EFFECTS OF GIRDLING ON WOOD PROPERTIES AND DRYING CHARACTERISTICS OF *ACACIA MANGIUM*

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Received March 2014

BASRI E, YUNIARTI K, WAHYUDI I, SAEFUDIN & DAMAYANTI R. 2015. Effects of girdling on wood properties and drying characteristics of *Acacia mangium*. Basic properties and drying quality of 9-year-old *Acacia mangium* wood from plantation of the Forest Research and Development Agency in Bogor, Indonesia were studied in order to evaluate effects of girdling periods (0, 4 and 8 months) applied before cutting the trees. Results showed that 8 months of girdling resulted in 50.8% reduction in initial (green) moisture content of wood i.e. from 122 to 60% with no occurrence of end splitting in logs during felling. In general, wood quality of girdled tree is better than that of non-girdled tree. Wood density and holocellulose content increased, while tangential and radial shrinkage ratio, ash, silica, lignin, wood pentose and extractive contents decreased. Based on drying characteristics, basic drying schedule for 8-month-girdled wood was at temperature of 50–80 °C and relative humidity of 80–28%, while that for 4-month-girdled wood and control, temperature of 40–65 °C and relative humidity of 83–38%. The longer girdling period also decreased the percentage of honeycombing and degree of deformation during drying.

Keywords*:* Plantation, wood quality, drying quality, deformation

INTRODUCTION

Girdling is a silvicultural treatment applied to trees prior to felling. It is carried out by creating inward incisions around the stem from the peripheral area to the cambium zone. This treatment will stop the transport of sugars and other photosynthetic materials, so the tree will die naturally. As a result, wood moisture decreases and the wood becomes lighter. Besides reducing moisture content, girdling is also effective in reducing growth stresses, residual stresses and microfibril angle (Wahyudi et al. 1999). In Indonesia, girdling is commonly applied in teak plantation 24 months before harvesting (Wahyudi 2000).

Acacia mangium is a fast-growing tree species used in plantation forest in Indonesia. Total area of plantation forest of this species in the country has reached 1.78 million ha (Departemen Kehutanan 2013). Originally, the tree was planted for pulp and paper, but recently, the wood was also used for production of furniture due to its decorative appearance, sufficient strength and good machining properties. Usually, *A. mangium* tree from plantation area is harvested at a relatively young age (around 5 to 10 years). At that age, stem diameter reaches 15 to 30 cm which is enough for selling.

Acacia mangium lumber, especially the green sawn lumber, is very difficult to dry (Basri 2005, Gan & Amin 2011, Tenorio et al. 2012). Drying of green *A. mangium* lumber above 50 °C results in wood deformation and honeycomb. The presence of these defects is strongly correlated with its initial wood moisture content, juvenile wood portion as well as its growth stress and residual stress levels. According to Wahyudi (2000, 2005), younger *A. mangium* tree produces higher moisture content, higher juvenile

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wood portion, and higher growth stress and residual stress. Moisture content of 10-year-old of *A. mangium* wood in green condition can reach above 100% (Basri 2005). Juvenile wood portion of *A. mangium* trees in Indonesia ranged from 50 (22-year-old) to 100% (8-year-old) (Wahyudi 2005, Rulliaty 2008). Lower initial moisture content will result in shorter drying period, but the steeper the gradient of moisture content and residual stress, the more severe the deformation. Moisture characteristic has an important influence on wood properties and performance. Therefore, these factors have to be considered during drying in order to obtain better quality of dried timber.

In this study, effects of girdling on initial moisture content, wood density, wood shrinkage, ratio between tangential and radial shrinkages (T/R-ratio), chemical compounds and basic drying schedule were examined. A simple experiment using tropical plantation wood species showed that girdling period below 1 year had already affected several wood properties (G Pari, personal communication). Therefore, this experiment, 4- and 8-month girdling periods were studied.

MATERIALS AND METHODS

Nine-year-old *A. mangium* wood from trial plantation forest belonging to the Forest Research and Development Agency, Bogor, Indonesia were used in this study. The topography of the plantation is flat, 51.8 m above sea level, with podzolic–haplik soil type of pH 4.8 and climate type A as in the Classification of Schmidt–Ferguson (Sudrajat et al. 2006). The trees were girdled 2–3 cm in depth 4 and 8 months prior to cutting. Girdling was created at the height of 25 cm above the ground. For each category (control and girdling), three healthy trees were cut. All tree samples were randomly selected based on similarity in diameter, i.e. 30 cm at breast height.

