BIOMASS CHANGES OF AN *ACACIA MANGIUM* PLANTATION IN SOUTHERN CHINA

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REN, H. & YU, Z. 2008. Biomass changes of an *Acacia mangium* plantation in southern China. *Acacia mangium* has been planted in large areas of southern China ever since its introduction into China in 1979. This article reports on *A. mangium* biomass accumulation over a period of 15 years in a plantation in southern China. The biomass of *A. mangium* increased from the first to the seventh year, after which the growth slowed down. Eleven-year-old *A. mangium* can facilitate the conversion of degraded lands into mixed native species forests. This paper also points out that N and P deficiencies may be an inhibitive factor to biomass growth.

Keywords: Biomass accumulation, vegetation recovery

REN, H. & YU, Z. 2008. Perubahan biojisim ladang *Acacia mangium* di selatan China. *Acacia mangium* telah ditanam di selatan negeri China sejak tahun 1979. Kertas kerja ini melaporkan timbunan biojisim *A. mangium* dalam tempoh 15 tahun di sebuah ladang di selatan China. Biojisim *A. mangium* meningkat dari tahun pertama ke tahun ketujuh tetapi kemudiannya menurun. Pokok *A. mangium* yang berusia 11 tahun dapat membantu menukarkan tanah ternyah gred kepada hutan beraneka spesies asli. Kertas kerja ini turut menunjukkan bahawa kekurangan N dan P mungkin merupakan faktor penghalang bagi pertambahan biojisim.

INTRODUCTION

Acacia mangium is an evergreen leguminous species native to northern Queensland in Australia and Papua New Guinea. It was introduced to Malaysia in 1966 (Norisada *et al.* 2005) and was subsequently used for large-scale planting in many countries in South-East Asia, tropical America and Africa. It was introduced to China in 1979 (Pan *et al.* 1996) and due to its numerous advantages such as wide adaptation, tolerance to drought, resistance to pests, soil-improving property due to nitrogen fixation, fast growth and high yield, it has been extensively planted in the tropical and subtropical zones of the country since the mid 1980s. By 2003, its total coverage area in China and southern Asia was more than 600 000 ha, making it one of the major timber species for plantation, second only to *Eucalyptus* (Ren *et al.* 1996).

Numerous studies of *A. mangium* have been carried out, e.g. on its biological properties (Ren *et al.* 1996), introduction and growth characteristics (Logan 1986, Ren *et al.* 1995, Paudyal & Majid 2000, Otsamo 2002), heredity (Atipanumpai 1989), resistance to plant diseases and insect pests (Irianto *et al.* 2006), biological nitrogen fixation (Ribet & Drevon 1996), biomass and productivity (Xu *et al.* 1998, Hogberg & Wester 1998, Ren *et al.* 2000), nutrition cycle (Li *et al.* 1990, Saharjo & Watanabe 2000), and restoration of degraded soil (Otsamo 2000, Norisada *et al.* 2005, He *et al.* 2006). In this study, biomass accumulation was monitored in an *A. mangium* plantation in southern China for a period of 15 years. In addition, we analyzed the underlying causes that inhibit biomass growth.

MATERIALS AND METHODS

Research site

The *A. mangium* plantation is located in Heshan Hilly Land Comprehensive Experimental Station, which lies in the Guangdong Province at approximately 112° 53' E and 22° 40' N. This

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experimental area features low, gentle hills and a mild climate, with an average annual temperature of 21.7 °C. The average annual rainfall is 1801 mm although it is not evenly distributed and the dry and wet seasons are distinct. Approximately 80% of the rainfall occurs during the monsoon. This area has reddish soil that is acidic and an organic matter content of 0.56–1.64%. The native vegetation is subtropical monsoon evergreen broad-leaved forest. A substantial part of the native vegetation has been degraded due to human disturbance (Ren *et al.* 1995).

