CHAPTER 4

RESULTS
4.1 Growth and morphology

The bole

Clearly distinguishable differences were observed between the boles of the seedling trees and the vegetatively propagated trees. Seedling trees are mostly straight growing tall trees with a stout terete bole, while the trees raised from cuttings showed a tendency for leaning growth. The canopy of the seedling trees are restricted to the top and the cuttings showed a wide spread heavy canopy (Fig.4 A,B).

Branching

Field observations of the trial planting of seedlings and cuttings, showed that branches emerge in the seedlings after two to three years. The trees developed from the cuttings produce early branching even from the first year of planting. Branching starts at a height of 1 to 2 meter and ramifies trichotomously (Fig.5 A, B).

Leaves

The leaves are palmately lobed and the number of lobes varied from 3-5. Rarely 2, 3, 4 and 7 lobes are observed (Fig. 6A) in Location II.

Flowering

*M. glaziouii* produces flowers at the age of 12 to 18 months. However in the experimental plantings of the seedlings as well as cuttings, flowering was observed even
at the age of 8 months (Fig. 6B). The flowers do not show much variation, except a bluish tinge in those collected from Location II (Fig. 6C). Usually the flowering season is March-April, but off-season flowering also has been observed in the species during October to December. Fruitset is comparatively low during off-season flowering.

**Seeds**

The fruit is a tricarpellary, six grooved, globular, dry dehiscent capsule. Each fruit contains three tiny plano-convex seeds with prominent mottlings (Fig. 7 A, B). Each seed weighs about 0.58 g and about 1740 seeds are required to make one kilogram. Seeds are having a very thick shell of about 1 - 1.5 mm thickness, which under normal condition seldom breaks (Fig. 7 C).

**Shoot shedding**

The young seedlings of 1 to 2 years growth under the stress conditions show a peculiar adaptation. By the onset of summer the leaves are gradually shed acropetally and the foliage is reduced. At the peak summer season complete abscission takes place giving a lean stick like appearance (Fig. 8A). During this period, as a second stage, the shoot and buds down to the lower node start drying (Fig. 8B). This phenomenon slowly continues from the top downwards. In the third stage, a certain length of the shoot gets detached. By the onset of the favourable season one of the axillary buds develop and
continues growth. This habit is seen in both locations. It is also noted in the mature trees (Fig. 8C). After complete wintering, the branchlets start drying up to 2–4 internodes downwards and the dried portions are shed off.

**Wintering**

Observations on the commencement of wintering were taken from the beginning of the summer months. Yellowing of leaves started by the end of December and continued till January. By the end of January wintering leaf-fall was more or less complete (Fig. 9A). Almost all the trees in Location II have undergone complete defoliation. However, few genotypes among the wild population still retained a portion of the foliage. The interval between defoliation and refoliation was comparatively prolonged in *M. glaziovii* compared to *Hevea*. Wintering in *H. brasiliensis* is normally completed within about 2 months and refoliation takes place shortly.

**Stomatal distribution**

*M. glaziovii* is amphistomatic and the stomata are distributed in the abaxial and adaxial epidermis of leaves (Fig. 9B). However, in the adaxial side they are confined to the vicinity of midribs and veinlets of the epidermis in limited numbers and comparatively larger in size (Fig. 9C). A few stomata are also noticed in the petioles.
The frequency of stomatal distribution, epidermal cells, and stomatal index of the abaxial side of the leaves were ascertained (Table 6). The number of stomata per one square millimeter ranged from 510 - 660 and the average number observed was 593. The number of epidermal cells per one square millimeter ranged from 2450 - 3370, the average value being 3052.

The stomatal index i.e., the number of stomata per unit area to the number of epidermal cells per unit area is 16.42.

<table>
<thead>
<tr>
<th>Tree Number</th>
<th>Leaf area cm²</th>
<th>Number of stomata/mm²</th>
<th>Number of epidermal cells/mm²</th>
<th>Stomatal index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>408.34</td>
<td>625</td>
<td>2690</td>
<td>18.85</td>
</tr>
<tr>
<td>2</td>
<td>413.58</td>
<td>630</td>
<td>2450</td>
<td>20.45</td>
</tr>
<tr>
<td>3</td>
<td>302.97</td>
<td>550</td>
<td>2750</td>
<td>16.67</td>
</tr>
<tr>
<td>4</td>
<td>260.56</td>
<td>535</td>
<td>2600</td>
<td>17.07</td>
</tr>
<tr>
<td>5</td>
<td>293.27</td>
<td>660</td>
<td>3290</td>
<td>16.71</td>
</tr>
<tr>
<td>6</td>
<td>243.30</td>
<td>600</td>
<td>3370</td>
<td>15.11</td>
</tr>
<tr>
<td>7</td>
<td>455.39</td>
<td>580</td>
<td>3430</td>
<td>14.46</td>
</tr>
<tr>
<td>8</td>
<td>302.57</td>
<td>510</td>
<td>3330</td>
<td>13.28</td>
</tr>
<tr>
<td>9</td>
<td>373.41</td>
<td>650</td>
<td>3340</td>
<td>16.29</td>
</tr>
<tr>
<td>10</td>
<td>281.16</td>
<td>590</td>
<td>3270</td>
<td>15.28</td>
</tr>
</tbody>
</table>

Mean 333.46 593 3052 16.42
SE: 21.94 14.99 113.9 0.63
4.2. Propagation

4.2.1. Seed propagation

Germination of seeds under all the five treatments were observed at weekly intervals. 15 percent germination was first recorded during the third week in the first treatment (grinding) (Fig. 10A). The rate of germination was increased to 21 and 24 percent during the fourth and fifth week respectively. Germination was continued up to the seventh week and later no more germination was recorded. The next effective treatment was the light burning of the seeds where 11 percent germination was recorded from the fourth week till the eighth week, with the highest percentage in the sixth week. Saltwater treatment was found to be effective to the minimum level of 5 percent, and that too after a lapse of five weeks. No germination was observed in the acid treated seeds and in the control (untreated) (Table 7).

The observations revealed that when the endosperm is given the opportunity to imbibe water, the seed germinates. The maximum germination percentage obtained in the grinding technique can be attributed to this factor. While in all the other cases it was observed that the shell gets disintegrated slowly after the treatment, allowing water absorption. But since these treatments have no uniform action on the seed coat, germination time
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of seeds sown</th>
<th>Number of seeds germinated each week</th>
<th>Germination percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Grinding</td>
<td>100</td>
<td>15 21 24 10 2 - - - - -</td>
<td>72</td>
</tr>
<tr>
<td>2. Salt water</td>
<td>100</td>
<td>- - - - - - - 2 1 1 - - 1</td>
<td>5</td>
</tr>
<tr>
<td>3. Acid (Con. H₂SO₄)</td>
<td>100</td>
<td>- - - - - - - - - - -</td>
<td>0</td>
</tr>
<tr>
<td>4. Burning</td>
<td>100</td>
<td>- - - - 2 1 5 2 1 - -</td>
<td>11</td>
</tr>
<tr>
<td>5. Untreated (Control)</td>
<td>100</td>
<td>- - - - - - - - - - -</td>
<td>0</td>
</tr>
</tbody>
</table>
also showed much difference.

Grinding of the shell in the frontal side, in such a way that the endosperm is just exposed, is the most effective treatment to induce germination in Ceara rubber seeds. It was also observed that seedlings raised in polybags with punch holes gave maximum survival in the field during transplanting (Fig. 10B).

4.2.2. Vegetative propagation

Observations on sprouting of the cuttings were made from the first week after planting. First sprouting protrusions were observed on the third week in treatments T2 and T5 and gradually progressed. Sprouting percentage ranged from 2.50-80. Maximum sprouting of 80% was observed in the treatment (T5) where 40 cm long brown cuttings were used. No sprouting were observed in the tender green sticks of T1 treatment. However, in T4 with 40 cm long green cuttings 2.50 percent sprouting was observed (Table 8).

