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HEARTWOOD, SAPWOOD AND BARK CONTENT OF *BOMBACOPSIS QUINATA* IN COSTA RICA

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PÉREZ, D., KANNINEN, M., MATAMOROS, F., FONSECA, W. & CHAVES, E. 2004. Heartwood, sapwood and bark content of *Bombacopsis quinata* in Costa Rica. The Costa Rican government has promoted the establishment of high yielding plantations, expecting to produce high quality timber. Nowadays the management of some species have been uncertain, since wood quality and yield are becoming lower than expected. Heartwood content is a determinant characteristic for *Bombacopsis quinata*, a widely appreciated species in the country. The aim of this study was to evaluate the heartwood, sapwood and bark content of young and advanced aged *B. quinata* trees. The research was based on the hypothesis that heartwood content increases with increasing age. By means of stem analysis, the heartwood, sapwood, and bark volume was measured on trees of different ages (10 to 27 years). The highest heartwood proportion found in *B. quinata* was 13.6%, and the lowest 0.1%. The sapwood ranged between 70.0 and 87.2% while the bark, from 9.4 to 23% of the total stem volume. No clear differences in heartwood content could be observed between trees of similar age from dry and wet zones. Rotation periods for *B. quinata* in Costa Rica should be extended to produce high quality timber with increased heartwood content.

Key words: Silvicultural management – stem analysis – stem volume – wood quality

PÉREZ, D., KANNINEN, M., MATAMOROS, F., FONSECA, W. & CHAVES, E. 2004. Kandungan kayu teras, kayu gubal dan kulit kayu *Bombacopsis quinata* di Costa Rica. Kerajaan Costa Rica menggalakkan penubuhan hutan ladang berhasil tinggi dengan harapan menghasilkan balak berkualiti tinggi. Pada masa ini, pengurusan sesetengah spesies menjadi tidak pasti kerana kualiti dan hasil kayu berkurangan daripada tahap yang dijangka. Kandungan kayu teras merupakan ciri penentu *Bombacopsis quinata* iaitu spesies yang berharga di negeri ini. Tujuan kajian ini ialah untuk menilai kandungan kayu teras, kayu gubal dan kulit kayu *B. quinata* yang muda dan berusia. Penyelidikan berasaskan pada hipotesis yang menyatakan kandungan kayu teras meningkat apabila umur pokok meningkat. Isi padu kayu teras, kayu gubal dan kulit kayu pokok berusia antara 10 tahun hingga 27 tahun ditentukan secara analisis batang. Nilai kayu gubal paling tinggi dalam *B. quinata* ialah 13.6% dan paling rendah, 0.1%. Kandungan kayu gubal berjulat antara 70.0% hingga 87.2% sementara kulit kayu adalah

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antara 9.4% hingga 23% daripada isi padu batang keseluruhan. Tiada perbezaan yang nyata dicerap dalam kandungan kayu teras antara pokok yang sama usia dari zon kering dan zon lembap. Tempoh pusingan *B. quinata* di Costa Rica patut dilanjutkan untuk menghasilkan balak berkualiti tinggi dan mempunyai kandungan kayu teras yang lebih banyak.

Introduction

Fast growing and high yielding forest plantations are becoming an important source of wood in the tropics. In these areas, where the economy is based on agricultural and forest activities, the need to increase wood productivity is a primary task. When selecting tree species for large plantation programme, reforestation projects should consider not only the survival and growth of trees, but also the quality and utilisation potential of the timber (Laurila 1995). For fast growing species in particular, these criteria are of great importance since commercial dimensions are reached in a relatively short period and the wood quality may be lower than expected.

Estimations of heartwood formation help to define differences in durability and other wood characteristics of timber species (Bhat 1995). The heartwood is the wooden portion inside a tree where the production of live cells has ceased and the materials of reserve (for example starches) have been removed or become more lasting substances (Anonymous 1983, Miller 1999).

