

The growth of *Kandelia candel* seedlings in mangrove habitats of the Zhangjiang estuary in Fujian, China

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Abstract: Propagules of *Kandelia candel* collected from the Zhangjiang estuary were planted in mangrove habitats along the intertidal gradient. The rooting rates of *K. candel* propagules varied spatially. The lowest rate occurred in *Avicennia marina* forest (69.7%). The rates were higher in *K. candel* forest (90.0%), at the fringe of the mangrove forest (89.3%) and on the bare tidal flat outside the mangrove forest (82.7%). After one year, the survival rates of seedlings planted under *A. marina* forest, *K. candel* forest, at the fringe of the mangrove forest, and on the bare tidal flat were 13.7%, 54.7%, 76.0%, and 34.7%, respectively. Among the surviving *K. candel* seedlings, those at the fringe of the mangrove forest and on the bare tidal flat had greater height, stem diameter, leaf number, leaf area, and biomass than those under *A. marina* and *K. candel* forests. These results demonstrated that establishment and growth of *K. candel* seedlings occurred successfully at the fringe of the mangrove forest, but were the worst under *A. marina* forest. The performance of *K. candel* seedlings was independent of physico-chemical characters of sediment. However, interspecies competition, propagule predation by insects and crabs, and the incident light had significant effects on seedling survival and growth.

Key Words: mangroves; *Kandelia candel*; growth; Fujian (Zhangjiang estuary)

1 Introduction

Mangrove vegetation can be observed in tropical and subtropical marine intertidal zones, which plays an important role in the ecological protection of the coastline. As a result of being submerged by seawater periodically, mangrove species exhibit unusual reproductive adaptation to vivipary that enables them to grow in the intertidal habitat^[1]. Thus the viviparous hypocotyl, seedling and sapling are important stages in the population regeneration of mangrove systems^[2]. The study on propagule dispersal, establishment, and early growth stages of mangrove species may help explain the distribution and zonation patterns of adult stands of mangroves^[3].

The establishment and early growth of mangrove seedlings are influenced by a number of biotic and abiotic factors. Factors known to affect these processes include: light availability^[4–7], soil characteristics^[4,6,8–11], tidal current^[8,12], salinity^[4,7,13], animal predation^[14–17], propagule size^[17–19], propagule dispersal properties^[3,20,21], interspecific competition^[8,22], and so on.

In this study, a field experiment was carried out in Zhangjiang Estuary Mangrove National Natural Reserve Fujian, Yunxiao county, Fujian, China. Different sampling sites along the intertidal gradient were selected from the forest region to the bare tide flat area. The survival of propagules of *Kandelia candel*, the growth of its seedlings, and ecological factors in each sampling site were monitored at specific time intervals. The aim of our study was to evaluate the establishment and early growth of the mangrove species *K. candel* in the intertidal zone, and to develop a better understanding of the biotic and abiotic factors influencing the regeneration of its seedlings. These findings would help restoration and afforestation of the local mangrove ecosystems.

2 Materials and methods

2.1 Study site

The study was conducted in Zhangjiang Estuary Mangrove National Natural Reserve Fujian, Yunxiao (23°55'N, 117°26'E), Fujian, China, with a subtropical marine monsoon climate.

Annual mean air temperature was 21.2°C, the highest monthly mean temperature was 28.9°C (in August), and the lowest monthly mean temperature was 13.5°C (in January). Annual mean rainfall was 1714.5 mm. The surface seawater temperature ranged between 14.9 and 25.6°C, and the salinity of the seawater ranged between 12 and 26. Tides were semidiurnal and the tidal variation ranged between 0.43 and 4.67 m with a mean tidal variation of 2.32 m. And the tidal level ranged between 2.00 and 2.80 m with a mean sea level of 0.46 m (the mean sea level of the Yellow Sea as the sea level datum)^[23].

The sampling sites were chosen beside the Zhuta village, Dongxia town, China after an investigation of the whole reserve area. The mangrove forests are characterized by a belt (105 m in width) of mainly *K. candel* and *Avicennia marina* along the shore, and the substrate surface is relatively flat. From a horizontal distance of 0 to 20 m downshore stands the *A. marina* forest, from 20 to 40 m stands the *K. candel* forest, and from 40 to 100 m stands the *A. marina* forest. From 105 to 120 m stands salt marsh of *Spartina alterniflora*. Between the forest fringe and the salt marsh, *K. candel* and *Aegiceras corniculatum* occur as scattered, individual saplings. Three transects were established running from landward to seaward (0–120 m), and the beach profile of the sampling sites were measured (Fig. 1). At the seaward site of 120 m, the beach mudflat elevation was 1.03 m (0.57 m elevation above the mean sea level). All the sampling sites regularly experience tidal water twice daily.