The results indicate that for vegetative propagation of M. glaziovii, brown sticks of 40 cm length are most suitable than other types of cuttings. However, mature sticks with hardened periderm also can be used with satisfactory sprouting. Green shoots gave the lowest success of 2.50 percent, and this can be attributed to its tenderners which causes drying after planting.
<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number sprouted each week after planting</th>
<th>Total sprouted</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6  7  8  9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T₁ - Tender green, 20 cm long</td>
<td>0  0  0  0  0  0  0  0  0</td>
<td>0  0  0  0  0  0  0  0  0</td>
<td>0  0  0  0  0  0  0  0  0</td>
</tr>
<tr>
<td>T₂ - Brown, 20 cm long</td>
<td>0  0  1  3  5  13  12  3  0</td>
<td>37</td>
<td>46.25</td>
</tr>
<tr>
<td>T₃ - Mature, 20 cm long</td>
<td>0  0  0  1  6  9  13  3  0</td>
<td>32</td>
<td>40.00</td>
</tr>
<tr>
<td>T₄ - Tender green, 40 cm long</td>
<td>0  0  0  0  0  0  1  1  0  2</td>
<td>2  2.50</td>
<td></td>
</tr>
<tr>
<td>T₅ - Brown, 40 cm long</td>
<td>0  0  4  11  17  15  14  3  0  64</td>
<td>64</td>
<td>80.00</td>
</tr>
<tr>
<td>T₆ - Mature, 40 cm long</td>
<td>0  0  0  4  10  18  14  1  0  47</td>
<td>47</td>
<td>58.75</td>
</tr>
</tbody>
</table>

Table 8. Vegetative propagation of M. glaziovii cuttings
Simultaneous with the above experiment, cuttings were also planted after giving a 2 cm wax covering on the top cut end. No appreciable difference was noted by imposing wax coating.

As in the case of seedlings, cuttings raised in ground beds resulted in several casualities while transplanting. This may be due to the pulling out shock and resultant root damage. Cuttings raised in 15 cm x 25 cm polybags with punch holes, gave maximum survival on transplanting to the field (Fig. 10 C, D).

4.3. Leaf disease

On microscopic examination of the disease affected specimens single celled hyaline elongated conidia with rounded ends were noticed in plenty. The parasitic fungus has been identified as *Gloeosporium* sps. The surrounding plantations of *H. brasiliensis* in Location I is affected by the fungus and inoculum of the pathogen is available in plenty.

4.4. Bark structure

The most important economically important part of *M. glaziovii* is its bark, which on systematic wounding produces the latex.

The tender bark is green and mature bark is dark brown in colour. The thickness of bark varies from tree
to tree and ranged from 5.00 to 11.00 mm with an average value of 8.45 mm at the age of twelve years. The inner bark is smooth and protected by an outer well defined thin, hard and peelable periderm characterised by adherent flakes of rhytidome (Fig. 11 A, B). The thickness of periderm varies from 2.00 to 3.50 mm. Numerous large and elongated lenticels are distributed horizontally in parallel lines throughout the periderm (Fig. 11 C). However, lenticels are absent in the zones where the rhytidome is protruded as scaley structures.

The bark beneath the periderm layer is smooth with pronounced protrusions of the lenticels. When the periderm is peeled off the bark appears white or green in colour (Fig. 11 C,D). The greenish bark is rich in total chlorophyll compared to the bark which is white in colour. The bark retains high moisture content throughout the seasons.

Generally the bark of _M. glaziovii_ consists of the following three zones.

An outer hard zone (periderm with rhytidome) made up of phellum, phellogen and phelloderm,

a middle semi-hard zone comprising of the secondary phloem elements, secondary laticiferous tissue and sclerified cells and
an inner soft zone (contiguous to cambium) consisting of secondary phloem and secondary laticiferous tissues.

4.5. Laticiferous system

The laticiferous system of *M. glaziovii* is a compound, articulated anastamosing network (Fig. 12 AB). From cambium outwards their distribution is confined as individual rows or rings sandwiched by secondary phloem (Fig. 12 C) similar to that of *H. brasiliensis*. The latex vessels within a row are tangentially interconnected ultimately forming a network like structure. However, between rows such interconnections are absent or ill-defined.

The number of laticifer rows are maximum in the soft bark zone contiguous to cambium and their number gradually diminishes towards the hard bark region. Moreover, in the soft bark region the laticifer rows are found to be arranged close to each other and those found in the hard bark are kept widely apart (Table 9). Certain rows of latex vessels found in the hard bark zone often show discontinuity due to the occurrence of stone cells developing from phloem rays and phloem parenchyma (Fig. 12 D). The stone cells are characterised by its narrow lumen and lignification.
Table 9. Comparison of bark thickness, distance from cambium to inner row of latex vessels and average distance between latex vessel rows of *M. glaziovii* and *H. brasiliensis*.

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Bark thickness (mm)</th>
<th>Distance from cambium to inner row of latex vessels (mm)</th>
<th>Average distance between latex vessel rows (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>10.0</td>
<td>9.0</td>
<td>0.504</td>
</tr>
<tr>
<td>2</td>
<td>11.0</td>
<td>10.0</td>
<td>0.396</td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
<td>9.0</td>
<td>0.324</td>
</tr>
<tr>
<td>4</td>
<td>9.0</td>
<td>10.2</td>
<td>0.288</td>
</tr>
<tr>
<td>5</td>
<td>9.0</td>
<td>9.0</td>
<td>0.360</td>
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<tr>
<td>6</td>
<td>8.0</td>
<td>10.0</td>
<td>0.396</td>
</tr>
<tr>
<td>7</td>
<td>9.0</td>
<td>8.0</td>
<td>0.360</td>
</tr>
<tr>
<td>8</td>
<td>8.0</td>
<td>9.0</td>
<td>0.342</td>
</tr>
<tr>
<td>9</td>
<td>8.0</td>
<td>10.0</td>
<td>0.288</td>
</tr>
<tr>
<td>10</td>
<td>7.5</td>
<td>8.8</td>
<td>0.288</td>
</tr>
</tbody>
</table>

Mean: 8.45 9.32 0.355 0.286 0.327 0.187
S.E.: 0.51 0.23 0.02 0.04 0.02 0.01

\[ M = M. \text{glaziovii} \quad H = H. \text{brasiliensis} \]
However, unlike in *Hevea*, the stone cells are oriented
more or less parallel to and alternating with the
laticifers in *Manihot*. Therefore majority of the
laticifers in the bark of the latter are not disrupt in
their continuity.

The secondary phloem is composed of sieve tubes,
companion cells, phloem parenchyma and phloic rays.
The phloic rays are mostly biseriate and rarely
uniseriate and multiseriate with well distinct upright
and procumbent cells. The ploem parenchyma occurs in
narrow bands with compactly arranged angular cells
without any intercellular spaces.

Observations on the anatomical traits are
summarised in Table 10. Tree to tree variation was
noticed in all the anatomical parameters studied as
well as tree girth. Except the distance between
cambium and inner row of laticifers and the mean
distance between laticifers, all the other characters
showed lower mean values in *Manihot* bark compared to
those of *Hevea* bark. The thickness of laticifer free
zone contiguous to cambium in *M. glaziovii* was 24% more
compared to that in *H. brasiliensis*. The average
distance between laticifers was higher by 75% in the
former compared to that of *Hevea*.
Table 10. Comparison of girth, bark thickness and number, density and diameter of latex vessels and frequency of stone cells of *M. glaziovii* and *H. brasiliensis*.

