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PHENOLOGICAL TRAITS OF MANGROVE *Kandelia obovata* GROWN IN MANKO WETLAND, OKINAWA ISLAND, JAPAN

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Abstract

Phenological traits of *Kandelia obovata* (S., L.) Yong was investigated on the basis of seasonal leaf recruit, leaf death and leaf growth. The seasonal leaf growth was estimated using the logistic growth curve. Leaf recruitment, leaf death and reproductive cycle were obtained by survey data. This study results showed that new leaf recruitment occurred during the year indicating high productivity of mangrove *Kandelia obovata* forest. The highest leaf recruit was in July, while it was the lowest in January. However, the highest leaf death was in August, whereas it was the lowest in January. Growth pattern of leaves varied among seasons as of winter leaves are taken longger time to get their maximum size, while other season leaves are taken short time to get their maximum size. Period from flowering to mature propagules of *K. obovata* trees is considered to be around 12 months, while most the propagules become mature in the next spring season (April and May), which indicated shorter reproduction cycle.

Keywords : Phenological traits, Leaf recruitment and death; Leaf growth; Reproductive cycle; *Kandelia obovata*

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INTRODUCTION

Mangrove ecosystem plays important part in the global carbon cycle, and therefore occupies a position of increasing importance in the climatic debates and in the mitigation program. The mangroves play very important role in the coastal area as nursery grounds and breeding sites for various animals, a renewable resource of wood; sites for accumulation of sediment and nutrients and offer protection against coastal erosion, cyclones and tsunami (Twilley 1995). Mangrove forest is known to maintain the ecological equilibrium in coastal waters and preserve rich biological resources and species diversity (Saenger 2002). Productivity assesment of mangrove forest is one of the most vital keys for studying functions of mangrove forest ecosystem, and therefore, phenological study on mangroves is very important to know the mangrove productivity, material and nutrient cycling, as well as predicting mangrove adaptation to the climate change.

Mangrove phenology is an important subject for investigating the effect of climatic factors on mangrove growth and productivity. Phenological traits of mangroves are essential for understanding of mangrove's ability to adapt growth and breeding strategies to ambient conditions. Phenological traits on mangroves are known influenced by climatic factors like day length (Duke 1990), air temperature (Duke 1990;

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Fernandes 1999;) and rainfall (Fernandes 1999). Vegetative and reproductive phenologies of mangrove communities are known to linking with seasonal variations in temperature and rainfall (Fernandes 1999; Gwada et al. 2000; Carolina and Ertemeijer 2002).

Many phenological studies on mangrove forest are mentioned their seasonal trends of leaf recruit, leaf fall and reproduction cycle (Fernandes 1999; Gwada et al. 2000; Ochieng and Ertemeijer 2002; Coupland et al., 2003; Mehling 2006). However, the information of mangroves phenological traits in term of seasonal leaf area growth, leaf recruit and death together with repduction cycle is scare. These data are fundamental for assessing the effect of climatic factors on mangrove growth and productivity. Therefore, the objectives of this study was to elucidate the phenological traits of a *K. obovata* in term of seasonal patterns in leaf recruit, leaf death and leaf growth, as well as reproduction cycle.

MATERIAL AND METHOD

Study Site

This study was carried out from April 2005 to March 2006 at Manko Wetland, which is located in the southern part of Okinawa Island, Japan (26° 11′ N and 127° 40′ E). The Manko Wetland mangrove is dominated by *Kandelia obovata* (S., L.) Yong. The wetland has been recognized as an important area in the transit point or wintering area for migratory birds, and has been registered with the Ramsar Covention since 1999. This mangrove is monospecific dominant with crowded stands.

Leaf recruit, leaf death and leaf growth

One sample tree (tree height *H*, 3.1 m, stem diameter at 10 % of H $D_{0.1H}$, 4.1 cm) was selected for the direct observation of leaf recruit and survivorship. New leaves of the sample tree were labeled and recorded twice a month, while fallen leaves were monthly counted. Twenty newly flushed leaves from the sample tree respectively in April, August and October 2005, and January 2006 were chosen to pursue the growth of leaves, whose length and width were measured twice a week. The data of climatic factors were taken from Meterogical office, Naha City, Okinawa, Japan

RESULT AND DISCUSSION

Climatic factors

Figure 1 depicts monthly trends in climatic parameters at the study site including day length, global solar radiation, temperature, sunshine time, precipitation and relative humidity (Data from Okinawa Meteorological Observatory). Monthly mean temperature, global solar radiation and sunshine time were found to be the higher in July, while monthly mean day length, precipitation and relative humidity were found to be the higher in June. The lowest monthly mean temperature, global solar radiation, mean day length and mean relative humidity were in December. Monthly precipitation and sunshine time were the lowest in July and March, respectively.

