DOI: 10.13656/j.cnki.gxkx.1998.01.017
广西科学 Guangxi Sciences 1998, 5 (1): 58~ 61

Morphological Character and Biomass of *Rhizophora stylosa* Seedlings*
红海榄幼苗的形态特征及其生物量

Liang Shichu
梁士楚

(Guangxi Mangrove Research Center, Nanzhulu, Beihai, Guangxi, 536007)
(广西红树林研究中心 北海市南珠路 536007)

Abstract The morphological character and biomass of one-year-old *Rhizophora stylosa* seedlings were investigated. The measuring data contained both morphological variables, such as plant height, stem height, basal diameter of stem, number of nodes, number of leaves, root length, root height and leaf area, and biomass of root, hypocotyl, stem, leaf and the whole plant. Based on the data observed, 34 regression models on the morphological variables and biomass of the seedlings were set up using linear, multilinear and non-linear regression.

Key words *Rhizophora stylosa*, seedlings, morphological character, biomass, regression models

摘要 对红海榄 1年生幼苗的株高、茎高、基径、节数、叶数、根长、根高和叶面积等主要形态因子以及根、胚轴、茎、叶等器官的生物量进行了测定。根据实测的数据,采用一元线性、多元线性和非线性回归进行拟合,得到 34个红海榄幼苗主要形态因子和生物量的回归模型。

关键词 红海榄 幼苗 形态特征 生物量 回归模型
中图法分类号 Q 948.885.31

Mangroves are salt-tolerant forest ecosystems occurring in the intertidal zones of tropical and subtropical coasts. They possess very important social, economical and ecological benefits for the coastal population. Unfortunately, human's activities, such as shrimp farming, salt manufacturing, agricultural expansion and urbanization, have caused a colossal loss of mangroves in many related maritime countries. Even the remaining mangroves are degraded by unreasonable exploitation and utilization. It is urgent to stop destroying mangroves, and to conserve and restore the forest. Usually, mangrove seedling survival is poor, the natural regeneration of mangroves is relatively slow. We need to have a greater knowledge of the growth laws of mangrove seedlings. Therefore, an intensive program has been undertaken and the results are presented in a series of papers of which this one deals with the morphological character and biomass of one-year-old *Rhizophora stylosa* seedlings.

1 Materials and methods

On September 4, 1994, over 200 mature viviparous seedlings of *Rhizophora stylosa* were collected from their parent trees in Shankou mangrove nature reserve, Beihai, Guangxi, China (21°26′N, 109°43′E), and transplanted into 5 liter plastic plots (with perfortated bases) filled with sand. The plots were placed into other larger plastic plots and irrigated with nature sea-water. About one third of the hypocotyls of the viviparous seedlings was embedded in the sand. On September 5, 1995, 60 plants of viable undamaged seedlings were harvested. The following primary data were collected: plant height (H), stem height (SH), basal diameter of stem (SD), number of nodes (NN), number of leaves

1997-05-13收稿。
* Sponsored by the National Science Foundation of China (No. 39360019).

(LN), leaf area (LA), root length (RL), root height (RH), and dry weight of root (W_r), hypocotyl (W_h), stem (W_s), leaf (W_l) and whole plant (W_t). Root systems were carefully washed free from sand using a spray gun. Dry weight was determined after 72 hours in an oven at 80℃. Leaf area was calculated using a linear regression formula of leaf areas (LA) on leaf fresh weight (WFL)[1,2]. The relationship between leaf area and leaf fresh weight of one-year-old *Rhizophora stylosa* seedlings is shown in Figure 1.