On the basis of the “Vegetation of China”^[24], there are two vegetation types (mangrove and salt marsh) in this study site. The mangrove includes *K. candel* formation and *A. marina* formation, and the salt marsh is composed of *S. alterniflora* formation.

(1) *K. candel* formation: Dominated by *K. candel*, and interspersed with less common *A. corniculatum*. 3 to 6 m in height (the mean height 4.5 m), the mean DBH 5.7 cm, the canopy

density 80%, and the density of adult trees 30 individuals per 100 m².

(2) *A. marina* formation: Dominated by *A. marina*, and interspersed with less common *K. candel* or *A. corniculatum*. 1.5 to 3.0 m in height (the mean height 2.4 m), the mean basal trunk diameter 14.0 cm, the canopy density 70%, the density of adult trees 15 clusters per 100 m², and the density of straw-like roots (pneumatophores) (472 ± 63) individuals per m².

(3) *S. alterniflora* formation: *S. alterniflora* forms the monospecific community 1.5 to 2.0 m in height, and the canopy density 80% to 90%. Seedlings of *A. corniculatum* or *K. candel* scattered around the community.

2.2 Experimental design

2.2.1 Establishment, growth, and survival of seedlings

The appropriate time to collect and plant the propagules of mangrove species is at the initial stage or during the metaphase when the propagules begin to be detached from the trees. The propagules are mature and in good conditions, and tend to settle down in the substrate^[25]. It is suitable to collect the propagules of *K. candel* between the first ten days of March and the first ten days of May in the Zhangjiang estuary in Fujian, China. On April 11, 2002, 600 mature, undamaged propagules of *K. candel* were collected from trees near the study area. These propagules were weighed (mean fresh weight (14.35 ± 2.27) g), their lengths were measured (mean length (22.24 ± 1.66) cm), and they were planted the next day.

On the basis of the status of the beach profile and the vegetation zonation, the fringe with a horizontal distance from 0 to 20 m down-shore and the bare tidal flat with a horizontal distance beyond 120 m down shore are disturbed by humans. So the field experiment was conducted at positions with a horizontal distance from 20m to 120 m down-shore. From the landward sampling site under *K. candel* forest with a horizontal distance of 25 m down-shore, eight sampling sites (from S1 to S8) were established at 10m to 15 m intervals along the intertidal gradient in the study areas. Each sampling site established three parallel quadrats (1 × 1 m² in size) at 5 m intervals

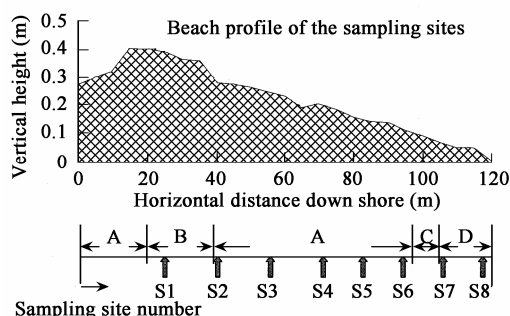


Fig. 1 Beach profile, vegetation zonation, and horizontal distance of sampling sites location down shore at Zhuta of Yunxiao, Fujian, China (A: *Avicennia marina* forest; B: *Kandelia candel* forest; C: fringe; D: *Spartina alterniflora*)

Table 1 Horizontal distance down shore and vegetations of sampling sites

Sampling site	Horizontal distance down shore (m)	Vegetation zonation
S1	25	<i>Kandelia candel</i> forest
S2	40	boundary between <i>K. candel</i> and <i>Avicennia marina</i> forest, under <i>K. candel</i> forest
S3	55	<i>A. marina</i> forest
S4	70	<i>A. marina</i> forest
S5	85	<i>A. marina</i> forest
S6	95	<i>A. marina</i> forest, 5 m inside the forest fringe
S7	105	forest fringe
S8	120	bare tidal flat outside the <i>Spartina alterniflora</i>

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