Leaf recruit and death

Table 1 represents the seasonal leaf recruit and death in mangrove *Kandelia obovata* tree. Seasonal changes in leaf recruit and death varied throughout the year. The leaf recruit and death were the highest in summer (July or August), while were the lowest in January. The highest leaf recruit and death in summer may be due to the highest global solar radiation and monthly mean temperature (Fig. 2),

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which indicated that leaf recruit and death in mangrove *Kandelia obovata* synchronize with the seasonal changes in climatic factors.

Table 1. Monthly leaf recruit and leaf death of mangrove Kandelia obovata tree (Data April 2005-March 2006)

Month	Number of leaf recruit	Number of leaf death
April	125	25
May	88	45
June	102	53
July	157	96
August	57	151
September	79	63
October	111	57
November	54	56
December	33	31
January	22	9
February	30	19
March	65	18

Figure 3 depicts growth patterns of leaf area in different seasons. The growth process was well described with the logistic growth curve as follows:

$$u = \frac{U}{1 + k e^{-\lambda t}} \qquad (1)$$

where U, λ and k are the maximum leaf area, intrinsic rate of increase and constant, respectively. The growth patterns of leaf area showed unequal trends among seasons. The values of U, λ and k for spring leaves were estimated as 10.97 (cm^2), 0.081 ($cm^2\ d^{-1}$) and 2.53, respectively. In addition, the values of U, λ and k for summer leaves were estimated as 10.56 (cm^2), 0.10

of U, λ and k for winter leaves were respective estimated as 14.46 (cm^2), 0.054 ($cm^2\ d^{-1}$) and 4.42. The half-expansion period (t*) of leaf area is defined as:

$$t^* = \frac{\ln k}{\lambda} \qquad (2)$$

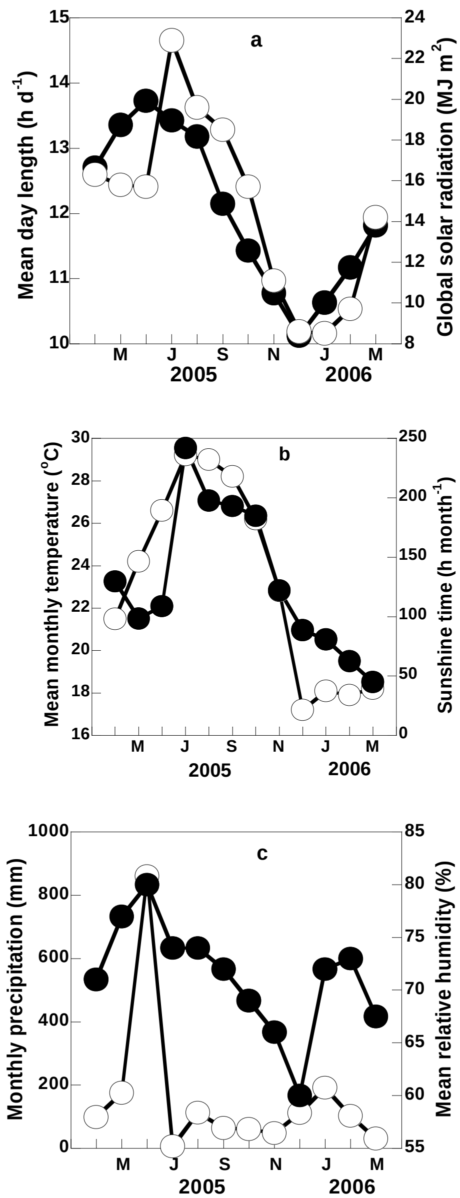

Figure 1.

(a) Seasonal patterns in total solar radiation ○ and day length ●,
(b) Seasonal patterns in sunshine time ○ and temperature ●
(c) Seasonal patterns in precipitation ○ and relative humidity ●.

