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Structure of the Bark and Clonal Variability in *Hevea brasiliensis* Muell. Arg. (Willd. ex A. Juss.)

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ABSTRACT

Detailed studies have been made on the structure of the bark of ten *Hevea* clones and the clonal variabilities with regard to the density and size of ray groups, density of laticifers per row per unit circumference of the tree, diameter of laticifers and the extent of connection between laticifers. Clonal variability was highly significant with regard to the density of ray groups, ray height, ray width in the laticifer layer and the laticifer characters. The influence of ray characters on the orientation of laticifers and thereby its quantity is discussed. The scope of using anatomical parameters for clone identification is examined.

Key words: *Hevea brasiliensis*, Para rubber tree, laticifers, bark (structure), anatomy, clonal variability, rubber.

INTRODUCTION

Hevea brasiliensis, the Para rubber tree, belonging to Euphorbiaceae, is the main source of natural rubber. Natural rubber is recovered from the latex contained in the laticifers which is collected through a process of controlled wounding, known as tapping, of the bark of the trunk. The structural organization of the bark of *Hevea brasiliensis* and the variability of laticiferal characters have received much attention (Bobilioff, 1923; Kaimal, 1951; Gomez and Chen, 1967; Gomez, Narayanan and Chen, 1972; Ho, Narayanan and Chen, 1973; Narayanan, Gomez and Chen, 1973; Narayanan, Ho and Chen, 1974; Panikkar, 1974; Gomez, 1982). Correlation studies between various yield component factors have established the influence of vigour, bark thickness and the number of latex vessel rows on the yield of *Hevea* clones (Narayanan *et al.*, 1973; Ho *et al.*, 1973). Direct correlation between initial flow rate and the number of rows of laticifers has also been reported (Sethuraj, Sulochanamma and George, 1974), although the variability in yield could not be explained fully on the basis of the available information. The present work is an attempt to collect more information on the structure of *Hevea* bark and the clonal variability with regard to certain anatomical characteristics.

MATERIALS AND METHODS

The materials for the study were collected from ten clones in a trial laid out in 1971, in a randomized block design with three replications. The clones studied were Ch 153, GT 1, Harbel 1, IAN 45-713, IAN 45-873, PB 5/51, PR 107, RRIM 701, RRIM 703, and Wagga 6278. Samples of virgin bark were collected from one tree each from three plots per clone in 1980 at a height of 125 cm from the bud union and fixed in formalin acetic alcohol mixture. Sections of 80 μm thickness were cut in the tangential plane using a sledge microtome. The sections were stained with Sudan III and observed under the microscope. The characters studied were the following.

(1) Number of ray groups per microscopic field in the layer of laticifers.
(2) Height and width of ray groups in the laticifer layer as well as the sieve tube layer.

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(3) Number of laticifers per row per 1·25 mm circumference of the tree.
(4) Diameter of laticifers.
(5) Number of connections per 0·22 mm height of the laticifers.

The measurements were recorded from the sections of the bark between 500 and 1500 μm from the cambium. To assess the density of ray groups the number of ray groups per microscopic field was counted at standard magnification. The height and width of three ray groups at random positions were measured from each section using a screw micrometer. The ray height and the ray width at the longest and the broadest part respectively were measured. The size of ray groups in the sieve tube layer was studied for six clones only. To study the laticifer characters, the number of laticifers within a unit length of the micrometer scale was observed. The laticifers at random points were measured and the number of connections between laticifers within a unit height in the anastomosing portions was recorded. The tree averages were based on nine observations recorded from three sections for all characters under study. The area of the microscopic field and the unit circumference of the tree were calculated using a stage micrometer. The data were statistically analyzed (Panse and Sukhatme, 1957), for clonal variability.

