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ORIGINAL ARTICLE

Inheritance pattern and genetic correlations among growth and wood quality traits in Para rubber tree (*Hevea brasiliensis*) and implications for breeding

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Abstract

Inheritance pattern of wood traits viz. specific gravity, fibre dimensions and fibre-derived biometrical indices and their interactions among themselves and with that of growth are reported in *Hevea brasiliensis*. Girth ($h^2 = -0.02 \pm 0.44$ to $h^2 = 0.35 \pm 0.24$) showed moderate genetic control. Among wood traits, specific gravity ($h^2 = 0.15 \pm 0.31$ to $h^2 = 0.33 \pm 0.28$) was found to be under moderate genetic control. Fibre traits viz., fibre length ($h^2 = -0.26 \pm 0.30$ to $h^2 = 0.50 \pm 0.34$), fibre diameter ($h^2 = 0.19 \pm 0.49$ to $h^2 = 0.70 \pm 0.11$), fibre lumen diameter ($h^2 = -0.18 \pm 0.35$ to $h^2 = 0.56 \pm 0.47$) and fibre wall thickness ($h^2 = -5.17 \pm 5.26$ to $h^2 = 0.50 \pm 0.50$) were under moderate to strong genetic control. Among fibre-derived indices, flexibility coefficient ($h^2 = 0.48 \pm 0.21$ to $h^2 = 0.89 \pm 0.29$) showed moderate to very strong genetic control. The Runkel ratio ($h^2 = -0.40 \pm 0.27$ to $h^2 = 0.42 \pm 0.29$) and slenderness ratio ($h^2 = -0.36 \pm 0.29$ to $h^2 = 0.43 \pm 0.28$) showed moderate genetic control. Girth showed very strong positive genetic correlation with fibre wall thickness and strong positive correlation with fibre width indicating scope of indirect selection potential for these traits. Wood specific gravity was not correlated with either girth or fibre traits. Hence, it would be possible to concomitantly improve growth and fibre traits without adversely affecting wood specific gravity. Moderate to very high estimates of heritability for fibre traits, girth and specific gravity indicated that considerable genetic gain can be realised for these traits. Implications of the above findings in genetic improvement of wood in *Hevea* are discussed.

Keywords *Hevea brasiliensis* · Wood quality · Inheritance · Genetic improvement · Genetic correlation

Introduction

Hevea brasiliensis (Willd. ex. A. de Juss.) Müll. Arg., the Para rubber tree, belonging to family Euphorbiaceae (diploid, $2n = 36$), is monoecious, entomophilic and predominantly outbreeding. The Para rubber tree, which is native to Amazon forests of Brazil, has been successfully domesticated outside its natural range of distribution in several countries particularly in the Far East. The tree yields copious amounts of latex (primary global source of natural rubber particle called 'isoprene') which is a strategic raw material for tyres and thousands of other rubber-based industrial products. Although latex productivity (or rubber yield) continues to be the primary objective of *Hevea* breeding programme, wood productivity is also gaining importance, offering wide scope for selection and improvement (Mydin 2014). Several fast-growing rubber clones producing more timber biomass besides yielding appreciable amount of latex (called 'latex-timber clones') have already been developed in rubber growing countries including Malaysia and India (Ong 2000).

Extensive research in many softwood and hardwood tree species has shown that most wood qualities as well as tree form and growth characteristics that affect wood are inherited strongly enough to obtain rapid gains through genetic manipulation (Smith 1967; Zobel and Talbert 1984). Although heritability of latex yield and related traits has been well established in *Hevea*, no such information is available on inheritance pattern of wood traits.

While proportion of wood biomass produced by a rubber clone is determined by its growth rate and is strongly influenced by tapping (Gooding 1952; Silpi et al. 2006), quality of

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wood is determined by its different structural components. Use of genetically improved planting material generated through exploitation of wide variation in strongly inherited wood traits can greatly minimise defects in timber (Harris 1983). In order to achieve the above, it is essential to identify criteria for selection and improvement of specific wood quality traits in *Hevea* for different end uses either for timber or paper industry. This necessitates detailed investigation on heritability and genetic correlations of important anatomical characteristics of rubber wood which will also help to design specific genetic improvement programme employing appropriate selection and breeding strategies (Tembe et al. 2010). In view of the above, a study was carried out to estimate variation and heritability of growth, specific gravity, fibre and fibre-derived biometrical indices in *Hevea* and assess their interactions. In following sections, we present hitherto unreported information on inheritance pattern of wood traits and their interrelationships in *Hevea*.