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Girth (mm)</th>
<th>Bark thickness (mm)</th>
<th>No. of latex vessels</th>
<th>Density of latex vessels per 1 mm circumference of the tree</th>
<th>Diameter of latex vessels (μ)</th>
<th>Frequency of stone cell per cm² C.S. area</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>90</td>
<td>10.0</td>
<td>9.0</td>
<td>17</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>122.9</td>
<td>83.1</td>
<td>11.0</td>
<td>10.2</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>62.9</td>
<td>93.1</td>
<td>5.0</td>
<td>9.0</td>
<td>14</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>101.9</td>
<td>94.1</td>
<td>9.0</td>
<td>10.2</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>5</td>
<td>110.9</td>
<td>95.1</td>
<td>9.0</td>
<td>9.0</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>6</td>
<td>93.9</td>
<td>88.1</td>
<td>8.0</td>
<td>10.0</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>7</td>
<td>79.9</td>
<td>89.1</td>
<td>8.0</td>
<td>9.0</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>8</td>
<td>79.9</td>
<td>89.1</td>
<td>8.0</td>
<td>10.0</td>
<td>17</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>80.8</td>
<td>85.9</td>
<td>7.5</td>
<td>8.8</td>
<td>15</td>
<td>38</td>
</tr>
</tbody>
</table>

Mean: 89.9, 88.0, 8.45, 9.32, 15.7, 34.4, 28.5, 33.72, 14.15, 18.97, 331.69, 448.27
S.E.: 6.28, 1.53, 0.51, 0.23, 0.52, 1.28, 0.93, 0.47, 0.31, 0.35, 19.89, 16.22

*M = M. glaziovii*  
*H = H. brasiliensis*
Wide range of variation was observed in the total number of laticifer rows and the frequency of stone cells between the bark of the two species. The mean number of laticifer rows was 15.7 and 34.4 in the former and latter respectively, and the difference was found to be more than double. Similar situation was also observed in the frequency of stone cell. *Manihot* bark had 334.69 stone cells per 1 cm$^2$ cross sectional area, compared to 488.27 per 1 cm$^2$ in *Hevea*.

The laticifer rows are oriented wide apart in *Manihot* as indicated by the higher mean values (0.327 mm) compared to that of 0.187 mm in *Hevea brasiliensis*.

4.6. Bark moisture

Mean fresh weight of *M. glaziovii* samples was 1.2 g and the mean weight of the oven dry samples was 0.42 g. MC content in the bark was found to be 186%.

Fresh weight and oven dry weight of the bark samples of *Hevea brasiliensis* are 1.44 and 0.71 respectively. The moisture content was found to be 103%. MC in the bark of *M. glaziovii* is 83 percent more than that in *H. brasiliensis* (Table 11).

4.7. Bark chlorophyll

Chlorophyll content in the tissue of the ceara rubber trees, having green bark, is considerably higher.
Table 11. Moisture content of bark of *M. glaziovii* and *H. brasiliensis* during summer season.

<table>
<thead>
<tr>
<th>Observations</th>
<th><em>M. glaziovii</em></th>
<th><em>H. brasiliensis</em></th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fresh weight (g)</td>
<td>1.20</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>Mean Oven dry weight (g)</td>
<td>0.42</td>
<td>0.71</td>
<td>$\frac{W_1 - W_0}{W_0} \times 100$</td>
</tr>
<tr>
<td>Moisture content (%)</td>
<td>186.00</td>
<td>103.00</td>
<td>(Rawat and Mirdula Negi, 1993)</td>
</tr>
<tr>
<td>Species</td>
<td>Chlorophyll content (mg/g fr. wt)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. glaziovii</em></td>
<td>36.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(green bark)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. glaziovii</em></td>
<td>8.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(white bark)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>H. brasiliensis</em></td>
<td>17.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12. Chlorophyll content in the bark tissue
(36 mg per gram fresh weight) compared to the trees having white bark under the periderm (Fig. 11 C, D) (8.25 mg/g fresh weight). The reason for this significant variation is not known.

Bark chlorophyll in *H. brasiliensis* has been estimated as 17 mg/g fresh weight (Table 12).

4.8. Latex vessel turgor

The turgor pressure of *M. glaziovii* was measured as 1.0 MPa (Table 13). While the turgor pressure of *Hevea brasiliensis* is 1.5 MPa (Buttery and Boatman, 1964, 1966, 1967; Milford et al., 1969; Raghavendra et al., 1984), which is slightly higher than *M. glaziovii*. It was also observed that the latex vessel turgor of *M. glaziovii* suddenly decreased within 5-10 minutes.

4.9. Latex vessel plugging

Very significant difference in plugging index (PI) was observed in the data collected from Location I and II. The average PI of the trees in Location I was 16.72 while that in Location II was 10.98 (Fig. 13). Initial flow rate in Location I was 11.26 ml per minute, while that in Location II was 3.5 ml/minute. In total volume also marked difference was noted. However, in both the locations plugging index was much
## Table 13. Turgor pressure of *M. glaziovii* and other laticiferous species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Turgor pressure (MPa)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Manihot glaziovii</em></td>
<td>1.0</td>
<td>Present study</td>
</tr>
<tr>
<td><em>Hevea brasiliensis</em></td>
<td>1.5</td>
<td>Buttery and Boatman (1966)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Milford et al. (1969)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raghavendra et al. (1984)</td>
</tr>
<tr>
<td><em>Ficus elastica</em></td>
<td>1.0</td>
<td>Buttery and Boatman (1966)</td>
</tr>
<tr>
<td><em>Cryptostegia grandiflora</em></td>
<td>1.2</td>
<td>Raghavendra (unpublished)</td>
</tr>
<tr>
<td><em>Euphorbia pulcherrima</em></td>
<td>0.8</td>
<td>Buttery and Boatman (1966)</td>
</tr>
<tr>
<td><em>Nerium oleander</em></td>
<td>0.6</td>
<td>Downtown (1981)</td>
</tr>
</tbody>
</table>
higher than that in H. brasiliensis (Table 14, 15). Observations further showed that PI varies from tree to tree and location to location also.

4.10. Yield and yield potential

Dry rubber yield of ten M. glaziovii trees in Location I propagated through vegetative methods during different months in the year 1992 is presented in Table 16. The mean yield ranged from 2.58 g to 5.76 g, obtained during the months of July and March respectively. June-July-August quarter of the year recorded and average of 3.47 g. Mean high yield of 5.49 g was obtained during the month of January, February, March and December.

The coefficient of variation in yield between plants is low (7.8 to 16.4 percent) which indicates that tree to tree variation in yield is negligible, in Location I. Table 16 also shows that the monthly contribution to total yield was less than 5% only during July. During the month of peak yield 10.44% of the annual yield was contributed in March. December, January and February had a monthly contribution of above 9.5% towards total yield. That these four months are responsible for 40% of the annual yield, is of interest in commercial exploitation, when applicable.
<table>
<thead>
<tr>
<th>Tree number</th>
<th>Initial vol. 5 minutes (ml)</th>
<th>Total vol. (ml)</th>
<th>Plugging index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>14</td>
<td>17.14</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>9</td>
<td>17.70</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>16</td>
<td>17.50</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>13</td>
<td>16.92</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>12</td>
<td>16.66</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>16</td>
<td>16.25</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>14</td>
<td>17.14</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>12</td>
<td>15.00</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td>14</td>
<td>15.71</td>
</tr>
<tr>
<td>10</td>
<td>13</td>
<td>15</td>
<td>17.33</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>11.3</strong></td>
<td><strong>13.5</strong></td>
<td><strong>16.72</strong></td>
</tr>
<tr>
<td><strong>SE</strong></td>
<td><strong>0.57</strong></td>
<td><strong>0.64</strong></td>
<td><strong>0.26</strong></td>
</tr>
</tbody>
</table>
Table 15. Girth, bark thickness, volume of latex and PI of *M. glaziovii* in Location II