The *A. mangium* plantation was established in 1984 on a low hill and it covered an area of 2 ha. Before reforestation, the area was covered with sparse *Pinus massoniana* forest. Then lumbering was conducted and planting holes with dimensions of 50 × 50 ×40 cm were dug. Each hole was filled with 1000 g organic fertilizer (approximately 0.64% P and 9.2% N). Saplings aged one year old were planted at 2.5 × 2.5 m spacing. Other plants in the plantation includes shrubs such as *Litsea cubeba, Ficus hirta, Wikstroemia indica, Rhaphiolepis indica, Breynia fruticosa, Helicteres angustifolia, Litsea glutinosa, Gardenia jasminoides, Clerodendron fortunatum, Melastoma candidum, Mallotus apelta,* and *Psychotria rubra*. Herbs and lianas are mainly *Mussaenda pubescens, Embelia laeta, Blechnum orientale* and *Dicranopteris linearis* (Peng & Yu 1992, Ren *et al.* 2000).

Methodology

Tree diameter at breast height (dbh) and height were measured biennially for the entire plantation. The Mosaic Stratified Cutting Method was adopted for biomass study. In 1987, 1990, 1994 and 1998 we harvested 7, 10, 1 and 1 tree respectively, and excavated tap roots (diameter ≥ 2.0 cm), lateral roots (0.5–2 cm) and absorption roots (< 0.5 cm). We divided each sample plant into its component parts and dried them at 65 °C to attain the dry weight of each component. To calculate the biomass, we used a relative growth relationship formula. The relative growth formula of every organ of *A. mangium* was based on whole-harvest data acquired from samples cut in 1987 that were larger than, smaller than, and equal to the standard plant (the formula was amended after testing in 1990, 1994 and 1998, with the coefficient of correlation r of each formula > 0.91, which was significantly correlative). From the biomass regression model for every component, we calculated the community biomass based on the stand density, current annual dbh and height. The biomass increment of the tree layer was calculated using the regression growth equation with dbh and height as basic parameters (Norisada *et al.* 2005). The stand litter was collected monthly using 13 boxes placed on the ground (Li *et al.* 1990, Ren *et al.* 2000). For the biomass of the understorey, we established three 1 × 1 m quadrats and measured the height of shrubs and herbs. The names of species, individual number and crown spread of the shrubs and herbs were reported in Ren *et al.* (2000).

We also measured the net photosynthesis rate of leaves as well as their transpiration rate using Li-6200 Photosynthesis System (Li-COR Co. Ltd., Lincoln, Nebraska, USA). In addition, the water content and chlorophyll content of the leaf of *A. mangium* were also tested in autumn (Peng & Yu 1992).

RESULTS

Physiological characteristics of the leaf

Field measurements of the matured sun-exposed leaves of *A. mangium* in autumn (Figure1) indicated that both the net photosynthesis and the transpiration rates increased over time after sunrise and attained the peak value at 10:00 am. Subsequently, it dropped to the lowest value at 5:00 pm. The water content of the leaf of *A. mangium* reached 91.2%; the chlorophyll content was 39 $\mu g/cm^2$; chlorophyll a/b ratio 2.8; average daily net photosynthesis rate 9.30 ± 0.51 $\mu mol/m^2s$; and average daily transpiration rate 2.62 ± 0.17 $mmol/m^2s$. The net photosynthesis value was distinct from those of native trees. For example, net photosynthesis rates of *Schima superba, Cinnamomun burmani, C. camphora, Castanopsis hickellii* were 6.94, 5.88, 6.83 and 6.07 $\mu mol/m^2s$ respectively (Peng & Yu 1992, Cai *et al.* 1995). Such a high photosynthesis rate observed in this study may be the reason for the fast growth and high yield observed in *A. mangium.*