Materials and method

Experimental material

The experimental population consisted of progenies of 11 full-sib families (derived from a hybridization programme involving 25 parental clones in various combinations) and their parent clones (Table 1). The above population was planted in 1993 in a small-scale trial at Central Experimental Station of Rubber Research Institute of India located at Chethackal (Pathanamthitta Dt., Kerala, India) adopting a replicated simple lattice design (5 × 5 design, four replicates, seven trees per replication; total number of trees, 700). In order to assess wood parameters, wood core samples were extracted from 20-year-old experimental trees at a height of 150 cm using an increment borer. Growth in terms of girth was measured at a height of 150 cm at the same time when wood samples were extracted. All trees in the trial were analysed. Wood specific gravity (SG) of rubber clones was estimated based on green volume and oven dry weight (Otegbeye and Kellison 1980). Fibre traits were assessed following the micro-technique method described by Johansen (1940). The biometrical indices such as the Runkel ratio, slenderness ratio and flexibility coefficient were derived from fibre dimensions as per standard procedures (Ogbonnaya et al. 1997).

Table 1 Details of parental clones and full sibs

Clone	Parentage*	Origin	Full-sib family
RRII 33	Ortet	India	RRII 105 × PB 217
RRII 105	Tjir 1 × Gl 1	India	RRII 105 × PB 5/51
RRII 118	Mil 3/2 × Hil 28	India	RRII 105 × PB 86
RRII 203	PB 86 × Mil 3/2	India	RRII 105 × PR 107
RRII 208	Mil 3/2 × AVROS 255	India	RRII 105 × RRII 118
Gl 1	Ortet	Malaysia	RRIM 600 × Gl 1
PB 217	PB 5/51 ×PB 6/9	Malaysia	RRIM 600 × PB 235
PB 235	PB 5/51 × PB s/78	Malaysia	RRIM 600 × RRII 203
PB 242	PB 5/51 × PB 32/36	Malaysia	RRIM 600 × RRII 33
PB 28/59	Ortet	Malaysia	PB 242 × RRII 105
PB 5/51	PB 86 × PB 24	Malaysia	PB 5/51 × RRII 208
RRIM 600	Tjir 1 × PB 86	Malaysia	
PB 86	Ortet	Malaysia	
PR 107	Ortet	Indonesia	

*Ortet—primary clone developed through selection from seedling population

Narrow sense heritability and genetic correlation

Narrow sense heritability of growth and wood traits was estimated based on parent-offspring regression (Zobel and Talbert 1984; Falconer and Mackay 1996). The regression (b_{op}) was computed using following equation:

$$b_{op} = \frac{COV_{op}}{\sigma_p^2}$$

(where b_{op} is the regression of offspring on parent, cov_{op} is the covariance of offspring on parents and σ_p^2 is the variance of parents).

In above analysis, the mean values of parents and progenies were subjected to regression where the sloping line indicated the linear regression of offspring on midparent. Narrow sense heritability (h^2) for a specific trait was then directly estimated from the slope of the line (b). The regression equation is as follows:

$$y = bx + e$$

(where y is the average of progeny values, b is the regression coefficient (slope of line), x is the midparent value and e is the error which indicates lack of fit of values to the line)

For estimation of heritability, data from progenies and parents was grouped according to Steinhoff and Hoff (1971) as follows: (1) progeny on female parents, (2) progeny on male parents and (3) progeny on midparent. When values of progenies and only one of the parents (either female or male) are used, the regression coefficient (b) equals half the narrow sense heritability. However, when values of progenies and midparent are used, the regression coefficient (b) equals narrow sense heritability (Zobel and Talbert 1984). The standard errors of heritability estimates were obtained from the results of regression analysis as suggested by Falconer and Mackay (1996).

Genetic correlation was computed based on the offspring-parent relationship (Falconer and Mackay 1996). For computing genetic correlation between two traits, 'cross-variances' were calculated from the product of value of x in parents and value of y in offspring. The cross-variance represents half the genetic covariance of the two traits and equals ½ COV_A. Genetic correlation (r_A), was computed using COV_{xy} ('cross-variance') and COV_{xx} and COV_{yy}, the offspring-parent covariances of each trait separately, as follows:

$$r_A = \frac{COV_{xy}}{\sqrt{COV_{xx}COV_{yy}}}$$

In general, cross-variance may be calculated from x in parents and y in parents or vice versa. In the present study, since both the values were available, the arithmetic mean was used. The standard error of genetic correlation $\sigma_{(r_A)}$ was computed based on Falconer and Mackay (1996) as follows:

$$\sigma_{(r_A)} = \frac{1-r_A^2}{\sqrt{2}}\sqrt{\left[\frac{\sigma(h_x^2)\ \sigma(h_y^2)}{h_x^2\ \ h_y^2}\right]}$$

(where σ denotes standard error, h_x^2 and h_y^2 are heritability estimates of traits x and y respectively).