From each tree, 1-m long log was extracted from the bottom of the trunk. The log was divided into two parts, i.e. wood disc (Figure 1, A, 5 cm in thickness) and shorter log (B, the remaining about 95 cm in length). The disc was used for measurement of wood basic properties, while the log was for drying experiment.

Basic property measurement

Physical properties, namely, moisture content in green condition, air- and oven-dry density, as well as wood shrinkages from green to air- and to oven-dry conditions were measured according to the ASTM D143-94 (ASTM 2007). From each disc (A), three specimens at the heartwood region were collected. Therefore, a total of 27 wood samples were used for basic property measurement (three girdling periods × 3 trees × 3 samples). Sample size for moisture content

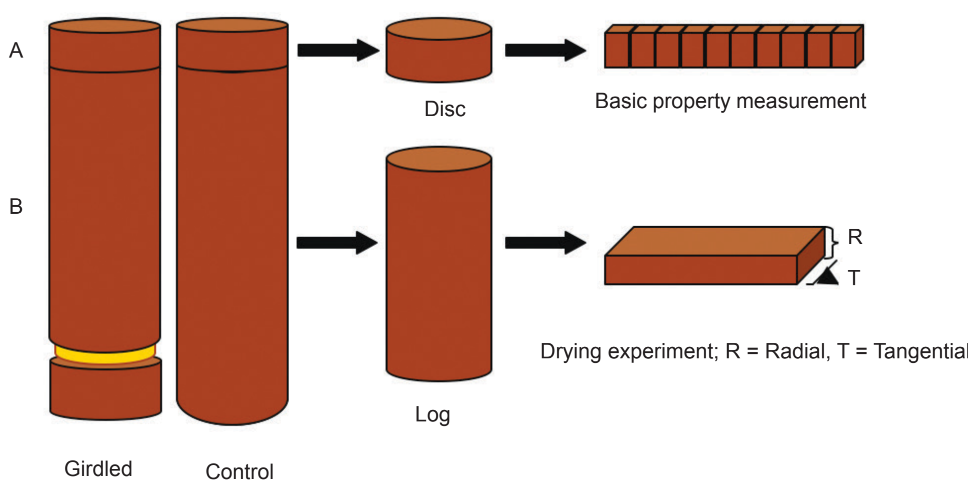

Figure 1 Sample preparation

and density measurements was 3 cm × 3 cm × 3 cm while for shrinkage, 3 cm × 3 cm × 1 cm.

To measure relative amounts of chemical components, wood powder (40–60 mesh) was prepared from disc without any separation of heartwood and sapwood. Holocellulose content was determined according to the methods by Young (1972), while ash content was determined according to ASTM D1102-84 (ASTM 2007). Lignin content was determined according to ASTM D1106-96 (ASTM 2007) and extractive substances were determined using several standards, i.e. extractive content in ethanol–benzene according to ASTM D1107-96 (ASTM 2007), extractives in 1% NaOH, ASTM D 1109-84 (ASTM 2007) and extractives in cold and hot waters, ASTM D1110-84 (ASTM 2007). Pentose and silica contents were measured using TAPPI T 223 cm-10 (TAPPI 2010) and T 245 cm-07 respectively (TAPPI 2007). All chemical analyses were conducted in duplicate.

Drying test

Drying test was performed following Basri (2011). For this purpose, the 95-cm long log (B) was converted into tangential board of 2 cm (thick) × 10 cm (width) × 20 cm (length) (Figure 1). For each category (non-girdled, 4 and 8 months girdling), 10 boards of heartwood portion, free from visual defects, were randomly selected and used for this experiment. The samples were then oven dried at 100 °C until average moisture content of 1% was reached. Every sample was evaluated for drying defect and scored from I to VII (Table 1); higher score meant greater defect.

By referring to the drying conditions in Table 1 and dry bulb temperature and wet bulb depression in the Forest Products Laboratory Manual (Simpson 1991), basic drying schedule was determined. The minimum and maximum temperatures as well as wet bulb depression were used as indicators to determine the basic drying schedule for each category (non-girdled, 4 and 8 months girdling).