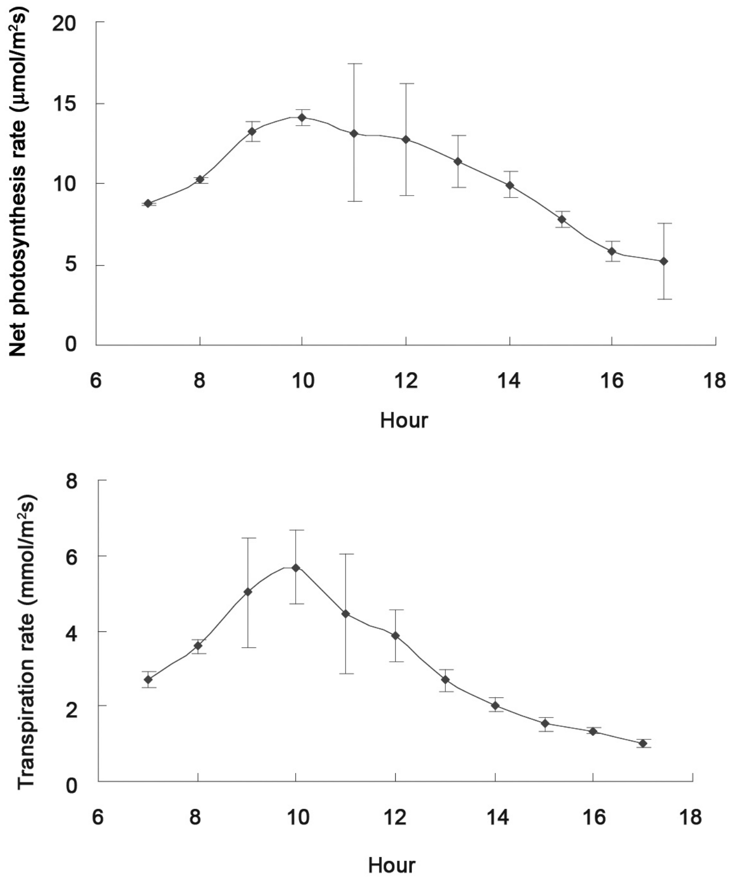

Figure 1 Daily changes of net photosynthesis rate and transpiration rate (18–21 October 1996)

Tree height and dbh

The tree height grew slowly in the first two years, increased rapidly after that and attained a peak value in the seventh year, with an annual increment of 2.88 m (Figure 2). The average height of *A. mangium* at 11 years was 15.00 m and the average annual growth was 1.49 m. The growth rate declined thereafter.

The total dbh growth trend is similar to the increase in height (Figure 2). Average dbh (excluding bark) of 19.01 cm was attained in the 11th year with an annual average growth of 1.86 cm. The increase in dbh was slow in the first three years and it increased rapidly from the third to the ninth year; the peak was attained in the fifth year (annual increment 3.64 cm). Subsequently, values for total dbh dropped.

Biomass

The relative growth relationship formula of every organ and total biomass are as follows:

Trunk biomass (Ws)
$$\lg W_s = -0.221 + 0.609 \lg (D^2H) \quad r = 0.99$$

Branch biomass(Wb)
$$\lg W_b = -0.243 + 0.458 \lg (D^2H) \quad r = 0.91$$

Leaf biomass(Wl)
$$\lg W_l = -0.424 + 0.561 \lg (D^2H) \quad r = 0.91$$

Total biomass(Wt)
$$\lg W_t = -0.154 + 0.568 \lg (D^2H) \quad r = 0.98$$

where
lg = logarithm
D = dbh
H = height

Acacia mangium biomass accumulation increased with age from planting right up to the 11th year and dropped slightly after that (Figure 3). The slight decrease in biomass after the 11th year may be due to branch damage or breakage under windy conditions. In fact, in the years