Bombacopsis quinata (*B. sepium*) is a native tree species (Bombacaceae) of the Neotropics, with natural distribution in Central America (Honduras, Nicaragua, Costa Rica and Panama) and northern South America (Colombia and Venezuela). It occurs at elevations from sea level to 900 m, in areas where annual precipitation ranges from 800 mm (northern Colombia) to 3000 mm (Cabo Blanco, Costa Rica). A strong, well-defined dry season of 2 to 6 months characterises its natural range (Rojas 1981, Anonymous 1991, Chaves & Fonseca 1991, Kane *et al.* 1993, Vásquez & Ugalde 1995, Urueña 1999).

In Costa Rica, about 20 000 ha of *B. quinata* have been planted with the support of a national incentive program since 1979 (Anonymous 1996). These plantations are expected to produce high quality timber at short rotation periods of 30 years or less (Hughell 1991, Arguedas & Torres 1992, Kammesheidt 1998, Urueña 1999).

Bombacopsis quinata can reach over 30 m in height and more than 100 cm diameter at breast height (DBH) in natural forests. The heartwood is reddish in colour and the sapwood a cream or white hue. The wood is known for its durability and workability. It is used for furniture, doors, window and ceiling frames, roof construction, interior panelling, particleboard, plywood and veneer (Kane *et al.* 1993, Urueña 1999).

There are a few studies that report the heartwood content of *B. quinata* trees in Central and South America (Moya & Córdoba 1995, Urueña 1999). However, such studies have been carried out in Costa Rica only and on trees of eight years old or younger.

Although *B. quinata* timber without heartwood has been categorised (according to laboratory tests) as fast drying and of good quality, showing slight sweeps (curves on stems caused by environmental conditions such as wind or slope rather than genetic) which cause a loss of only 2% over the sawn volume (Moya & Córdoba

1995), the presence of heartwood is a key characteristic for high value end-products. This species is classified as high quality timber mainly for the aesthetic aspect provided by the high percentage of heartwood and for its durability. *Bombacopsis quinata* trees without heartwood may not be considered superior in quality and value than fast grown, softwood species, such as *Gmelina arborea*.

Bark content estimation is also of high importance, since tree volume is normally merchandised without bark and, therefore, volume projections must deduct the portion lost on the bark. The content of bark in tropical species, such as *Tectona grandis*, can vary between 14 and 37% of the total volume (Pérez & Kanninen 2003). Therefore, the heartwood as well as the bark content (and indirectly the sapwood) are determinant quality characteristics and proper attention has to be given in order to find linkages between management systems and their formation.

The aim of this study was to evaluate the heartwood, sapwood and bark content in young and mature *B. quinata* trees to make recommendations of management options that can lead to important increments in wood quality, i.e. heartwood content.

Materials and methods

Cross-sectional wood samples were collected from plantations in private farms of different zones in Costa Rica (Figure 1). Thirteen plantations were selected from six sites covering different climatic conditions (Table 1) and plantation densities (180 to 1600 trees ha^{-1}). A total of 26 trees with ages between 10 and 27 years were felled for stem analysis. From each plantation, one to three individuals (dominant and/or co-dominant) were selected for harvesting.

Stem cross-sectional samples (disks) were taken from each felled tree at 0.3 and at 1.3 m from the base. Starting at the height of 2.0 m, sections were taken along the stem at 2.0 m intervals. For each section, diameters over bark, under bark and that of the heartwood were calculated as the averages of two cross-sectional

