Growth and Yield of *Acacia mangium* Based on Permanent Sampling Plots in a Plantation

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ABSTRACT *Acacia mangium* is a very fast growing species belonging to the family fabaceae. It has been introduced in plantations in Sarawak, Malaysia for its rapid growth and wide range of adaptability. These plantations are anticipated to play the important roles in maintaining the commercial supply of logs thus reducing timber demand from the natural forests. Many plantations now used genetically improved material whose characters and properties have been improved through many years of research. Thus the study of growth and yield are crucial in order to have a more proper planning and management of this forest resource. This study assessed the growth and yield of the two acacias namely *Acacia mangium* superbulk or *Acacia* superbulk which is actually a second generation *A. mangium* and *Acacia* hybrid. The data obtained from permanent sampling plots (PSPs) of DAIKEN Plantation Sdn. Bhd. Bintulu were analysed to determine their mean annual increment (MAI) and periodic annual increment (PAI) in terms of diameter at breast height (DBH) and volume. Survival rate reduced as age of stand increased. Although DBH and height increased in size but the mean annual height and DBH increments decreased with age. The largest mean DBH recorded for *Acacia* superbulk and *Acacia* hybrid PSPs were 23.6 and 25.6 cm, respectively. Mean total height measured for *Acacia* superbulk and *Acacia* hybrid PSPs were 32.4 and 30.2 m, respectively. The highest volume mean annual increment was 27.4 m^3/ha/yr (6.9 years old) and 26.5 m^3/ha/yr (7.4 years old) for *Acacia* superbulk and *Acacia* hybrid, respectively. Initially growth in volume increased then began to decrease from seven years. Results of the four PSPs indicated that the maximum growth in volume per ha was attained at approximately seven years old stands.

KEYWORDS: *Acacia mangium* superbulk; *Acacia* hybrid; Growth and yield; Mean annual increment (MAI); Periodic annual increment (PAI).

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INTRODUCTION

Sarawak government is committed to establish one million hectares of planted forests. Tree planting in Sarawak begun in early 1970s and in 1997 the Forest Ordinance was amended to allow for the establishment of commercial scale forest plantations with the issuance of License for Planted Forest (LPF). The areas under the LPF are all degraded forests and shifting cultivation areas and it does not involve forested areas. The main aim for establishing forest plantations in Sarawak is to have sustainable supply of timber for wood-based industries. As of June 2014 a total of 335,049 ha of planted forest had been established in which 230,110 ha or 69% of the area was planted with acacia species (Kuan *et al*., 2014).

Acacia mangium is one of the major fast growing species used in plantation forestry in Malaysia. In the state of Sarawak, two planting material had been used and these are second generation *Acacia mangium* and *Acacia* hybrid. Second generation of *Acacia mangium* are *Acacia mangium* trees produced through artificial selection of seeds obtained from best phenotype. Second generation of *Acacia mangium* is also known as *Acacia* superbulk. *Acacia* hybrid is the hybridization between *Acacia mangium* and *Acacia auriculiformis*. The two acacias are reportedly to have better growth and more resistance to pest and diseases in which they had obtained the desired traits from the parental species (Jusoh *et al*., 2014). Acacia superbulk planted was meant for fibre production specialized in the making of fibreboard and *Acacia* hybrid for furniture, construction and veneering.

The commitment on sustainable forest management and establishment of large commercial forest plantations are among the proactive measures to make sure continuous supply of timber. The implementation of sustainable forest management practices would reduce timber production from natural forest. Thus planted forests are anticipated to play an important role to maintain the commercial logs supply. However inadequate monitoring and reporting regarding growth and yield of planted forests can hamper its role as supplementing log supply. Permanent sampling plots are a robust method for assessing growth performance in planted forests. For Sarawak who relies on plantation forests for their forest industry thus it is necessary to study the growth and yield of the new breeds so that proper management techniques can be established. The purpose of this study was to determine the growth rate and yield of *Acacia* superbulk and *Acacia* hybrid based on permanent sampling plots.

METHODOLOGY

Study Area

Data were obtained from approximately 10-year-old permanent sampling plots (PSPs) of DAIKEN Sarawak Sdn. Bhd. plantation. This forest plantation is situated approximately 60 km from Bintulu, Sarawak. The plantation is located at 03°21.347′ N and 113°27.129′ E. As of July 2015 the total planted area was 4500 ha in which bulk or 85% of the area was planted with *Acacia* superbulk. The area is flat to undulating with slope of less than 15% and altitude ranges from 60 to 100 m above sea level.

Data from Permanent Sampling Plot

A total of four permanent sampling plots (PSPs) measuring 30 m x 30 m, two representing each *Acacia* superbulk and *Acacia* hybrid were chosen for this study. These selected PSPs were well maintained and trees were measured regularly. Plots were marked using wood pillars and each trees were painted red and numbered using aluminium tags. These PSPs were maintained by DAIKEN Sarawak Sdn. Bhd. where DBH and total height were measured periodically. The planting space employed by Daiken Sarawak Sdn. Bhd. was 3 m x 3 m and plots measuring 30 m x 30 m contain 100 trees during planting. Mean annual increment (MAI) and periodical annual increment (PAI) were determined based on the data obtained from these PSPs.