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Girth (cm)</th>
<th>Bark thickness (mm)</th>
<th>Initial vol. 5 minutes (ml)</th>
<th>Vol. of latex per tapping (ml)</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>112</td>
<td>15</td>
<td>7</td>
<td>15</td>
<td>9.32</td>
</tr>
<tr>
<td>2</td>
<td>107</td>
<td>16</td>
<td>22</td>
<td>32</td>
<td>13.75</td>
</tr>
<tr>
<td>3</td>
<td>130</td>
<td>17</td>
<td>23</td>
<td>47</td>
<td>9.78</td>
</tr>
<tr>
<td>4</td>
<td>112</td>
<td>16</td>
<td>11</td>
<td>22</td>
<td>10.00</td>
</tr>
<tr>
<td>5</td>
<td>115</td>
<td>16</td>
<td>11</td>
<td>30</td>
<td>7.33</td>
</tr>
<tr>
<td>6</td>
<td>142</td>
<td>15</td>
<td>24</td>
<td>38</td>
<td>12.63</td>
</tr>
<tr>
<td>7</td>
<td>140</td>
<td>16</td>
<td>20</td>
<td>34</td>
<td>11.76</td>
</tr>
<tr>
<td>8</td>
<td>140</td>
<td>15</td>
<td>23</td>
<td>39</td>
<td>11.79</td>
</tr>
<tr>
<td>9</td>
<td>122</td>
<td>14</td>
<td>16</td>
<td>28</td>
<td>11.42</td>
</tr>
<tr>
<td>10</td>
<td>118</td>
<td>13</td>
<td>18</td>
<td>30</td>
<td>12.00</td>
</tr>
<tr>
<td>Mean</td>
<td>123.8</td>
<td>15.3</td>
<td>17.5</td>
<td>31.5</td>
<td>10.98</td>
</tr>
<tr>
<td>SE</td>
<td>3.96</td>
<td>0.35</td>
<td>1.81</td>
<td>2.7</td>
<td>0.56</td>
</tr>
<tr>
<td>CV</td>
<td>11.00</td>
<td>7.2</td>
<td>32.7</td>
<td>27.0</td>
<td>16.12</td>
</tr>
</tbody>
</table>
Table 16. Treewise mean yield during 1992

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Monthly mean yield (g t⁻¹ t⁻¹)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
<td>Feb</td>
</tr>
<tr>
<td>1</td>
<td>5.88</td>
<td>5.81</td>
</tr>
<tr>
<td>2</td>
<td>6.80</td>
<td>6.65</td>
</tr>
<tr>
<td>3</td>
<td>6.15</td>
<td>6.53</td>
</tr>
<tr>
<td>4</td>
<td>4.93</td>
<td>4.95</td>
</tr>
<tr>
<td>5</td>
<td>4.68</td>
<td>4.65</td>
</tr>
<tr>
<td>6</td>
<td>4.30</td>
<td>4.35</td>
</tr>
<tr>
<td>7</td>
<td>4.60</td>
<td>5.58</td>
</tr>
<tr>
<td>8</td>
<td>5.20</td>
<td>5.15</td>
</tr>
<tr>
<td>9</td>
<td>5.70</td>
<td>5.65</td>
</tr>
<tr>
<td>10</td>
<td>5.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SE</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>5.33</td>
<td>0.24</td>
<td>14.07</td>
</tr>
<tr>
<td>Feb</td>
<td>5.43</td>
<td>0.23</td>
<td>13.25</td>
</tr>
<tr>
<td>Mar</td>
<td>5.76</td>
<td>0.16</td>
<td>8.85</td>
</tr>
<tr>
<td>Apr</td>
<td>4.89</td>
<td>0.15</td>
<td>9.81</td>
</tr>
<tr>
<td>May</td>
<td>4.44</td>
<td>0.23</td>
<td>16.44</td>
</tr>
<tr>
<td>June</td>
<td>3.00</td>
<td>0.10</td>
<td>10.92</td>
</tr>
<tr>
<td>July</td>
<td>2.58</td>
<td>0.11</td>
<td>13.95</td>
</tr>
<tr>
<td>Aug</td>
<td>3.81</td>
<td>0.22</td>
<td>17.80</td>
</tr>
<tr>
<td>Sept</td>
<td>4.92</td>
<td>0.23</td>
<td>14.83</td>
</tr>
<tr>
<td>Oct</td>
<td>4.75</td>
<td>0.18</td>
<td>312.007</td>
</tr>
<tr>
<td>Nov</td>
<td>4.85</td>
<td>0.12</td>
<td>80</td>
</tr>
<tr>
<td>Dec</td>
<td>5.45</td>
<td>0.18</td>
<td>10.45</td>
</tr>
</tbody>
</table>
(Fig.14). In the same angle the low yield during June to August, especially in June and July will also have relevance. Considerably low yield of 3.47 g was obtained during June-July-August quarter. Yield potential of the tree was calculated on the basis of available tapping days per year. *M. glaziovii* is expected to grow in regions where rainfall is low. As such under alternate day tapping system, about 150 tapping days will be available.

A spacing of 4.6 x 4.6 m can be considered as reasonable for proper growth and development of *M. glaziovii*. Assuming this spacing an area of one hectare will have a planting density of 479 trees. It is reasonable to consider that about 450 trees will be available for exploitation, allowing about 30 trees for natural failures.

Taking into account the mean yield per tree per tap obtained during each month and the respective number of tapping days in a month, the productivity per month ranges from 25.8 g per tree in July to 74.88 g per tree in March (Table 17). The total annual yield per tree actually recorded during 1992 is thus 701.19 g. Assuming a mature stand of 450 tree per hectare for exploitation, the estimated production potential is thus 315 kg per hectare per year.
Table 17. Yield and estimated yield potential of *M. glaziovii*.

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean yield dry rubber (g/tree/tap)</th>
<th>Available number of tapping days per month</th>
<th>Estimated yield per tree per month (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>5.33</td>
<td>13</td>
<td>69.29</td>
</tr>
<tr>
<td>February</td>
<td>5.43</td>
<td>13</td>
<td>70.59</td>
</tr>
<tr>
<td>March</td>
<td>5.76</td>
<td>13</td>
<td>74.88</td>
</tr>
<tr>
<td>April</td>
<td>4.89</td>
<td>13</td>
<td>63.57</td>
</tr>
<tr>
<td>May</td>
<td>4.44</td>
<td>13</td>
<td>57.72</td>
</tr>
<tr>
<td>June</td>
<td>3.02</td>
<td>10</td>
<td>30.20</td>
</tr>
<tr>
<td>July</td>
<td>2.58</td>
<td>10</td>
<td>25.80</td>
</tr>
<tr>
<td>August</td>
<td>3.81</td>
<td>13</td>
<td>49.53</td>
</tr>
<tr>
<td>September</td>
<td>4.92</td>
<td>13</td>
<td>63.96</td>
</tr>
<tr>
<td>October</td>
<td>4.75</td>
<td>13</td>
<td>61.75</td>
</tr>
<tr>
<td>November</td>
<td>4.85</td>
<td>13</td>
<td>63.05</td>
</tr>
<tr>
<td>December</td>
<td>5.45</td>
<td>13</td>
<td>70.85</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>150</td>
<td>701.19 g</td>
</tr>
</tbody>
</table>
4.10.1. Potential of wild germplasm

During the course of the exploration for wild germplasm of *M. glaziovii*, a few days observational tappings were done on selected seedlings of the wild population. The observation was carried out during February 1992, when there was no rain at all (Table 3). The result showed an entirely different performance in Location II (George and Reghu, 1993).