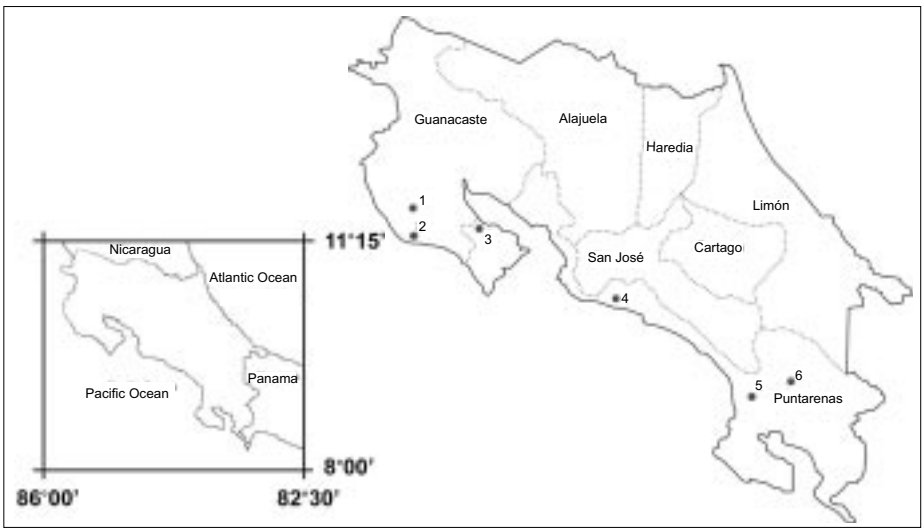


Figure 1 Location of the site where *Bombacopsis quinata* trees were felled for the study. For site codes, see Table 1.

Table 1 Bioclimatic variables of the sites where *Bombacopsis quinata* trees were harvested

Site code	Location	Precipitation (mm year^{-1})	Dry months*	Elevation (m)	Mean annual temperature (°C)	Plantation density (trees ha^{-1})
1	Nicoya	2223	4	120	27.0	1160
2	Samara	1659	6	100	26.1	1111
3	Jiracal	1700	6	60	26.8	400
4	Parrita	3450	3	80	27.0	1480
5	Palmar Norte	3650	3	80	27.0	740
6	Buenos Aires	3630	4	300	27.0	180

* = Months with rainfall less than 100 mm

measurements (direction north-south and east-west). The heartwood, sapwood and bark cross-sectional area (cm^2) were calculated as a geometric circle. The total volume (cm^3) of sapwood, heartwood and stem (with and without bark) was calculated using the Smalian formulae (Clutter *et al.* 1983). The last stem section from the last-taken disk to the tip of the tree was calculated as a geometric cone.

Results

The heartwood proportion of total stem volume found in *B. quinata* ranged between 0.1 and 14% (average of 4.26%) (Table 2). The sapwood proportion ranged between 70 and 87% (80.3%), and the bark ranged from 9 to 23% (15.5%).

The trend line representing the proportion of heartwood increased slightly with increasing age, while that for sapwood almost remained constant (Figure 2a). The proportion of bark decreased with increasing age. On the other hand, sapwood showed no variations with increasing DBH. Heartwood and bark showed clearer variations with DBH than with age (Figure 2b).

The percentage of cross-sectional area of heartwood at different stem heights decreased from the base of the tree to the top, while sapwood and bark proportions increased (Figure 3).

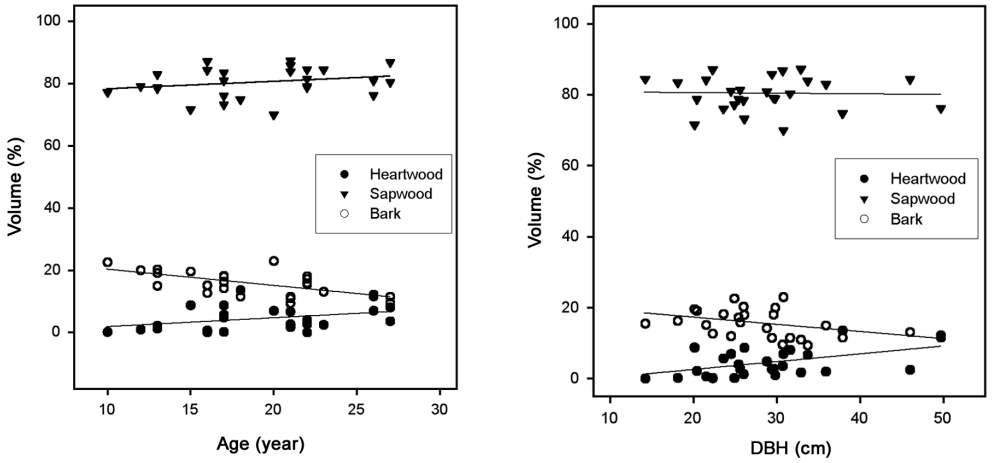
By means of stem analysis, the heartwood, sapwood and bark volume were measured along the stem on trees of different ages. In a 23-year-old tree, from a total volume of 1.79 m^3, 13.1% corresponded to bark, 84.4% to sapwood, and only 2.5% to heartwood. Heartwood was located from the base of the tree up to a height of 5.0 m (Figure 4a). The stem analysis of an 18-year-old *B. quinata* tree is shown in Figure 4b. From a total volume of 0.93 m^3, only 13.6% corresponded to heartwood, 74.8% to sapwood, and 11.6% to bark.