Data analyses

Saphiro–Wilk W test was used to determine data distribution. Differences in wood properties between treatments (control,

Table 1 Drying condition based on degree of defects

Type of defect	Drying condition (°C)	Defect class						
		I (< 5%)	II (5–10%)	III (10.1–20%)	IV (20.1–40%)	V (40.1–60%)	VI (60.1–80%)	VII (> 80%)
End and surface checks	Initial temperature	70	65	60	55	50	40	38
	Wet bulb depression	6.5	5.5	4	4	3	2	2
	Final temperature	95	90	85	80	70	65	50
Deformation	Initial temperature	70	66	58	54	50	40	38
	Wet bulb depression	6.5	6	5	4	4	3	3
	Final temperature	95	88	83	80	70	65	50
Honeycombing	Initial temperature	70	55	50	48	48	40	–
	Wet bulb depression	6.5	4.5	4	3	3	2.5	–
	Final temperature	95	83	77	73	71	70	–

Source: Basri (2011) and Simpson (1991)

4 and 8 months girdling), except for chemical components, were analysed using one-way ANOVA and continued by Tukey's HSD post-hoc test if data were statistically different. All analysis were conducted using Statistica®.

For chemical components, average value of each parameter was calculated, while for drying experiment, the qualitative data was presented descriptively.

RESULTS AND DISCUSSION

Physical property

Mean green moisture content, wood shrinkage either from green to air-dry or green to oven-dry conditions, and T/R-ratio from green to air-dry conditions in control wood were higher than those of girdled wood (Table 2). In contrast, density values of control wood in air-dry and oven-dry conditions were lower than those of girdled wood. Between girdled trees, 4-month- girdling produced lower quality wood compared with 8 months. The former had higher green moisture content, higher wood shrinkages both from green to air-dry and from green to oven-dry conditions, and also T/R-ratio but lower wood densities in air-dry and oven-dry conditions. Therefore, the longer the girdling period, the more stable the dimensions of wood. In general, the greater the difference between T/R-ratio in shrinkage, the greater the degree of warp (Bowyer et al. 2007, Basri et al. 2009).

Compared with wood from non-girdled tree (control), moisture contents of wood from 4- and 8-month-girdled trees were much lower. The average reductions were 30.3 and 50.8% respectively (Table 2). All values were above the fibre saturation point. With the highest reduction in moisture content, the 8-month-girdled log was the lightest. Lighter log is easy to handle and reduces transportation fees. Energy consumed during drying of wood with lower initial moisture content will be less and drying period will be shorter than that of wood with higher initial moisture content.

There was no end splitting when 8-month-girdled trees were felled, while in the 4-month-girdled trees, the occurrence of end splitting was very small. These phenomena contrasted with those of non-girdled trees which produced the highest level of end splitting. Therefore, it is no

Table 2 Wood properties of girdled wood

Wood property	Girdling period (months)			p-value
	0 (control)	4	8	
Green (initial) moisture content (%)	122 ± 20 a	85 ± 12 b	60 ± 8 c	0.00**
Air-dry density (g cm^{-3})	0.45 ± 0.02 a	0.47 ± 0.03 a	0.51 ± 0.01 b	0.03*
Oven-dry density (g cm^{-3})	0.40 ± 0.03 a	0.41 ± 0.02 a	0.45 ± 0.01 b	0.03*
Radial shrinkage from green to air-dry condition (%)	1.73 ± 0.11 a	1.64 ± 0.07 a	1.47 ± 0.02 b	0.02*
Tangential shrinkage from green to air-dry condition (%)	5.27 ± 0.29 a	4.84 ± 0.12 b	3.17 ± 0.01 c	0.00**
Radial shrinkage from green to oven-dry condition (%)	2.78 ± 0.39 a	2.70 ± 0.44 a	2.58 ± 0.04 a	0.48
Tangential shrinkage from green to oven-dry condition (%)	7.87 ± 0.79 a	6.81 ± 0.60 b	5.99 ± 0.12 c	0.00**
T/R-ratio in shrinkage from green to air-dry condition (%)	3.04 ± 0.14 a	2.95 ± 0.11 a	2.16 ± 0.03 b	0.03*
T/R-ratio in shrinkage from green to oven-dry condition (%)	2.83 ± 0.36 a	2.52 ± 0.36 ab	2.32 ± 0.04 b	0.03*

R = radial direction, T = tangential direction; number of samples = 27; value followed by the same letter showed no difference according to Tukey's HSD post-hoc test, * = significantly different at $\alpha < 0.05$, ** = significantly different at $\alpha < 0.01$

doubt that girdling can reduce growth stresses as well as their gradients from pith towards the bark (residual stresses). Decreasing growth stress and more constant residual stress within a trunk will result in lowering end splitting of logs. This finding is in agreement with findings by Wahyudi (2000) and Biechele et al. (2009). These will also reduce distortion in log and sawn board as well as variability of wood quality, within and among trees.