The volume of latex measured for the ten trees ranged from 15 to 47 ml with an average latex yield of 31.5 ml. The values of bark thickness, girth and plugging index ranged from 13 to 17 mm, 107 to 142 cm and 7.33 to 13.75 respectively. The average values for these characters were 15.3 mm, 123.8 cm and 10.98 respectively (Table 15). Coefficient of variation estimated was highest for the character total volume of latex (27.0) followed by plugging index, girth and bark thickness (16, 12, 11.0 and 7.2). While the dry rubber yield in Location II, where the trees had a generative propagation history, could not be estimated, an approximate assessment can be made assuming an average d.r.c. of 23.6% which was recorded in Location I during the summer months. Based on this, the yield per tapping is 7.44 g compared to the mean yield per tree per tap of 4.5 g in Location I. Above all, of the ten trees of
comparable growth, the variation in volume yield of latex per tap was from 15 ml to 47 ml. At the same time the variation in bark thickness did not influence the yield much (Table 15).

4.11. Properties of latex

The important observations on the characteristics of latex from *Manihot* are summarised in Table 18, in comparison with those of *Hevea* latex. The latex was milky white in appearance as in the case of *Hevea*. No seasonal variation in colour was noticed. Variation in the colour of the latex among the individual trees was also not observed. The latex has a characteristic odour which is distinct from that of *Hevea* latex. Both rod shaped and oval particles are seen in the latex in brownian movement (Fig.15).

The acidic or alkaline reaction of a latex is usually measured in terms of pH. *Hevea* latex is very nearly neutral with a pH varying between 6.5 and 7.0. However, *Manihot* latex has a slightly lower pH, in the range of 6.3 to 6.5 with a typical value of 6.35. The specific gravity of *Manihot* latex is 1.0075 while that of *Hevea* latex is only 0.9828. It indicates that the latex from *Manihot* is slightly heavier than water while the rubber prepared from it is lighter as is seen later.
### Table 18: Properties of latex

<table>
<thead>
<tr>
<th>Property</th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Milky white</td>
<td>Milky white</td>
</tr>
<tr>
<td>pH</td>
<td>6.35</td>
<td>6.80</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.0075</td>
<td>0.9828</td>
</tr>
<tr>
<td>Brookfield viscosity, Cps</td>
<td>51</td>
<td>43</td>
</tr>
<tr>
<td>Total solids content, %</td>
<td>32.3</td>
<td>36.6</td>
</tr>
<tr>
<td>Dry rubber content, %</td>
<td>25.3</td>
<td>33.7</td>
</tr>
<tr>
<td>Non-rubber solids, %</td>
<td>7.0</td>
<td>2.9</td>
</tr>
<tr>
<td>Effect of coagulants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Formic acid</td>
<td>Coagulates</td>
<td>Coagulates</td>
</tr>
<tr>
<td>(ii) Acetic acid</td>
<td>Coagulates</td>
<td>Coagulates</td>
</tr>
<tr>
<td>(iii) Water</td>
<td>Coagulates No coagulation</td>
<td></td>
</tr>
<tr>
<td>Spontaneous coagulation</td>
<td>Within 7 h</td>
<td>Within 8 h</td>
</tr>
</tbody>
</table>
Viscosity of a liquid is a measure of its resistance to flow and is expressed in centipoises. The viscosity of Manihot latex is highly variable and is found to be in the range of 42-56 cps. This is, in fact, close to that of Hevea latex of comparable solids content. Viscosity of the Manihot latex is found to increase significantly with storage and on dilution with water, as is described later.

Total solids content of Manihot latex is only in the range of 27 to 33 percent, with a typical value of 32.3 percent, which is lower than that of Hevea. Dry rubber content of the latex is found to be much lower, in the range of 20-26 percent with a typical value of 25.3 percent. However, it must be pointed out here that the Manihot trees were tapped almost daily during the course of these investigations, while Hevea latex was collected from trees which were tapped only on alternate days. One of the most significant differences between latex from Hevea and Manihot is the markedly higher non-rubber solids content in the latter. It varies between 6.0 and 8.0 percent by weight with a typical value of 7.0 percent. This is more than double the value observed in the case of Hevea.

Hevea latex is coagulated with fatty acids such as formic acid and acetic acid. Effect of these
coagulants was studied in the case of *Manihot* latex. Although the latex was found getting coagulated with both the acids, coagulation was found not complete in most cases with the serum remaining turbid. However, it was observed that the latex was found to coagulate completely on keeping for a few minutes after dilution with water. Although dilution with water was found to cause an initial thickening of *Hevea* latex, the same was found decreasing on further dilution, with no coagulation. This difference in behaviour was further studied following changes in the viscosity of latex on dilution and storage and the results are depicted in Figures 16 and 17.

Bacterial activity in latex causes formation of volatile fatty acids which ultimately leads to coagulation. This is called spontaneous coagulation which, in the case of *Hevea* latex, takes place over a period of time ranging from a few hours to overnight. When both the latices were observed simultaneously, under identical conditions, it was found that *Hevea* latex coagulated within 8 h while *Manihot* latex in 7 h. The changes in viscosity of the latices during storage are depicted in Figures 18 and 19.

4.12. Properties of dry film of the latex

Upon drying, especially at a low temperature, the entire solids content of latex gets dried up into
a film, which is the most ideal material for studying the composition of latex. In the present investigations samples of latex from both Manihot and Hevea were dried in glass petri dishes at 70°C in an air oven. The resulting films were subjected to further investigations. The results are given in Table 19.

The films were coherent in both the cases with the colour much deeper in the case of Manihot. Both the films were semitransparent (translucent). But the transparency, measured in terms of percent transmittance at 600 nm, was only 12.5 in the case of Manihot against 66 for Hevea. This significant difference might be contributed by the presence of a much larger quantity of non-rubber solids in the former.

The nitrogen content of the whole latex film was found to be 1.73 percent in the case of Manihot as against 0.72 percent in the case of Hevea. Nitrogen is contributed mostly by proteins in latex. The nitrogen content can be converted into protein content by multiplying with a factor of 6.15. Thus the total protein content of Manihot latex was found to be of the order of 10.64 percent as against 4.43 percent in Hevea. The acetone extract of the whole
<table>
<thead>
<tr>
<th>Property</th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Physical characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>Dark brown</td>
<td>Brown</td>
</tr>
<tr>
<td>Appearance</td>
<td>Coherant film</td>
<td>Coherant film</td>
</tr>
<tr>
<td>Transparency, %</td>
<td>12.5</td>
<td>66.0</td>
</tr>
<tr>
<td>transmittance at 600 nm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Chemical composition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetone extract, %</td>
<td>7.8</td>
<td>3.96</td>
</tr>
<tr>
<td>Nitrogen, %</td>
<td>1.73</td>
<td>0.72</td>
</tr>
<tr>
<td>Proteins, %</td>
<td>10.64</td>
<td>4.43</td>
</tr>
<tr>
<td>Ash content, %</td>
<td>3.96</td>
<td>2.03</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium, %</td>
<td>0.0389</td>
<td>0.0743</td>
</tr>
<tr>
<td>Potassium, %</td>
<td>0.3470</td>
<td>0.6740</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.0215</td>
<td>0.018</td>
</tr>
<tr>
<td>Magnesium, %</td>
<td>0.207</td>
<td>0.054</td>
</tr>
<tr>
<td>Iron, %</td>
<td>0.0250</td>
<td>0.0154</td>
</tr>
<tr>
<td>Manganese, ppm</td>
<td>7.75</td>
<td>Traces</td>
</tr>
<tr>
<td>Copper, ppm</td>
<td>0.75</td>
<td>7.5</td>
</tr>
</tbody>
</table>
latex film indicates its total resin content, which includes fats, fatty acids, sterols, sterol esters, phospholipids, etc. The acetone extract of the film was found to be in the range of 6.25-10 percent with a typical value of 7.8 percent, as against 3.96 percent for *Hevea*. Thus the resin content of *Manihot* latex also is much higher than that of *Hevea* latex.