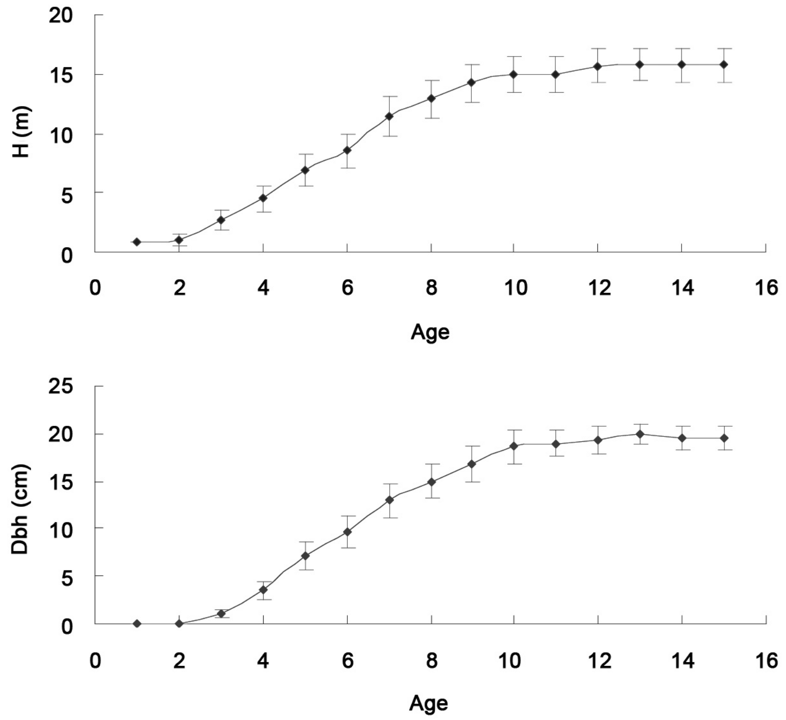

Figure 2 The change in height and dbh of *A. mangium* plantation during its development

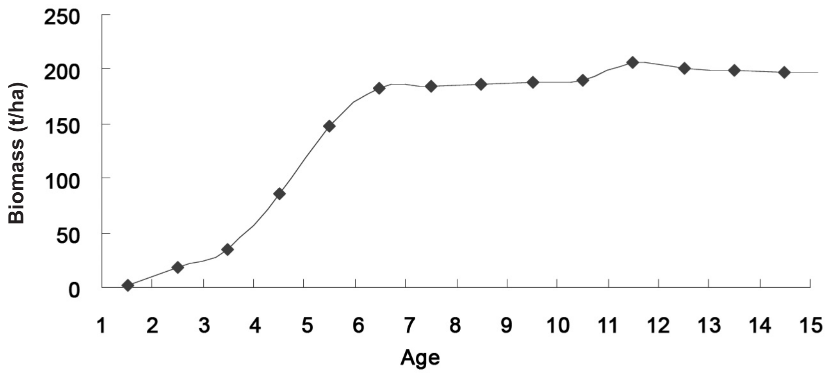

Figure 3 Biomass of *A. mangium* plantation during its development

in which typhoons were prevalent the biomass showed a drop.

As indicated in Table 1 the total *A. mangium* plantation biomass accumulated over 15 years was 196.96 t/ha, of which trunks comprised 119.10 t/ha, branches 20.03 t/ha, leaves 5.62 t/ha and roots, 40.09 t/ha. The proportions are as follows: trunk:branch:root:leaf = 21.2:3.0:8.7:1.0. The proportion of parts aboveground and parts underground was 3.01:1; this proportion was similar to data collected for the plantation at 11 years old. The biomass accumulation in *A. mangium* is high when compared with mixed coniferous forests, pure forests of *Pinus elliottii* and native forests of the same age (Peng & Yu 1992). Among the classes of roots at different ages of *A. mangium*, maximum biomass accumulation occurs in the coarse roots, followed by fine roots and absorptive roots.

Biomass data for the shrub and herb layers under *A. mangium* are shown in Table 2. The shrub layer showed an increase in biomass accumulation as the trees grow. On the other hand, the herb layer increased from four to seven years old but gradually decreased thereafter. Biomass of dead litter increased rapidly from four to 11 years old.