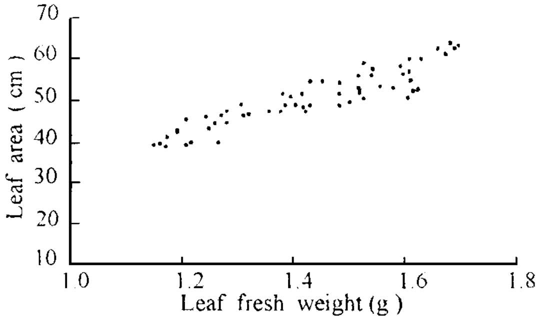

Fig. 1 Linear relationship between leaf area and leaf fresh weight of one-year-old *Rhizophora stylosa* seedlings

2 Results

2.1 Morphological statistical parameters and relative growth models

Eight morphological variables of one-year-old *Rhizophora stylosa* seedlings were measured quantitatively, with the results summarized in Table 1. It is evident from Table 1 that the statistical parameters show the patterns of:

(1) median of mode interval > arithmetic mean > median for height of plant and root;

(2) median of mode interval > arithmetic mean = median for stem height;

(3) arithmetic mean > median > median of mode interval for basal diameter of stem and leaf area;

(4) median > median of mode interval > arithmetic mean for root length;

(5) arithmetic mean = median = median of mode interval for number of nodes and leaves.

Four regression models, (1) $y = a + bx$, (2) $y = ax^b$, (3) $y = a(D^2H)^b$, (4) $y = a + b_1x_1 + b_2x_2$, were applied to the analyses of morphological variables measured. Based on the data observed, 6 fittest regression models are built up:

$H = 3.8308LA^{0.4330}$ ($r = 0.5549, s = 4.2557, RE = 0.060$)

$H = 35.2544 - 7.0369D + 0.0510LA$ ($r = 0.5947, s = 4.2435, RE = 0.059$)

$D = 0.4728 + 0.0002LA$ ($r = 0.2897, s = 0.0510, RE = 0.067$)

$D = 0.5055 - 0.0010H + 0.0003LA$ ($r = 0.3002, s = 0.0512, RE = 0.067$)

$LA = 216.4053(D^2H)^{0.2846}$ ($r = 0.5066, s = 54.0098, RE = 0.078$)

$LA = 3.7918 + 31.9303WF1$ ($r = 0.9229, s = 2.2699, RE = 0.037$)

2.2 Biomass and regression models

The statistical characteristics of biomass of one-year-old *Rhizophora stylosa* seedlings are shown in

Table 1 Statistical parameters of main morphological variables of one-year-old *Rhizophora stylosa* seedlings and their biomass

Item	Morphological variable								Biomass (g)				
	Plant height (cm)	Stem height (cm)	Basal diameter of stem (cm)	Node number	Leaf number	Leaf area (cm^2)	Root length (cm)	Root height (cm)	Root	Hypocotyl	Stem	Leaf	Whole plant
Sample size	60	60	60	60	60	60	60	60	60	60	60	60	60
Minimum	47.5	24.3	0.480	7	6	399.28	18.3	5.5	6.572	9.197	2.225	4.363	24.945
Maximum	72.5	37.5	0.712	11	16	720.40	32.7	10.5	10.824	18.421	3.587	7.905	40.226
Median	57.1	34.3	0.583	8	12	498.25	27.3	8.0	8.894	12.958	2.891	5.454	30.395
Mode interval	55.9~58.7	33.5~35.8	0.558~0.584	8	12	471.28~507.28	26.3~27.9	8.5~9.1	8.937~9.410	11.247~12.272	2.681~2.833	5.151~5.545	30.039~31.737
Frequent	0.27	0.35	0.33	0.75	0.27	0.27	0.27	0.25	0.33	0.27	0.17	0.27	0.28
Arithmetic mean	57.2	34.3	0.599	8	12	513.29	26.7	8.1	8.817	13.101	2.757	5.348	30.459
Standard deviation	4.6703	3.0798	0.0458	0.7471	2.2270	55.8210	4.3059	1.4755	1.4891	2.0048	0.3989	0.6182	2.9117
Variation coefficient	0.0816	0.0898	0.0765	0.0934	0.1856	0.1088	0.1613	0.1822	0.1689	0.153	0.1447	0.1156	0.0956

Table 1. Dry weight of hypocotyl, leaf and stem show a pattern of arithmetic mean> median> median of mode interval, root of median of mode interval > median> arithmetic mean, and whole plant of median of mode interval> arithmetic mean> median. The organ biomass of the seedlings is in order of hypocotyl> root> leaf> stem, their distribution ratio being 4.3 ∶ 2.9 ∶ 1.8 ∶ 0.9. Of all organs, hypocotyl is the largest in biomass, this fact indicating that hypocotyls not only help viviparous seedlings to naturally plant in soft intertidal environments, but also play very important roles in the establishment of a plumula into a shoot system.