The total mineral content of *Manihot* latex is also significantly higher as indicated by the ash content which is 3.96 percent as against 2.03 percent for *Hevea*. The ash was subjected to further chemical analysis to study the composition of the minerals in the latex. The results indicate that some of the common metallic ions are higher in *Manihot* while some others are lower, as is seen from Table 19. Thus manganese and iron are slightly higher in *Manihot* while magnesium is significantly higher. However, copper, sodium and potassium are found to be lower in *Manihot* than in *Hevea*.

4.13. Dry rubber properties

Dry rubber was prepared in the form of ribbed sheet as described in Chapter III from both *Manihot* and *Hevea* latices. The various properties of the dry rubber were measured using standard test procedures and the results are given in Table 20. When the
## Table 20. Properties of sheet rubber

<table>
<thead>
<tr>
<th>Property</th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of sheet</td>
<td>RMA 3</td>
<td>RMA 2</td>
</tr>
<tr>
<td>Dirt content, %</td>
<td>0.22</td>
<td>0.11</td>
</tr>
<tr>
<td>Volatile matter, %</td>
<td>1.61</td>
<td>1.12</td>
</tr>
<tr>
<td>Nitrogen, %</td>
<td>0.94</td>
<td>0.39</td>
</tr>
<tr>
<td>Proteins, %</td>
<td>5.78</td>
<td>2.40</td>
</tr>
<tr>
<td>Ash content, %</td>
<td>1.03</td>
<td>0.26</td>
</tr>
<tr>
<td>Acetone extract, %</td>
<td>4.26</td>
<td>2.91</td>
</tr>
<tr>
<td>Po</td>
<td>47</td>
<td>40</td>
</tr>
<tr>
<td>PRI</td>
<td>64</td>
<td>85</td>
</tr>
<tr>
<td>Mooney viscosity, ML(1+4)100°C</td>
<td>104</td>
<td>80</td>
</tr>
<tr>
<td>Gel content, %</td>
<td>38.7</td>
<td>62</td>
</tr>
<tr>
<td>Viscosity average molecular weight (Mv)</td>
<td>$1.16 \times 10^6$</td>
<td>$1.10 \times 10^6$</td>
</tr>
<tr>
<td>Accelerated storage hardening test,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta$ Po</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.972</td>
<td>0.964</td>
</tr>
<tr>
<td>Minerals,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium, %</td>
<td>0.0158</td>
<td>0.0117</td>
</tr>
<tr>
<td>Potassium, %</td>
<td>0.0309</td>
<td>0.0632</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.0180</td>
<td>0.0036</td>
</tr>
<tr>
<td>Magnesium, %</td>
<td>0.185</td>
<td>0.0523</td>
</tr>
<tr>
<td>Iron, ppm.</td>
<td>188</td>
<td>83</td>
</tr>
<tr>
<td>Manganese, ppm</td>
<td>7</td>
<td>Traces</td>
</tr>
<tr>
<td>Copper, ppm</td>
<td>0.3</td>
<td>Traces</td>
</tr>
</tbody>
</table>
sheets were graded as per the conventional visual grading system, the details of which are available in the Green Book (International Rubber Manufacturers' Association, 1962). The sheets from Hevea were found to have RSS 2 grade, but for colour while those from Manihot belonged to RSS 3 grade. The difference in the grade was mostly owing to the less translucent nature of the sheets from Manihot. Colour was light (in both cases) as in the present study the sheets were dried in hot air. However, a significant observation in the case of Manihot, was the appearance of a white powdery deposit on the surface of sheets which was developed on stretching. The extent of powder formation was more if the latex was coagulated without dilution.

The degree of contamination in dry rubber is assessed in terms of dirt content. This was found to be a little higher (0.22 percent) in the case of Manihot. Volatile matter indicates the degree of dryness and this was also higher (1.61 percent) in Manihot than in Hevea (1.12 percent). The higher protein content of Manihot latex results in a higher protein content in the dry sheet rubber (5.78 percent as against 2.4 percent in Hevea rubber). The presence of higher protein content in rubber prepared
after dilution and coagulation indicates that a major portion of the proteins in Manihot latex is associated with the rubber particles. The higher protein content associated with the rubber particles might be responsible for the difficulty in coagulating the latex fully with acids. It is also possible that the isoelectric point of some of these proteins might be much lower than that of the proteins in Hevea latex. As in the case of the whole latex film, dry rubber prepared from Manihot latex also has a higher acetone extract (4.26 percent as against 2.91 percent for Hevea), indicating that some of the resins, at least, are associated with the rubber phase.

The higher mineral content of Manihot rubber was indicated by its ash content which was 1.03 percent as against 0.263 percent for Hevea. It is noticed that the ash content in the sheet rubber is much lower than that in the whole latex film. But this difference in the ash content of the sheet rubber and that of the whole latex film is more in Hevea than in Manihot. Both magnesium and iron are significantly higher in Manihot rubber. Sodium, manganese and copper are also slightly higher in Manihot.
Plasticity of a rubber sample is a measure of its resistance to deformation and is determined in terms of the Wallace rapid plasticity number, Po. The higher the Po, the higher the resistance to deformation, and the more difficult its processability. Too low a value (values less than, say 30) are also not advisable. A Po of 47 recorded for Manihot rubber is well within the range recorded for Hevea rubber. Plasticity retention index is a measure of the resistance of the rubber to oxidation and a higher value is always considered advisable. PRI of Manihot rubber is found to be slightly lower compared to that of Hevea rubber. The lower PRI might be resulting from the higher manganese and iron contents of the rubber.

Hevea rubber usually undergoes hardening during storage. The extent of hardening is measured in terms of Po. In the accelerated storage hardening test, Po of normal grades of Hevea rubber increases significantly. The increase is usually of the order of 15-25 units. However, in the case of Manihot rubber the increase in Po in the accelerated storage hardening test is only 6 units which is within the specification limits for viscosity stabilised natural rubber. Like plasticity, Mooney viscosity also is a
measure of the processability of rubber, the lower the value, the easier the processability. In the case of Manihot rubber, Mooney viscosity is considerably higher. The higher Mooney viscosity is possibly resulting from the higher concentration of non-rubber constituents in Manihot rubber. However, gel content (macrogel) is found to be higher for Hevea rubber.

The viscosity average molecular weight of Manihot rubber has been found to be $1.16 \times 10^6$. This is close to the value obtained for Hevea rubber ($1.10 \times 10^6$).

The Fourier Transform Infrared spectra of Manihot and Hevea rubbers are given in Figures 20 and 21. These spectra are usually used to characterise the various chemical groups in the molecule and are very indispensable in the characterisation of polymeric materials. The spectra are found to be very much identical in the case of the two rubbers.

4.14. Processing properties

In order to study the vulcanization and reinforcing characteristics of Manihot rubber, it was compounded in an ASTM formulation (Table 4) and in a typical tyre tread formulation (Table 5). Hevea rubber was also compounded using the above
formulations for the purpose of comparison. The various processing characteristics of the mixes are given in Tables 21 and 22.

Mooney scorch is a measure of the tendency of a rubber mix to undergo premature vulcanization. A higher scorch time ensures longer shelf life for the mix. Both the rubbers are having almost identical scorch times in both the formulations. In the ASTM formulation, Mooney viscosity of Manihot rubber is found to be lower. A lower Mooney viscosity of the mix, in spite of a higher Mooney viscosity of the raw rubber indicates that the rate of break down was more in the case of Manihot. The vulcanization characteristics, measured using a Monsanto Rheometer at 150°C are also found to be identical in both the rubbers.