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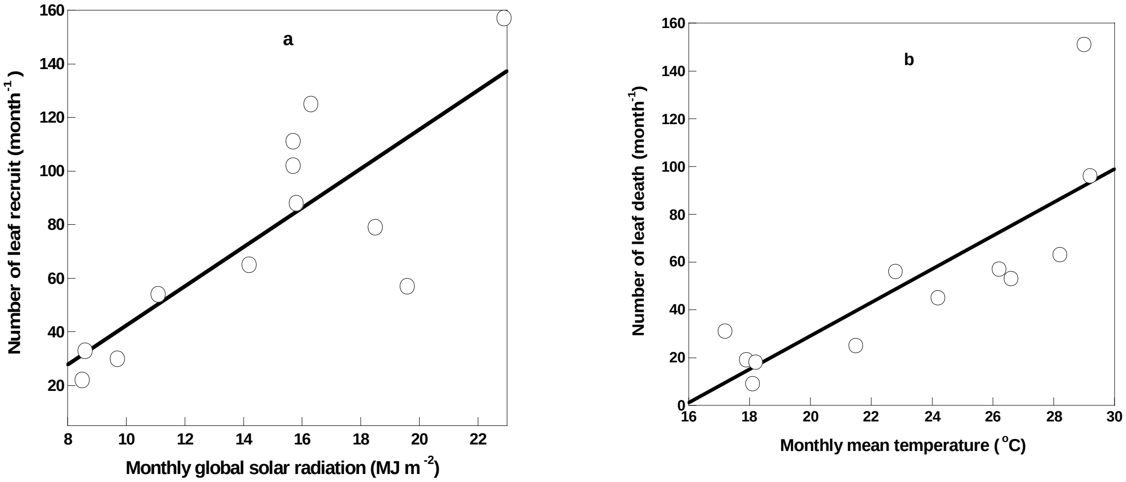

Figure 2. Relationships of leaf recruit and death to climatic factors: (a) Relationship of leaf recruit to global solar radiation, where $r = 0.799$, $p = 0.002$. (b) Relationship of leaf death to temperature, where $r = 0.816$, $p = 0.001$.

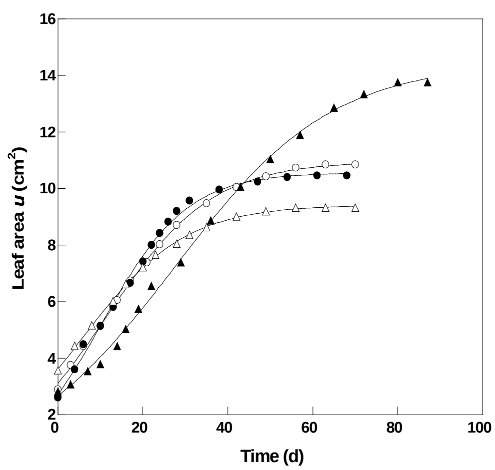

Figure 3. Seasonal patterns of leaf area growth: ○ Spring, ● Summer, △ Autumn and ▲ Winter seasons.

(cm^2 d^{-1}) and 2.89. The values of U, λ and *k* for autumn leaves were estimated as 9.42 (cm^2), 0.083 (cm^2 d^{-1}) and 1.61. On the other hand, the values

The values of half expansion periods of leaves growth were estimated as 11.5 days for spring leaves, 10.6 days for summer leaves, 5.8 days for autumn leaves and 27.5 days for winter leaves, respectively. The leaves recruited in spring, summer and autumn are grown faster, and taken short time to reach their maximum size. On other hand, the leaves flushed in winter seemed to be grow slower and taken longer time to get their maximum size. However, the autumn leaves showed the shortest half expasnion period. Therefore, it seems that growth patterns of leaf area of a *K. obovata* synchronize to the seasonal changes in climatic factors.

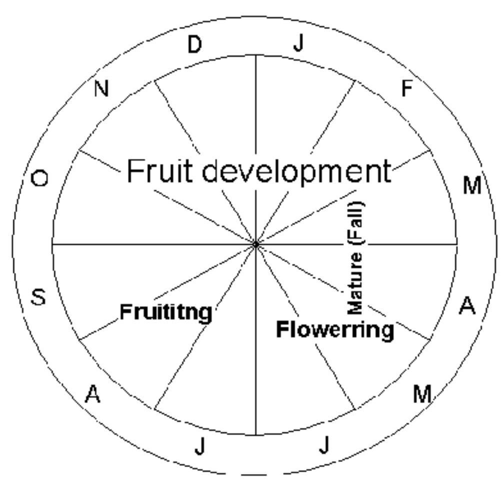

Figure 4. Reproduction cycle of a mangrove *Kandelia obovata* tree

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Figure 4 shows the reproduction cycle of a mangrove *K obovata* in Manko Wetland The flowering period occurs in spring, i.e. from April to June, while fruiting occurs in summer. However, propagules development is from summer (July) to spring (May) seasons. Most of propagules become mature in spring (April or May) of the next year, which indicates that reproduction cycle of a *K obovata* is approximately one year.

