STUDIES ON *MANIHOT GLAZIOVII* Muell. Arg. WITH SPECIAL REFERENCE TO ITS POTENTIALITY AS AN ALTERNATIVE SOURCE OF NATURAL RUBBER

THESIS
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BY

P. J. GEORGE
DEPUTY DIRECTOR
RUBBER RESEARCH INSTITUTE OF INDIA
KOTTAYAM - 686 009
INDIA

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CERTIFICATE

This is to certify that the thesis entitled **Studies on *Manihot glaziovii* Muell Arg. with special reference to its potentiality as an alternative source of natural rubber** is an authentic record of original research work carried out by Shri P.J.George (formerly Research Scholar, St. Berchman's College, Changanacherry and now Deputy Director, Germplasm, Rubber Research Institute of India, Kottayam) under my guidance and supervision, and that it has not been previously submitted for any other degree or diploma to him.

Dr. THOMAS JAMES
Professor of Botany (Rtd)
St. Berchman's College
Changanacherry
Kerala, India

22..03..1994

DECLARATION

I hereby declare that the thesis entitled **Studies on *Manihot glaziovii* Muell Arg. with special reference to its potentiality as an alternative source of natural rubber**, submitted by me to the Mahatma Gandhi University, Kottayam for the award of the Degree of Doctor of Philosophy in Botany, is a bonafide record of the research work carried out by me at St. Berchman's College, Changanacherry and the Rubber Research Institute of India and that no part thereof has been presented earlier for any degree or diploma of any other University.

P.J.GEORGE
Deputy Director (Germplasm)
Rubber Research Institute of India
Kottayam - 686 009
Kerala, India

22..03..1994

Dedicated to

my Beloved Parents

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[P.J. GEORGE]

C O N T E N T S

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Abbreviations used

ASTM	: American Society for Testing and Materials
BS	: British Standards
CMV	: Cassava Mosaic Virus
Chl. C	: Chlorophyll content
CS	: Cross section
d.r.c.	: Dry rubber content
FAA	: Formalin Acetic Alcohol
$g\ t^{-1}\ t^{-1}$	; Gram per tree per tap
ISO	: International Standards Organisation
$kg/ha^{-1}\ y^{-1}$	: Kilogram per hectare per year
LV	: Latex Vessel
MC	: Moisture content
NR	: Natural Rubber
PI	: Plugging Index
PRI	: Plasticity Retention Index
P_0	: Plasticity
PLV	: Latex vessel turgor pressure
PDA	: Potato dextrose agar
RLS	: Radial longitudinal section
S/2 d/2	: Half spiral alternate daily
SLF	: Secondary leaf fall
SALB	: South American Leaf Blight
TLS	: Transverse longitudinal section
USDA	: United States Department of Agriculture

CHAPTER 1

INTRODUCTION

Natural products from plant sources provide a large number of essential raw materials. Plants produce varieties of substances, some of which are secreted in special cells or tissue systems for a defined purpose, while others are merely byproducts of metabolism. Plant products like essential oils, pigments, alkaloids, organic acids, tannins, latex, resins, enzymes, vitamins, hormones etc., are some of the most important materials of value to mankind. Among these, petroleum like products such as low molecular weight hydrocarbons (terpenoids) and high molecular weight hydrocarbons (isoprene rubber) are some of the most important products. Major population of the hydrocarbon plants are laticiferous in nature, and they usually contain latex vessels, cells, etc. (Fahn, 1982).

Laticiferous plants are distributed widely, all over the world, ranging from small annual spurges to large trees. Most of the laticiferous species are dicotyledonous except certain monocots like Allium cepa (Hoffman,1933) and a few members of Allismataceae and Butaceae (Stant, 1964). Certain pteridophytes like Regnellidium of Marsiliaceae (Mahabale, 1949) and fungi like Lactarius and Peziza are also reported to contain rubber hydrocarbon in their cells (Pradhan and Mishra, 1982).

About 12,500 laticiferous species belonging to 900 genera (Esau, 1965), coming mainly under twenty families (Metcalfe, 1966, 1967) were reported. However, recent reports claim that about 35,000 to 38,000 species contain latex (Pradhan and Mishra, 1982). But, among these 35,000 species, only 2000 plants contain rubber hydrocarbon in their latex.

Rubber was known to man about 500 years ago. But the first record of rubber was made soon after the discovery of the New World by Columbus. During his second voyage, Columbus noticed that the inhabitants of Hispaniola (Haiti) played with balls made from the gum of a tree (Seeligman et al.,1910;Schurer,1958).The term "rubber" was first coined by an English Chemist, Joseph Priestly, in 1770, owing to the property of "Caoutchouc" to remove pencil marks by rubbing. The properties which make it so versatile and valuable include its plasticity and elasticity, its resistance to abrasion and electrical currents and also the fact that it is impermeable to liquids and gases.

Natural rubber is required in the manufacture of about 50,000 different products in the country (World Crops, 1957). But the indigenous production of natural rubber is not sufficient to meet the increasing demand.

The cultivation of Hevea brasiliensis in India is limited due to paucity of suitable areas, it would be better to encourage the search for other rubber bearing crops to exploit the potential of the subarid regions of the country (Menon, 1983). It is estimated that by AD 2010, the demand for natural rubber would be around seven lakhs tonnes (Menon, 1983).

The main source of Natural Rubber is Hevea brasiliensis which can be ideally cultivated only in a limited tropical zone. Any serious change in the political, economic or biological set up could endanger the world's supply of NR. The rubber plantations in South East Asia have escaped the devastating South American Leaf Blight. The USDA (1977) has given the warning that an accidental introduction of SALB spores, will bring the catastrophe. An alternative source or minor source of NR is highly essential to overcome any such situation. Of the laticiferous rubber bearing plant species other than H. brasiliensis, two apparently hold promise. These are Manihot glaziovii belonging to Euphorbiaceae and Parthenium argentatum, a member of the Asteraceae. The latter however requires mechanised cultivation procedures and mechano-chemical extraction techniques which are expensive. Moreover organised large scale group activity is also necessary. These are seemingly not apt for a country where labour is cheap and available in plenty (Estilai and Waines, 1987).

Hence search for other potential sources for natural rubber will be highly rewarding. Exploratory activity should not be limited to mere identification of rubber bearing species, but should be oriented towards production potential, suitability for marginal areas, adaptability to stress situations and promise for cultivation in non-traditional zones. This can be followed by field testing and genetic improvement.

In recent years, there has been much interest in developing and using more effectively plants that are able to tolerate arid and semiarid areas, particularly for industrial nonfood uses (Davis et al., 1983). The use of new crops grown in underused land areas could supplement our need for fuels and chemicals, as well as stimulate industrial and economic growth (Buchanan and Duke, 1981; Bungay, 1982; Calvin, 1983; Princen, 1983). This is particularly of significance to India with a dense population and a vast extent of land comprising of varied agroclimatic situations from the socio-economic considerations.

Under this circumstances, a study on the potentialities of M. glaziovii was taken up.

CHAPTER 2
REVIEW OF LITERATURE

2.1. Sources of natural rubber

Natural rubber of commerce, obtained from different species of wild plants, were earlier classified on the basis of their geographical origin (Seeligman *et al*., 1910). The classification was mainly into four classes, viz., American rubbers (South American rubbers and Central American rubbers), African rubbers (West African and East African rubbers), Asiatic rubbers and Oceanic rubbers.

The South American rubbers were obtained from different species of *Hevea* and *Micrandra*, *Manihot glaziovii*, *Hancornia speciosa*, *Calotropis procera* and *Sapium biglanduloum*, while the Central American rubbers were collected from *Castilloa* sp., *Parthenium argentatum*, *Vahea* sp., *Landolphia* sp., *Calotropis procera*, *Ficus elastica*, *Diandra* sp., etc. The African rubbers were obtained from species of *Landolphia*, *Ficus*, *Urostigma*, *Funtumia*, *Carpodinus*, *Clitandra*, *Vahea*, *Urceola*, *Cynachum*, *Hevea*, *Manihot*, *Parameria* and *Castilloa*. The sources of Oceanic rubbers were *Ficus elastica*, *Uriceola*, *Digeria* *Calotropis*, *Willughbeia*, *Leuconotis*, *Urostigma*, *Prohxa* and *Artocarpus*.

The sources of Asiatic rubbers were mainly *Ficus* and introduced species of *Urceola*, *Cynachum*, *Hevea*, *Manihot glaziovii*, *Castilla elastica*, *Parameria* etc. (Table 1).

Among the 2000 species known to contain rubber, at least 500 species have been exploited as rubber yielding plants (Bonner and Galston 1947). The rubber content of the latex in these plants varied from less than 1% to more than 20% of the dry weight (Raghavendra, 1991). Most of the laticiferous plants screened for rubber hydrocarbon, are of the low molecular group (Mw 58,400 - 157,000 compared to rubbers from *Hevea brasiliensis* (Mw 1,310,000) and *Parthenium argentatum* (Mw 1,280,000 (Swanson *et al*., 1979; Carr and Bagby, 1987). However Buchanan, *et al*., (1980) have remarked that such low-molecular weight rubbers may have additives in commercial processing of high-molecular weight natural and synthetic polyisoprenes and as hydrocarbon feed stocks.

The most important plants which were exploited as source of extractable quantity of rubber are *Hevea brasiliensis* Muell. Arg. (Para rubber). *Manihot glaziovii* Muell. Arg. (Ceara rubber) (Euphorbiaceae), *Castilla elastica* Cerv. *Ficus elastica* Roxb. (Moraceae), *Solidago leaven worthi* Torr. et Gray, *Parthenium argentatum* Gray. (Guayule), *Taraxacum Kok-saghyz* Rodm, *Acorzonera tau-saghyz* Lipschitz et Bosse (Compositae), *Cryptostegia grandiflora* R. Br, *Asclepias subulata* deena (Asclepiadaceae), *Landolphia* sp., *Funtumia elastica*

Table 1. SOURCES OF NATURAL RUBBER

Family	Botanical name	Country	Habit	Type of commercial rubber
Euphorbiaceae	Hevea brasiliensis Muell. Arg.	Amazon basin, Peru, Bolivia,Venezuela	Tree	Para rubber
	H. guianensis Aubl.	..	..	..
	H. benthamiana Muell. Arg	..	..	..
	Manihot glaziovii Muell. Arg.	North East Brazil		Ceara rubber (Manicoba rubber)
	M. dichotoma		..	..
	Sapium thompsonii	Columbia	..	
	Euphorbia intisy	Madagascar	..	
	E. resinifera	Morocco	Cactoid	
Moraceae	Castilla elastica Cerv	Central America	Tree	Castilla rubber (Panama rubber)
	C. ulei	High regions of Amazon	..	..
	Ficus elastica Roxb	India, Burma	...	India rubber (Assam rubber)
Apocynaceae	Funtumia elastica Stapf.	African Coast	..	
	Landolphia heudelotii D.C.	African Coast, Sudan	Climbing Vine	Lagos Silk rubber
	L. owariensis Pal.dee Beàuv	West Africa	..	Red Congo rubber
	L. Madagascariensis (Boj.), K.Schum	Madagascar	..	..
	Clitandra sp.	Tropical Africa	..	Black Congo rubber (Root rubber)
Compositae	Parthenium argentatum Gray.	Northern Mexico	Shrub	Guayule rubber (Mexican rubber)
	Scorzonera tau-saghyz Lipschitz et Bosse	Russia	..	Russian dandelion rubber
	Taraxacum koksaghyz	Cremea	Shrubs	..
Asclepiadaceae	Cryptostegia grandiflora R.Br	Madagascar	Vine	Madagascar rubber (Palay rubber)
	Hancornia speciosa	Brazil (Bahia Matto Grosso)		Mangabeira rubber
	Calotropis procera R.Br.	Venezuela	Shrub	White Assam rubber
	Urceola elastica	North-west Bengal	Tree	Assam rubber

Stapt, Carpodinus laneceolatus K. Sehum. (Apocynaceae) Hancornia speciosa, Urceola and Vahea sp., (Seeligman, et al.,1910;Martin, 1942; Polhamus, 1962; Reynolds, 1971; George and Panikkar, 1980). Recently there has been much interest in cultivating plants rich in hydrocarbon-like materials as renewable sources of chemicals for use as fuel and chemical feedstock (Nielsen et al., 1977; Buchanan et al., 1978 a, b; Calvin, 1979; Wang and Huffman, 1981; Lipinsky, 1981). Milkweeds also (Asclepiadaceae) have been proposed as a renewable source for fuel and chemicals (Whiting, 1943; Gaertner, 1979; Erdman and Erdman, 1981; Dehgan and Wang, 1983).

2.2. Manihot glaziovii

M. glaziovii commonly known as Ceara rubber belongs to the rubber family Euphorbiaceae. This species was discovered by a French Botanist Dr.Glaziow, in the neighbourhood of Rio de Janeiro and was later described and named after him by Muller in Martin's Flora Braziliensis,xi, part ii(Seeligman et al., 1910). Like the Para rubber tree H. brasiliensis, Ceara rubber tree also is a native of Brazil. It is also referred by the name Manicoba. Unlike H. brasiliensis, M. glaziovii does not originate at the Amazon basin, but in the states of Ceara, Piaui, Pernambouc and Bahia (Fig. 1) in the central regions of the North East (Hamlyin Atlas, 1977; Serier, 1988). These regions are characterised by erratic agro-climatic conditions. The irregular rainfall gives an annual average of 600-700 mm, with the extremes from 0 to 1400 mm. Further there have been years wherein there was no rain at all and years when the country was inundated. The terrain goes up to 1000 m of altitude and contains acid salts weak in p^H.

In the genus Manihot, there are about 200 species, with a geographical distribution extending from the California Bay to Peru (Serier, 1988). The investigation report of Rogers and Appan (1970) revealed that there are only 98 species under the genus, and all the other reported species are repetitions, and the inventory is smaller if these repetitions are taken into account. The popular members of the genus are M. esculenta commonly known as manioc which yields the edible tuber 'tapioca' or cassava, M. glaziovii, M. heptaphylla, M. palmata, M. dichotoma, and M. paiuhyensis (Polhamus, 1962; Chopra, 1977; Usher, 1984). Intermediate forms are also commonly seen especially in the regions where it was introduced. These are the natural hybrids of M. glaziovii and M. esculenta (Jones, 1959) and commonly known as tree cassava.