RESULTS

Rays

The phloem rays in *H. brasiliensis* are heterogeneous and they contain tannin cells. Uniseriate and multiseriate rays are present. In the laticifer layer the ray groups were of different shapes. Four main shapes of ray groups were identified. (i) dumbbell-shaped with a narrow middle portion (Fig. 1 A); (ii) oval in outline (Fig. 1 B); (iii) spindle-shaped, where the end portions were long, narrow and only one cell wide (Fig. 1 C); (iv) cricket bat-shaped, with a broad part and a long narrow tail on one end (Fig. 1 D). Though more than one type was present in the same tree, the rays of a clone in the laticiferous layer were predominantly of one of these four types. It appeared that the ray size and shape were influenced by the orientation of latex vessels. In certain clones the laticifers were more wavy than in others. Clones with the more wavy laticifers generally had short and broad rays.

Tables 1 and 2 show the extent of variability in ray characters among the clones under study. The size and distribution of ray groups in the laticiferous layer (Table 1) and those in the sieve tube layer (Table 2) were studied separately. In the laticifer layer, 18–30 ray groups were present in an area of 1·25 mm^2 in various clones and the clonal variability was highly significant. The highest density was observed in Harbel 1 followed by Ch 153, Wagga 6278 and RRIM 701, whereas IAN 45-873 and IAN 45-713 had the lowest density of ray groups.

The height and width of ray groups in the laticiferous layer were significant clonal characteristics. The ray height varied from 273·60 to 429·33 μm in different clones. The highest rays were observed in IAN 45-873. GT 1 and IAN 45-713 also came under this group with regard to the ray height. The shortest ray groups were found for RRIM 701. The other clones having short rays were Harbel 1, RRIM 703, Ch 153 and Wagga 6278. PB 5/51 and PR 107 had rays of medium height.

The range of ray width among the clones was 40·62–53·07 μm. The maximum ray width was found for IAN 45-713. The other broad-rayed clones were Wagga 6278, IAN 45-873, PR 107 and RRIM 703, whereas narrow rays were characteristic for Ch 153, RRIM 701, PB 5/51, Harbel 1 and GT 1.

In the sieve tube layer, the ray height and ray width were higher compared to those in the laticifer layer, the mean height and mean width being 384·60 and 60·84 μm respectively as against 336·23 and 46·71 μm in the laticifer layer. The clonal differences in ray width in the sieve tube layer were not statistically significant.