Table 2 also presents the change of wood density in air-dry and oven-dry conditions after girdling. Compared with that of control wood, wood density in air-dry condition increased by 4.4 and 13.3% for 4- and 8-month girdling respectively. Density of oven-dry wood increased by 2.5 and 12.5% respectively. The findings are similar to a study using teakwood, whereby wood quality of girdled wood is better than that of non-girdled wood (Wahyudi 2000).

Dimensional shrinkage and T/R-ratio from green to air-dry conditions as well as from green to oven-dry conditions were better in the 8-month girdling compared with the rest of the wood samples. Dimensional shrinkage and T/R-ratio were lowest in the 8-month girdling (Table 2). T/R-ratio of less than 2 will result in more stable wood (Bowyer et al. 2007, Basri et al. 2009).

Based on basic properties studied, it could be deduced that, in general, wood quality of 8-month-girdled trees was the best. The wood produced was lighter, easier to handle, stronger, free from end splitting and stable. Moreover, decay and other deteriorations due to fungus and insect were not observed during the study.

Chemical component

Except for holocellulose, all chemical components in girdled wood tended to decrease. As girdling period increased, reduction in ash, silica, lignin, pentose and extractive contents increased (Table 3).

Chemical components were affected by girdling period. The 4-month-girdled trees had 10% reduction in ash content, 15% in cold water extract and 17% in hot water extract. In 8-month-girdled trees, average reduction was almost doubled. At the same time, silica contents, which did not show any changes earlier, reduced up to 25% compared with control. Average reductions of extractives soluble in 1% NaOH and ethanol–benzene as well as lignin and pentose were 0–5 and 2.6–8.5% for 4- and 8-month girdling respectively.

Change in holocellulose was very small. It increased from 74.4 (control) to 75.6% (4-month girdling) and to 76.1% (8-month girdling). Increased holocellulose content indicated that girdling had positive impact on the quality of wood.

Decrease in extractives content contributed to the change in wood colour (Figure 2). The 8-month-girdled wood (C) was lighter than control (A) and 4-month-girdled wood (B).

Table 3 Chemical components of girdled wood compared with control

Component (%)	Girdling period				
	0 (Control)	4 months	% of change	8 months	% of change
Ash	1.0	0.9	-10	0.8	-20
Silica	0.4	0.4	0.0	0.3	-25
Lignin	27.3	26.7	-2.2	26.6	-2.6
Pentosan	18.4	17.5	-4.9	17.2	-6.5
Holocellulose	74.4	75.6	1.6	76.1	2.3
Cold water extracts	2.0	1.7	-15.0	1.4	-30.0
Hot water extracts	3.5	2.9	-17.1	2.7	-22.9
1% NaOH soluble extracts	15.9	15.5	-2.5	15.4	-3.1
Ethanol–benzene extracts	7.1	7.1	0.0	6.5	-8.5

Percentages were based on moisture-free weight of wood samples; wood moisture contents were 11.06% for control, 12.86% for 4-month girdling and 10.79% for 8-month girdling; number of samples = 9

Drying characteristics

All wood samples in the study had drying defects of varying classes depending on the wood origin (Table 4). The non-girdled wood had 20–40% of end and surface cracks (defect class of IV) and > 60–80% of deformation and honeycombing (both class VI). The 4-month-girdled wood had 10–20% of end and surface cracks (class III), > 60–80% of deformation (class VI) and > 40–60% of honeycombing (class V). The 8-month-girdled wood was the best with only 5–10% of end and surface checks and honeycombing (class II) and > 20–40% deformation (class IV).

The 8-month-girdled wood had the best drying quality compared with the other two categories. Drying quality of the former was fair (d), while the 4-month-girdled and control woods were low (f) (Table 4). It can be seen that percentage of honeycombing and degree of deformation in control and 4-month-girdled wood were higher compared with those of 8-month-girdled wood. Compared with the control, percentage of honeycombing and collapse significantly decreased in 8-month-girdled wood (Figure 2).