Determination of Growth and Yield

To determine growth and yield, MAI and PAI were calculated by dividing growth parameters by tree age. Mean annual increment was calculated by the change in DBH, height and volume divided by age of tree (Avery & Burkhart 2002). Since the measurement of DBH and height of the PSP was taken periodically, periodical annual increment (PAI) was calculated instead of current annual increment (CAI). Periodic annual increment is the change in the size of a tree between the beginning and ending of a growth period, divided by the number of years that was designated as the growing period (Avery & Burkhart 2002).

Determination of Tree Volume

The geometrical shape of *A. mangium* tree was considered as cone shape along stem of tree. The form factor for conical shape tree is 0.33 (Philip, 1994). Using basal area at breast height, total tree height and form factor of 0.33, tree volume was calculated as 0.33 x basal area x total tree height. Mean annual increment of wood volume of each tree was calculated by dividing it with age of the tree.

RESULTS AND DISCUSSION

Acacia superbulk

Mean survival rate of *Acacia* superbulk decreased with age from 79% to 57% after 9.8 years of planting (Table 1). The results also showed that *A. mangium* superbulk diameter size and height increased with age and 9.8 years old stand recorded mean DBH and total height of 3.6 cm and 32.4 m, respectively. This suggests that as the number of trees per unit area decreases their diameter and height increases.

Mean annual increment of DBH and height decreased with age. Generally, the DBH MAI decreased from 4.0 cm/yr to 2.4 cm/yr after 9.8 years of planting. In several sites in Indonesia, high DBH MAI (more than 4 cm/yr) were recorded for stand less than 3 years old, after which the diameter MAI values generally decline towards 1.5 to 2 cm/yr (Krisnawati et al., 2011). Figure 1 shows that from the age 6.9 years to 9.8 years, the DBH MAI decreased from 2.8 to 2.4 cm/yr. This showed that after 6.9 years of planting, the DBH MAI was almost steady. This indicates that the growth rate in term of diameter size was constant after the age of 6.9 years. The DBH PAI decreased until 6.9 and from that onwards PAI was constant.

In terms of volume, its MAI increases steadily with until aged six years old (Figure 1). Then after six years volume MAI decreases. Mean annual increment of *Acacia* superbulk PSP recorded the highest with 27.4 m^3/ha/yr at six years old after planting. The least MAI was 19 m^3/ha/yr at 9.8 years old. This indicates that *Acacia* superbulk growth was vigorous in the early growing stages then it sharply reduced at the later stages. The robust growth in the early growing stages then reducing growth rate with age in acacia species has been reported elsewhere (Krisnawati *et al*., 2011; Dhamodaran & Chacko, 1999; Feldpausch *et al*., 2007).

Table 1. Mean survival rate, DBH and total height of *Acacia* superbulk at different age of PSP

Age (Years)	Survival Rate (%)	Mean DBH (cm)	Mean height (m)
4.0	79	16.2	21.2
4.4	72	17.1	23.1
5.2	61	18.4	24.0
6.0	68	18.8	27.0
6.9	67	19.7	29.0
8.4	63	21.3	31.3
9.8	57	23.6	32.4

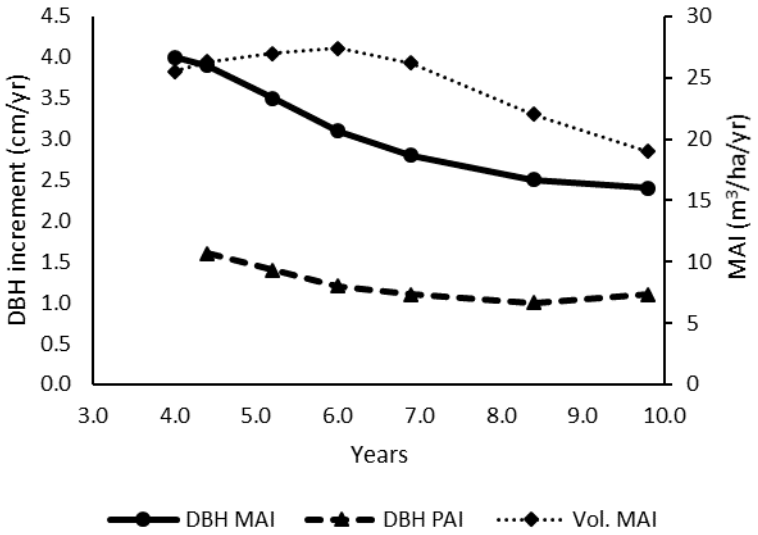

Figure 1. Mean and periodical annual increment of *Acacia* superbulk with age.

Acacia hybrid

The survival rate of *Acacia* hybrid decreased with age similar to *Acacia* superbulk (Table 2). At the age of 10.3 years only 41% of the planted tree of *Acacia* hybrid survived. As with *Acacia* superbulk, diameter size and height of *Acacia* hybrid increased with age and 10.3 years old stand recorded mean DBH and total height of 25.3 cm and 30.4 m, respectively.