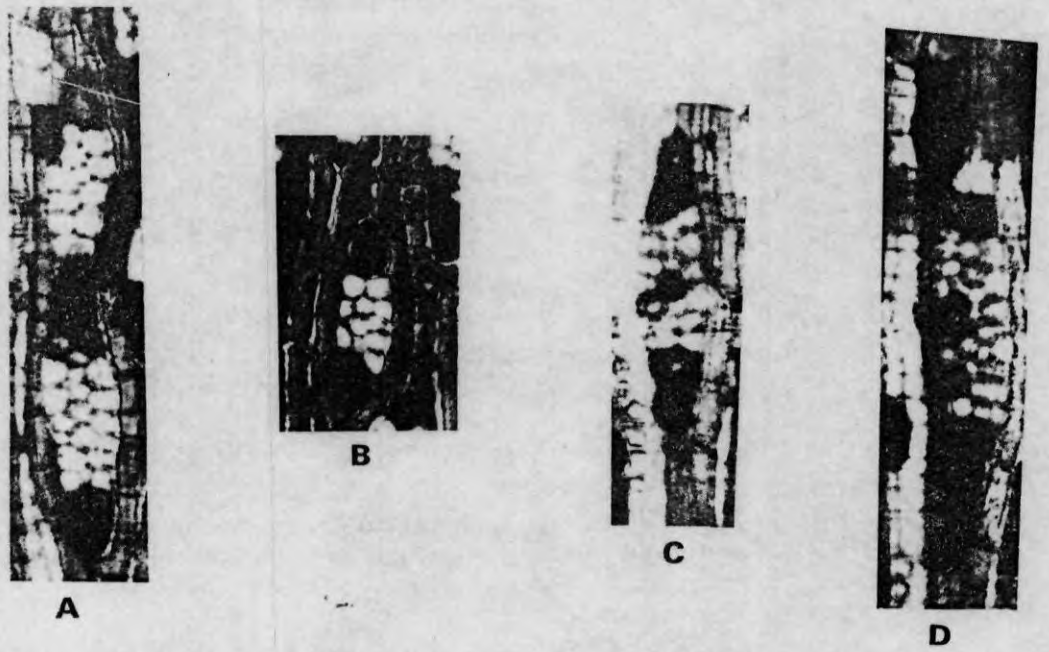

FIG. 1. The shape of phloem rays in the latex vessel layer in *Hevea brasiliensis*. ×312. A, Dumbbell-shaped; B, oval; C, spindle-shaped; D, bat-shaped.

TABLE 1. *Clonal differences of the phloem ray characters in the laticifer layer in* Hevea brasiliensis

Clone	Density of ray groups per 1·25 mm²	Size of ray groups (μm)	
		Height	Width
Ch 153	29·61	292·27	40·67
GT 1	24·42	420·67	44·13
Harbel 1	30·00	279·67	42·53
IAN 45-713	18·92	380·00	53·07
IAN 45-873	18·47	429·33	51·33
PB 5/51	23·92	368·93	41·20
PR 107	26·67	334·40	51·33
RRIM 701	28·58	273·60	40·80
RRIM 703	27·33	280·67	49·47
Wagga 6278	28·94	302·80	52·57
Mean	25·69	336·23	46·71
s.e.	0·58	17·32	2·73
CV	3·93%	8·12%	0·13%
CD			
$P < 0·05$	1·73	51·44	8·11
$P < 0·01$	2·36	70·51	11·14

Laticifers

It was observed that the depth at which functional laticifers occurred varies from clone to clone, but it was not beyond 500 μm from the cambium in any of the 10 clones under study. The vessel characters are shown in Table 3. The diameter of vessels, density of vessels and density of connections were highly significant clonal characters.

TABLE 2. *Clonal variations in the height and width of phloem rays in the seive tube layer of* Hevea brasiliensis

Clone	Size of ray groups (μm)	
	Height	Width
IAN 45-713	416·67	70·53
IAN 45-873	421·67	59·20
PB 5/51	428·33	64·13
PR 107	343·33	61·73
RRIM 701	292·53	50·40
Wagga 6278	405·07	59·07
Mean	384·60	60·84
s.e.	22·69	5·75
CV	10·22%	16·37%
CD		
$P < 0·05$	71·56	—
$P < 0·01$	101·69	—

TABLE 3. *Clonal variations in laticifer characters in* Hevea brasiliensis

Clone	No. of laticifers per row per 1·25 mm² circumference of the tree	Diameter of laticifers (μm)	No. of connections between laticifers within 0·22 mm height
Ch 153	30·67	17·33	7·84
GT 1	26·83	16·67	6·50
Harbel 1	28·12	18·40	5·89
IAN 45-713	24·92	19·33	7·67
IAN 45-873	26·57	23·87	5·83
PB 5/51	29·33	21·47	8·89
PR 107	24·01	19·33	8·28
RRIM 701	27·67	20·18	6·94
RRIM 703	27·86	26·87	6·29
Wagga 6278	25·67	18·40	7·11
Mean	27·16	20·18	7·12
s.e.	0·79	0·79	0·45
CV	5·04%	6·79%	10·96%
CD			
$P < 0·05$	2·35	2·35	1·34
$P < 0·01$	3·22	3·22	1·84

The highest diameter of laticifers was a notable character in RRIM 703. The lowest laticifer diameter was observed for GT 1 and the range among the clones was 16·63–26·87 μm. Wagga 6278, Harbel 1 and Ch 153 had narrow laticifers whereas IAN 45-873, PB 5/51, RRIM 701, PR 107 and IAN 45-713 had medium laticifer width.