Generally, dimensional stability of girdled wood was higher than that of non-girdled wood since its moisture content was lower. Dimensional and volumetric shrinkages of girdled wood were also smaller. When moisture content of wood is low, hydroxyl groups of the cellulose are closer to each other, and as a result, a stronger bond is produced (Panshin & de Zeeuw 1980). Therefore, the wood becomes more stable.

Based on drying properties tabulated in Table 4 and also dry bulb temperature and wet bulb depression, we conclude that basic drying schedule as tabulated in Table 5 is suitable for 8-month-girdled wood, while drying schedule in Table 6 is suitable for control (non-girdled) and 4-month-girdled wood. For the 8-month-girdled wood, temperature of 50–80 °C and relative humidity of 80–28% are recommended, while for control and 4-month-girdled wood, temperature of 40–65 °C and relative humidity of 83–38%. The harsher drying conditions for 8-month-girdled wood indicated that longer girdling period could increase the sensitivity of *A. mangium* wood to high temperature during drying process.

CONCLUSIONS

Wood quality of girdled tree was better than that of non-girdled tree. Wood density and holocellulose content increased, while moisture content, T/R-ratio, as well as ash, silica, lignin, wood pentose and extractives contents decreased. There was no evidence that end splitting occurred during felling. Eight-month-girdled tree had the best quality. The wood was lighter, stronger, free from end splitting and more stable. Longer girdling period resulted in better quality of dried lumber. Percentage of honeycombing and degree of deformation (collapse) during drying were small. Recommended basic drying schedule for 8-month-girdled wood was temperature range of 50–80 °C and relative humidity of 80–28%, while for 4-month-girdled and non-girdled wood, temperature range of 40–65 °C and relative humidity of 83–38%.

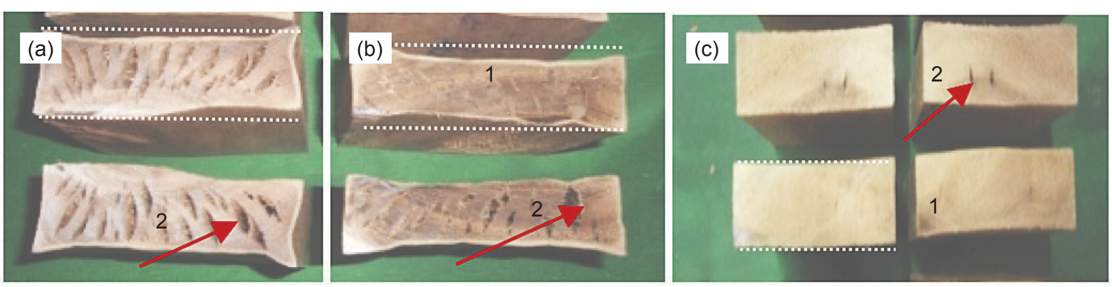

Figure 2 Colour differences, deformation (1) and honeycombing (2) during quick drying test in (a)control, (b) 4-month-girdled wood and (c) 8-month-girdled wood

Table 4 Drying qualities of girdled and non-girdled *Acacia mangium* wood

Girdling period (months)	Initial moisture content (%)	Defect type and class			Drying quality
		End and surface cracks/checks	Deformation/ collapse	Honeycombing	
0 (Control)	122	IV	VI	VI	f
4	85	III	VI	V	f
8	60	II	IV	II	d

Classes of defects: I = < 5%, II = 5–10%, III = > 10–20%, IV = > 20–40%, V = > 40–60%, VI = > 60–80% and VII = > 80%; classification for drying quality: a = very good, b = good, c = quite good, d = fair, e = rather low f = low, and g = very low

Table 5 Basic drying schedule for 8-month-girdled *Acacia mangium* wood

Moisture content (%)	Temperature (°C)	Relative humidity (%)
Green–< 30	50	80
30 < 25	55	72
25 < 20	60	62
20–15	65	45
< 15	80	28

Table 6 Basic drying schedule for control and 4-month-girdled *Acacia mangium* wood

Moisture content (%)	Temperature (°C)	Relative humidity (%)
Green–< 30	40	83
30 < 25	45	78
25 < 20	50	71
20–15	55	57
< 15	65	38

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support from The Forest Tree Seed Technology Center, Forest Research and Development Agency, Bogor for supplying the 9-year-old *A. mangium* trees. We also thank F Ishiguri from the Utsunomiya University, Japan for advice and suggestions.

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