4.15. Physical properties of vulcanizates

Properties of the gum vulcanizates (ASTM 1A formulation) are given in Table 23 and those of the tyre tread formulation in Table 24. Hardness of the gum vulcanizates from Manihot rubber is noticeably higher. However, when black is added to the rubber no difference in hardness was observed. Modulus values are also higher in the case of the gum vulcanizates from Manihot rubber. In this case also addition of black causes the difference to disappear.
Table 21. Processing characteristics of gum compounds

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooney scorch at 120°C, min.</td>
<td>12.56</td>
<td>11.33</td>
</tr>
<tr>
<td>Mooney viscosity, ML(1+4) 100°C</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>Rheometric properties,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Minimum torque, d.N.M.</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>(ii) Maximum torque, d.N.M.</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>(iii) Cure time, min.</td>
<td>13.5</td>
<td>13.5</td>
</tr>
<tr>
<td>(iv) Cure rate index</td>
<td>9.091</td>
<td>9.52</td>
</tr>
</tbody>
</table>
Table 22. Processing characteristics of HAF filled compounds

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mooney scorch at 120°C, min</td>
<td>11.5</td>
<td>11.12</td>
</tr>
<tr>
<td>Mooney viscosity, ML(1+4) 100°C</td>
<td>48</td>
<td>50</td>
</tr>
<tr>
<td>Rheometric characteristics,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Minimum torque, d.N.M.</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>(ii) Maximum torque, d. N.M.</td>
<td>61</td>
<td>71</td>
</tr>
<tr>
<td>(iii) Cure time, min</td>
<td>12.5</td>
<td>13</td>
</tr>
<tr>
<td>(iv) Cure rate index</td>
<td>10.53</td>
<td>9.80</td>
</tr>
<tr>
<td>Property</td>
<td>Manihot</td>
<td>Hevea</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>Hardness, Shore A</td>
<td>38</td>
<td>32</td>
</tr>
<tr>
<td>Modulus at 100% elongation, $N/mm^2$</td>
<td>1.12</td>
<td>0.77</td>
</tr>
<tr>
<td>Modulus at 300% elongation, $N/mm^2$</td>
<td>2.08</td>
<td>1.47</td>
</tr>
<tr>
<td>Tensile strength, $N/mm^2$</td>
<td>19.6</td>
<td>23</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>1493</td>
<td>1439</td>
</tr>
<tr>
<td>Tear strength, kN/m</td>
<td>26.5</td>
<td>29.3</td>
</tr>
<tr>
<td>Property</td>
<td>Manihot</td>
<td>Hevea</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>Hardness, Shore A</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Modulus at 100% elongation, N/mm²</td>
<td>2.4</td>
<td>2.54</td>
</tr>
<tr>
<td>Modulus at 300% elongation, N/mm²</td>
<td>8.9</td>
<td>9.25</td>
</tr>
<tr>
<td>Tensile strength, N/mm²</td>
<td>22.7</td>
<td>26</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>725</td>
<td>752</td>
</tr>
<tr>
<td>Tear strength, kN/m</td>
<td>39.6</td>
<td>43.9</td>
</tr>
<tr>
<td>Resilience, %</td>
<td>46.34</td>
<td>50.94</td>
</tr>
<tr>
<td>DIN abrasion loss, mm³</td>
<td>136.8</td>
<td>106.4</td>
</tr>
<tr>
<td>Heat build-up, ∆T, at 50°C</td>
<td>32.5</td>
<td>29.4</td>
</tr>
<tr>
<td>Compression set, 22 h at 70°C</td>
<td>22.8</td>
<td>23</td>
</tr>
<tr>
<td>Crack growth resistance, kilocycles</td>
<td>110</td>
<td>88</td>
</tr>
<tr>
<td>Ozone resistance at 50 pphm ozone and 40°C</td>
<td>Crack formed in 2 h</td>
<td>Crack formed in 2 h</td>
</tr>
</tbody>
</table>

Ageing properties,

Retention of properties after ageing for 10 days at 70°C

<table>
<thead>
<tr>
<th></th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength, %</td>
<td>92.1</td>
<td>95.7</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>79.4</td>
<td>76.7</td>
</tr>
<tr>
<td>100% Modulus, %</td>
<td>134.6</td>
<td>134.6</td>
</tr>
<tr>
<td>300% Modulus, %</td>
<td>119</td>
<td>131.2</td>
</tr>
</tbody>
</table>

Retention of properties after ageing for 3 days at 100°C

<table>
<thead>
<tr>
<th></th>
<th>Manihot</th>
<th>Hevea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength, %</td>
<td>57.3</td>
<td>52.9</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>46.6</td>
<td>44.7</td>
</tr>
<tr>
<td>100% Modulus, %</td>
<td>154.2</td>
<td>142.1</td>
</tr>
<tr>
<td>300% Modulus, %</td>
<td>153.0</td>
<td>128.5</td>
</tr>
</tbody>
</table>
Tensile strength was found to be lower for Manihot rubber both in the gum and the filled formulations. As expected, the increase in tensile strength as a result of addition of black was not found significant. However, elongation was found to be more or less identical. Tear strength of the gum vulcanizate was slightly lower in Manihot. Addition of carbon black was found to cause significant increase in tear strength in both the rubbers. Even in the black filled vulcanizates tear strength was found to be slightly inferior in the case of Manihot.

Resilience is a measure of the rebound property of rubber and is an important basic character of any rubber. Results in Table 24 indicate that Manihot rubber is less resilient than Hevea rubber. A lower resilience leads to higher beat build up and the present results confirm this. Compression set is again a measure of the elasticity of a vulcanizate. A lower set is always desirable. In this case also both the rubbers are more or less similar. Unsaturated rubbers like NR are easily attacked by even traces of ozone and this leads to cracks in rubber under strain. When the vulcanizates were exposed to 50 parts per hundred million of ozone at 40°C, as per ASTM D 518-Method B, both the rubbers developed cracks in less than 2 h.
Resistance to crack growth due to cyclic flexing was found to be higher in the case of Manihot rubber. However, abrasion resistance was found to be slightly inferior compared to Hevea rubber as is indicated by a higher abrasion loss.

Ageing is the process of degradation in properties of rubber when exposed to heat and air for long periods. Resistance to thermal ageing was measured in terms of the percentage retention in some of the critical properties after exposure of vulcanizes in an air oven at 70°C and 100°C. The results, as given in Table 24, indicate that ageing resistance of Manihot rubber is similar to the of Hevea rubber.

4.16. Ceara rubber wood

General structure

The wood of M. glaziovii is diffuse porous, straight grained, medium coarse textured and moderately low density (400-450 kg/m³) light hardwood with whitish yellow colour when freshly cut and turns straw colour during drying. The exposed and debarked zone of green timber is prone to fungus infection within two to three days after felling and then gradually shows susceptibility to insect (borer) attack. However, the intensity of insect attack is comparatively less than that of Hevea wood.
The heart wood formation is ill-distinct and the growth rings are absent or ill-defined. However, the finished surface of wood disc displays growth ring like structures (Fig. 22 A) which are formed due to the orientation of the apotracheal banded axial parenchyma in the form of concentric rings in association with the tension wood arcs on either sides of these bands as observed in the cross sectional view of the wood sections (Fig. 22 B).

The wood tissue is composed of vessel elements (pores) fibers, axial parenchyma and ray parenchyma. The vessel elements are medium to large and are distributed as solitary as well as radial multiples (Fig. 22 B). The vessel is characterised by its bordered pitted walls (Fig. 23 C). Unlike Hevea wood, majority of the vessels of ceara wood are lacking tyloses in their lumen though tyloses are seldom seen in few vessel lumen.

