

## 論 文 要 旨

## Abstract

## 論文題目

Title Production ecology of the pioneer mangrove *Kandelia candel* (L.) Druce stands

Production ecological studies of a pioneer mangrove of *Kandelia candel* (L.) Druce at Manko Wetland, Okinawa Island, were carried out. The interception of photosynthetic photon flux density (PPFD) by the canopy, carbon and nitrogen stocks, allometric relationships, population structure, biomass allocation, litterfall, and aboveground net primary production were investigated. The apparent light extinction coefficient  $K$  and the light extinction coefficient of woody organs  $K_C$  were  $0.502 \pm 0.041$  (mean  $\pm$  SE)  $\text{m}^{-2} \text{m}^2$  and  $0.785 \pm 0.046 \text{m}^{-2} \text{m}^2$ , respectively. The light extinction coefficient of leaves  $K_F$  was  $0.427 \text{m}^{-2} \text{m}^2$  from the indirect method,  $K_F = K - aK_C$  ( $a$  is a proportional constant of cumulative wood area density  $C$  to cumulative leaf area density  $F$ ) and  $0.432 \pm 0.026 \text{m}^{-2} \text{m}^2$  from the direct method,  $I_R / I_{Rc} = \exp(-K_F F)$  ( $I_R$  and  $I_{Rc}$  represent relative PPFD, respectively before and after artificial leaf defoliation). The sun leaves contained significantly higher amount of C and N than the shade leaves. There were strong relationships of the relative PPFD to the C ( $R^2 = 0.702$ ,  $P < 0.05$ ) and N ( $R^2 = 0.908$ ,  $P < 0.01$ ) contents of leaves on a leaf area basis. Using these relationships, C or N in leaves of the whole canopy were estimated as  $3.553 \text{Mg ha}^{-1}$  and  $104.6 \text{kg ha}^{-1}$ , respectively. The C pools in aboveground ( $35.12 \text{Mg ha}^{-1}$ ) and belowground ( $26.89 \text{kg m}^{-2}$ ) biomass were nearly similar. Soil C pool ( $58.91 \text{Mg ha}^{-1}$ ) was almost equal to the C pool ( $62.01 \text{Mg ha}^{-1}$ ) of biomass, indicating that the mangrove forest stored a huge part of C in the soil. The N pools in aboveground ( $442.0 \text{kg ha}^{-1}$ ) and belowground ( $312.1 \text{kg m}^{-2}$ ) biomass were also nearly equal. The soil N stock was  $2545 \text{kg ha}^{-1}$ , which was very high in comparison with the N stocks in biomass ( $754.1 \text{kg ha}^{-1}$ ). In the allometric relationships, the independent variable  $D_{0.1}^2 H$  ( $D_{0.1}$  stem diameter at a height of  $H/10$ ,  $H$  tree height) showed better accuracy of estimation for phytomass and leaf area than  $D^2$  ( $D$ , DBH) or  $D^2 H$ . The  $M-w$  diagram plotted on a log-log coordinates indicates that the mangrove stand consisted of only one stratum. The  $m^*-m$  analysis showed a single individual random distribution for only the main stems. When the forks under breast height were counted as individual trees, it showed a compact colony random distribution. Self-thinning line showed a slope of  $-1.3$  closer to  $-4/3$ , indicating that monospecific stands of the mangrove follow the self-thinning rule. The estimated biomass allocation in leaves, branches, stems, roots, top and total were  $5.609$  (3.68%),  $28.76$  (18.9%),  $46.14$  (30.2%),  $71.82$  (47.2%),  $80.51$  (52.8%) and  $152.3 \text{Mg ha}^{-1}$  (100%), respectively. Biomass density per unit of mean tree height was  $22.3 \text{Mg ha}^{-1} \text{m}^{-1}$ . Aboveground net primary production (ANPP) was  $29.9$  and  $32.2 \text{Mg ha}^{-1} \text{yr}^{-1}$ , respectively based on the stem analysis and the field measurement. Litterfall rate showed a strong seasonality with a peak at the end of summer (August-September). A large proportion of litterfall (ca. 68.3%) was represented by leaves and the total amount of annual litterfall constituted ca. 33.1 to 35.7% of the ANPP.

