g AFDW/m^2) was recorded for *T. hemprichii* compared with other seagrass *C. serrulata* growing in this seagrass bed[25]. Of this biomass, 74% of total dry material was below ground biomass. The BGB percentage of *T. hemprichii* in this study was comparable to the percentage of total biomass (76%) of the species reported in the seagrass bed of Sabah, Malaysia[26]. Based on the statistics computed, the BGB showed positive correlation with the ABG of *T. hemprichii* ($r=0.664$, $p<0.05$).

The seagrass *T. hemprichii* has a ratio of AGB:BGB of 1:2.897. Brouns[27] showed much higher ratio (1:4.08) for the same species. Kiswara[18] estimated a 1:3.02 of AGB:BGB ratio in the seagrass bed of Indonesia. However, it may be say that the variations in seagrass biomass were dependent on the species type and their environmental conditions such as water quality and circulation, sediment status and nutrient content. Seagrass leaf biomass was greater in the thick sediment of the bank compare to the thinner sediments of the basin[26]. Sediment depth and water depth have also been recognized as important factors in controlling seagrass biomass[28,29]. Seagrass beds or habitats bordered by mangroves were found to provide dense biomass in shallow marine ecosystem[19,26]. Higher biomass of the belowground materials may provide a better anchorage for the plants and a higher storage capacity for carbohydrates and nutrients[30,31]. Furthermore, the root to shoot ratio may change with seasons. Comparing the BGB (1:1.50) of *C. serrulata*[25], the present study indicates that root and rhizome of *T. hemprichii* (1:2.87) was more developed than *C. serrulata*. It was assumed that *T. hemprichii* may be a better species in consolidating the sediment of areas exposed to erosion. Besides providing organic detritus and habitats for microorganisms in the marine environment, the above and belowground plant parts served to function in reducing water current velocity and in stabilizing the soft sea bottom. These activities also served to reduce the surface erosion of coastal floor[5]. In this regard, seagrasses have been recognized as a suitable natural tool for coastal zone management to prevent sea bottom erosion[32].

Leaf growth and production: The maximum growth rate of *T. hemprichii* was observed at 11.45 mm/ shoot/day, with a mean value of 7.04±1.35 mm/shoot/day. Leaf growth rate was not significantly different between quadrats (ANOVA, $p>0.05$, $n=150$). The leaf growth rate of *T. hemprichii* in the study area was lower than those reported from the South Sulawesi, Indonesia and Bootless Bay, Papua New Guinea (Table 1). Ogden and Ogden[33] found that the growth rates varied from 1.2 to 4.3 mm/shoot/day, which is considerably lower than the rate measured in this study (7.04±1.35 mm/shoot/day). This difference may be due to environmental factors or the geographical location of the respective seagrass bed. On the other hand, previous studies showed that the growth of seagrass meadows was strongly affected by light and nutrient availability[34,35], temperature[36], sedimentation[37] and turbulence[38,39]. Leaf production of *T. hemprichii* in this study showed positive correlation ($r=0.60$, $p<0.05$) with leaf growth rates and shoot biomass relied on the leaf growth ($r=0.40$, $p<0.05$) indicating constant growth activity of the seagrass during the study period. Any stress such as grazing, damaged of leaves due to wave actions and human activities on leaf growth will affect the productivity and biomass (standing crop) of *T. hemprichii.*

The leaf production of *T. hemprichii* varied from 0.6–1.8 mg DW/shoot/day (0.41–1.46 mg AFDW/shoot/day) with the mean value of 1.13±0.03 mg

DW/shoot/day (0.89±0.27 mg AFDW/shoot/day) in this study area. The aerial production value that was calculated from the mean shoot density (632.14±113.77 shoots/m^2) was 0.71±0.02 g DW/m^2/day or 0.56±0.17 g AFDW/m^2/day. The production of leaf blade material was closely related ($r=0.707$, $p<0.05$) to the shoot biomass of this seagrass. Similar relationship ($r=0.84$) was found for *T. hemprichii* in Bootless Bay, Papua New Guinea[27]. The daily leaf production rate (0.56±0.17 g AFDW/m^2/day) of *T. hemprichii* in this area was lower than Bootless Bay, Papua New Guinea (Table 1). Brouns[27] suggested that the production of *T. hemprichii* of seagrass bed of Papua New Guinea was influenced by tidal fluctuation. However, in the seagrass beds of Philippines, the day length and number of extreme low tides during daytime were found to be the most influential factors creating negative effects on the seagrass production[23].

The mean value of turnover rate was calculated at 3.69±0.79 percent/day for *T. hemprichii.* Turnover rate commonly used to describe seagrass growth is defined as the specific leaf production rate of 100%. This rate is equivalent to the production biomass (P/B) ratio[27]. Turnover rate of *T. hemprichii* was positively correlated with leaf production ($r=0.639$, $p<0.05$). The turnover rate of *T. hemprichii* was lower compared with another seagrass *C. serrulata*, which is growing in this seagrass bed[25]. Zieman *et al.*[40] estimated that the turnover rate of *T. testudinum* was 1.85–2.4 percent/day in the seagrass bed of Florida Bay, USA and 3.0 percent/day in the Papua New Guinea[27]. The turnover rate of 1.2 percent/day was recorded for *T. testudinum* in Cuba[41]. The estimated mean turnover rate (3.69±0.79 percent/day) of *T. hemprichii* in this study was higher than the estimated value of Brouns[27], Zieman *et al.*[40] and Buesa[41]. This variation revealed that tropical seagrass *T. hemprichii* has a higher rate of production all year around compared to seagrasses of subtropical and temperate regions[27,42].

The relative production rate (RPR) for *T. hemprichii* was in the range of 0.02-0.16 g/g AFDW/day, with a mean value of 0.07±0.03 g/g AFDW/day (0.06 g/g DW/day). The estimated value of RPR of *T. hemprichii* in this study was comparable with other reported studies (Table 1). *T. hemprichii* showed greater RPR than *C. serrulata* in this seagrass bed[25]. This proved that based on RPR value, *T. hemprichii* produced more organic matter daily than *C. serrulata* in this study area. The mean value of plastochrone interval of leaves (PIL) during the study period was 12.03±1.01 days for *T. hemprichii* in this study area. The greater PIL of seagrass would probably allow more epiphytes attachments, which is an important food source for marine fishery resources[43]. The present estimated PIL value of *T. hemprichii* was higher than the values reported in Bootless Bay, Papua New Guinea and South Sulawesi, Indonesia (Table 1). However, the short plastochrone intervals (e.g. leaf plastochrone interval=12.03±1.01 days) of *T. hemprichii* allow a faster plant response to growth than the long plastochrone intervals (e.g. leaf plastochrone interval=28 days) of larger seagrass such as the eelgrass, *E. acoroides* found in the study area[25]. Duarte[39] stated that the length of plastochrone interval, which is strongly species specific, would limit the capacity of plants to respond to environmental variabilities. The short plastochrone interval of small seagrasses allows faster plant responses to seasonal fluctuations than the long module plastochrone interval of larger seagrasses. In addition, the very long plastochrone intervals of large seagrasses could effectively buffer seasons, environmental variabilities, leading to the limited seasonality observed for Mediterranean seagrass and may uncouple seasonal growth patterns from environmental forcing[44].

ACKNOWLEDGMENTS

Authors are grateful to the Department of Biology, Universiti Putra Malaysia for providing facilities. We are also indebted to two anonymous referees for their valuable comments and suggestion to improve this manuscript. This research is funded by Malaysian Government through Intensification of Research in Priority Areas (IRPA) Projects no. 08-02-04-019.

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