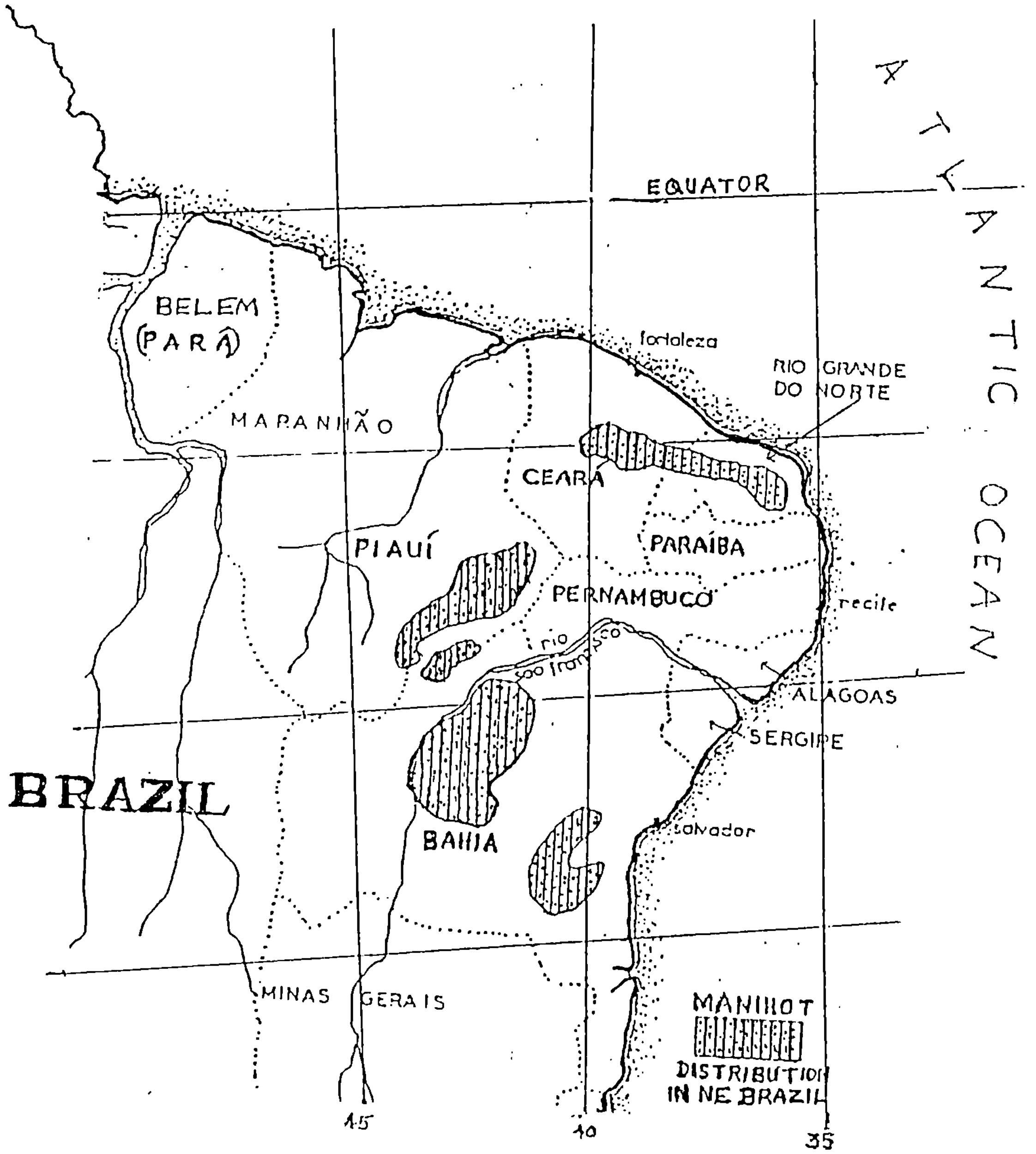


Fig. 1. Distribution of M. glaziovii in North-East Brazil

M. glaziovii which produces the commercial Ceara rubber was exploited in Brazil for a considerable period before it was botanically identified by Dr.Glaziow. Around seventy species of *Manihot* are said to occur in Brazil, but it was generally stated until quite recently that *M. glaziovii* alone yielded rubber of commercial importance, though certain other species also were cultivated in South America for the purpose of rubber. *M. piauiensis* is one among them, which occurs more frequently in the states of Piaui and Bahia. The trees are comparatively smaller, of about 6-10 m height, with a bole of about one meter and has a bushy appearance. The bark shows close similarities to that of *Hevea*. Another cultivated species is *M. dichotoma* is a native of the dry region of the state of Bahia.

M. glaziovii is a tree which attains about 8 to 15 m height, with a spreading canopy. Branches emerge and spread out trichotomously at a height of about 3 to 5 m above ground level. The trunk is terete and stout covered with a peelable leathery rhytidome. The leaves are palmately lobed usually with three lobes. The leaves are oblong-oval, glabrous, light green in colour and glaucascent.

The tree produces flowers at the age of 18 months. The panicles are 7 to 9 cm long bearing unisexual flowers. Flowering is usually in March-April (Ramrao, 1914). The male flowers are seen at the top, having sepals much shorter than those of the female flowers which are located at the lower part of the panicle.

The fruit is a three lobed, globular capsule, distinguished by six grooves.

M. glaziovii is propagated in nature through seeds as well as by cuttings. Vegetative propagation is also possible. The crude method for propagation, adopted by the natives, was to burn the seeds with dry grass. But in the natural habitat, seeds germinate when the season becomes favourable.

However, different rapid multiplication techniques have been tried and recommended for propagating *M. esculenta* (Cock *et al*., 1976; Kamalam *et al*., 1977; Lozano *et al*., 1977; Dahniya and Kallom, 1983). Some of **of**
these methods are likely to be applicable in the case of *M. glaziovii* also. However, a reliable standard method of propagation either through seeds or by cuttings is not available in the case of *M. glaziovii*.

Introduction of *M. glaziovii* to the African countries took place, a little before 1900. It was introduced to Congo and Senegal. The plants survived well and best result had been obtained from Dar-es Salaam. In 1912 there were 45000 ha of manicoba, planted in the German Colonies of East Africa. Schultz (1942) had reported that among all the laticiferous plants introduced and tried in Argentina, *M. glaziovii* was the best rubber producing plant. *M. glaziovii* was introduced to Ghana in 1900, as a rubber bearing plant (Opoku, 1966). The species was introduced to the West Indies as a rubber yielding plant along with *H. brasiliensis* and *Sapium* sp. (Howard and Powel, 1963).

Seeds and plants of *M. glaziovii* were brought to Kew in 1876 by Sir Robert Cross. In 1877 a few plants and seeds were sent to Singapore, Calcutta and Ceylon. By the end of 1878, sufficient plants were multiplied in Ceylon and distributed to other botanical gardens. Thus the manicoba was spread to almost all over the world (Serier, 1988).

2.2.1. Introduction and cultivation in India

Though there is some reference about the introduction of *M. glaziovii* in India (CSIR, 1962; Serier, 1988) there is no clear evidence on any serious attempts for commercial cultivation of Ceara rubber in the country. However, there is a record of its experimental cultivation in the Government owned experimental gardens situated in the Nilgiris during 1902. The report says that Ceara rubber, Castilla rubber and Para rubber were tried on experimental basis in Kallar and Burliar Estates situated at an elevation of 1300 m MSL during the reign of the British. Samples of dried rubber were sent to the Imperial Institute for analysis and the reports were published (Imp. Inst ., 1911). It is interesting to note that samples were received from African countries and India (Table 2) as early as 1908. Experimental planting was done in Nilgiris in 1902 and opened for tapping in 1908. It is also reported that the plants were found in Malabar, Assam and Orissa (Umrao et al., 1983).

Regarding the suitability of M. glaziovii to the dry forests, the remarks of the great explorer of the Amazon Valley, Sir Henry Wickham as shown in his book on 'Para Indian Rubber', published in 1908 is worth mentioning.

"The ceara, named after the Brazilian province of that name, is a tree of quite different character. Its native locality is high, stoney, arid and in places almost semidesert, "scrub-covered" country.

The latex from the ceara rubber tree, like that of the Hevea, is of the "film" formation type. If properly

Table 2. Analysis of Ceara rubber samples from various countries

Source of sample	Year of collection	Contents (%)			
		Caoutchouc (rubber)	Resin	Protein	Ash
East Africa	1908	67.2	12.0	13.8	7.0
Uganda	1908	76.5	8.0	12.5	3.0
Kisumu	1908	66.4	9.7	15.5	8.4
Nyasaland	1908	78.6	10.8	8.4	2.2
Sudan	1908	81.9	5.9	10.0	2.2
Nigeria	1908	67.2	3.6	23.9	5.3
<u>South India</u>					
Nilgiris	1908	82.5	6.4	9.8	1.3
Wynadu	-	92.5	4.3	-	-

(Compiled from the reports of Imp. Inst.)

cured, the rubber resultant therefrom is remarkable for its strength and tenacity. The chracteristic bark of the manihots has a habit of flaking off in thin layers, somewhat in the manner of the European Birch Tree. In the East it has never, as yet, I think, had justice done to it. It has too often been set out on land, and under rainfall, totally unsuited to it. In Ceylon especially, there are large areas of dry forest lands, which should be admirably adapted to this tree; and considering the high quality of the rubber produced when well cured, it would, surely, be better planted out in such districts closely resembling as they do the natural requirements and conditions of this tree, rather than to try to plant the Hevea, a tree native to the Amazon Valley (Wickham, 1908).

The remark made by the father of the 'Para rubber Introduction' is exactly true in the case of ceara rubber. Though the British planters introduced and tried all the three rubber yielding plants viz., H. brasiliensis, Castilla elastica and M. glaziovii, owing to the several advantages and superiority of Hevea, the other two were neglected. Thus Para rubber found its respectable position in the most ideal agricultural fields of the Indian continent and the nearby islands of Ceylon, Malaysia, Indonesia and other S.E.Countries. But H. brasiliensis never economically survived in the dry regions of these countries. In the meantime the suitable prospective life support species for such semi-arid regions was conveniently discarded.

Thus M. glaziovii became a museum specimen in the botanical gardens and certain research institutes (Magoon et al., 1970; Nehru et al., 1989). The availability of its genetic materials in India is not reported elsewhere. George and Reghu (1993) have reported the occurence of a large population of semi-wild plants of M. glaziovii in the dry forests of Mettur Hills.

A number of diseases and pests have been found to attack M. glaziovii in the wild population as well as in the cultivated fields, especially in Africa (Golato and Meossi, 1977). Some new incidence of disease and pathogens were reported from Tanzania. The reports published since 1980, showed that M. glaziovii is affected by the pathogenic fungus Periconia manihoticola. Attack of Erynnyis ello on Ceara rubber plants caused defoliation in Brazil (Teri and Keswani, 1981).

Different pests are also reported to attack Ceara rubber. In North-Eastern Brazil, attack by the Tetrancychid mite, Mononychellus tanajoa, which feeds on the folliage causing severe damage is recorded (Bastos and Magalhaes, 1981; Bastos et al., 1985). In the

Ceara state of Brazil about 88% of the plants of M. glaziovii, were found to have shoots with dry tips as a result of damage caused by the borer Hypothenemus obscurus (Bastos et al., 1981).

In Brazil, it is reported that the leaves of M. glaziovii are attacked by a dark grey caterpillar belonging to the Lepidoptera of the Sphynogidee family. The affected trees are stripped off completely without any foliage (Serier, 1988).

M. glaziovii is an important species in the crop improvement programme in Cassava. It is being used as a donor parent for resistance to cassava mosaic virus (CMV). The first hybrids between M. esculenta and M. glaziovii showing resistance to CMV were obtained in Tanzania (Nichols, 1947; Jennings, 1957; Hahn et al., 1973, 1980; Allem and Shahn, 1988).

2.2.2. Exploitation

The bark and laticiferous system of Ceara rubber is comparable to that of Hevea, with the exception of the peelable rhytidome. Hence almost a similar exploitation system was adopted in the earlier period by the natives. Different tapping systems were adopted from site to site. Pricking and incisions with sharp hacking knives etc., were the common old practice (Serier, 1988). In West Africa, the methods adopted were very crude, involving splitting and opening the bark in several places and allowing the latex to settle on the ground. The latex coagulum was in turn collected along with the dirt.

The Ceara rubber plants of the Brazilian forests were subjected to exploitation for latex usually at the age of three years. The average girth of the trees at that age would be around 25-40 mm. The ground surrounding the base of the tree used to be cleared and banana leaves spread to collect the latex. The bark from the bottom of the trees upwards to a height of about 150 cm was split in several places in different directions. The Manihot latex, thicker than that of Hevea, flows slowly rarely reaching the ground. A major portion of the latex coagulates on the bark crevices itself. The trees were left for several days to facilitate natural drying and the rubber was detached either by rolling them into a ball or by folding the coagulum. Without any further preparation the crude rubber was marketed as Ceara scraps (Seeligman et al., 1910).

Tapping is a skilled operation and the main point of skill is to cut as much latex vessels as possible without any injury to the cambium which lies very near to the latex vessel rows. The system takes into account the anatomy of laticiferous system, convenience of tapping etc.

Different tapping methods were tried and suitable systems were developed and recommended in the case of Hevea. (Dijkman, 1951; Edgar, 1958; Dejong and Warrier, 1965; Radhakrishna Pillai, 1980; Ridley, 1987).

When a tree is tapped, the latex is expelled out due to the turgor pressure. The flow stops after a while by an inbuilt coagulation system. The latex and rubber lost are regenerated during the interval between two tappings (Sethuraj, 1968). The laticifers are quite turgid in vivo keeping a balanced equilibrium with the adjascent parenchymatous tissue.

No suitable tapping technique had been developed in the case of Manihot. Due to the lack of an effective tapping system, the quality of rubber also was poor. There were different qualities of Ceara rubber. The first quality was a blonde rubber collected in the beginning of the season. The second quality rubber was mostly collected at the onset of the rainy season. The third quality comprised of collections from the tree base, which naturally was filled with earth and dirt. The lack of a proper tapping and collecting system, reduced the industrial yield to below 50 percent.

An advanced method of tapping tried in Brazil was a 'V' cut tapping at the level of the collar region. It was stated that the productivity of tapping diminishes when the height of the cut increases from the ground (Serier, 1988). These observations were reported in the case of *M. piauiensis*.

This type of tapping leads to a harvest by a semi-buried system as the cup is kept below the ground level, which is a difficult position for tapping and collection. Moreover the latex gets polluted by light dirts brought by wind. Further the tapping wound is likely to get infected by various fungal diseases, subsequently leading to damage of yielding trees.

The earliest attempt of any planned exploitation for *M. glaziovii* was indicated by Leo Zehnter when he communicated in 1912 his experiences in tapping (Serier, 1988). A clear response to wound manifesting in an augmentation of latex at the renovation of incision was narrated. However, it was only in 1951, a tapping experiment was conducted in the Boukodo Station, in Brazil (Borget, 1952) in a plot of Ceara rubber planted in 1944. The result showed that the best yield was obtained in a frequent, but light, tapping system on the bark from which the periderm had been removed. An average yield of about 60 kg/ha/year was recovered. A recent experiment conducted in 1984-85 at Pernambouc, had produced 25 kg of rubber per hectare per month in the dry season. It was interesting to note that, in the above experiment, 1% of the trees produced more than 25 g of rubber per tree for each tapping.

Tapping tests for 15 days in dry season and 15 days in rainy season were conducted at the University of Fortaleza at Ceara. An average yield of 415 kg were obtained from a stand of 400 trees (Serier, 1988). Recent report from Brazil states that the average production of *Hevea* NR was 468 kg/ha/year and that of *Manihot* was 414 kg/ha/year (Rodrigues *et al*.,1991).

2.2.3. Laticiferous system

M. glaziovii shows a lot of similarities with *H. brasiliensis*. The chromosome number (2n = 36) is the same (Nassar *et al*., 1986). The laticiferous system in both are also comparable in structure. However, studies in depth have not been carried out on the laticiferous system, as well as latex synthesis in Ceara rubber. The works and reports in this field with regard to para rubber may be of relevance while discussing the less investigated Ceara rubber.

In both species the product of economic importance is rubber, which forms the major constituent in the latex. Latex is synthesised in the specialised latex vessels which is present in almost all parts except the pith (Bobilioff, 1918; 1923; Aggelon-Bot, 1948; Schweizer, 1949). The anatomical structure of the virgin and renewed bark of H. brasiliensis was reviewed by Panikkar (1974). The bark is delineated from the wood by a layer of cambium which by repeated divisions proliferate new tissues towards both sides. The mature bark has an outermost corky layer, and innermost soft zone, and an intermediate hard zone. The outermost zone comprises of the rhytidome. The rhytidome in the case of M. glaziovii is flaky and leathery, which can be easily peeled off leaving the smooth bark.