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本申請論文は那覇市と豊見城市に跨る漫湖湿地（1999年にラムサール条約に登録された）に生育するマングローブ（メヒルギ）林の生産生態学的研究を実施したものである。その研究成果は、以下のように要約される。

1. マングローブに関しては世界で始めて群落光合成生産に関与する葉のみの（非同化器官の遮光を除いた）吸光係数の測定を行い、メヒルギは陽樹である特性を反映して林冠の内部まで強い光を透過する生産構造を持っていることを明らかにした。

2. 樹木個体の各器官（葉、枝、幹）重量及び葉面積を推定するために、樹高  $H$ 、胸高直径  $D$ 、樹高の1割高での幹直径  $D_{0.1}$ 、生枝下高での幹直径  $D_B$  及びそれらの組み合わせを独立変数とし各器官重、葉面積を従属変数とする相対成長関係を調べた。その結果、従来  $D$ 、 $H$ 、 $D_B$  及びこれらの組み合わせを独立変数とする相対成長式よりも、 $D_{0.1}^2 H$  を独立変数とする相対成長式が各器官重及び葉面積を推定するために最適であった。

3. 陸上の森林の地下部バイオマスは地上部バイオマスの2-3割であるのに対して、メヒルギ林の地下部バイオマスは地上部バイオマスにほぼ等しく、地下部に多量の光合成生産物を分配し、泥質土壌において地上部を支えることを可能にしていた。

4. 湿地に生育しているため土壌は酸素欠乏状態にあり土壌中に堆積された有機物は分解が進まず、土壌中の炭素蓄積量はバイオマスの炭素蓄積量にほぼ等しかった。これは、土壌微生物の活性が低いため土壌中の炭素蓄積量が多くなる亜寒帯林と同様な炭素蓄積様式であり、メヒルギ林が亜熱帯域にあるにもかかわらず、温暖化ガスである  $\text{CO}_2$  の吸収源として、また、炭素の貯蔵庫として有効に機能していた。

5. 年輪測定に成功し、メヒルギ林の成長曲線を世界で始めて明らかにすることにより、メヒルギ林が高い一次生産力を持っていることを実証した。

以上のような新しい知見の内、2報が既に公表されていること。また、8月10日に行なわれた口頭発表、それに引き続いて行なわれた質疑・応答の結果を考慮して、審査委員会は本申請論文が博士号（Ph.D.）を与えるに十分な内容であると判断し、学位論文及び最終試験を合格と認定した。

(様式第5-2)

17年 8月 12日

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学位 (博士) 論文審査及び最終試験の終了報告書

学位 (博士) の申請に対し、学位論文の審査及び最終試験を終了したので、下記のとおり報告します。

記

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成績評価	学位論文 (合格) 不合格	最終試験 (合格) 不合格
論文題目	Production ecological studies on a pioneer mangrove <i>Kandelia candel</i> (L.) Druce stand at Manko Wetland, Okinawa Island	
審査要旨 (2000字以内)		

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The light extinction coefficient of leaves ( $K_f$ ) excluding the light attenuation by woody organs is one of the most important parameters for estimating the canopy photosynthetic production. Reported database says that the  $K_f$  value for the *K. candel* stand is the first time for mangrove forests. As compared with some terrestrial broadleaf forests, the mangrove stand showed low  $K$  (apparent light extinction coefficient) and  $K_f$  values indicating that high PPFD penetrates into the mangrove canopy, which confirms the heliophyllic nature of the species. Although mangroves flourish in the high temperature zones, the large storage of organic C and N in the soil indicates the slow decomposition rate of soil organic matter in mangroves. The high belowground biomass storage (low top/root ratio) and high top/ $H$  ratio of mangroves indicates that mangroves play a significant role in carbon sequestration and amelioration of greenhouse effect. Instead of DBH or  $D^2H$ ,  $D_{0.1}^2H$  was found to be the most suitable independent variable in the allometric equation for estimating the biomass and leaf area index of *K. candel* stands. The two methods (stem analysis and field measurement) for estimating biomass increment yielded closer values. This suggests the applicability of annual ring analysis to the mangroves in the subtropical regions. The high growth efficiency of *K. candel* makes it highly productive species. The *K. candel* may be recommended as a suitable species for the rehabilitation program of degraded mangrove habitats and for mitigating the global degradation of mangroves.

This study brought about some new findings about production properties of *K. candel* as mentioned above. Therefore, the thesis committee judged that this thesis is satisfactory in scope and quality as a dissertation for the degree of Doctor of Philosophy in the field of Marine and Environmental Sciences.