4. Discussion

The present study clearly showed the phenological traits of a mangrove *Kandelia obovata* (S., L.) Yong, which has been correlated with seasonal changes in climatic factors. Many studies reported that phenological events in mangroves and other tropical trees can be influenced by environmental factors like day length (Duke 1990; Rivera and Borchert, 2001), air temperature (Saenger and Moverley, 1985; Duke 1990; Fernandes 1999; Coupland et al., 2005) and rainfall (Fernandes 1999; Gwada et al. 2000; Ochieng and Ertemeijer 2002; Coupland et al., 2005) or water status (Naidoo, 1989). Our results suggest that phenological events of a mangrove *K. obovata* synchronize to the seasonal changes in climatic factors of Okinawa region, such as global solar radiation, temperature, sunshine time, precipitation and humidity.

The leaf recruit and death of a mangrove *K. obovata* are strongly correlated to the seasonal changes in global solar radiation (r = 0.799, p = 0.002; Fig. 2a) and temperature (r = 0.816, p = 0.001; Fig. 2b). Leaf recruit and death were the highest in summer, whereas the lowest in autumn. Similar trends in leaf production were observed by Gwada et al. (2000) in *Kandelia candel* at Sashiki village, Okinawa Island, Japan, by Lopez partillo and Ercura (1985) in *Avicenna germinants* in Mexico and by Ochieng and Erftemeijer (2002) in *Avicennia marina* at Grazi Bay, Kenya. However, different patterns in leaf recruit and death were observed by Coupland et al. (2005) in *Avicenna marina*, *Sonneratia alba* and *Rhizophora stylosa* and by Cristensen and Wium-andersen (1977) in *Rhizophora apiculata*.

New leaves recruitment in mangrove *Kandelia obovata* occur through the year, which indicates high productivity of mangrove in this region. It is different as compared with *Ceriops australis* at north-eastern Australia, which the canopy of *Ceriops australis* is effectively dormant for six months of the year during dry season (Duke et al., 1984). Leaf production in mangrove was very much tied to changes in temperature (Saenger and Moverley 1985). However, leaf flush in *Kandelia candel* at the Okinawan mangrove, Japan was most closely linked to temperature and humidity, the two factors being closely interdependent (Gwada et al. 2000). Similarly, Duke (1990) also reported that changes in temperature, rainfall and moisture level are likely to control mangrove leaf production. Although the leaf recruit and death of a mangrove *Kandelia obovata* were strongly linked to the seasonal changes in global solar radiation and temperature, the other factors, such as sunshine time, precipitation and humidity are probably among the important factors influencing the phenological events on mangrove trees in this region.

Trend in leaf area growth for a mangrove *Kandelia obovata* also synchronize to the seasonal changes in climatic factors. It appears that winter leaves are the longer leaf area growth and taken time to get their maximum size as compared the other seasons. Mehltreter and Palacios-Rios (2003) reported that monthly leaf growth of the mangrove *Acrostichum danaeifolium* grown in the Gulf of Mexico was significantly correlated with mean temperature and precipitation. In the present study, growth patterns of leaf area are probably linked to seasonal changes in temperature, precipitation and relative humidity. It shows that the averages temperature, precipitation and humidity in winter were about 18^{o}C, 135 mm and 71 %, respectively, and were probably effective for leaf area growth as compared with the other seasons.

The timing of the reproductive cycle of a *Kandelia obovata* is also seasonally. Flower occurs in spring (April-June), while propagules occurs in summer (July-August). Most the propagules become mature in the next spring season (April and May). It suggests that the period from flowering to mature propagules of *K. obovata* is considered to be around 12 months which is lower as compared to 3 years for *Rhizophora apiculata* and 1-1.5 year for *Bruguiera gymnorhiza*, *Cerip tagal* and *R. stylosa* (Hutchings and Saenger 1987), while it was slightly longer than 9 months for propagule development in *Avicennia marina* (Clarke and Myerscough 1991). Reproductive phenological of a *Kandelia obovata* forest was different as compared with the other mangroves, i.e. the flowering and fruiting patterns of Amazonian mangrove (*Avicennia*, *Rhizophora* and *Laguncularia*) occur throughout the year, which is the peak flowering and fruiting in dry period, and between the end dry period and the onset of the wet season (Fernandes 1999).

There might be existed some synchronizations between productions of flowers, fruits or propagules and leaves in mangrove *Kandelia obovata* forest. This study results suggest that production of vegetative and reproductive organs in a mangrove *Kandelia obavata* are probably inter-correlated in coordination each other. Duke et al. (1984) suggested that coordination between production of flower/fruit and leaves may be an indication of resource partitioning within plant. The potential resource partitioning within mangroves was observed by Coupland et al (2005) in *Sonneratia alba*, i.e. leaf recruit in *S. alba* was clear dejection during the time of peak flowering and fruiting.