Density of distribution of laticifers was highest for Ch 153, followed by PB 5/51 and Harbel 1. Low density of laticifers was observed in PR 107, Wagga 6278 and IAN 45-713. The number of laticifers per row per 1·25 mm circumference of the tree ranged from 24·01 to 30·67 among the clones.

The connections between laticifers are concentrated in certain portions where two or more laticifers of the same row are close together. The density of connections in the

anastomosing portions was found to be a clonal character. Within 0·22 mm height of the latex vessels, six to nine connections were present in various clones under study. Higher intensity was noticed in PB 5/51, followed by PR 107, Ch 153 and IAN 45-713 in order. The laticifers in the other clones were less anastomosing, the lowest density of interconnections being observed in IAN 45-873 and Harbel 1.

DISCUSSION

The laticifers in the bark of *Hevea* are arranged in regular rows almost parallel to the cambium and they are therefore in concentric rings as seen in cross-sections of the tree. These rings are separated by zones of sieve elements and phloem parenchyma cells. It was noted that the shape and size of ray groups in the laticifer layer and the sieve tube layer differed, and the ray characters as well as the magnitude of anastomosing were highly significant clonal characters. Earlier studies on the relationship between various structural characters and yield in *Hevea brasiliensis* had revealed that the number of laticifer rings was the most important single factor related to yield. Gomez *et al.* (1973) had considered in detail the factors affecting the quantitative determination of laticiferous tissue. In addition to the number of rings of laticifers the density of laticifers per ring, the diameter of laticifers, the circumference of the ring and the distance between rings were determined as factors influencing the quantity of laticiferous tissue.

FIG. 2. The structure of *Hevea* bark in the tangential view. × 250. R, ray group; L, latex vessels; T, tannin cell; C, connections. The general structure is like an expanded meshwork. The laticifers run axially interweaving with the ray groups and are interconnected.

The laticifers in the bark of *Hevea* are organized like an expanded meshwork (Fig. 2). The mesh of the expanded meshwork pattern is convex lens-shaped where the latex vessels are running upward interweaving with the ray groups. This structural organization results in a close relationship between ray characters and the orientation

of laticifers. Moreover, the differences in ray characters in the laticifers and sieve tube layers revealed the interrelationship between laticifer characters and ray characters. This indicated the possibility of utilizing the ray characters as a criterion for determining the orientation of laticifers. Since the laticifers are tubular structures, the variation in their wavy nature is likely to have some bearing on the rate of latex flow on tapping. A wavy alignment will naturally have increased length and thereby the quantity of laticiferous tissue. The relationship of this character with the rate of latex flow on tapping is yet to be studied.

The intensity of anastomosing was another interesting feature observed in *Hevea* clones. Though it had been reported earlier that *Hevea* has an articulated anastomosing type of laticifers (Bobilioff, 1923; Panikkar, 1974) not much attention had been paid to the clonal variations in the intensity of anastomosing. Since the laticifers in *Hevea* consist of a system of interconnected tubes and the drainage area is extended towards the sides due to this structure, the clonal variability in the intensity of anastomosing deserves much attention.

Though the extent of yield variability among clones is very high, morphological variations are not so marked. Therefore clone identification based on gross morphological characters is not always reliable. Leaf characters along with certain seed characters like seed coat striations and lateral depressions are conventionally utilized, by experience, for identification of certain popular clones. Saraswathy Amma, Markose and Panikkar (1981) have reported the magnitude of clonal variabilities in size and weight of fruits as well as seeds as parameters for identification of clones of *Hevea*. This method also has some limitations as it is applicable only after the flowering stage, and as the availability of fruits is seasonal. The size and weight of the fruits and seeds are also highly influenced by the stages of maturity and other factors.

The anatomical characters described here are clonal characteristics, and the clonal variations are highly significant. The structural characters, as viewed in the tangential plane, are more stable and reliable as they are less influenced by environmental variability. Moreover, the availability of bark is not a limiting factor. Therefore the bark anatomical parameters can also be utilized for identification of *Hevea* clones.

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