Results and discussion

Variability for growth, wood fibre traits and biometrical indices

Averages including standard errors for growth, wood fibre traits and biometrical indices are given in Table 2. Parent- and family-wise mean values for individual traits are separately provided (Tables 3 and 4). Based on fibre length recorded from parental clones and their full sibs, fibres could be classified as medium-sized which is in conformity with previous studies (Bhat et al. 1984; Reghu et al. 1989). However, there are few reports identifying rubber wood fibres as short fibres (Jahan et al. 2011). Considerable variations in fibre length have also been reported in rubber trees of clonal and seedling origin at different ages (Naji et al. 2011). Since fibre length significantly influences mechanical properties and shrinkage of rubber wood, it has been considered as a critical factor in determining quality of wood (Naji et al. 2011).

There was considerable variation for fibre and fibre lumen diameter and fibre wall thickness in parental clones and their progenies (Tables 3 and 4). Similar clonal variation for fibre traits has been reported in *Hevea* (Naji et al. 2011). Physical properties of sheets made from hardwood pulp fibres are very much dependent upon fibre characteristics and that fibre with thick walls result in paper having low burst and tensile strengths, a high degree of resistance to tear and a very low folding endurance (Horn 1978).

Wood specific gravity as recorded in the present study is in conformity with those observed in various species of *Hevea* (Brown 1997; Naji et al. 2011). Intra- and inter-clonal differences for wood specific gravity have been reported in many hardwoods including *Hevea* (Naji et al. 2011; Chukwuemeka 2016).

Biometrical indices derived from wood fibre characteristics viz. the Runkel ratio, slenderness ratio and flexibility coefficient are considered as important traits for pulp and paper production. While the Runkel ratio is related to paper conformability (Higgins et al. 1973), slenderness ratio determines tearing strength and folding endurance of paper (Yahya et al. 2010). Flexibility coefficient is another important criterion which determined quality of fibres and their suitability for pulp and paper industry. Hence, the above derived wood properties have been proposed for use as selection indices for quality breeding (Ohshima et al. 2005).

Among parental clones, the Runkel ratio ranged from 0.67 in RRIM 600 to 0.83 in PB 5/51. Full-sib family RRIM 600 × Gl 1 had a maximum Runkel ratio (0.81) compared to RRII

Table 2 Range (*R*) and averages (*n*) including standard errors (S.E.) for growth and wood fibre traits in parental clones and full-sib families

	Parental clones		Full-sib family	
Trait*	*R*	*n* (S.E.)	*R*	*n* (S.E.)
FL (μm)	1008.8–1242.7	1110.54 (18.97)	1025.3–1213.9	1114.64 (18.97)
FD (μm)	22.2–28.4	23.82 (0.40)	22.7–25.3	24.1 (0.24)
FLD (μm)	12.7–15.8	13.6 (0.2)	12.8–15	14.0 (0.2)
FWT (μm)	4.7–6.3	5.2 (0.12)	4.5–5.4	5.1 (0.1)
SG	0.62–0.69	0.66 (0.01)	0.63–0.71	0.67 (0.01)
Girth (cm)	60.8–93.0	72.13 (3.18)	71.3–90.6	79.4 (1.85)
RR	0.67–0.99	0.77 (0.02)	0.6–0.81	0.73 (0.02)
SR	0.35–0.51	46.8 (1.1)	42.4–50.9	46.3 (0.75)
FC	0.54–0.62	0.57 (0.01)	0.56–0.63	0.58 (0.01)

**FL* fibre length, *FD* fibre diameter, *FLD* fibre lumen diameter, *FWT* fibre wall thickness, *SG* specific gravity, *RR* the Runkel ratio, *SR* slenderness ratio, *FC* flexibility coefficient