For the 23-year-old tree, the proportion of sapwood cross-sectional area at different stem heights remained almost constant at 80% (Figure 5a). The bark tended to decrease with increasing diameter, while the heartwood started at a stem diameter of 35 cm (at 5.0 m of height), reaching its maximum (almost 8%) at a diameter of 50 cm and decreasing afterwards to 4% near to the base of the tree.

The heartwood, sapwood and bark proportions at different stem diameters of the 18-year-old tree are illustrated in Figure 5b. In this case, the heartwood proportion reached a maximum of 35%, while the sapwood decreased from 85 to

Table 2 Bark, sapwood and heartwood content of *Bombacopsis quinata* trees harvested in Costa Rica

Tree code	Age (years)	DBH (cm)	Total height (m)	Total volume (m^3)	Heartwood volume (m^3)	Sapwood volume (m^3)	Bark volume (m^3)	Heartwood volume (%)	Sapwood volume (%)	Bark volume (%)
1	10	24.90	15.30	0.2967	0.0007	0.2290	0.0670	0.20	77.20	22.60
2	12	29.80	15.80	0.4197	0.0037	0.3300	0.0860	1.00	79.00	20.00
3	13	26.00	16.60	0.3739	0.0049	0.2930	0.0760	1.30	78.40	20.30
4	13	20.40	11.90	0.1891	0.0041	0.0970	0.0880	2.20	78.70	19.10
5	13	35.90	19.50	0.7706	0.0126	0.6400	0.1180	2.00	83.00	15.00
6	15	20.10	14.10	0.1940	0.0170	0.1390	0.0380	8.80	71.60	19.60
7	16	22.30	17.30	0.2504	0.0004	0.2200	0.0300	0.17	87.10	12.70
8	16	21.50	13.70	0.2114	0.0014	0.1800	0.0300	0.64	84.20	15.10
9	17	18.10	14.30	0.1740	0.0040	0.1400	0.0300	0.22	83.50	16.30
10	17	28.80	15.90	0.4200	0.0200	0.3400	0.0600	4.86	80.90	14.20
11	17	26.10	15.30	0.3300	0.0300	0.2400	0.0600	8.74	73.30	18.00
12	17	23.60	15.50	0.2500	0.0100	0.1900	0.0500	5.71	76.10	18.20
13	18	37.90	23.00	0.9320	0.1270	0.6970	0.1080	13.60	74.80	11.60
14	20	30.80	22.30	0.6761	0.0491	0.4720	0.1550	7.00	70.00	23.00
15	21	29.40	23.00	0.5800	0.0200	0.4900	0.0700	2.66	85.80	11.50
16	21	33.70	20.50	0.7200	0.0500	0.6000	0.0700	6.74	83.90	9.40
17	21	32.90	22.00	0.7100	0.0100	0.6200	0.0800	1.77	87.20	11.00
18	22	25.60	19.00	0.3900	0.0100	0.3200	0.0600	2.72	81.40	15.90
19	22	14.20	16.20	0.1110	0.0010	0.0900	0.0200	0.06	84.40	15.50
20	22	29.60	19.80	0.6000	0.0200	0.4700	0.1100	2.78	79.10	18.10
21	22	25.40	18.40	0.3700	0.0200	0.2900	0.0600	4.04	78.70	17.20
22	23	46.00	25.70	1.7865	0.0445	1.5080	0.2340	2.50	84.40	13.10
23	26	24.50	19.10	0.4131	0.0301	0.3350	0.0480	7.00	81.00	12.00
24	26	49.70	18.05	1.2900	0.1600	0.9800	0.1500	12.19	76.20	11.60
25	27	31.60	23.60	0.7100	0.0600	0.5700	0.0800	8.11	80.40	11.50
26	27	30.70	24.10	0.5900	0.0200	0.5100	0.0600	3.63	86.60	9.60
Mean	19	28.40	18.50	0.5300	0.0281	0.4200	0.0800	4.26	80.30	15.50