The fibers are libriform and aseptate similar to that of Hevea wood. The fibers are short or long and their length is ranged from 1080-1950 m with an average value of 1577 m. The average width of fibers is 40 m within a range of 30-50 m.

Tension wood formation is a common phenomenon in ceara wood similar to that of Hevea wood. Tension
wood is either compact or diffuse with well developed
gelatinous fibers, distributed as successive arcs or
bands separated by apotracheal axial parenchyma
(Fig. 22B). In addition to this, gelatinous fibers
occur in discrete groups in the matrix of normal
fibers (Fig. 23A).

The gelatinous fibers are characterised by its
unlignified or partially lignified secondary
cellulosic layer, usually detached from the adjacent
well forming convoluted violet rings when stained with
toluidine blue 'O' (Fig. 23A). The gelatinuous
fibers are also displays a violet colouration in their
radial (Fig. 23 B) and tangential plane (Fig. 23 C).
Nevertheless, the normal fibers are lignified and do
not possess the secondary cellulosic layer and thereby
manifests a deep blue stainability (Fig. 23 A, C).

The axial parenchyma is apotracheal or
paratracheal in distribution and the former types
formed as wavy bands alternating with wood fibers
(Fig. 22 B).

The rays are uninseriate, biseriate or
multiseriate and heterocellular with distinct upright
and procumbent cells (Fig. 23 C) the ray cells are
abundant with starch grains and other reserve
metabolites. Crystal deposits are observed in axial
parenchyma cells (Fig. 23 D) whereas ray cells are
devoid of crystal deposits.

Wood processing

As ceara wood is susceptible to fungal and insect attack, attempts were made to ascertain the penetration capacity of water borne wood preservative.

The preservative penetration is found to be through and through in both ceara wood and Hevea wood. The mean density of treated ceara wood is 402.3 kg/m$^3$ at 15.9% moisture whereas the density at the same moisture level of Hevea wood is 538.4 kg/m$^3$ (Table 25).

Table 25. Density, moisture percentage and chemical penetration of Boron treated ceara wood and Hevea wood.

<table>
<thead>
<tr>
<th>Tree type</th>
<th>Sample</th>
<th>Density kg/m$^3$</th>
<th>M.C.%</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceara wood</td>
<td>S$_1$</td>
<td>402.7</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S$_2$</td>
<td>404.3</td>
<td>16.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S$_3$</td>
<td>401.3</td>
<td>15.4</td>
<td>Through and through</td>
</tr>
<tr>
<td></td>
<td>S$_4$</td>
<td>400.3</td>
<td>15.7</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>402.3</td>
<td>15.9</td>
<td></td>
</tr>
<tr>
<td>CV</td>
<td></td>
<td>0.4</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Hevea wood</td>
<td>S$_1$</td>
<td>531.3</td>
<td>15.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S$_2$</td>
<td>526.5</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S$_3$</td>
<td>553.8</td>
<td>15.9</td>
<td>Through and through</td>
</tr>
<tr>
<td></td>
<td>S$_4$</td>
<td>542.0</td>
<td>15.8</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>538.4</td>
<td>15.9</td>
<td></td>
</tr>
</tbody>
</table>
4.17. Ceara rubber seed oil

The oil content of *Manihot* seed kernel was estimated by Soxhlet extraction with n-hexam and was found to be 40.88 percent. The important physical characteristics of the oil were determined by standard methods and the results are given in Table 26.

Table 26. Physical characteristics of the seed oil of *M. glaziovii*

<table>
<thead>
<tr>
<th>Physical properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iodine value</td>
<td>129.24</td>
</tr>
<tr>
<td>Saponification value</td>
<td>200</td>
</tr>
<tr>
<td>Acid value</td>
<td>1.95</td>
</tr>
</tbody>
</table>
FIG. 4

A. Leaning growth of the trees raised by cuttings.

B. Spreading canopy of the vegetatively propagated tree.
FIG. 5

A. Young seedlings in the experimental plot.

B. Early branching habit of young plants raised through cutting.
FIG. 5
FIG. 6

A. Leaves of *M. glaziovii* showing variation in the number of lobes.

B. Early flowering and fruitset in one year old plant (Cutting).

C. Flowers showing colour variation.
FIG. 6
A. Seeds of *M. glaziovii* (X ½).

B. Seed showing mottlings.
   Stereo photomicrograph X 14.

C. Cross section of seed showing thick shell and kernel.
   Stereo photomicrograph X 12.
FIG. 8

A. Shoot drying of young seedlings in natural habitat.

B. Different stages of shoot drying.

C. Shoot drying in the mature tree.
FIG. 9

A. Wintering in *M. glaziovii*.

B. Stomatal distribution in the abaxial epidermis of leaf. Photomicrograph (Phase contrast X 512).

C. Stomatal distribution in the adaxial epidermis of leaf. Photomicrograph (Phase contrast X 512).
FIG. 10

A. Seed showing ground portion of the shell (at arrow) prior to sawing. Stereophotomicrograph X 14.

B. Seedlings of *M. glaziovii* raised in polybags.

C. Polybag plants of cuttings in the nursery.

D. Polybag plants of seedlings in the nursery.
FIG. 11

A. The bole showing flaky rhytidome.

B. Periderm with lenticels.
   Stereophotomicrograph X 12.

C. Smooth, inner green bark showing parallelly arranged lenticels (at arrows).

D. Smooth, inner white bark.
FIG. 12

A. Tangential view of compound, articulated and anastomosing laticiferous net work. Stereophotomicrograph X 100.

B. Tangential view of latex vessels with interconnections (at arrows) X

C. Radial section of bark showing parallelly arranged rows of latex vessels (at arrows) X 130.

D. Cross section of bark showing distribution of stone cells (at arrows) and laticifer rows (at arrow heads). Stereophotomicrograph X 12.
1. *M. glaziovii* in good laterite soil and good rainfall

2. *M. glaziovii* in dry granitic soil and low rainfall

3. *H. brasiliensis* in good laterite soil and good rainfall

Fig. 13. Latex vessel plugging in *M. glaziovii* in two agroclimatically different localities and *H. brasiliensis*
Fig. 14. Monthly contribution (%) towards annual dry rubber yield in *M. glaziovii*
FIG. 15

Photomicrograph (Phase contrast) of fresh latex of *M. glaziovii* showing rod shaped (at arrows) and round (at arrow heads) particles X 2000.
Fig. 16. Effect of 1:1 dilution and storage on viscosity of Manihot latex.
Fig. 17. Effect of 1:1 dilution and storage on viscosity of Hevea latex.
Fig. 18. Effect of storage on viscosity of Hevea latex
Fig. 19. Effect of storage on viscosity of Manihot latex
Fig. 20. FTIR Spectrum of Manihot rubber
Fig. 21. FTIR Spectrum of *Hevea* rubber
FIG. 22

A. Cross-sawn wood disc of *M. glaziovi* (Ceara wood) showing banded axial parenchyma (at arrows) and tension wood arcs (at arrow heads) X 7.10¹.

B. Transaction of wood showing distribution of pores, apotracheal banded axial parenchyma (at arrows) and distinct tension wood fibers (at arrow heads) X 50.
FIG. 23

A. Transection of wood showing gelatinous fibers with unlignified convoluted cellulosic layers (at arrow) and lignified normal fibers (at arrow head) X 320.

B. Radial section of wood showing gelatinous fibers (at arrows) and normal fibers (at arrow head)
Stereo photomicrograph X 100.

C. Tangential section of wood showing vessel elements with bordered pitted walls (at arrow head) and rays contiguous to normal and gelatinous fibers (at arrows)
Stereophotomicrograph X 75.

D. Tangential section of wood showing crystal deposits (at arrows) in the axial parenchyma cells
Photomicrograph (Phase contrast X 560).