2.2.4. Latex

The term latex is used for fluids, many with a milky appearance due to the suspension of small particles in a liquid dispersion medium, usually found in plants. The composition of latex varies in different species. According to Esau (1965), the dispersed particles are commonly hydrocarbons of the terpene type which include essential oils, balsams, resins and rubber. Members of the Papaveraceae contain alkaloids in their latex. Euphorbia latex is rich in Vitamin B1 and that of Carica contains the proteolytic enzyme papain. Other inclusions like crystals of oxalates and malates and rarely starch grains also are present in latex of various species (Metcalfe and Chalk, 1950).

The latex of H. brasiliensis is a hydrosol and rubber is seen as dispersed particles (Bonner and Galston, 1947). Besides rubber it contains other substances like carbohydrates, proteins, resins, inorganic salts etc. (Archer et al., 1963; 1967; Archer, 1980). Latex is of cytoplasmic origin and is often considered to be cytoplasm itself in a specialised form (Milanez, 1946; Andrews and Dickenson, 1960). Heusser (1930) reported that the rubber particles in latex are ovoid and spherical in shape while Andrews and Dickenson (1960) found them always spherical atleast in young plants. Tobler (1914) and Stewens and Stewens (1940) found that in M. glaziovii both spherical as well as rod shaped rubber particles occur. The rubber particles in H. brasiliensis latex measure 50A° to 3.00μm in diameter with the majority around 0.5μm (Gomez and Moir, 1979), while those in the latex of M. glaziovii have a particle size of 10 microns (Heusser, 1930).

2.2.5. Latex and dry rubber

Studies on the latex and rubber content of M. glaziovii date back to 1918 (Serier, 1988). Apparently the interest was shortlived and the studies discontinued. Lack of advanced studies on the properties of Ceara rubber, creates difficulty to compare it with the current norms of natural rubber.

The latex of M. glaziovii has a lot of similarity with that of H. brasiliensis. However latex of the former coagulates spontaneously. Spontaneous coagulation leads to early cessation of latex flow resulting in poor yield. The latex is thicker than Hevea latex. Some attempts were made to develop devices to prolong the flow of latex through the tapping channel so that it could be collected in collection cups. A few drops of ammoniacal solution was allowed to run down the tapping cut. The latex thus obtained was later coagulated by adding common salt and dried in natural heat. Various stimulant materials like pepper also were tried to promote the flow of latex. The quality of rubber collected from the latex was reported to be far superior to that of the dried scrap collected from the bark of the tree (Polhamus, 1962). The latex can also be coagulated by exposure to air or smoke (Marsland, 1943; Hill, 1952).

The latex of Manihot consists of homogeneous sticky mass with low extensibility. On coagulation, the particles form irregular clumps and finally fuse to form a homogeneous mass (Heusser, 1930). The latex coagulum, prepared from latex diluted by adding water gives a better quality rubber, which after drying gets a light tan to amber colour. This was usually a high grade of rubber and Dannerth (1917) stated that since 1910 this type of rubber became popular in America for the manufacture of high grade products.

The earlier reports on the results of chemical examination of Ceara rubber was published in 1911 (Imp. Inst , 1911) in the Bulletin of the Imperial Institute. Ceara rubber samples collected from the British Colonies and Protectorates, were examined in the Scientific and Technical Department of the Imperial Institute (Table 2). From the chemical analysis results of samples of Ceara rubber collected from various countries belonging to different continents, the rubber percentage was more (82.5%) from the samples collected from South India. In the case of other non-rubber constituents also, the Indian sample was found to be of better quality. Rodrigues et al., (1991) have reported that Hevea NR and Manihot NR have the same structure and close hydrocarbon contents. Slight difference in molecular weight has been reported by Bennet (1944) and Seifriz (1945).

2.2.6. Ancillary products

Ceara rubber seeds contain about 35-42% of a greenish yellow drying oil (CSIR ,1962). Serier (1988) has reported that the Manihot seed oil was once used in automobiles as a substitute for diesel oil, in Brazil.

Freeman and Wessel (1964) has reported that M. glaziovii has been widely cultivated as a shade tree in the cocoa plantations in Nigeria. *M. glaziovii* is reported to be a good source of green manure. Menon and Ramankutty (1962) have reported that paddy yield can be increased to more than 10 percent by applying *M. glaziovii* green leaf at the rate of 6000 lbs per acre. It is undoubtful that the Ceara rubber population in a semi-arid marginal land will provide afforestation and subsequently enrich the poor soil, in addition to the returns from dry rubber.

CHAPTER 3

MATERIALS AND METHODS

3.1. Locations

Manihot glaziovii Muell. Arg. growing in two entirely different agroclimatic regions were made use of for making various observations and conducting different experiments.

The first site, referred in the thesis as Location I, represents the trees growing in the Experiment Station of the Rubber Research Institute of India, Kottayam, Kerala. This station is located on a hillock at an elevation of 73 m MSL. The area received a mean precipitation of 4080 mm per annum during 1992. The soil is mostly laterite and lateritic and well drained. A small area in the Experiment Station supports a vegetatively propagated population of M. glaziovii planted in 1981.

The second location is in the Mettur Hills of Tamil Nadu. This hillstation is situated about 60 km from Salem District and is a continuation of the Yercaud-Shevroy Hill tract. The elevation is 1100 m MSL and the area is almost of granitic rocks(Fig.2A) and shallow soil. Almost all the valuable timber yielding trees in this area were cut and now there remains only shrubs and scattered semi-wild seedling population of M. glaziovii. Rainfall is scanty and highly erratic. The mean annual precipitation during the period 1988-1992 was 934 mm.

3.2. Experimental materials

In Location I, the population of M. glaziovii was raised by vegetative propagation through cuttings, and planted in 1981, at a spacing of three metres apart. The trees were not tapped previously, and no cultural operations were carried out as they are meant as an alternative forage species for honey bees.

The trees in the second location are a population of wild seedlings of different age groups. The plants are not grown in a defenite spacing but are scattered. Most of the trees are found growing in the granite crevices and hard rocky grounds (fig. 2 B).

3.3. Brief description of the experimental trees

At both the locations a preliminary screening of the entire population was made based on girth measurements. The observational plants were selected from those having a girth range of 100-150cm at a height of 100 cm from the ground level. The trees in Location I, raised through cuttings, are well developed. Most of the trees show a leaning tendency and early branching. The trees in Location II are of seedling origin. The early history of these plants could be traced back to 1908, when an enterprising European planter brought the seeds of *M. glaziovii* and *Hevea brasiliensis* for experimental planting. But due to the high altitude and the low rainfall conditions, *Hevea* became a failure and *M. glaziovii* got established. The trees were tapped for rubber for a few years. Later the area has been bought by a local person. Since then tapping was discontinued. In the meantime the trees produced seeds profusely and natural propagation took place in this locality and in the surrounding hill slopes resulting in the formation of a semi-wild population.

3.4. Rainfall

Data on total rainfall and the number of rainy days have been collected from the agrimetereological records of the Rubber Research Institute of India and the estate records of Chandhappa Estate, Mettur for Location I and II respectively. The information relevant to the five year period 1988-1992 has been summarised in Table 3. The mean annual rainfall in the Rubber Research Institute of India Experiment Station (Location I) has been 3377.8 mm and the number of rainy days being 135. In sharp contrast, the mean annual rainfall and the number of rainy days in Location II are 934.0 mm and 59 respectively. It may be noted from the table that the total rainfall in Location I has been three and a half times of that in Location II.

Table 3. Rainfall and number of rainy days

	Location I	Location II
Mean annual rainfall (mm)	3377.8	934.0
Mean number of rainy days	135	59

The number of rainy days has been less than half in Location II compared to that in other experimental site.

3.5. Methods

3.5.1. Growth and morphology

The trees raised through cuttings (Location I) were observed for wintering habit and morphological characters. Leaf samples were examined for variation in the number of lobes. Laboratory observations on the distribution of stomata and occurrence of leaf diseases also were carried out. Visual observations on the commencement of wintering were taken from the beginning of the summer months and continued till refoliation.

Micromorphology of the leaves of the experimental trees in Location I has also been studied. Five mature leaves each from the experimental trees were collected. Leaf area was measured using a Licor Leaf Area Meter.

For stomatal studies two expanded mature leaves were collected from ten trees at comparable nodal positions of the branches. Collection was done between 9 am and 10 am on the date of observation. Leaf bits were taken out from the middle portion of the leaflets. The samples were boiled for 7 to 8 minutes in 3 per cent KOH and washed in several changes of water as suggested by Senanayake (1969). Epidermal peels from the abaxial side and adaxial side were taken out for observations.

Stomatal frequency was ascertained by counting the number of stomata per square millimeter by means of a calibrated CCD colour camera system attached to a phase contrast microscope. Ten camera fields per tree were scored for calculating the stomatal density. Similarly, the frequency of epidermal cells per square millimeter was also ascertained. Since the stomatal distribution in the adaxial side (upper side) is restricted to the vicinity of the midribs and veinlets in limited numbers, the density per unit area was not ascertained.

Computation of the stomatal index (number of stomata per unit area to the number of epidermal cells per unit area) was done by the method recommended by Meidner and Mansfield (1968).

General observations on growth pattern and morphology were recorded on the population available at Location II. Cuttings of ten genotypes selected at random from this location were brought to Location I where they were multiplied and established in the field. Observations on growth, morphology, etc. were made on these plants also.

3.5.2. Propagation

Seed propagation Propagation studies were conducted both with seeds and with cuttings. Fresh seeds were collected from Location I and various treatments were tried to enhance maximum germination.

Seed coat grinding The frontal end of each seed was ground using a motorised grinding stone. The hard seed coat was thus removed at this portion until the kernel was just visible. 100 seeds were thus prepared and soaked in water for 24 hours. The seeds were planted in germination beds.

Soaking in salt water 100 seeds were soaked in salt water for six hours. Then the seeds were planted in germination beds.

Acid treatment 100 seeds were soaked in Con.H_2SO_4 for 6 hours and then washed thoroughly in fresh water. The seeds were then planted in germination beds.

Burning the seeds 100 seeds were spread over paper packing materials and burned in such a way that only the hard seed coat was slightly burnt. The treated seeds were then put on germination bed.

Control (untreated) 100 untreated fresh seeds were simultaneously planted as control.

All the germination beds were regularly sprinkled with water and the number of seeds germinated were recorded.

Vegetative propagation

Different types of cuttings were tried for propagation. Tender green, brown and mature branches were collected from the experimental trees in Location I. The planting materials (cuttings) were prepared in two lengths, ie., 20 cm and 40 cm and the experiment was laid out with four replications of 20 points each.

T_1 - tender green cuttings 20 cm length

T_2 - brown cuttings 20 cm

T_3 - mature with periderm 20 cm

T_4 - tender green 40 cm

T_5 - brown 40 cm

T_6 - mature 40 cm

The cuttings were planted at random on raised beds at a spacing of 60 cm. The sticks were planted in such a way that about 10 cm, ie., one leaf scar, is buried in the soil. The experiment with the same treatments was repeated after waxing the top end of the cuttings in molten paraffin, to about 2 cm. Weekly observations were made and the number of cuttings sprouted was recorded.

3.5.3. Leaf disease

Disease symptoms appeared on certain plants were investigated. Young plants growing in Location I including the germplasm brought from Location II, were found affected by a mild yellowing symptom of the young leaves. Leaf samples showing lesions on the lamina were collected and examined in the laboratory. The leaves showed shrivelling. On the affected area minute dark spots and an ashy coating were noticed. The affected leaf portions were tissue cultured in Potato Dextrose Agar medium (PDA) after surface sterilisation with 0.01% $HgCl_2$.

3.5.4. Bark studies

Structure of the bark, latex vessels and related aspects were studied in detail for which ten trees of M. glaziovii of the same age were selected in Location I. Bark thickness at 100 cm height from ground level was measured using a Schlicpers' guage. Bark samples were collected from each of the ten trees, at a height of 100 cm. The samples were fixed in formalin-acetic-alcohol (FAA). For comparison ten trees of H. brasiliensis (Clone GT 1) of the same age were also chosen and samples collected in the same manner.

Free hand sections of the bark samples were taken at radial longitudinal, tangential longitudinal and transverse planes (RLS, TLS, CS) respectively using a base sledge microtome. Sections were taken at 30 μm to 60 μm thickness and stained in Sudan III and Sudan IV. The stained sections were mounted in glycerine gelly.

To isolate the complete network of the laticifer system from the bark without sectioning, the procedure suggested by Zhao Ziu-Qian (1987) was adopted. Bark samples of 10-20 cm length were softened by boiling in

10% KOH for about 15-20 minutes. The softened samples were then washed repeatedly in distilled water to be free of the dark brown contents. The peridermal layer of the bark samples were then removed. The laticiferous tissue thus exposed was gently dissected under a stereo scopic microscope. The laticifers were then dehydrated with methyl alcohol series, for about 10-15 minutes in each grade. The dehydrated tissue was then stained in Sudan III or Sudan IV. The stained tissue was spread carefully on microslides and mounted in glycerine jelly.

Microscopic observations were made with the help of a Leitz Aristoplan Microscope and Wild M.8 Stereo microscope. Quantitative anatomical observations and measurements were done using a calibrated CCD - TV attached to the Aristoplan microscope. Photomicrographs were taken using Wild MPS 4/52 Photo Automat.

The following characters were recorded for bark anatomical investigations:

Bark thickness (mm),

Total number of latex vessel rows,

Density of latex vessels per row per 1 mm circumference of the tree,

Diameter of latex vessels (μm),

Distance from cambial zone to the innermost row of latex vessels (latex vessel free zone) (mm),
Distance between latex vessel rows (mm) and
Frequency of stone cells per 1 cm^2 area of the sampled bark.

For the estimation of moisture content in the bark, samples were collected from the trunk of five trees of M. glaziovii. For comparison, samples were also collected from five trees of H. brasiliensis of the same age. Collection was made during the peak summer season in February. The bark samples, 3 cm square in size, were scooped out using a bark scooper, at a height of 100 cm from ground level. The marked samples were immediately stored in an airtight container. The weight of each was recorded. The samples were then subjected to oven drying at 105°C for 48 hours. The oven dry weight was recorded and the percentage of moisture content (MC) was calculated applying the formula:

$$MC = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

For the determination of total chlorophyll in the bark, one square cm samples of bark of each were collected from the trees of M. glaziovii and H. brasiliensis of comparable age and growth. The samples were tightly kept in small vials in the field and immediately brought to the laboratory for testing.

The outer corky zone of the bark at 1 mm thickness was removed from the samples and the total area and weight were recorded. The samples were then cut into 1 square mm pieces and incubated in 3 ml N, N-dimethyl formamide (DMF) under darkness for 24 hours to extract the chlorophyll pigments. The extract was then decanted into a spectrophotometer cuvette and the absorption at 664 and 648 nm by using a Shimadzu Spectrometer was recorded. The total chlorophyll content was calculated using the formula suggested by Moran (1982).

$$Cl\ (\ g/ml) = 7.04\ A664 + 20.27\ A647$$

(expressed in g/g fr. weight)

3.5.5 Exploitation and yield potential

Studies on yield was conducted both at Location I and Location II. Ten mature trees belonging to 1981 planting were selected at Location I and ten seedling trees at random in the wild population at Location II. Only trees having a girth of 45 cm and above at a height of 100 cm from the ground level were selected for yield studies. Regular alternate day tapping was done in Location I, for 12 months commencing from January to December 1992. Location II, being wild stand in a remote area without any facilities, only one round of recording of the yield data was undertaken (Fig. 3 A,B).