(a) (b)

Figure 2 Variation in bark, sapwood and heartwood content with (a) age and with (b) DBH of *Bombacopsis quinata* trees in Costa Rica

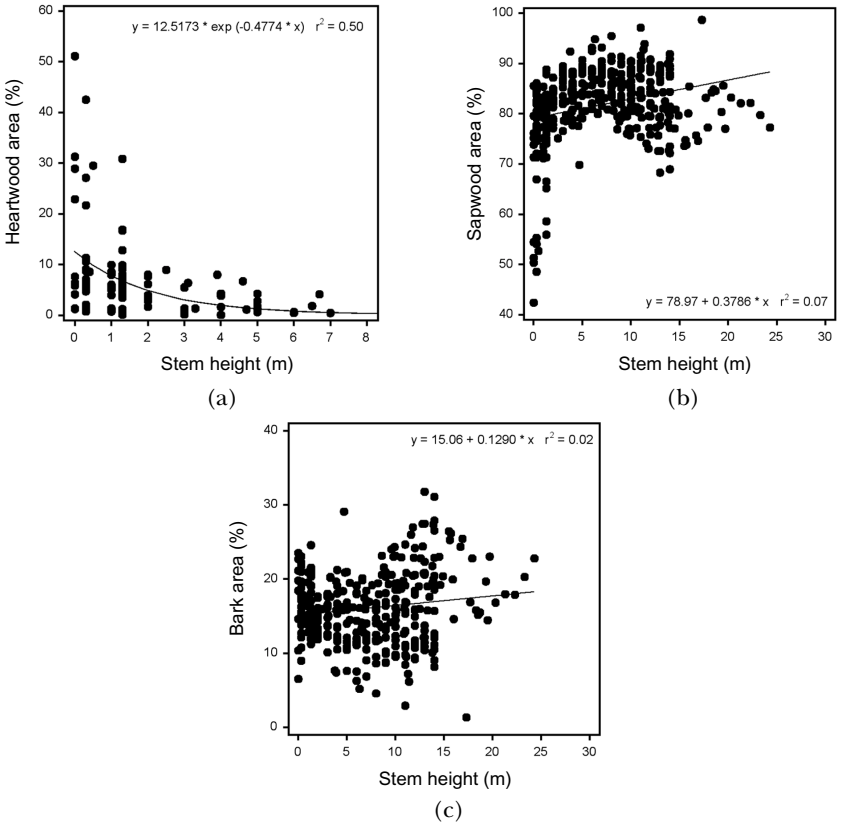


Figure 3 Cross section areas of (a) heartwood, (b) sapwood and (c) bark at different stem heights of *Bombacopsis quinata* in Costa Rica