DISCUSSION

The total biomass of *A. mangium* increased gradually with its age from planting until the11[th] year, but dropped slightly and stabilized after that (Table 1, Figure 3). The proportion of biomass of different parts of tree changed as the tree aged; the biomass of the trunk increased with age, but that of leaves decreased after four years. In the root system, coarse roots accumulated biomass with age but fine and absorptive roots showed a decline after 11 years. This study indicates that plantation of *A. mangium* should be limited to a 11-year-period, beyond which increase in biomass should not be expected.

Seedlings and young trees of *A. mangium* can nodulate without inoculation and the day and night changes in nitrogen fixation activity results in double peak curves (Ding *et al.* 1989). Nitrogen fixation activities from May to October were 4.4–10.8 μmol (ethylene)·g (fresh nodule)/h and from November to April, 0.1–6.1 μmol (ethylene)·g (fresh nodule)/h. Ding *et al.* (1989) who studied the same site reported that nodule biomass in the 4-, 5-, 6- and 7-year-old *A. mangium* communities were 415, 402, 324 and 280 kg/ha respectively and that almost no nodule formation was observed in 8-year-old communities. Using results by Ding *et al.* (1989) and that obtained from this current study, we compared the rapid growth period of the biomass at 1–7 years with the period of nodule biomass amount. The nitrogen fixation capability of a 7-year-old community was 117 kg/ha. The disappearance of nodule in the 8-year-old plantation evidently contributed to the decline in tree growth.

Li *et al.* (1995) also conducted N and P research on this plantation. N accumulation in *A. mangium* was found to be maximum in leaves followed by the bark and timber. However, the total N accumulation in the stem and bark was greater than that in leaves. In addition, N accumulation in the surface litter was substantial and was the major N source in the ecosystem. N absorbed and fixed by *A. mangium* is transferred to the soil mainly as litter.

From the various parts of *A. mangium*, leaves accumulate the most P (Li *et al.* 1995). However, the total P accumulation in stem and bark is far greater than that in leaves alone. P in the surface litter only accounts for a small percentage of the total accumulation in the forests. It has been suggested that P deficiency is the inhibitive factor resulting in slow growth of *A. mangium* (Ribet & Drevon 1996, Xu *et al.* 1998).

An 11-year-old *A. mangium* forest accumulates considerable nutrient elements in the system and provides improved condition for interplantation of native trees. The interspace between the tree layer and shrub layer furnishes growing space for mesophyte and shade-adapted native trees; hence *A. mangium* can facilitate the conversion of degraded lands into mixed native species forests.

Table 1 Biomass allocation in *Acacia mangium* at different ages (t/ha)

Age (year)	Leaf	Annual branch	Perennial branch	Dead branch	Trunk	Bark	Coarse root	Fine root	Absorptive root	Total
4	8.19	2.72	6.83	4.47	38.22	8.95	14.77	0.62	0.46	85.23
7	7.30	5.28	18.38	8.83	97.89	10.71	34.90	0.64	0.52	185.01
11	6.39	5.23	20.74	4.23	118.65	11.86	37.52	0.85	0.70	206.21
15	5.62	4.68	12.23	3.12	119.10	12.12	39.06	0.67	0.36	196.96

Table 2 Biomass and distribution of the understorey *Acacia mangium* plantation at different ages

Stand age (year)	Living ground-cover (t/ha)						Dead ground-cover (t/ha)	
	Shrub layer		Herb layer		Subtotal			
4	2.39	(21.73)	2.68	(24.36)	5.07	(46.09)	5.93	(53.91)
7	4.13	(25.73)	3.18	(19.27)	7.31	(45.00)	8.12	(55.00)
11	4.68	(22.71)	1.70	(8.25)	6.38	(30.96)	14.23	(69.04)
15	5.59	(27.35)	1.74	(8.51)	7.33	(35.86)	13.11	(64.14)

Values in parentheses are percentages.

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