Table 3 Girth, fibre traits and biometrical indices of parental clones

Clone	FL* (μm)	FD* (μm)	FLD* (μm)	FWT* (μm)	SG*	Girth (cm)	RR*	SR*	FC*
RRII 203	1179.5	24.6	14.1	5.5	0.69	88.0	0.78	47.95	0.57
RRII 118	1242.7	24.2	13.4	5.0	0.66	93.0	0.75	51.35	0.55
RRII 33	1105.6	23.3	13.2	5.0	0.68	64.8	0.76	47.45	0.57
RRII 105	1121.3	23.7	13.7	5.3	0.67	69.2	0.77	47.31	0.58
PB 5/51	1067.7	23.3	12.7	5.3	0.64	63.1	0.83	45.82	0.55
RRIM 600	1008.8	28.4	15.8	5.3	0.67	74.8	0.67	35.52	0.56
PB 28/59	1108.2	22.2	12.8	6.3	0.68	74.8	0.98	49.92	0.58
PB 217	1145.7	23.3	13.9	4.7	0.69	82.6	0.68	49.17	0.60
RRII 208	1115.3	24.6	13.8	5.6	0.62	62.2	0.81	45.34	0.56
PB 235	1208.9	23.7	13.2	5.4	0.69	90.9	0.82	51.01	0.56
PB 242	1024.8	22.5	13.1	5.3	0.64	61.4	0.81	45.55	0.58
Gl 1	1148.1	23.0	13.5	4.7	0.63	63.1	0.70	49.92	0.59
PB 86	1037.5	22.6	14.1	4.8	0.66	60.8	0.68	45.91	0.62
PR 107	1033.4	24.1	13.7	4.8	0.62	61.2	0.70	42.88	0.57

*Details of abbreviation given in Table 2

105 × PB 86 (0.60). Fibres with a lower Runkel ratio are preferred in production of paper with good strength properties (Valkomies 1969; Bektas et al. 1999). In the present study, a lower Runkel ratio of fibres of parental clones (mean 0.77) and their full sibs (mean 0.73) indicated the suitability of their fibres for paper and pulp industry. Among parental clones, slenderness ratio ranged from 35.5 in RRIM 600 to 51.4 in RRII 118. Among full-sib families, PB 5/51 × RRII 208 recorded maximum SR (50.9) compared to RRIM 600 × RRII 203 (42.4). Fibres with optimum slenderness ratio of more than 33 result in better-formed and well-bonded paper (Rafat 2011). Mean slenderness ratio of parental clones and their full-sib families was more than 46 indicating suitability of their fibres for paper production as reported in other tree species (Xu et al. 2006). Flexibility coefficient of the parental clones was maximum in PB 86 and minimum in RRII 118 and PB 5/51. Among full sibs, the ratio was maximum in family RRII 105 × PB 86 and minimum in RRIM 600 × Gl 1. The overall range of flexibility coefficient (0.54–0.63) of parental clones and full sibs indicated that their fibres fell within the desirable range (Istas et al. 1954; Bektas et al. 1999).

Heritability of growth and wood traits

Heritability estimates for growth, wood traits and biometrical indices are given in Table 5. Heritability of girth ($h^2 = -0.02 \pm 0.44$ to $h^2 = 0.35 \pm 0.24$) indicated that it is under moderate genetic control corroborating earlier estimates (Tan et al. 1975; Tan 1979). While wide ranges (9–93%) of heritability estimates have been estimated for girth in Para rubber tree (Gonçalves et al. 2004; Narayanan and Mydin 2011), non-significant estimates have also been reported (Alika 1985).

Table 4 Girth, fibre traits and biometrical indices of full-sib families

Family	FL* (μm)	FD* (μm)	FLD* (μm)	FWT* (μm)	SG*	Girth (cm)	RR*	SR*	FC*
RRIM 600 × Gl 1	1050.9	22.7	12.8	5.2	0.71	71.4	0.81	46.30	0.56
PB 242 × RRII 105	1167.3	25.3	14.6	5.4	0.70	77.1	0.74	46.14	0.58
RRIM 600 × RRII 203	1025.3	24.2	14.1	5.3	0.69	77.4	0.75	42.37	0.58
PB 5/51 × RRII 208	1174.7	23.1	13.2	4.9	0.68	84.5	0.74	50.85	0.57
RRII 105 × PR 107	1213.9	24.5	14.6	4.9	0.63	77.1	0.67	49.55	0.60
RRII 105 × PB 5/51	1126.0	24.1	13.8	5.2	0.68	71.3	0.75	46.72	0.57
RRII 105 × PB 86	1087.1	23.9	15.0	4.5	0.67	76.1	0.60	45.49	0.63
RRII 105 × PB 217	1148.2	25.0	14.5	5.2	0.65	77.8	0.72	45.93	0.58
RRIM 600 × RRII 33	1025.8	24.1	13.7	5.2	0.67	85.5	0.76	42.56	0.57
RRII 105 × RRII 118	1094.9	23.4	13.8	4.8	0.68	90.6	0.70	46.79	0.59
RRIM 600 × PB 235	1147.0	24.8	14.2	5.3	0.66	84.9	0.75	46.25	0.57