One object of the biomass study of mangrove seedlings is to build up a related regression model that can help us to find out their growth laws. On the other hand, the model built can be used as an indirect method to estimate the biomass of seedlings that are of the same species and of an age, and grow in the similar habitat. Each organ biomass of the seedlings is expressed by four types of regression models: (1) $W = a + bD$, (2) $W = aD^b$, (3) $W = a(D^2H)^b$, (4) $W = a + bD + cD^2$. The results are shown in Table 2. For root and stem biomass, all the models are significant at 0.01 level. For hypocotyl bimass, no models are significant at acceptable confident limits. For leaf biomass, models (1) and (2) are significant at 0.01 level. For whole plant biomass, model (3) is the only regression that is significant at acceptable confident limits. As for the precision of a regression model, it is dependent mainly on its correlation coefficient, r, and relative error, RE. It is evident from Table 2 that the models that are at higher significant levels have r values ranging from 0.2911 to 0.8669 and RE values from 0.042 to 0.091.

In order to understand the relative growth character of organ biomass of the seedlings, the following correlative models are established.

(1) Regression models between whole plant biomass and above- and underground organ biomass

$W_t = 19.6366 + 1.2274W_r (r = 0.4471, s = 2.6573, RE = 0.069)$

$W_t = 16.4148 + 1.0720W_h (r = 0.8253, s = 1.6775, RE = 0.042)$

$W_t = 19.0195 + 3.9152W_s (r = 0.4875, s = 2.5938, RE = 0.068)$

$W_t = 15.7815 + 2.6123W_l (r = 0.6069, s = 2.3612, RE = 0.062)$

$W_t = 5.2863 + 0.9551W_h + 2.2806Ws + 1.0671Wl (r = 0.9461, s = 0.9760, RE = 0.025)$

Table 2 Biomass regression models for organs of one-year-old *Rhizophora stylosa* seedlings

Organ	Regression model	r	s	RE
Root	$W_r = 3.6786 + 8.8739D$	0.4218	0.9812	0.091
	$W_r = 11.8822D^{0.5933}$	0.4104	0.9838	0.091
	$W_r = 3.7997(D^2H)^{0.2770}$	0.4511	0.9616	0.085
	$W_r = 15.0009 - 29.0029D + 30.9407D^2$	0.4308	0.9852	0.091
Hypocotyl	$W_h = 16.0460 - 4.9134D$	- 0.1144	2.2727	0.142
	$W_h = 11.4805D^{-0.2282}$	0.1172	2.2782	0.140
	$W_h = 12.8917(D^2H)^{-0.0006}$	0.0007	2.2952	0.142
	$W_h = 49.1799 - 114.8782D + 90.5444D^2$	0.1662	2.2751	0.144
Stem	$W_s = -0.0618 + 4.9781D$	0.7166	0.2580	0.066
	$W_s = 4.9840D^{1.0508}$	0.7249	0.2595	0.065
	$W_s = 0.5810(D^2H)^{0.5338}$	0.8669	0.1884	0.042
	$W_s = -6.6759 + 26.5972D - 17.8011D^2$	0.7314	0.2544	0.064
Leaf	$W_l = 3.3575 + 3.7726D$	0.2911	0.6603	0.085
	$W_l = 6.9109D^{0.4147}$	0.3116	0.6594	0.083
	$W_l = 2.3520(D^2H)^{0.2869}$	0.5075	0.5954	0.088
	$W_l = -21.7956 + 87.2511D - 68.7358D^2$	0.4206	0.6316	0.081
Whole plant	$W_t = 23.0201 + 12.4117D$	0.2225	2.8963	0.073
	$W_t = 34.3007D^{0.2391}$	0.2200	2.9005	0.072
	$W_t = 17.8080(D^2H)^{0.1767}$	0.3829	2.7373	0.070
	$W_t = 35.7379 - 29.7964D + 34.7539D^2$	0.2253	2.9197	0.073