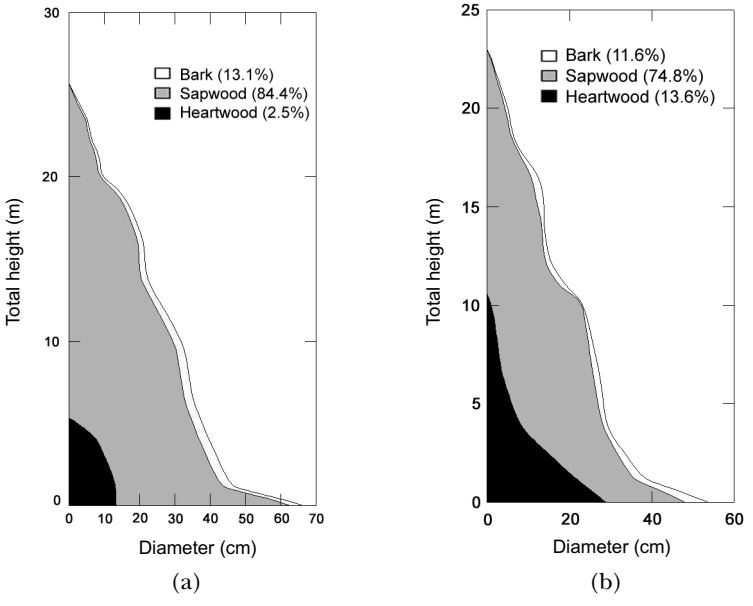


Figure 4 Bark, sapwood and heartwood stem analysis of (a) a 23-year-old *Bombacopsis quinata* tree harvested in a moist region in Costa Rica and of (b) an 18-year-old *B. quinata* tree harvested in a dry region in Costa Rica

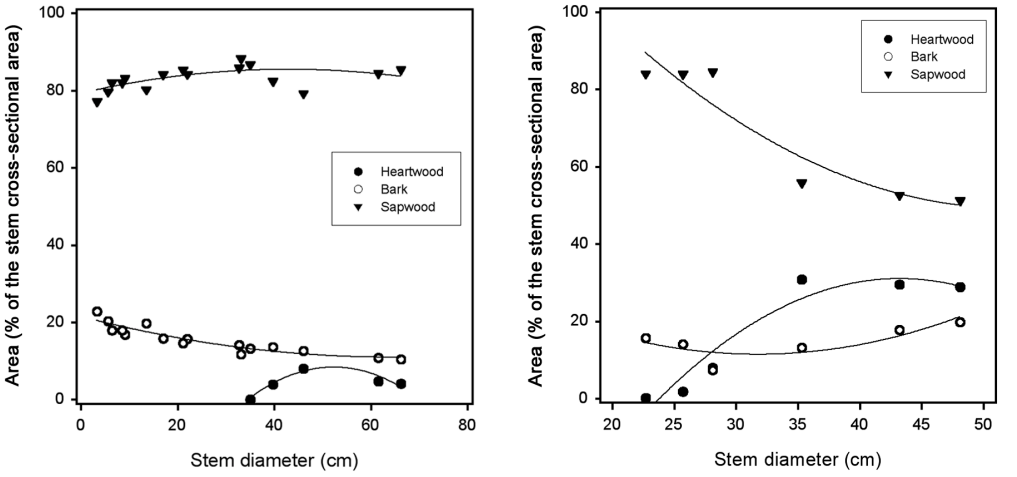


Figure 5 Variation in bark, sapwood and heartwood cross-sectional areas at different stem diameters of (a) a 23-year-old *Bombacopsis quinata* harvested in a moist region in Costa Rica and of (b) an 18-year-old *B. quinata* harvested in a dry region in Costa Rica

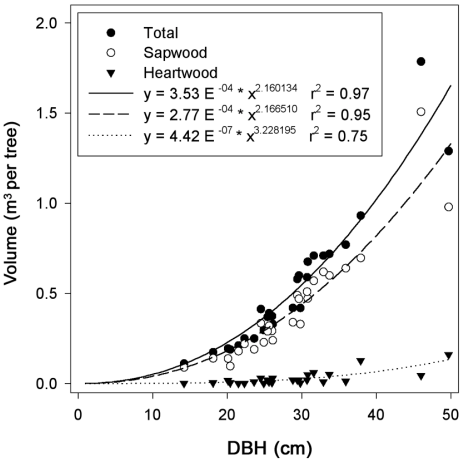


Figure 6 Relationship between total, sapwood and heartwood volume with DBH of *Bombacopsis quinata* trees in Costa Rica

50% and the bark increased from 15 to 20%, both with increasing stem diameter. Total stem, sapwood, and heartwood volumes increased exponentially with DBH; however, the heartwood showed a lower increment than the other two variables (Figure 6).