*Details of abbreviation given in Table 2

Table 5 Narrow sense heritability (h^2) of growth, wood traits and biometrical indices

Parental combination	FL* (μm)	FD* (μm)	FWT* (μm)	FLD* (μm)	SG*	G* (cm)	RR*	SR*	FC*
Offspring-'midparent'	0.15 (0.61)	0.70 (0.11)	0.50 (0.50)	− 0.18 (0.35)	0.33 (0.28)	0.35 (0.24)	− 0.40 (0.27)	0.25 (0.11)	0.67 (0.38)
Offspring-female parent	0.50 (0.34)	0.35 (0.06)	− 5.17 (5.26)	− 0.15 (0.17)	0.15 (0.31)	− 0.02 (0.44)	0.42 (0.29)	− 0.36 (0.29)	0.48 (0.21)
Offspring-male parent	− 0.26 (0.30)	0.19 (0.49)	0.27 (0.25)	0.56 (0.47)	0.17 (0.16)	0.24 (0.13)	− 0.05 (0.44)	0.43 (0.28)	0.89 (0.29)

*Details of abbreviation given in Table 2; values in parentheses are standard errors

Clones with better growth are also generally capable of producing more wood biomass in addition to latex yield as exemplified by latex-timber clones like RRII 203, RRII 118, PB 235 and the recent RRII 400 series clones including RRII 414 and RRII 430 (Mydin 2014).

There was moderate to strong genetic control of wood specific gravity ($h^2 = 0.15 \pm 0.31$ to $h^2 = 0.33 \pm 0.28$). Wood specific gravity, which has strong influence on quality of wood, paper and pulp products, is under strong genetic control (Zobel 1961). Trees grown using wind-pollinated seeds from parent trees with the high specific gravity possessed high specific gravities compared to those trees raised from parent trees with lower specific gravity (Zobel and Rhodes 1957).

Fibre length showed moderate to high heritability ($h^2 = -0.26 \pm 0.30$ to $h^2 = 0.50 \pm 0.34$). After density, wood fibre has been considered as important trait for genetic analysis (Zobel and Jett 1995). Among other fibre traits, fibre length, which is an important trait influencing pulp and paper properties, has been found to be under moderate to strong genetic control in conifers (Goggans 1964) and hardwoods (Einspahr et al. 1963). Strength, surface and bonding properties of fibre products are affected by fibre length and therefore, for many purposes, longer fibres have been considered desirable (Nicholls and Dadswell 1959). In *Pinus* spp. fibre length was found to be under strong genetic control and fibre length of the progeny was more influenced by the female than by the male parent (Jackson and Green 1957). The above study in *Pinus* spp. also revealed that hybrids from parents with long tracheids had longer tracheids than progeny from trees with short tracheids which indicated significance of parental selection in breeding for fibre length. In *Hevea*, clones possessing wood with long and thick-walled fibres and having higher specific gravity are preferred as source for general utility timber (Allwi and Izani 2006).

While fibre diameter showed moderate to high heritability ($h^2 = 0.06 \pm 0.19$ to $h^2 = 0.70 \pm 0.11$), fibre lumen diameter ($h^2 = -0.18 \pm 0.35$ to $h^2 = 0.56 \pm 0.47$) and cell wall thickness ($h^2 = -5.17 \pm 5.26$ to $h^2 = 0.50 \pm 0.50$) showed moderate to high heritability. Open-pollinated progeny tests of loblolly pine showed non-significant to very high heritability estimates for double cell wall thickness, radial tracheid diameter, radial cell width and tangential cell width (Goggans 1965). Though few supporting evidences have been found for definite genetic control of the above cell dimensions, they are not under strong control as that of tracheid or fibre length. Nevertheless, indirect evidences from inheritance studies on wood specific gravity and late wood proportion in conifers supported strong inheritance of cell dimensions (van Buijtenen and Zobel 1998).