The periderm was peeled off from the portion of the trunk proposed to be opened. The angles of the tapping channel was demarcated using a specially fabricated template. The trunk was vertically marked into two equal halves. One half was again marked to get a half spiral at a slope of 30° angle. A groove was prepared along this line on the bark with the help of a marking knife (Fig.3C). A metal spout was fixed on the bark at the lower end of the channel to lead the flowing latex to the collection cup. The tapping channel was then renewed by shaving off a thin layer of bark on alternate days, following the S/2 d/2 system recommended for *Hevea*. The latex thus collected in the cups from the experimental trees were subjected for various studies. The latex obtained on two normal tapping days per month were allowed to coagulate in the collection cups and the coagulum was collected and labelled on the next day. It was then pressed in a sheeting roller and kept for air drying for a day. It was then dried in the electric oven for 72 hours. The dried rubber was then weighed and the weight determined. Yield potential was estimated on the basis of the number of tapping days on which the tree has been exploited during the year, using the formula:-

$$\text{Estimated yield per ha per year} = \frac{gt^{-1}t^{-1} \times d \times s}{1000}$$

Where $gt^{-1}t^{-1}$ = g per tree per tap

d = number of tapping days and

s = stand per hectare

The actual number of tapping days was 150 and the number of trees per hectare was assumed to be 450 at a spacing of 460 cm x 460 cm.

3.5.6. Latex vessels and latex flow

Pre-tapping latex vessel turgor in the bark was measured using disposable manometers as described by Raghavendra et al. (1984). No.49 polythene surgical tubings were sealed at one end fitted with 21 guage hypodermic syringe needle at the other end. The periderm was removed and the manometer needle was inserted into the bark of the tree just below the tapping cut. The remaining air column was measured and the pressure potential was read from a standard graph. The recordings were taken at 7 am and the latex vessel turgor was calculated from the data. Plugging of latex vessels was also examined. Latex vessel plugging in M. glaziovii has been recorded in the wet and dry seasons in Location I and in dry season in Location II. The volume of latex obtained during the first five minutes after tapping has been recorded with the help of a stop watch. Then the total volume of latex also has been measured. Plugging Index (PI) was calculated using the formula suggested by Milford and Pardekooper (1969):

$$PI = \frac{\text{Mean initial flow rate (ml/min)}}{\text{Total yield vol (ml)}} \times 100$$

Estimation of Magnesium level in the fresh latex of *M. glaziovii* has been done by EDTA titration method.

3.5.7. Properties of latex

Colour and odour

Colour and odour of the fresh latex were examined and microscopic examination of the fresh latex was done, and photomicrograph was taken using phase contrast microscope.

Viscosity

Viscosity of latex was determined as per ISO D 1652-1974 using a Brookfield viscometer model RVT at 25°C. The latex sample was taken in a 600 ml glass beaker and placed in a water bath maintained at 25°C. Latex was stirred gently until its temperature became uniformly 25°C. The speed of rotation was selected as 50 rpm, and after 30 seconds the equilibrium reading was taken. The reading was multiplied by the appropriate factor to get the viscosity in centipoises.

pH

The pH of the latex was determined as per ISO D 976-1977 using an ELICO pH meter equipped with glass electrode. The pH meter was first calibrated using a 0.01 M borax solution having a known pH of 9.18 at 25°C. After calibration the electrode was washed with water and immersed in the latex. The reading was taken when the latex attained 25°C.

Specific gravity

Specific gravity of latex was determined following ISO 705-1974 and using a standard specific gravity bottle of 50 cm^3 capacity at 25°C.

Total solids content (TSC)

TSC was determined for the latex according to ISO 124-1974. About 2 g of the sample latex was taken in a weighed petri dish of approximately 60 mm diameter and the dish accurately weighed again, to find out the weight of the sample. The contents of the dish were gently swirled to ensure that the latex covered the bottom. The dish was placed, uncovered, in an air oven at a temperature of 70°C until the sample lost its whiteness or for at least 16 h. The dish with the contents was cooled in a desiccator and weighed again. Drying and weighing were repeated till successive weighings agreed. TSC was calculated as percentage by mass of the original latex.

Dry rubber content (d.r.c.)

ISO 126-1982 was modified for the determination of dry rubber content of the latex. The modification was that no acid was used for coagulation, as the latex coagulated on its own upon dilution. About 5 g of the sample was weighed by difference from a 50 ml conical flask and was poured into a 100 ml beaker. About 10 ml of distilled water was added and the latex stirred well and allowed to stand. A clean coagulum was obtained after a few hours, which was pressed into a uniform sheet of thickness not exceeding 2 mm. The sheet was washed well in running water and dried in an air oven at 70°C until it had no white patches. The dried sheet was then cooled in a desiccator and weighed. Drying and weighing were repeated till successive weighings agreed. DRC was calculated as percentage by mass of the original latex.

Spontaneous coagulation

The tendency of the Manihot latex to undergo spontaneous coagulation was followed by measuring the viscosity of the latex, periodically at room temperature (30°C). As spontaneous coagulation is accompanied by a gradual thickening, viscosity measurement at different intervals of time provided an easy method of following spontaneous coagulation.

Effect of dilution

As dilution of the latex with water caused severe destabilisation and coagulation, the effect of extent of dilution and period after dilution were followed by measuring changes in the viscosity of latex. The viscosity measurements have been made at room temperature (30°C).

Coagulation behaviour

Latex of M. glaziovii could be easily coagulated by dilution with water. Coagulation by acid is not as complete as in the case of Hevea latex. Coagulation behaviour was studied visually and by following changes in viscosity.

3.5.8. Properties of dry films of the latex

In order to find out the properties of the dry film from the whole latex, about 100 g each of the sample latex was poured into a 750 mm (dia) glass petri dish and gently swirled to ensure that the latex fully covered the bottom of the dish. The dish was then placed in an air oven at 70°C and dried till the weight of the dish with the film became constant. The following properties of the film were determined.

Colour, transparency and physical form

Colour of the film was observed visually, while transparency was assessed by measuring the per cent transmittance at 600 nm using a Shimadzu UV-Visible

Recording Spectrophotometer with a 5 x 1 cm size strip of the film attached to a glass plate of the same size. Transmittance of the supporting glass plate was adjusted to 100 in all measurements. The physical form of the film was also examined visually.

Acetone extract

Acetone extractables in the dry film from latex was determined using a Soxhlet extractor, following ASTM D 297-1990. About 5 g of the sample film was cut into small pieces and weighed accurately. It was covered in Whatman filter paper No.41 and placed in the extractor. Extraction was carried out for 16 h. The extract in the round bottom flask of the extraction assembly was quantitatively transferred to a weighed 250 ml beaker. It was then evaporated to dryness,first over a steam bath and finally in an air oven at 70°C for 16 h. The beaker was cooled in a desiccator and weighed. Drying, cooling and weighing were repeated till successive weighings agreed. The difference in the original and final weights of the beaker gave the actual weight of the extract. It was calculated and expressed as per cent by mass of the original sample taken.

Nitrogen content

Nitrogen content of the dry film was determined by a micro Kjeldahl method as per ISO 1656-1974, using a catalyst mixture consisting of 30 parts of potassium sulphate, 4 parts of copper sulphate pentahydrate and 1 part of selenium powder. About 0.1 g of an accurately weighed sample was taken in a 30 ml Kjeldahl flask and mixed with about 0.65 g of the catalyst mixture and 3 ml of concentrated sulphuric acid. The contents were boiled carefully till the mixture became clear green in colour. After cooling the digest was diluted with 10 ml of water and quantitatively transferred to the distillation unit. About 15 ml of 10 N sodium hydroxide solution was added and the mixture distilled for 10-12 min collecting the distillate in 10 ml of 0.5 N boric acid containing a few drops of a mixed indicator. After distillation, the distillate was titrated against 0.02 N sulphuric acid, the colour change being green to violet. A blank titration also was carried out using all the reagents but with no sample. The percentage of nitrogen in the sample was calculated from the formula

$$\frac{0.025\ (V_2 - V_1)}{m}$$

where V_1 = the volume of 0.02 N sulphuric acid required for the sample,

V_2 = the volume of 0.02 N sulphuric acid required for blank and

m = the mass in grams of the sample.

Ash content

Ash content was determined according to ASTM D 297-1981. About 10 g of accurately weighed sample, cut into small pieces, was wrapped in Whatman No.41 ashless filter paper and placed in a 50 ml silica crucible. The crucible was placed in a muffle furnace whose temperature was slowly raised to 525°C and maintained at that level for 2 h. When all the carbon has been oxidised, the crucible was cooled in a dessiccator and weighed. A blank determination was also done with the same type of filter paper.

Mineral composition

The mineral composition of the latex solids was determined starting with the ash obtained from a known weight (10 g) of the sample. The ash was extracted with 10 ml of 1 : 1 hydrochloric acid over a steam bath. The extract was filtered and quantitatively transferred to a 100 ml volumetric flask and made up to the mark. The concentration of calcium, magnesium, copper, manganese, iron, sodium and potassium were determined using this solution.

Determination of iron

This was determined as per ISO 1657-1975. An aliquot of 10 ml of the made up solution was transferred to a 50 ml volumetric flask. 10 ml of sodium acetate/acetic acid solution and 1 ml of 1, 10-phenanthroline solution (0.5 g dissolved in 500 ml water) were added and the solution made upto 50 ml. Absorbance of the solution was measured at 510 nm using a spectrophotometer. The reading was corrected by substracting the absorbance of the blank.

A calibration curve was prepared using a standard iron solution containing 0.01 mg of iron in 1 ml of solution.

By means of the calibration curve, concentration of iron in the sample solution was determined and from that iron content in the sample calculated and expressed as parts per million.

Determination of copper

Copper in the ash was determined as per ISO/R 1654-1971. The method involved formation of copper diethyldithiocarbamate by reaction with zinc diethyldithiocarbamate in chloroform. The optical density of the chloroform solution was measured at 435 nm using a spectrophotometer. A calibration curve was prepared using solutions of known copper content. The concentration of copper in the sample solution was determined from the calibration curve and expressed as parts per million.

Determination of manganese

Manganese in the ash was also determined spectrophotometrically as per ISO 1655-1975. Manganese was oxidised to permanganate by reaction with potassium periodate under standard conditions. Optical density of the solution was measured at 525 nm using a spectrophotometer and the manganese content was read from a calibration curve prepared using solutions of known manganese content. The result was expressed as parts per million.

Determination of calcium, magnesium, sodium and potassium

Calcium and magnesium in the ash were estimated using an atomic absorption spectrophotometer model GBC 902. The concentration of sodium and potassium were determined using a flame photometer.

3.5.9. Properties of dry rubber

Dry rubber of M. glaziovii was prepared from fresh latex by a slightly different method compared with Hevea rubber. The latex was first sieved through a 40 mesh sieve to remove foreign matter. It was then diluted with twice its volume of water in a shallow dish and allowed to stand overnight. Coagulation was complete and a soft but coherent coagulum obtained. The coagulum was passed 4-5 times through a set of smooth steel rolls to get a sheet of approximately 3 mm thickness. The sheet was then passed once through a grooved set of steel rolls to get a ribbed sheet. The sheet was washed thoroughly in running water and allowed to drip in shade for a few hours before drying in hot air at a temperature of 50-60°C. The final moisture content of the sheet was less than 0..02 percent. Preparation of sheet rubber from Hevea latex was carried out as per standard procedures as described by Kuriakose and Sebastian (1980).

Grading

Grading of the sheet was done by the visual grading system following the Green Book. Colour and general appearance of the sheets were visually examined.

Homogenisation of the sample

For determining the various properties of the dry rubber, the sample was first homogenised as per ISO 1796-1982, using a 150 x 300 mm two-roll mill as described in ISO 2393-1973. For this about 600 g of the sample was passed through the mill nip set at 1.3 mm. After each pass the rubber was rolled and the roll was introduced endwise into the nip for the next pass. On the tenth pass the rubber was sheeted and used for the various tests.

Volatile matter

About 10 g of the homogenised sample was weighed accurately and placed in a glass dish kept in an air oven maintained at a temperature of 100°C for 1 h. The sample was then cooled in a desiccator and weighed. Heating, cooling and weighing were repeated till two successive weighings agreed. The volatile matter content was calculated as a percentage of the original mass according to ISO 248-1979.

Dirt content

This was determined on the homogenised sample as per ISO 249-1974. About 10 g of the sample, cut into small pieces, was kept under mineral turpentine containing 1 g of rubber peptisising agent (tolyl mercaptan) in a stoppered conical flask. After 16 h the flask and the contents were heated to 130-140°C until a smooth solution was obtained. The solution was then filtered through a weighed 45 μm sieve. The residue on the sieve was washed several times with hot solvent until it was free from rubber. Finally the sieve was washed twice with petroleum spirit and dried at 100°C for 30 min. The dirt content was calculated as a percentage by mass of the dry rubber.

Mooney viscosity

This was determined on the homogenised sample using Negretti Mark III Mooney viscometer according to ISO/R 289 - 1963 at 100°C.

Plasticity (Po) and plasticity retention index (PRI)

These were determined on the homogenised sample as per ISO 2007-1981 and ISO 2930-1981, using a Wallace Rapid Plastimeter and a PRI Ageing Oven. About 30 g of the homogenised sample was passed three times through the mill, the nip having been adjusted to get a sheet thickness of about 1.7 mm. The sheet was immediately doubled and lightly pressed between hands. Six test pieces were punched out from the doubled sheet and these were divided into two sets of three each, one set for test before ageing (Po) and the other set for test after ageing (P_{30}).

The second set was placed in a tray which was placed in the oven maintained at 140°C, exactly for 30 min. After 30 min the tray with the test pieces was removed from the oven and was allowed to cool to room temperature. Plasticity of the aged and unaged test pieces was determined using the Wallace Rapid Plastimeter having 10 mm platens. The median values for the plasticity numbers of the unaged and aged test pieces were taken as Po and P_{30} respectively, from which PRI was calculated as

$$PRI = \frac{P_{30} \times 100}{Po}$$

Accelerated storage hardening test

Test pieces for this were prepared as in the case of Po/PRI determination. One set of test pieces was used for testing Po, and the other set kept over phosphorus pentoxide in a stoppered glass bottle, at 70°C for 24 h. After 24 h the plasticity of the aged set was also determined. The number of units increased as a result of ageing over P_2O_5 was found out.

Mastication behaviour

Mastication behaviour was assessed using a 150 mm x 300 mm two-roll mixing mill. About 600 g of the homogenised sample was used. The rubber was passed twice between the rolls without banding with the nip set at 0.2 mm. It was then banded with the nip set at 1.9 mm. A stop watch was started immediately after banding. About 50 g of the rubber was withdrawn at different intervals of time and the Mooney viscosity of each sample withdrawn was measured. The mastication behaviour of the rubber was easily assessed from a plot of Mooney viscosity against time of mastication.

The ash content, nitrogen content and acetone extract of the dry rubber were determined as in the case of the total solids film.

Infrared Spectrophotometry

A solution of 0.5 per cent concentration was prepared by dissolving the rubber in spectrograde chloroform and a thin film was cast on an NaCl disc. The IR spectrum was recorded using a Shimadzu FT-IR Spectrophotometer Model 8101 M.

Gel content

About 0.4 g of the rubber sample was placed in 100 ml toluene in a stoppered conical flask in the dark. After 20 h, exactly 10 ml solution was transfered into a dried and weighed petri dish and the solvent evaporated until a constant mass was obtained. Gel content was determined as follows:

$$A \times 10 = B$$

$$\text{Gel, \%} = \left(\frac{C-B}{C}\right) \times 100$$

Where A = Mass of the dried solution (10 ml)

B = Mass of the total dried solution

C = Mass of the original sample

Determination of viscosity average molecular weight ($\bar{M}_V$) by Ubbelohde viscometer

The relative viscosity (η rel) of the rubber solution in toluene was determined at four different concentrations from 0.05 - 0.2 per cent at 25°C using an Ubbelohde viscometer. The viscosity number (η red) was calculated using the equation $\eta\ \text{red} = \frac{(\eta\ \text{rel}^{-1})}{C}$ and it was plotted against concentration. The intrinsic viscosity (η) was determined by extrapolating to zero concentration. The viscosity average molecular weight (Mv) is given by the Mark - Houwink - Sakurada equation.