Similarly MAI of DBH and height of *Acacia* hybrid decreased over time. The MAI of DBH were 3.4 and 2.5 cm/yr for 4.4 to 10.3 years old trees, respectively and these values were within the range of DBH MAI of as reported by Sein and Mitlohner (2011) which was 1.2 to 4.5 cm/yr and averaged at 2.6 cm/yr. However, MAI of height was constant from 4.4 to 5.7 years then decreased steadily. The MAI for height was 4.0 m/yr during the early growing stages and reduced to 2.4 m/yr at 10.3 years old trees. These values of height MAI was also in agreement with Sein and Mitlohner (2011) which stated that height MAI was between 1.7 and 5.5 m/yr and averaged at 3.6 m/yr. This also indicated that there was a rapid increased in height of *Acacia* hybrid for the first 6.5 years. Height MAI of more than 4 m/yr had been reported in older stands in several sites in Riau (Siregar *et al*., 2008) and in South Sumatra (Hardiyanto & Wicaksono, 2008).

For *Acacia* hybrid DBH PAI decreases in the early stages of growing. Subsequently DBH PAI increased from 1.5 cm/yr to 2.2 cm/yr after 7.4 years of planting. However, the trend for volume MAI is the opposite for DBH MAI, where it increased in the beginning until 7.4 year old then start to decrease from then onwards (Figure 2). The largest volume MAI was recorded at 26.5 m^3/ha/yr in 7.4 years old trees and the lowest was 20.4 m^3/ha/yr in 10.3 years old.

This suggests that the overall wood volume increased in the beginning then decreased at the later stage of growing period and Krisnawati *et al*. (2011) noted that growth of *Acacia mangium* generally declines rapidly after 8 years. Stand basal area and volume per ha of *A. mangium* tree increased with age then after 8.5 years it started to decreased (Heriansyah *et al*., 2007).

Table 2. Mean survival rate, DBH and total height of *Acacia* hybrid at different age of PSP

Age (Years)	Survival Rate (%)	Mean DBH (cm)	Mean height (m)
4.4	94	14.0	17.5
5.1	88	16.0	20.5
5.7	86	16.7	22.5
6.5	83	18.3	24.0
7.4	77	19.9	25.8
8.9	53	23.3	27.7
10.3	41	25.3	30.2

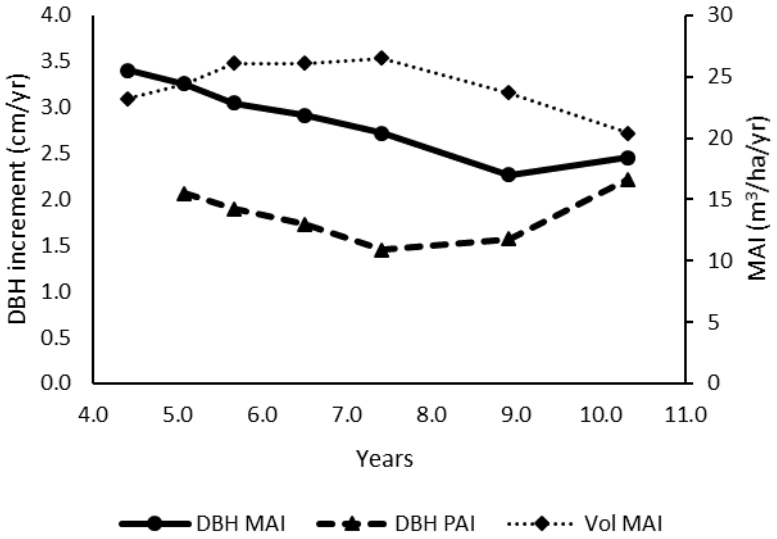

Figure 2. Mean and periodical annual increment of *Acacia* hybrid with age.

The wood volume MAI of these PSPs was relatively low compared to other reports probably due the form factor used to calculate tree volume which was 0.33. The same Daiken area had shown to have MAI of 39 m^3/ha/yr to 10 cm top diameter using form factor of 0.61 for 9.75 years old *Acacia* superbulk stand (Adam *et al.*, 2012). In general the MAI of *Acacia mangium* stand was 26 m^3/ha/yr at stand age of 7 years (Ngayop, 2013). An *Acacia mangium* plantation was reported to show MAI of at 29 m^3/ha/yr to 8 cm top diameter (Gardner, 2009). In Sumatra, Indonesia the normal growth rate was between 22 m^3/ha/yr and 35 m^3/ha/yr, depending on age of stand (Harwood & Nambiar, 2014).

CONCLUSION

This study was based on four PSPs and it might not represent the actual growth rate. However, the data obtained was consistent other results reported from other studies in terms of growth trend, where the growth rate were fast in the beginning and then decreased sharply at the end of growing period. Survival rate and DBH increment decreased with age. The mean growth and yield of these PSPs appeared to be peaked up to seven years old. For better understanding about the growth performance and productivity of *Acacia* superbulk and *Acacia* hybrid more PSPs data are essential.

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