No clear differences in heartwood content could be observed between trees of similar age from dry and wet zones.

Discussion

Bombacopsis quinata is a native species of relatively fast growth rate. Therefore, recommended rotations are close to 30 years. The present study indicates that, at

least in Costa Rica, this species forms low percentages of heartwood (less than 15% of total stem volume) at 27 years of age. Low proportions of heartwood content imply a wood production of low quality for timber.

Moya and Córdoba (1995) found no heartwood content in 8-year-old *B. quinata* harvested in the dry zone of Guanacaste, Costa Rica. Trees evaluated had a maximum DBH of 22 cm and a density of 1111 trees ha^{-1}. Nevertheless, the wood was categorised as fast drying and of good quality, showing a few small sweeps and a loss of only 2% over the sawn volume. According to the authors, wood of *B. quinata* from young plantations can be used for general construction and for more elaborated products as well.

The present results showed that there was a slight increment in heartwood content with age. However, at ages near 30 years, which was considered in Costa Rica as a possible rotation period for this species, the heartwood content might not be higher than 15% of the total volume.

While 10-year-old *B. quinata* trees produce only 0.2% heartwood, other species also cultivated in Costa Rica, such as *T. grandis*, *G. arborea*, and *Acacia mangium*, can produce more than 30% heartwood at the same age (Bhat 1995, Laurila 1995). On the other hand, Urueña (1999) reported heartwood contents between 19 and 36% of the total stem volume of 14-year-old *B. quinata* trees in Colombia, concluding that the heartwood started to form at 10 years of age. The author also reported that some *B. quinata* trees in Colombia had no heartwood in stands of 7.5 years old or less, while in stands of 10 years old the heartwood proportion was only 2% of the cross-sectional area at the base of the tree.

Similar to this, *Cedrus atlantica* has been reported to form low heartwood contents (< 15%) relatively late (35 years) in the European Mediterranean area (Hapla *et al.* 2000). In a study carried out in northern Sweden, the heartwood-sapwood ratio (at DBH) of 30-year-old Scots pine (*Pinus sylvestris*) was 0.07 (Mörling & Valinger 1999), compared with 0.28 obtained in the present study for *B. quinata*. In tree species growing in temperate regions, e.g. *Picea abis* growing at Vooremaa Ecology Station, East Estonia, the heartwood cross-sectional area exceeded that of the sapwood at ages over 100 years (Sellin 1994), while in tropical tree species such as *Eucalyptus tereticornis*, this happened at 8 to 9 years of age (Purkayastha *et al.* 1980).

The heartwood content within a tree decreased with height, meaning less heartwood area in the upper sections. Heartwood is practically absent after 7.0 m of height, but sapwood and bark contents were 80 and 20% respectively. The bark proportion decreased from 25 to 10% with increasing age; therefore, estimations of total volume under bark must consider these variations when predicting yield.

Nair and Chavan (1985), in a study of wood parameters in some timber trees (including *T. grandis*), found that the ratio of heartwood area to sapwood area at the apex and base showed strong positive correlation with tree height. This confirmed that when tree height increases the cross-sectional area of heartwood shows a definite increment without a concomitant change in sapwood area.

In the present study the stem diameter had no relation with the percentage of heartwood but was related to the sapwood volume. The low proportions of heartwood content made the sapwood volume almost equal to the tree total volume. For Hillis (1968), trees with retarded heartwood content are better regarded as sapwood trees.

Since the heartwood content of the sample trees was considerably low and in some individuals even absent, no further analyses were carried out to relate this variable with other factors, such as stand density, height dominance, growth rate, precipitation and soil.

Actual recommendations for rotation periods of 30 years (e.g. Hughell 1991, Arguedas & Torres 1992, Kammesheidt 1998, Urueña 1999) should consider the low content of heartwood in *B. quinata*. Rotation periods for *B. quinata* in Costa Rica should be extended if the objective is to obtain higher volumes of heartwood.

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