3.5.10. Processing properties of mixes

Cure characteristics

Cure characteristics of the rubber were determined on a gum and black filled mixes for which receipes are given in Tables4 and 5. The mix was prepared following the same standard and curing characteristics determined using a Monsanto Rheometer R 100 at 150°C. The various cure parameters were found out from the rheograph. The gum mix was moulded to optimum cure at 150°C into sheets of about 2.0 mm thickness using a 450 mm x 450 mm hydraulic press having steam heated platens. Dumbbell test pieces were punched out from the sheets which were conditioned for 24 h at 25°C and 65 R.H before testing, for various physical properties such as tensile strength, modulus, elongation at break, hardness and ageing resistance.

Mooney scorch time

Scorch time of the unvulcanized mixes was measured using a Negretti Mark III Mooney viscometer at 120°C. This was determined as the total time from the start to attain 5 Mooney units rise in viscosity after passing through the minimum.

3.5.11. Physical properties of vulcanizates

The physical properties of vulcanizates prepared from both the gum and filled mixes were determined according to the relevant ASTM test methods.

Tensile properties

Modulus at 300 per cent elongation, tensile strength and elongation at break were measured on dumbbell specimens using a Zwick 1474 universal testing machine at 25°C, following ASTM D 412-1987. The speed of pulling was 500 mm per minute. The specimens were cut from moulded sheets of approximately 2 mm thickness with the lengthwise portion parallel to the grain direction. Tensile strength and modulus were calculated based on the original cross sectional area.

Tear resistance

This was determined according to ASTM D 624-1986 using an unnicked 90° angle specimen (Die C) on a Zwick 1474 universal testing machine at 25°C and at a speed of pulling of 500 mm per minute. The tearing force in N was divided by specimen thickness in mm to get tear resistance in kN/m.

Resilience

Dunlop Tripsometer was used to measure rebound resilience as per BS 903, pt. 22, 1950. The sample was held in position by suction and was conditioned by striking with the indentor six times. The temperature of the specimen holder and the pecimen was maintained at 35°C. Rebound resilience was calculated as follows:

$$\text{Rebound resilience, \%} = \frac{1 - \cos\theta_2}{1 - \cos\theta_1} \times 100$$

Where θ_1 and θ_2 are the initial and rebound angles respectively. θ_1 was 45° in all cases.

Hardness

Shore A type durometer was employed to find out hardness of vulcanizates according to ASTM D 2240-1986.

Table 4

ASTM 1A FORMULATION (ASTM D 3184 - 1989)

Ingredients	Parts by weight
Natural rubber	100
Zinc oxide	5
Stearic acid	0.5
Mercaptobenzothiozole	0.5
Sulphur	3.5

The instrument uses a calibrated spring to provide the indenting force. Readings were taken after 15 sec of the indentation when firm contact has been established with the specimens.

Compression set

Samples of 1.25 cm thickness and 2.8 cm diameter, compressed to a constant deflection of 25 per cent were kept in an air oven at 70°C for 22 h, as per ASTM D 395-89, method B. After this period the samples were released from compression, cooled to room temperature and were allowed to recover for 30 min, and the final thickness measured. Compression set was calculated as,

$$\text{Compression set, \%} = \frac{t_0 - t_1}{t_0 - t_s} \times 100$$

where t_0 and t_1 were the initial and final thickness of the specimen and t_s, the thickness of the spacer bar used.

Heat build-up

Goodrich Flexometer conforming to ASTM D 623-1978, method A, was used for measuring heat build-up. The test was carried out with cylindrical specimens of 2.5 cm height and 1.9 cm diameter. The oven temperature was maintained at 50°C and the stroke adjusted to 4.45 cm. The load was 10.9 kg. The sample was preconditioned to the oven temperature for 20 min. The heat developed at

Table 5

FORMULATION OF TREAD TYPE COMPOUND

Ingredients	Parts by weight
Natural rubber	100
Zinc oxide	5
Stearic acid	2
Antioxidant 4010 NA	1
HAF black	50
Aromatic oil	5
PVI 50	0.2
CBS	0.65
Sulphur	2.5

the base of the specimen was sensed by a thermocouple and relayed to a digital temperature indicator. The temperature rise (ΔT, °C) at the end of 20 min was taken as heat build-up.

Ozone resistance

Resistance to ozone cracking was measured according to ASTM D 1171-1986, using the triangular test specimen. A Mast ozone chamber was used where ozone concentration was maintained at 50 parts per hundred million and temperature 40°C. The time for cracks to appear was noted in each case.

Abrasion resistance

Resistance to abrasion was determined according to DIN 53516-1977 using a Toyoseiki Abrader No.276. Cylindrical test specimens were moulded to optimum cure and conditioned for 24 h before testing. Aluminium oxide abrasive cloth having a grain size of 60 was used. Abrasion resistance was expressed in terms of volume loss of material in one run.

Crack growth

This was measured using a De Mattia Flexing Machine following ASTM D 813-1987 at room temperature. Moulded test specimens having circular grooves at the centre, were used. A cut of 2 mm length was introduced at the centre of the groove using a special piercing tool as specified in the standard. The machine was run at 300 cycles per min and the length of the creack measured periodically. Crack growth was expressed as the number of cycles required to reach a specified crack length.

Ageing resistance

Resistance to ageing was determined using a tubular ageing oven as per ASTM D 865-1988, at 70°C for 240 h and at 100°C for 72 h. The degree of ageing was assessed by measuring changes in tensile properties and was expressed as the percentage retention in properties.

3.5.12. Wood and Seed Oil

Wood structure

Two healthy trees of M. glaziovii about 12 years growth were chosen for the the study of wood features. Wood discs of 5 cm thickness were sawn out at 150 cm height from the ground level. For structural studies cubic blocks of 2 x 2 x 2 cm size were prepared from each wood disc along the diameter and fixed in FAA - fixative. For microscopy sledge microtome sections of 15 micrometer thickness were taken, stained with toluidine blue 'O' ('O' Brien et al., 1964) and mounted in D.P.X. mountant. For the diamensional studies of fibers, wood tissues of 2 x 2 x 2 mm size were macerated following Jefferey's method (Johansen, 1940) stained with mordant safranin (Berlyn and Miksche, 1976) and mounted in glycerine jelley. Hundred fibers at random were considered for recording the diamensional aspects of wood fibers. Prior to block preparation the wood discs were photographed in green sawn condition and microphotographs were taken using Wild MPS 46/56 Photoautomat.

Wood preservation treatment

Ceara rubber wood has been subjected to preservative impregnation treatment to ascertain its chemical penetration capacity.

Logs of about 120 cm length were selected from the trunk wood of *M. glaziovii*. For comparison logs of *H. brasiliensis* of identical age were also selected. Wood planks at 120 x 10 x 4 cm size were sawn and dipped in 10% Boric Acid Equivalent (BAE) for about 12 to 14 hrs. Then the planks were subjected to chemical impregnation adopting ocillating Vacuum Pressure method (IS 401-1967) as shown in Table below:

Type of preservative	Water soluble (leachable) type
Name of preservative	Boric Acid and Borax with Ripcord.
Concentration	5%
Method of chemical Impregnation	Vacuum Pressure method (150 PSI pressure

Loading time of preservative	20 cycles
Time of maximum pressure	1.5 to 2 hrs.
Time of initial vacuum	15 mts.
Time of final vacuum	15 mts.

After preservative impregnation the treated plants were seasoned in a steam heating hot air kiln (at 65°C and 39-40 R.H.) for about 7 to 10 days. The seasoned planks were then subjected to density test, final moisture percentage and preservative penetration adopting standard test procedures at Kerala Forest Research Institute, Peechi, Trissur.

Oil content in seed kernel

The oil content of the seed kernel was estimated by solvant extraction with n-hexane using a Soxhlet extractor. The extraction was done for about 6 h and the extract evaporated to dryness in a tared beaker. The beaker with the contents was cooled in a desciccator and weighed. Drying and weighings were repeated till consecutive weighings agreed. The oil content was calculated as,

$$\text{Oil content, percent} = \frac{W2}{W1} \times 100$$

Where W1 = the weight of the sample taken and

W2 = the weight of the extract.

Acid value

Acid value is the number of milligrams of potassium hydroxide required to neutralise the free fatty acids in one gram of oil. For this about 10 g of the sample was carefully weighed and dissolved in 50 ml of neutral ethyl alcohol in a 250 ml conical flask. The solution was titrated with 0.1 N sodium hydroxide solution using phenolphthalein indicator. The end point was the appearance of a pink colour. Acid value was calculated as,

$$\text{Acid value} = \frac{56.1 \times 0.1 \times V}{W}$$

Where V = the volume of 0.1 N sodium hydroxide and

W = the weight in g of the sample taken.

Saponification value

It is the number of milligrams of potassium hydroxide required to saponify 1 g of the sample. About 2 g of an accurately weighed portion of the oil was mixed with 25 ml of alcoholic potash and refluxed in a 250 ml conical flask for 30 min. The mixture was cooled and then titrated with standard hydrochloric acid using phenolphthalein as indicator. The end point was the disappearance of the pink colour. Saponification value was calculated as,

$$\text{Saponification value} = \frac{56.1 \times N \times V}{W}$$

Where N = normality of the hydrochloric acid,

V = volume of the acid required and

W = weight of the sample taken.

Iodine value

Iodine value is the number of grams of iodine absorbed by 100 g of the oil. It was estimated by Hanus method. Iodine value was calculated as,

$$\text{Iodine value} = \frac{V \times N \times 126.9}{10 \times W}$$

Where V = volume of thiosulphate solution,

N = normality of thiosulphate solution and

W = weight of sample taken.

FIG. 2

A. Wild seedling trees of M. glaziovii at 1100 MSL - Mettur hills.

B. M. glaziovii seedling tree on granitic ground (Location 2).

FIG. 2

FIG. 3

A. Vegetatively propagated trees under tapping (Location 1).

B. Seedling tree under tapping (Location 2).

C. Tools used for exploitation.

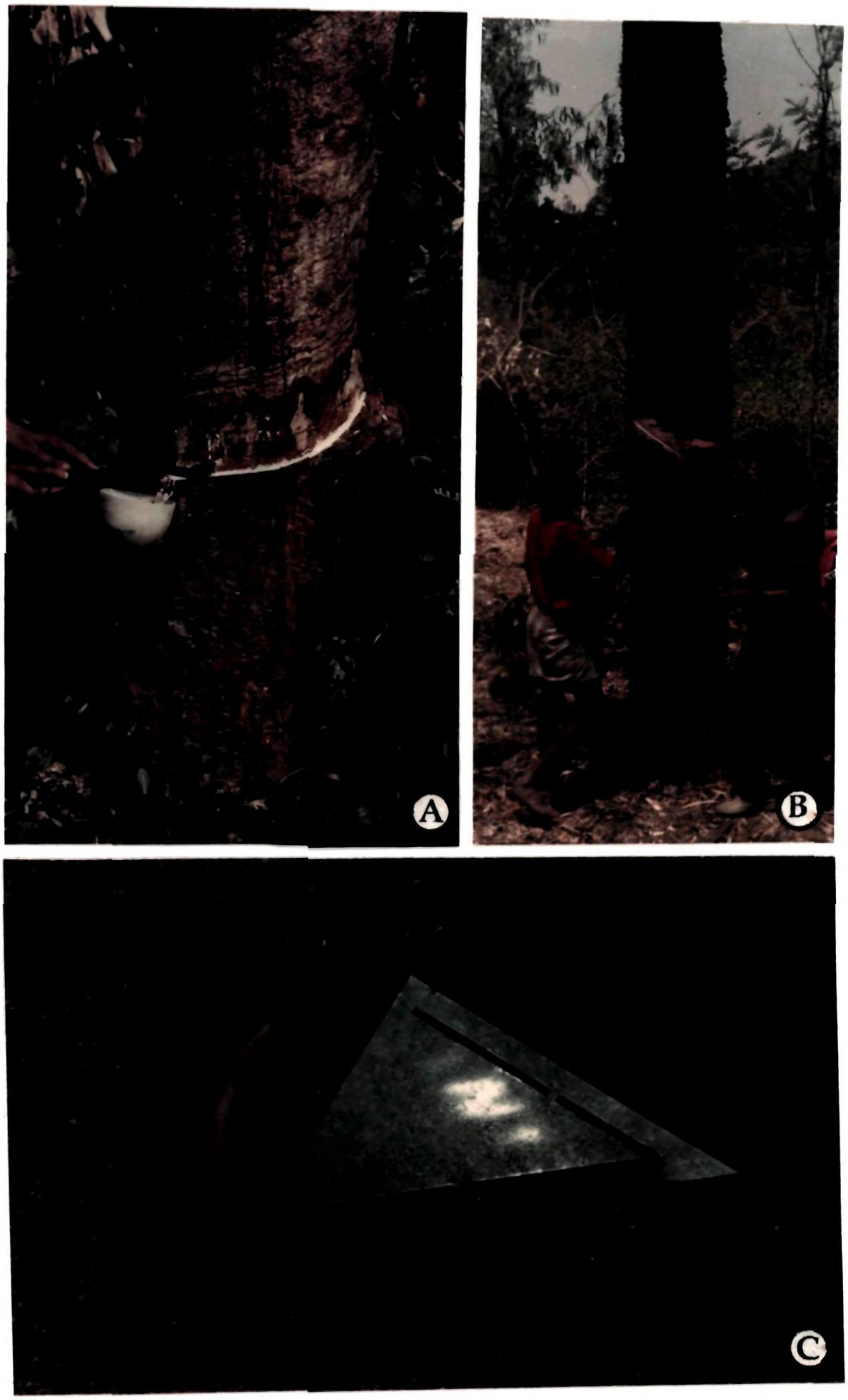


FIG. 3

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. glaziovii 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 abcission takes place giving a lean stick like appearence (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 upto 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.9 B). 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.9 C). 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 ie., the number of stomata per unit area to the number of epidermal cells per unit area is 16.42.

Table 6
Leaf area and stomatal frequency

Tree Number	Leaf area cm^2	Number of stomata/mm^2	Number of epidermal cells/mm^2	Stomatal index
1	408.34	625	2690	18.85
2	413.58	630	2450	20.45
3	302.97	550	2750	16.67
4	260.56	535	2600	17.07
5	293.27	660	3290	16.71
6	243.30	600	3370	15.11
7	455.39	580	3430	14.46
8	302.57	510	3330	13.28
9	373.41	650	3340	16.29
10	281.16	590	3270	15.28
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 upto 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 7. Seed treatment and germination

Treatment	Number of seeds sown	Number of seeds germinated each week										Germination percentage
		1	2	3	4	5	6	7	8	9	10	
1. Grinding	100	-	-	15	21	24	10	2	-	-	-	72
2. Salt water	100	-	-	-	-	-	2	1	1	-	1	5
3. Acid (Con.H_2SO_4)	100	-	-	-	-	-	-	-	-	-	-	0
4. Burning	100	-	-	-	2	1	5	2	1	-	-	11
5. Untreated (Control)	100	-	-	-	-	-	-	-	-	-	-	0

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 T_2 and T_5 and gradually progressed. Sprouting percentage ranged from 2.50-80. Maximum sprouting of 80% was observed in the treatment (T_5) where 40 cm long brown cuttings were used. No sprouting were observed in the tender green sticks of T_1 treatment. However, in T_4 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 8. vegetative propagation of *M. glaziovii* cuttings

Treatments	Number sprouted each week after planting									Total sprouted	%
	1	2	3	4	5	6	7	8	9		
T_1 - Tender green, 20 cm long	0	0	0	0	0	0	0	0	0	0	0
T_2 - Brown, 20 cm long	0	0	1	3	5	13	12	3	0	37	46.25
T_3 - Mature, 20 cm long	0	0	0	1	6	9	13	3	0	32	40.00
T_4 - Tender green, 40 cm long	0	0	0	0	0	0	1	1	0	2	2.50
T_5 - Brown, 40 cm long	0	0	4	11	17	15	14	3	0	64	80.00
T_6 - Mature, 40 cm long	0	0	0	4	10	18	14	1	0	47	58.75

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*.