(2) Regression models between organ biomass

$W_s = 1.5527 + 0.1553W_r$ ($r = 0.4543, s = 0.3295, RE = 0.093$)

$W_l = 4.1110 + 0.1710W_r$ ($r = 0.2681, s = 0.6649, RE = 0.089$)

$W_l = 2.4971 + 1.0683W_s$ ($r = 0.5726, s = 0.5658, RE = 0.077$)

3 Discussion

The adaptation of plants to environment is mainly to increase their fitness. For example, one-year-old *Avicennia marina* seedlings can grow the pneumatophores, flower and fruit, and produce viviparous seedlings which after maturation, can directly develop into new seedlings[2]. These are very important ecological and biological characteristics of mangroves adapting the continuously changing intertidal environments. Due to the presence of selective pressure, plants have to make adaptive responses, which constitute life history strategy[3]. In mangroves, seeds of some species, especially species in the family Rhizophoraceae, germinate while they are still attached to the parent trees. Such seedlings are called viviparous seedlings. Vivipary in mangroves has popularly been considered as an adaptation to the intertidal environment, allowing rapid growth of seedling roots after settling[4,5]. For one-year-old *Rhizophora stylosa* seedlings, the ratio of root to shoot biomass is 1.03, that is the biomass of underground parts is higher than that of aboveground parts. Establishment of the seedling is critical in the life cycle of all seed plants, but it is rendered difficult for mangroves by the unstable, variable substrates and the tidal influence. *Rhizophora stylosa* is a typical viviparous mangrove species, and produces viviparous seedlings consisting of an elongated hypocotyl with a plumula. shoot development does not occur until roots become established in the soil. The long hypocotyl may reach 50 cm in length[1,4], and may simply be a means of producing a large seedling that is less likely to be damaged by water movements. On the other hand, the hypocotyl may help to expose the shoot system of the seedling to atmosphere, at least at low tide. Therefor, the length of a hypocotyl may aid seedlings in overcoming the problems of anaerobic soils and in anchoring the plants in the often-fluid soils. Furthermore, the heavier hypocotyls are capable of taking root in both deep and shallow water because their weight affords a resistance to tidal buffeting.

In studying plant biomass, basal diameter and plant height are the variables relatively easily determined, which are often used as independent variables to fit a related regression equation. The fitted model is a better indirect method employed to estimate the quantitative characteristics of other relative growth factors, based on the data of basal diameter and plant height. Thirty-four regression models on the morphological variables and biomass of one-year-old *Rhizophora stylosa* seedlings were set up using linear, multilinear and non-linear regression, but only twenty-six out of which are significant at acceptable confident limits. Of the four types of regression models, only model (3), $W = a(D^2H)^b$, is suitable to fit the biomass of all organs except hypocotyl at significant levels. The biomass of a hypocotyl is dependent mainly on its developed length while they are still attached the parent trees, and therefor related less with the basal diameter and plant height of the seedling.

References

1 Liang Shichu. A study on growth relationship of some mangrove seedlings in Yingluo Bay, Guangxi. Journal of Guangxi Academy of Sciences, 1995, 11(4, 5): 48~53.

2 Liang Shichu. Morphological character and biomass of *Avicennia marina* seedlings. Chin J Appl Ecol, 1996, 7(4): 344~348.

3 Ban Yong. Evolution of life history strategy in plant. Chinese Journal of Ecology, 1995, 14(3): 33~39.

4 Lear R, Tumer T. Mangroves of Australia. University of Queensland Press, 1977, 30~81.

5 Clough, B F. Mangrove systems in Australia. Australian National University Press, 1982. 151~191.

(责任编辑: 蒋汉明)