5. Conclusion

New leaves recruitment in mangrove *Kandelia obovata forest* occur through the year indicating its high productivity. Leaf recruitment was highest in July (summer season), while it was lowest in January (winter season). The growth of leaves varied among seasons as of winter leaves are taken longger time to get their maximum size as compared other season leaves. However, larger leaf area was found for winter leaves, which is probably effective for *K. obovata* to capture as much as possible quite low radiation in winter compared with the other seasons. Period from flowering to mature propagules of *K. obovata* trees is considered to be around 12 months, while most the propagules become mature in the next spring season (April and May), which indicated shorter reproduction cycle.

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References

Alongi DM, Tirendi F, Clough BF. 2000. Below-ground decomposition of organic matter in forests of the mangrove *Rhizophora stylosa* and *Avicennia marina* along the arid coast of western Australia. Aquat Bot 68: 97-122

Clarke, P.J. and P.J. Myerscough (1991): Floral biology and reproductive phenology of *Avicennia marina* in southern Australia. Aust. J. Bot., 39, 283-293.

Coupland, T.G., E. I. Paling and K. A. McGuinness (2005): Vegetative and reproductive phonologies of four mangrove species from northern Australia. Aust. J. Bot., 53, 109-117

Christensen, B. and S. Wium-Andersen (1977): Seasonal growth of mangrove trees in southern Thailand. I. The phenology of *Rhizophora apiculata BL.* Aquat. Bot., 3, 282-286.

Duke, N.C. (1990): Phenological trends with latitude in the mangrove tree *Avicenna marina*. J. Ecol., 78, 113-133

Duke, N.C., J.S. Bunt and W.T. William (1984): Observation of the floral and vegetative phenologies of north-eastern Australia mangroves. Aust. J. Bot., 32, 87-99.

Fernandes, M.E.B. (1999): Phenological pattern of *Rhizophora* L., *Avicenna* L. and *Languncularia* Gaertn. F. in Amazonian mangrove swamp. Biotropica, 23, 555-567

Gwada, P., M. Tsuchiya and Y. Uezu (2000): Leaf phenological traits in the mangrove *Kandelia candel* (L.) Druce. Aquat. Bot., 68, 1-14

Hutchings, P. and P. Saenger (1987): Ecology of mangroves. University of Queensland Presss. St. Lucia, pp. 33-39.

Lopez-Partilo, J. and E. Ezcurra (1985): Litterfall of *Avicenna marina* L. in a one year cycle in a mudlat at the Laguna de Mecoancan, Tabasco, Mexico. Biotropica 17, 186-190

Mehling, U. (2006): Phenology of the red mangrove, Rhizophora mangle L., in the Caete estuary, Para, equatorial Brazil. Aquat. Bot., 84, 158-164.

Mehltreter, K. and M. Palacios-Rios (2003): Phenological studies of *Acrostichum danaeifolium* (Pteridaceae, Pteridophyta) at a mangrove site on the Gulf of Mexico. J. Trop. Ecol., 19, 155-162.

Ochieng, C.A. and P.L.A. Erftemeijer (2002): Phenology, literfall and nutrient resorption in *Avicennia marina* (Forsk.) Vierh in Gazi Bay, Kenya. *Trees*, 16, 167-171.

Rivera, G.. and R. Borchert (2001): Induction of flowering in tropical trees by a 30-min reduction in photoperiod: evidence from field observations and herbarium specimens. Tree Physiol., 21, 201-212.

Ross, M.S., P.L. Ruiz, G..J. Telesnicki and J.F. Meeder (2001):

ISSN: 2406-7334 | E-ISSN: 2406-7342 IJSTAS Vol: 2 No. 1 (2015) 89 - 96 |

Estimating aboveground biomass and production in mangrove communities of Biscayne National Park, Florida (U.S.A). Wetland Ecol. and Manage., 9, 27-37.

Saenger P (2002) Mangrove ecology, silviculture and conservation.Kluwer acadmic publisher.

Saenger, P. and J. Moverley (1985): Vegetative phenology of mangrove along the Queensland coastline. Proc. Ecol. Soc. Aust., 13, 257-265.

Twilley RR (1995) Properties of mangrove ecosystems related to the energy signature of coastal environments. In: Hall, CAS (Ed), maximum power: The idea and applications of HT Odum. University of Colorado Press, Boulder, pp. 43-62.

Wium-Andersen, S (1981): Seasonal growth of mangrove trees in southern Thailand. III. Phenology of *Rhizophora mucronata* Lamk. and *Scyphiphora hydrophylacea* Gaertn. Aquat. Bot. 10, 371-376.