Tree No.	Bark thickness (mm)		Distance from cambium to inner row of latex vessels (mm)		Average distance between latex vessel rows (mm)	
	M	H	M	H	M	H
1	10.0	9.0	0.504	0.180	0.350	0.174
2	11.0	10.0	0.396	0.216	0.435	0.204
3	5.0	9.0	0.324	0.342	0.240	0.171
4	9.0	10.2	0.288	0.324	0.321	0.164
5	9.0	9.0	0.360	0.216	0.549	0.180
6	8.0	10.0	0.396	0.216	0.256	0.232
7	9.0	8.0	0.360	0.198	0.336	0.140
8	8.0	9.0	0.342	0.324	0.299	0.255
9	8.0	10.0	0.288	0.558	0.303	0.182
10	7.5	8.8	0.288	0.288	0.264	0.169
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. *glaziovii* H = H. *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. braziliensis*.

Tree No.	Girth (mm)		Bark thickness (mm)		No. of latex vessels rows		Density of latex vessels per 1 mm circumference of the tree		Diameter of latex vessels (μ)		Frequency of stone cell per cm^2 C.S. area	
	M	H	M	H	M	H	M	H	M	H	M	H
1	60	90	10.0	9.0	17	36	21.4	33.4	14.56	17.88	330.71	440.94
2	122	83	11.0	10.2	18	30	26.4	30.6	14.40	19.60	228.35	360.63
3	62	93	5.0	9.0	14	38	29.0	35.0	14.56	20.20	263.78	452.76
4	101	94	9.0	10.2	16	37	29.8	32.6	15.36	19.60	309.05	539.37
5	110	95	9.0	9.0	13	37	30.6	34.0	13.40	18.68	326.77	511.81
6	93	88	8.0	10.0	14	32	31.8	35.0	14.16	18.28	322.83	421.26
7	99	82	9.0	8.0	17	38	27.2	32.6	14.36	17.76	311.02	464.57
8	93	82	8.0	9.0	16	27	30.0	35.4	15.36	19.40	437.01	397.64
9	79	89	8.0	10.0	17	31	29.6	33.8	12.16	17.48	377.95	444.88
10	80	85	7.5	8.8	15	38	29.2	34.8	13.20	20.80	409.45	448.82
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.

Observations	*M. glaziovii*	*H. brasiliensis*	Remarks
Mean fresh weight (g)	1.20	1.44	
Mean Oven dry weight(g)	0.42	0.71	$\frac{W_1 - W_0}{W_0} \times 100$
Moisture content(%)	186.00	103.00	(Rawat and Mirdula Negi, 1993)

Table 12. Chlorophyll content in the bark tissue

Species	Chlorophyll content (mg/g fr. wt)
M. glaziovii (green bark)	36.00
M. glaziovii (white bark)	8.25
H. brasiliensis	17.00

(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.

Species	Turgor pressure (MPa)	Source
Manihot glaziovii	1.0	Present study
Hevea brasiliensis	1.5	Buttery and Boatman (1966) Milford *et al*. (1969) Raghavendra *et al*. (1984)
Ficus elastica	1.0	Buttery and Boatman (1966)
Cryptostegia grandiflora	1.2	Raghavendra (unpublished)
Euphorbia pulcherrima	0.8	Buttery and Boatman (1966)
Nerium oleander	0.6	Downtown (1981)

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 14. Latex vessel plugging (Location I)

Tree number	Initial vol. 5 minutes (ml)	Total vol. (ml)	Plugging index
1	12	14	17.14
2	8	9	17.70
3	14	16	17.50
4	11	13	16.92
5	10	12	16.66
6	13	16	16.25
7	12	14	17.14
8	9	12	15.00
9	11	14	15.71
10	13	15	17.33
Mean	11.3	13.5	16.72
SE	0.57	0.64	0.26

Table 15. Girth, bark thickness, volume of latex and PI of *M. glaziovii* in Location II

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

Table 16. Treewise mean yield during 1992

Tree No.	Monthly mean yield ($g\ t^{-1}\ t^{-1}$)												Mean
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
1	5.88	5.81	6.23	5.58	5.22	2.45	2.45	4.45	5.90	5.50	5.35	5.65	5.04
2	6.80	6.65	6.58	5.88	5.78	3.15	2.73	5.45	6.50	5.65	5.50	6.45	5.59
3	6.15	6.53	6.50	5.20	5.25	2.85	2.50	3.20	3.95	4.50	4.60	6.20	4.79
4	4.93	4.95	5.65	4.83	3.70	2.75	2.40	3.88	4.95	4.65	4.80	5.10	4.38
5	4.68	4.65	4.93	4.70	4.70	2.60	3.47	3.70	4.75	4.70	5.00	4.93	4.40
6	4.30	4.35	5.80	4.65	4.25	2.90	2.55	3.85	5.10	5.50	5.00	4.58	4.40
7	4.60	5.58	5.28	4.68	3.80	3.10	2.25	2.95	4.17	4.55	4.95	4.85	4.23
8	5.20	5.15	5.50	4.45	4.30	3.45	2.90	3.60	4.60	4.30	4.75	5.50	4.52
9	5.70	5.65	5.73	4.58	4.00	3.25	2.50	3.80	4.80	4.20	4.30	5.70	4.52
10	5.00	5.00	5.43	4.35	3.45	3.50	2.13	3.20	4.50	3.95	4.30	5.50	4.19
Mean	5.33	5.43	5.76	4.89	4.44	3.00	2.58	3.81	4.92	4.75	4.85	5.45	55.23
SE	0.24	0.23	0.16	0.15	0.23	0.10	0.11	0.22	0.23	0.18	0.12	0.18	
CV	14.07	13.25	8.85	9.81	16.44	10.92	13.95	17.80	14.83	12.00	7.80	10.45	

(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*.

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

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 valume 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

Property	Manihot	Hevea
Colour	Milky white	Milky white
pH	6.35	6.80
Specific gravity	1.0075	0.9828
Brookfield viscosity, Cps	51	43
Total solids content, %	32.3	36.6
Dry rubber content, %	25.3	33.7
Non-rubber solids, %	7.0	2.9
Effect of coagulants		
(i) Formic acid	Coagulates	Coagulates
(ii) Acetic acid	Coagulates	Coagulates
(iii) Water	Coagulates	No coagulation
Spontaneous coagulation	Within 7 h	Within 8 h

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.19. Properties of total solids film

Property	*Manihot*	*Hevea*
A. Physical characteristics		
Colour	Dark brown	Brown
Appearance	Coherant film	Coherant film
Transparency, % transmittance at 600 nm	12.5	66.0
B. Chemical composition		
Acetone extract, %	7.8	3.96
Nitrogen, %	1.73	0.72
Proteins, %	10.64	4.43
Ash content, %	3.96	2.03
Minerals		
Sodium, %	0.0389	0.0743
Potassium, %	0.3470	0.6740
Calcium, %	0.0215	0.018
Magnesium, %	0.207	0.054
Iron, %	0.0250	0.0154
Manganese, ppm	7.75	Traces
Copper, ppm	0.75	7.5

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

Property	*Manihot*	*Hevea*
Grade of sheet	RMA 3	RMA 2
Dirt content, %	0.22	0.11
Volatile matter, %	1.61	1.12
Nitrogen, %	0.94	0.39
Proteins, %	5.78	2.40
Ash content, %	1.03	0.26
Acetone extract, %	4.26	2.91
Po	47	40
PRI	64	85
Mooney viscosity, ML(1+4)100°C	104	80
Gel content, %	38.7	62
Viscosity average molecular weight (Mv)	1.16×10^6	1.10×10^6
Accelerated storage hardening test,		
ΔPo	6	20
Specific gravity	0.972	0.964
Minerals,		
Sodium, %	0.0158	0.0117
Potassium, %	0.0309	0.0632
Calcium, %	0.0180	0.0036
Magnesium, %	0.185	0.0523
Iron, ppm.	188	83
Manganese, ppm	7	Traces
Copper, ppm	0.3	Traces

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 constitutents 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 1.16×10^6. This is close to the value obtained for Hevea rubber (1.10×10^6).

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 Table24. 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

Characteristic	Manihot	Hevea
Mooney scorch at 120°C, min.	12.56	11.33
Mooney viscosity, ML(1+4) 100°C	30	36
Rheometric properties,		
(i) Minimum torque, d.N.M.	6	5
(ii) Maximum torque, d.N.M.	43	43
(iii) Cure time, min.	13.5	13.5
(iv) Cure rate index	9.091	9.52

Table 22. Processing characteristics of HAF filled compounds

Characteristic	Manihot	Hevea
Mooney scorch at 120°C, min	11.5	11.12
Mooney viscosity, ML(1+4) 100°C	48	50
Rheometric characteristics,		
(i) Minimum torque, d,N.M.	8	9
(ii) Maximum torque, d, N.M.	61	71
(iii) Cure time, min	12.5	13
(iv) Cure rate index	10.53	9.80

Table 23. Properties of gum vulcanizates

Property	Manihot	Hevea
Hardness, Shore A	38	32
Modulus at 100% elongation, N/mm^2	1.12	0.77
Modulus at 300% elongation, N/mm^2	2.08	1.47
Tensile strength, N/mm^2	19.6	23
Elongation at break, %	1493	1439
Tear strength, kN/m	26.5	29.3

Table 24. Properties of HAF black filled vulcanizates

Property	Manihot	Hevea
Hardness, Shore A	64	64
Modulus at 100% elongation, N/mm^2	2.4	2.54
Modulus at 300% elongation, N/mm^2	8.9	9.25
Tensile strength, N/mm^2	22.7	26
Elongation at break, %	725	752
Tear strength, kN/m	39.6	43.9
Resilience, %	46.34	50.94
DIN abrasion loss, mm^3	136.8	106.4
Heat build-up, ΔT, at 50°C	32.5	29.4
Compression set, 22 h at 70°C	22.8	23
Crack growth resistance, kilocycles	110	88
Ozone resistance at 50 pphm ozone and 40°C	Crack formed in 2 h	Crack formed in 2 h
Ageing properties,		
Retention of properties after ageing for 10 days at 70°C		
Tensile strength, %	92.1	95.7
Elongation at break, %	79.4	76.7
100% Modulus, %	134.6	134.6
300% Modulus, %	119	131.2
Retention of properties after ageing for 3 days at 100°C		
Tensile strength, %	57.3	52.9
Elongation at break, %	46.6	44.7
100% Modulus, %	154.2	142.1
300% Modulus, %	153.0	128.5

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 Table24 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 vulcanizates 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/m^3) 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 parencyma 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. 22 B). In addition to this, gelatinous fibers occur in discrete groups in the matrix of normal fibers (Fig. 23 A).

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. 23 A). The gelatinuous fibers are also displays a violet colouration in their radial (Fig. 23 B) and tangential plane (Fig. 23 C). Neverthless, 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 deposites 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 (Table25).

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

Tree type	Sample	Density kg/m^3	M.C.%	Chemical
	S_1	402.7	16.5	
	S_2	404.3	16.1	
Ceara wood	S_3	401.3	15.4	Through and through
	S_4	400.3	15.7	
	Mean	402.3	15.9	
	CV	0.4	3.0	
	S_1	531.3	15.4	
	S_2	526.5	16.6	
Hevea wood	S_3	553.8	15.9	Through and through
	S_4	542.0	15.8	
	Mean	538.4	15.9	

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*

Physical properties	
Iodine value	129.24
Saponification value	200
Acid value	1.95