Fibre traits viz. fibre length, fibre diameter, lumen diameter and fibre wall thickness have greater influence on determining structural, physical and chemical properties of wood. These traits affect wood processing (e.g. drying), resistance to cutting and machining and pulpwood quality (Oluwafemi and Sotannde 2007). Further, physical and chemical properties of fibres greatly determine types of papers that are manufactured (Clark 1965). Different derived wood quality indices like the Runkel ratio and slenderness ratio greatly depend on various dimensions of fibres (Fujiwara et al. 1991). Hence, information on genetic control of the above fibre traits is to be emphasised while designing breeding programme for improving wood traits in *Hevea*.

Among the three biometrical indices, flexibility coefficient showed moderate to very strong genetic control ($h^2 = 0.48 \pm 0.21$ to $h^2 = 0.89 \pm 0.29$). The Runkel ratio ($h^2 = -0.40 \pm 0.27$ to $h^2 = 0.42 \pm 0.29$) and slenderness ratio ($h^2 = -0.36 \pm 0.29$ to $h^2 = 0.43 \pm 0.28$) showed moderate genetic control. Since the above three biometrical indices depend on the individual fibre parameters, breeding for individual fibre traits will also bring corresponding changes in these indices (Zobel and Jett 1995). Hence, it is important to have reasonable control over the cell dimensions without affecting the above desirable biometrical indices.

Genetic correlation of growth and wood traits

Girth showed negative genotypic correlation with fibre length but strong positive correlation with fibre diameter and fibre wall thickness (Table 6). It is generally known that fast-

Table 6 Genetic correlation between growth and fibre traits

	Fibre length	Fibre diameter	Fibre wall thickness
Girth	− 0.48 (0.90)	0.456 (0.18)	0.781 (0.23)
Fibre length	1.00	− 1.936 (− 1.5)	− 0.25 (1.32)
Fibre diameter		1.00	0.793 (0.10)

Values in parentheses are standard errors growing hardwood trees usually produced shorter fibres (Zobel and van Buijtenen 1989). Similar trend has been reported in conifers as well as hardwood species (Dutilleul et al. 1998). Wood density did not show correlation with growth rate confirming similar reports in several other tree species (Quilho and Pereira 2001). Few studies reported no correlation between growth rate and wood density while others reported a negative relationship in diffuse porous hardwoods (Wilkins and Horne 1991; Downes and Raymond 1997). In general, the correlation between specific gravity and growth rate are generally not very strong (van Buijtenen and Zobel 1998). Since data from present study support the above, it would be possible to concomitantly improve growth trait without adversely affecting wood specific gravity in *Hevea*.

Conclusions

With the concept of latex-timber clones (genotypes having potential for more wood production in addition to dry rubber), growth vigour has become an important trait for selection in *Hevea*. Moderate genetic control of girth suggest possibility of achieving significant quantitative improvement of wood biomass by breeding clones with better growth vigour. Since rubber yield is reported to be positively correlated with growth rate, it is possible to achieve better growth vigour without affecting rubber yield in *Hevea*.

Specific gravity showed moderate genetic control. Hence, it may be possible to genetically improve wood suitable for various end uses. Also, wood specific gravity did not show significant correlation with growth and important fibre trait like fibre length. Hence, it may be possible to exert independent control on these traits. Due to positive genetic relationships, selection for growth would possibly lead to concomitant improvement in fibre diameter and fibre wall thickness. Since there is negative relationship between growth and fibre length, it may not be possible to simultaneously attain vigorous growth and longer fibres. Several studies in other tree species have led to similar conclusions (Ivkovich et al. 2002; Fries and Ericsson 2006; Lenz et al. 2010). Pulp and paper properties and bonding properties of fibre products are significantly influenced by length of fibre and longer fibres have been found desirable. Hence, *Hevea* breeding would need to consider improvement of rubber productivity and growth without having adverse effect on important fibre traits. In such cases, it would be beneficial to follow 'index-based' selection, which relies upon optimised strategies using variable economic weights for desirable traits (Greaves et al. 1997; Fries 2012). Based on similar studies in other trees species, it has been suggested to identify specific families which deviate from reported patterns of genetic correlations ('correlation breakers') and utilise them to specifically combine high growth vigour and wood with long fibres (Fries 2012).

An extensive review on heritability of fibre characteristics and its implication in breeding for wood quality in several softwood and hardwood trees showed that a moderate improvement can be expected for length and diameter of fibre through hybridization as well as superior phenotypic selections or *plus trees* (Smith 1967). In this context, hybridization using suitable parental clones as well as selection of superior tress (*ortets*) with desirable wood traits can be beneficial for improving wood traits in *Hevea*.

Data archiving statement The above research work does not involve any molecular parameters and hence no data or sequences have been submitted to public databases.

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