FIG. 4

A. Leaning growth of the trees raised by cuttings.

B. Spreading canopy of the vegetatively propagated tree.

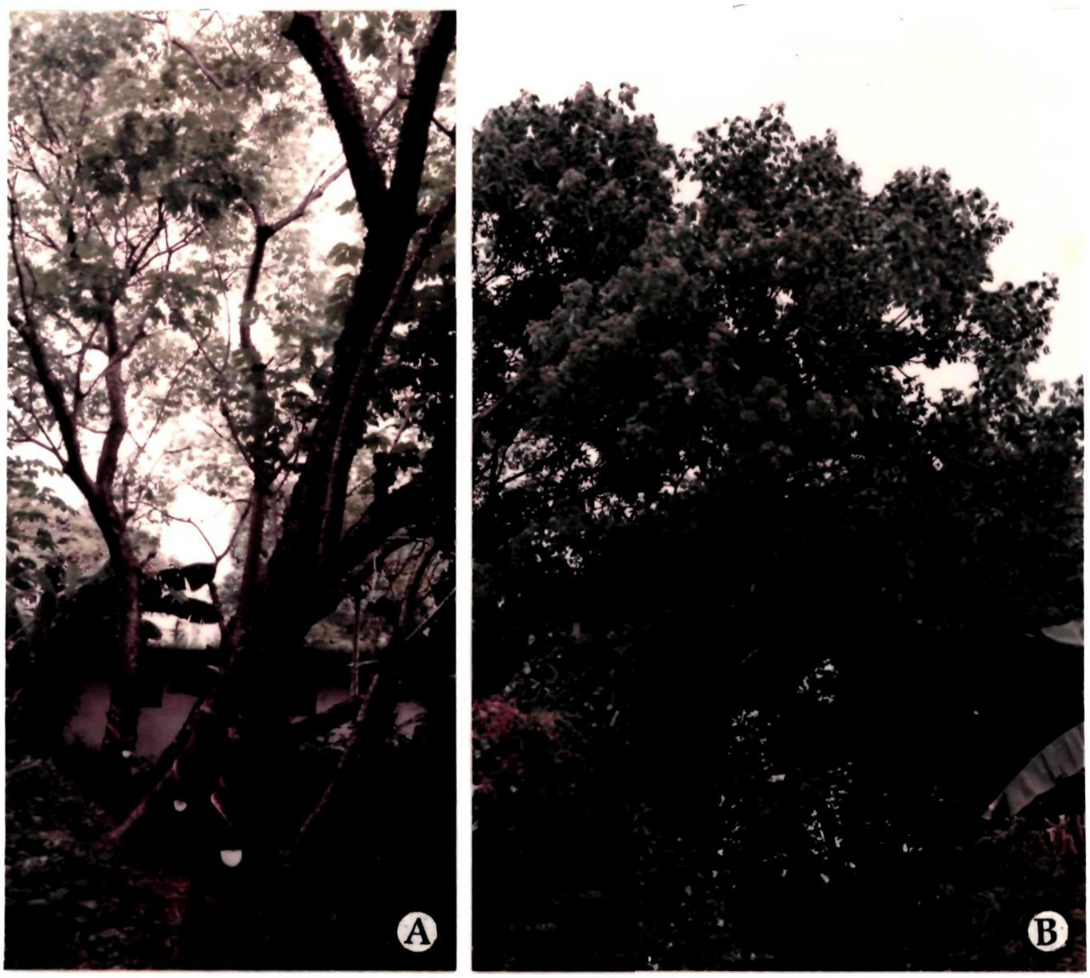


FIG. 4

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

CHAPTER 5
DISCUSSION

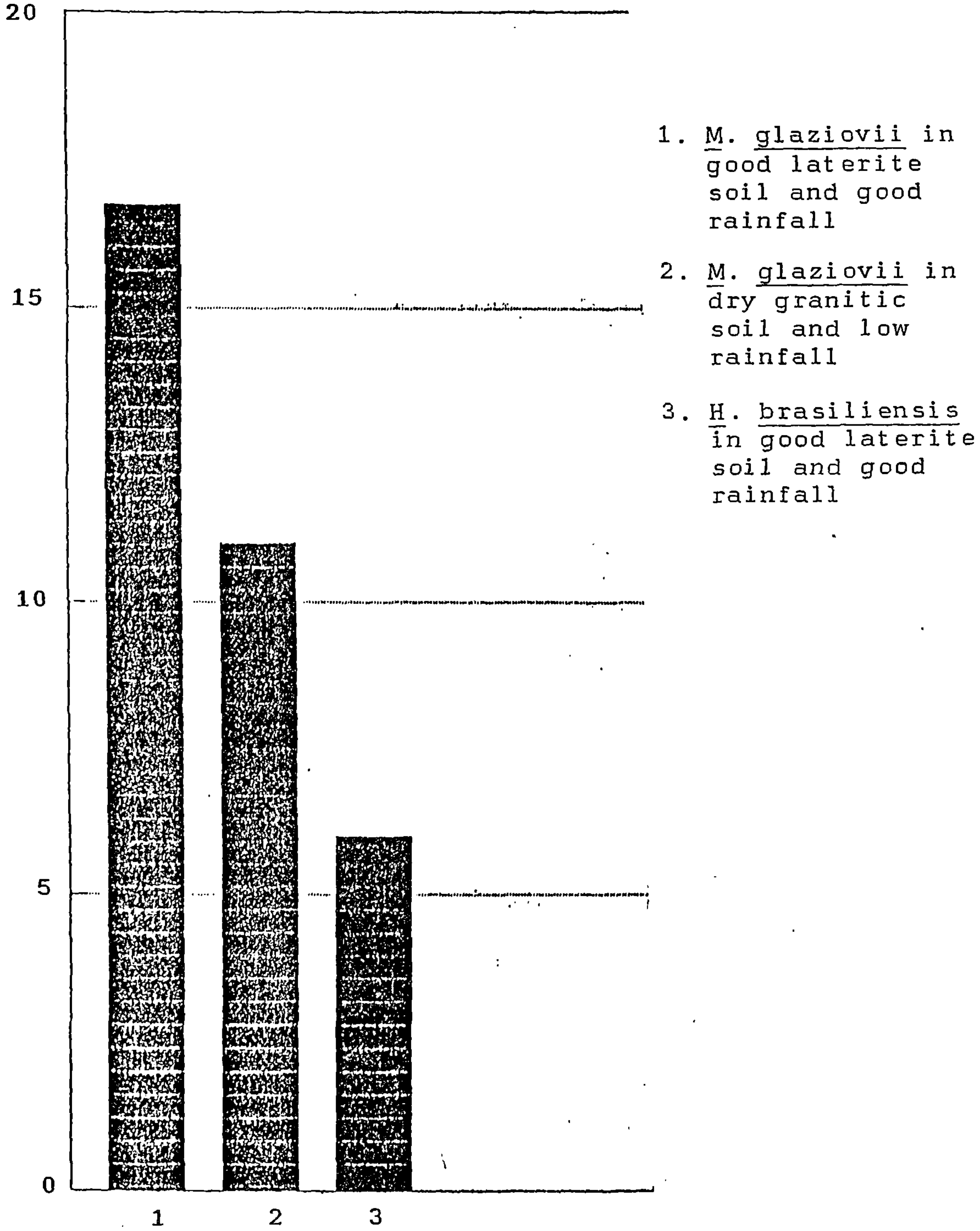


Fig. 13. Latex vessel plugging in M. glaziovii in two agroclimatically different localities and H. brasiliensis

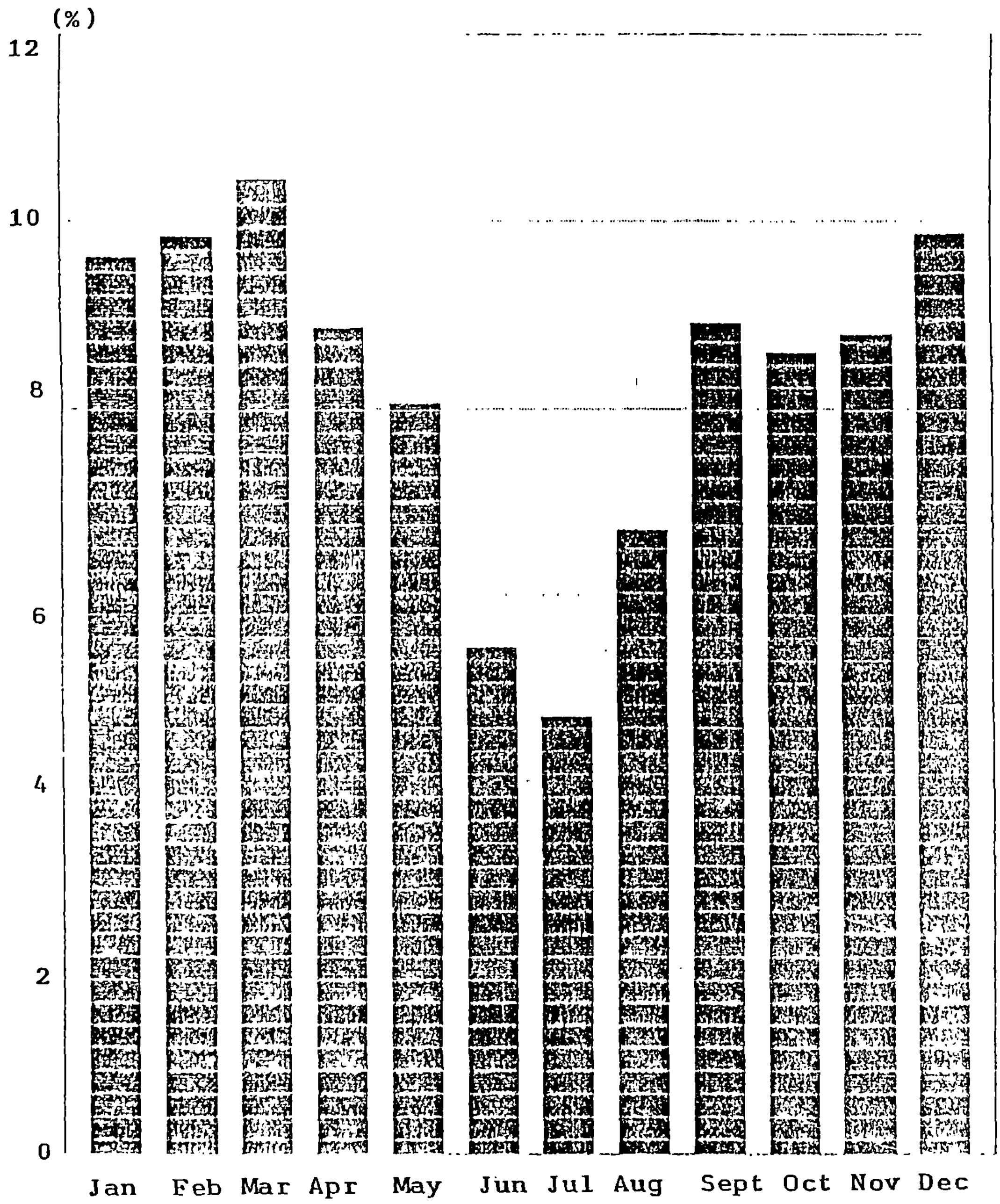


Fig. 14. Monthly contribution (%) towards annual dry rubber yield in *M. glaziovii*

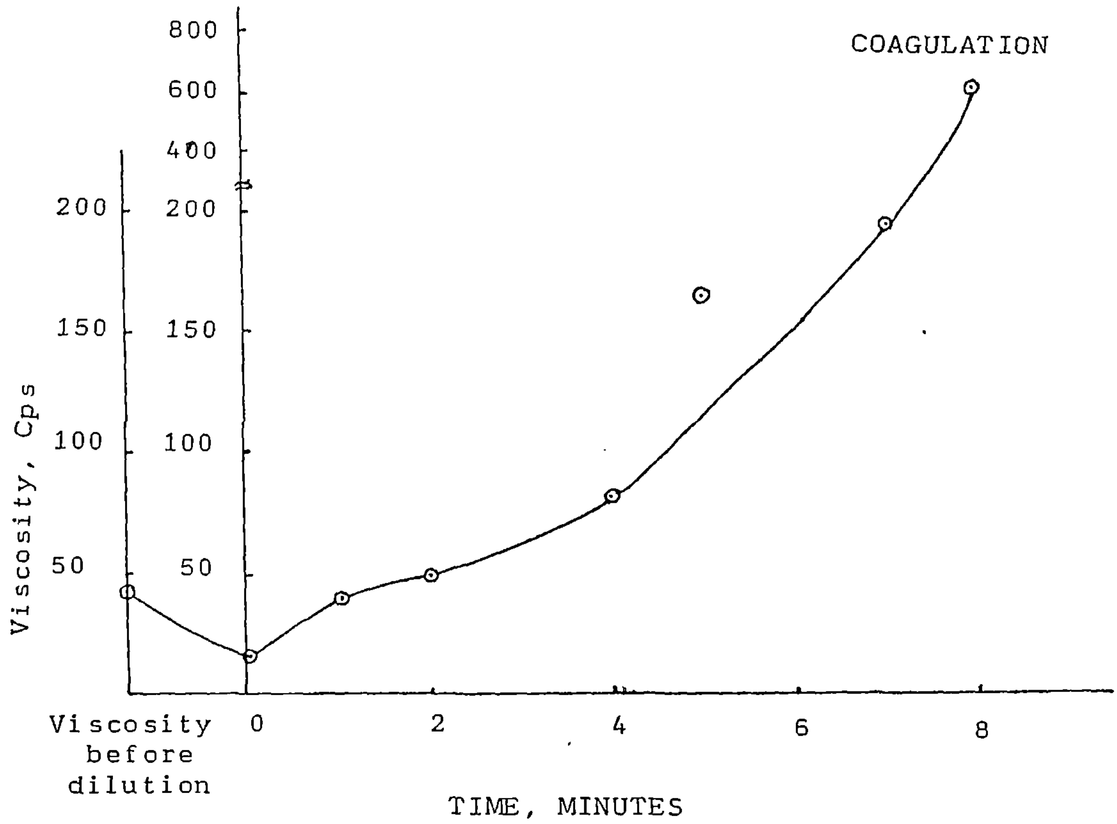


Fig.16. Effect of 1:1 dilution and storage on viscosity of *Manihot* latex.

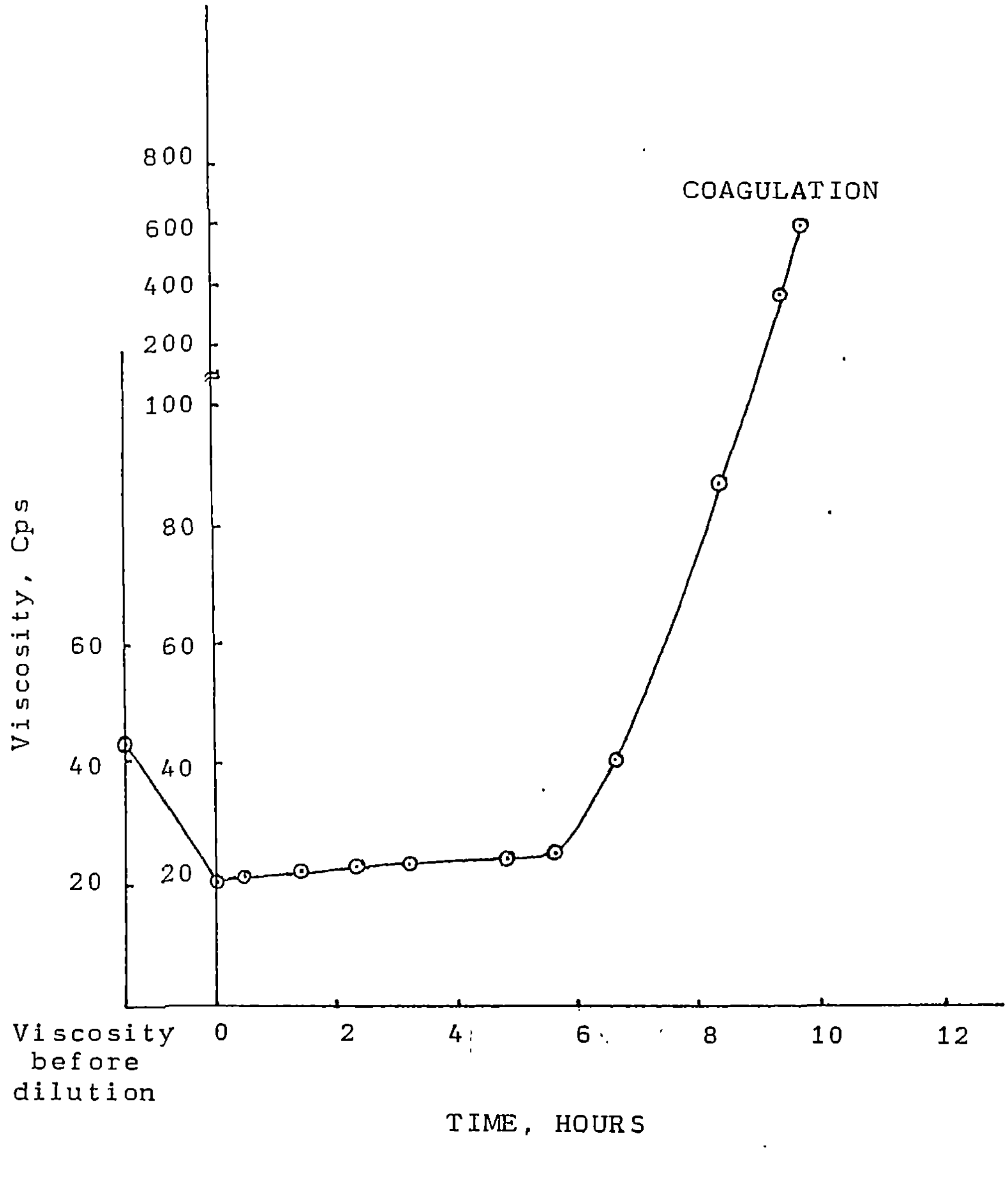


Fig.17.Effect of 1:1 dilution and storage on viscosity of Hevea latex.

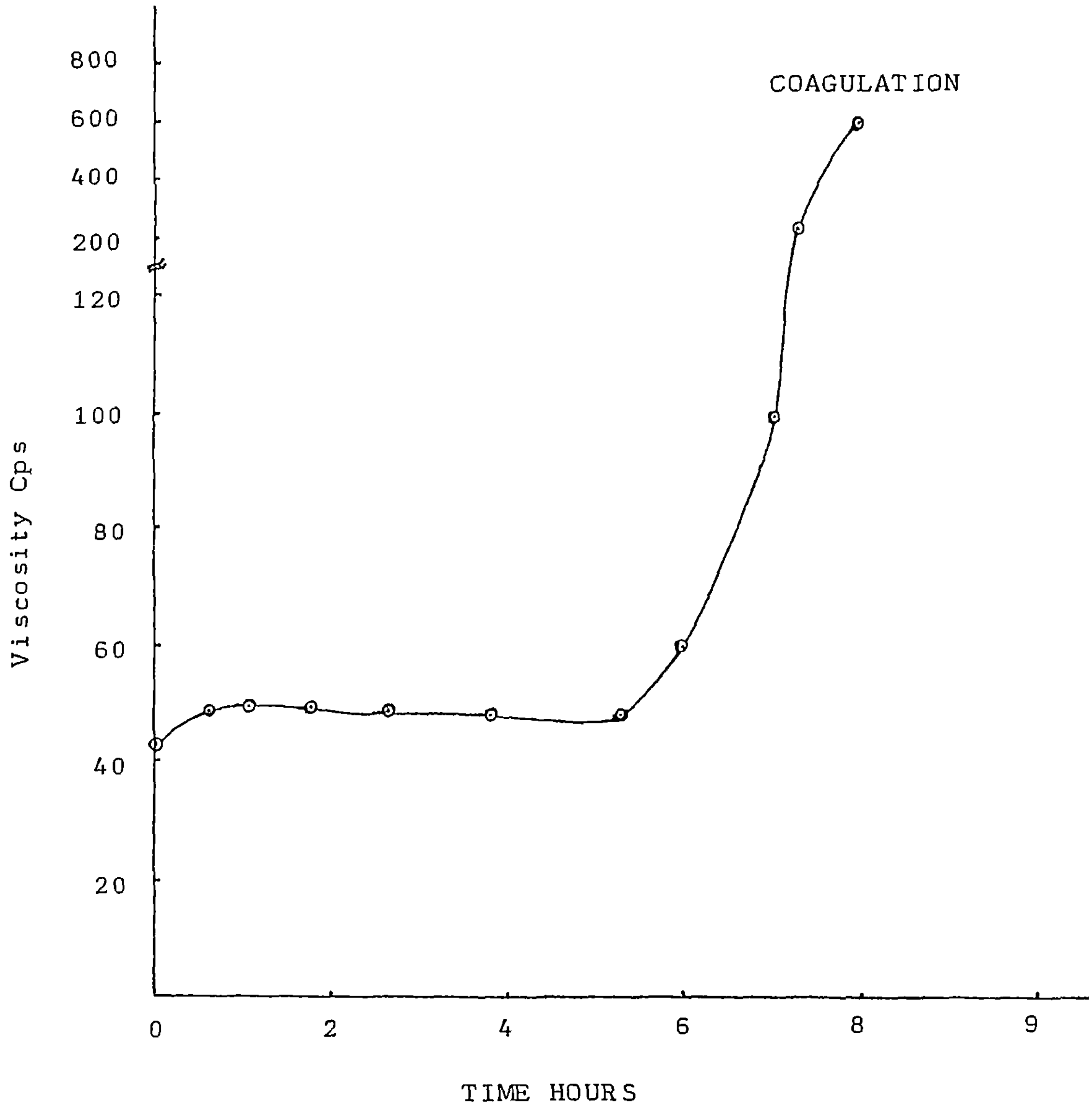


Fig. 18. Effect of storage on viscosity of <u>Hevea</u> latex

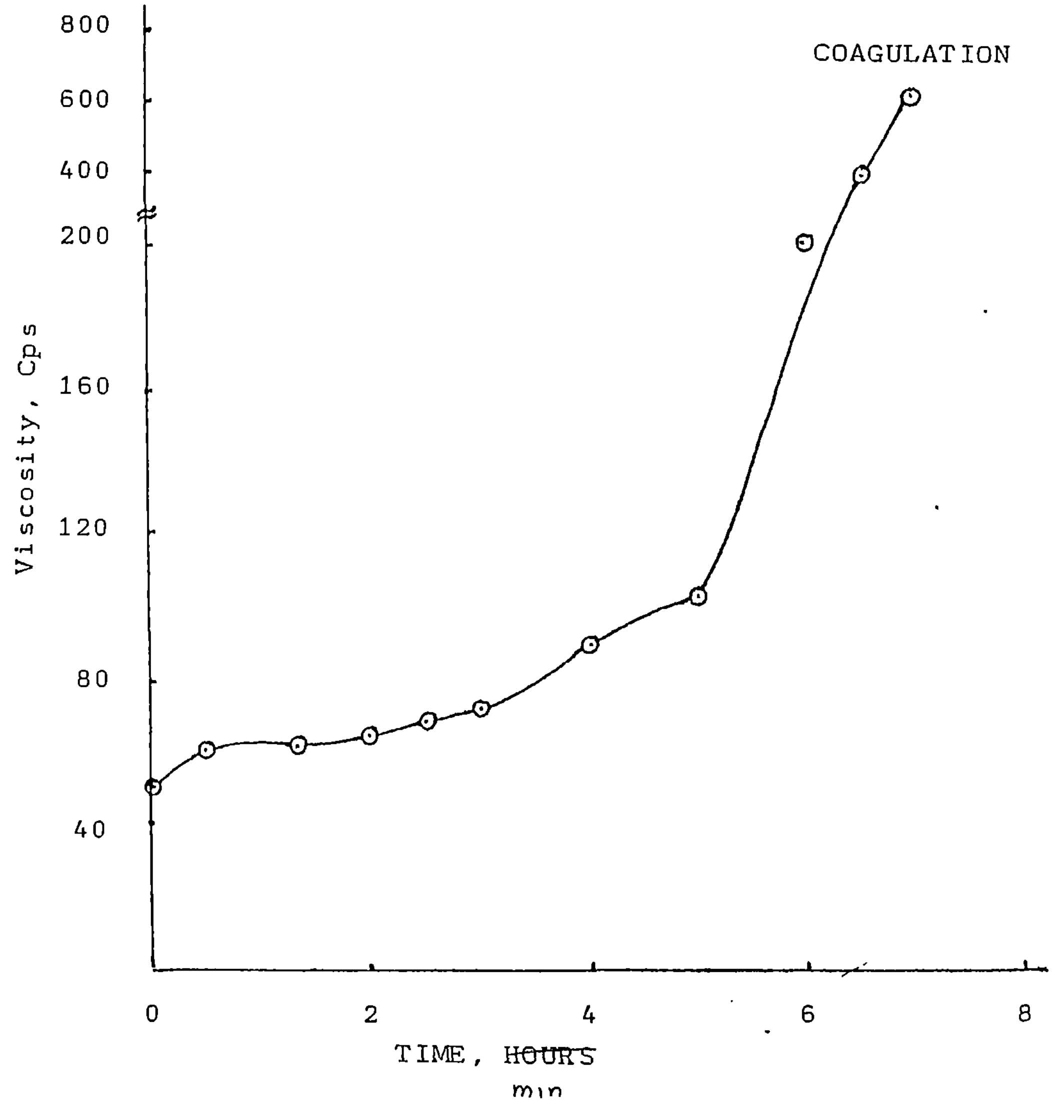


Fig.19. Effect of storage on viscosity of Manihot latex

Fig.20. FTIR Spectrum of <u>Manihot</u> rubber

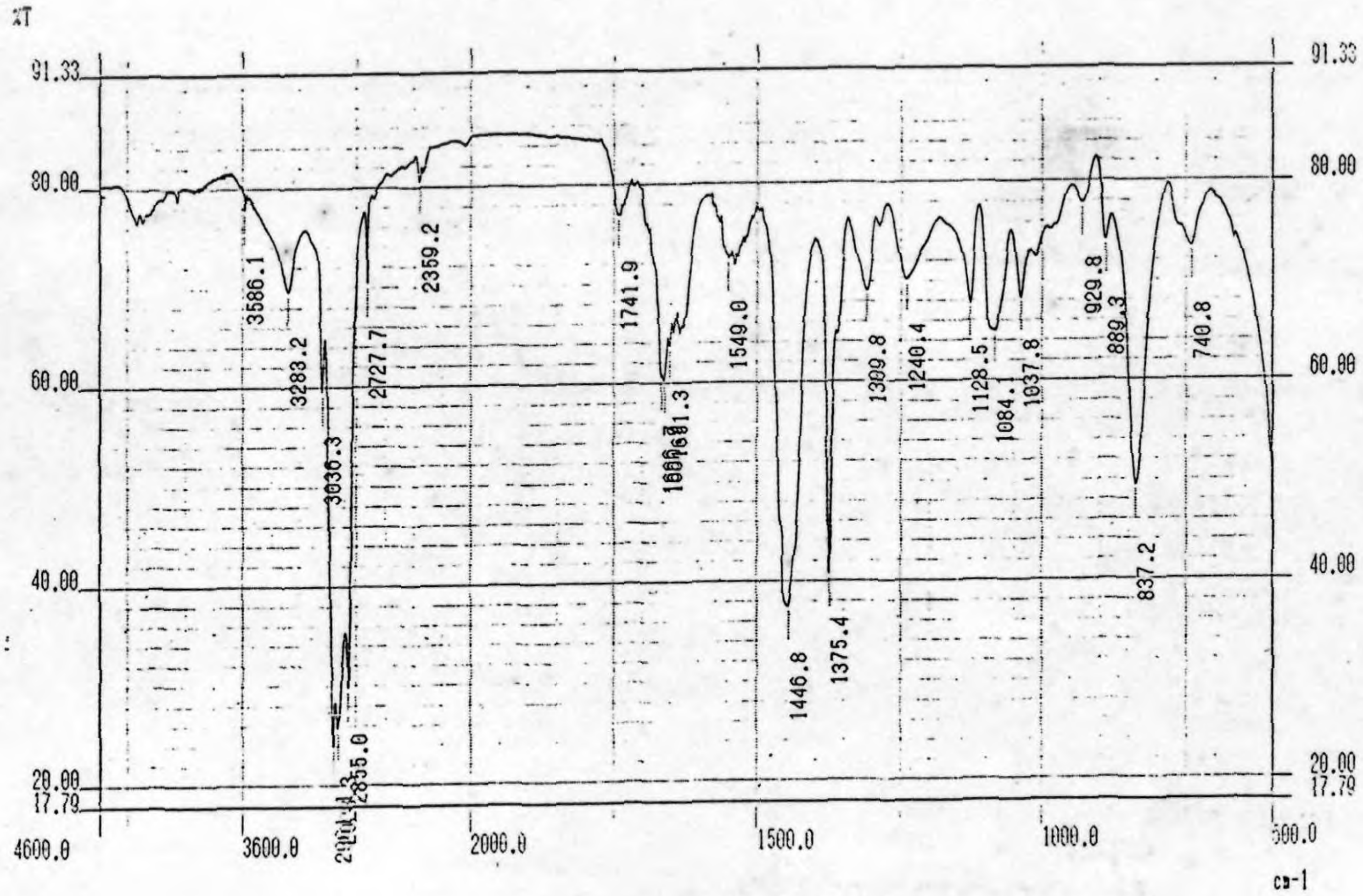
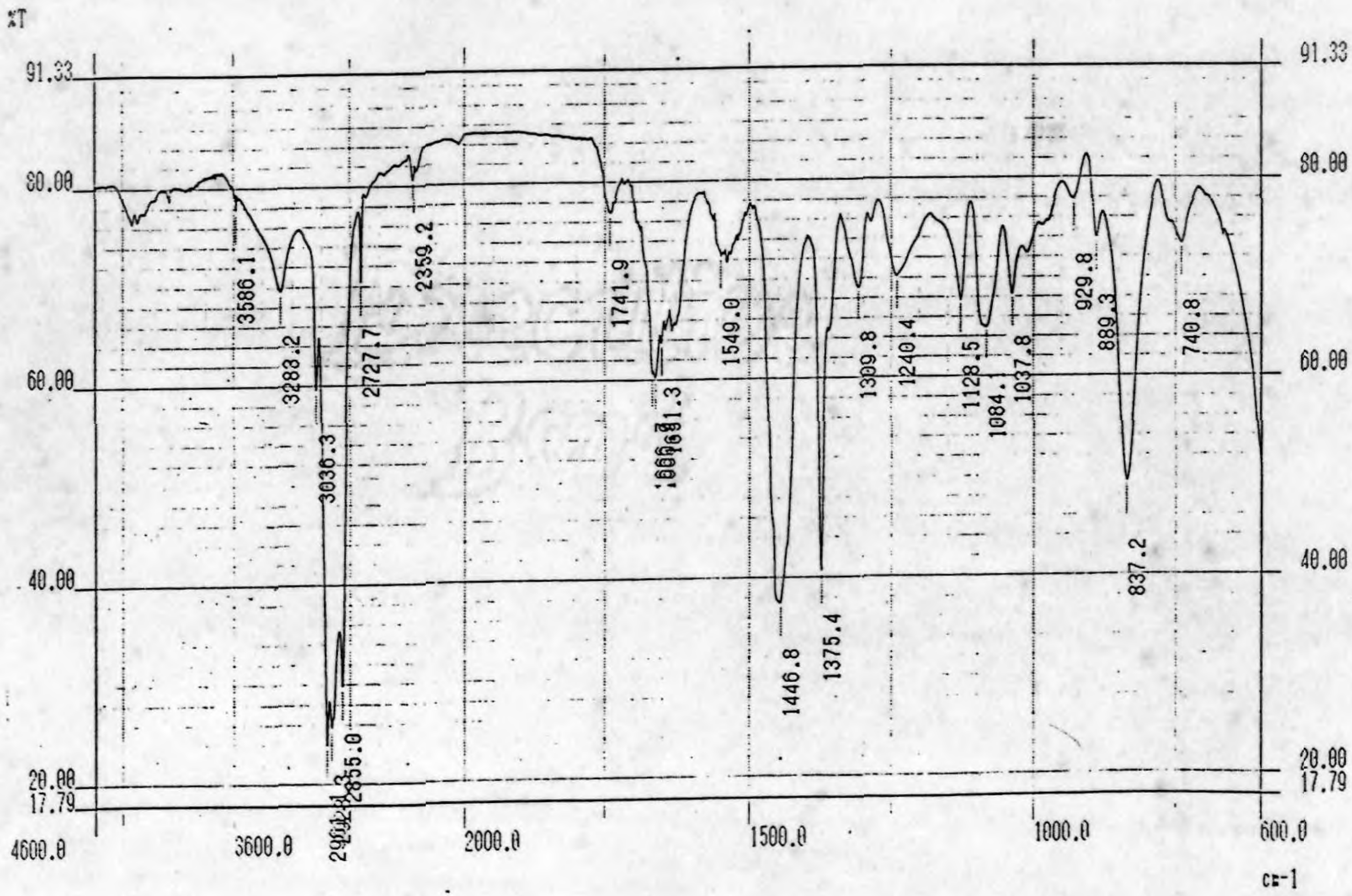


Fig. 21. FTIR Spectrum of <u>Hevea</u> rubber



5.1. General

Of the 3000 species of plants used by man for food and other purposes only 150 species have been commercially exploited for the day to day requirements. Now these limited numbers are further shortened to only 20 crop species (Randhawa, 1988). These high yielding varieties are now being threatened by various virulant disease pathogens and the man-made green house effects. This critical situation warrants suitable "Life Support Species" for the continuous supply of products. In spite of our rich flora that offers great promise, we are still relying only upon a very small fraction of the plant wealth. The need for producing more agricultural products for rapidly increasing human and livestock population in the second half of the current century necessitated bringing under the plough of more and more 'marginal lands'. It also necessitated the acceleration of degraded soils enrichment and fertility through afforestation. This has raised a serious thought to the concept of 'adopting plants suited to the environment'. Agricultural scientists are now active to collect, introduce and evaluate the vast array of underutilised plant species and also to breed for varieties which can well adapt themselves to the harsh environmental and degraded soil conditions. Their attempts resulted in the screening and identification of a large number of food plants, fodder and energy plants and industrial and hydrocarbon plants belonging to various agro-ecological habitats.

A great deal of interest and speculation has risen concerning the use of plant latex as a substitute for petroleum (Neilson _et al_., 1977; Calvin, 1979a, 1983; Dehgan and Wang, 1979; Maug, 1979). Among the other hydrocarbon plants, especially for NR, certain promising genotypes of guayule rubber, such as Arizona 2 and HG 8 were found to be of great potentialities. Moreover, the energy requirement and cost of the production of synthetic rubber is about 12 times more than that of NR (Spedding, 1981) in addition to the pollution hazards. A tree which can provide rubber, without pollution but protecting the sub-marginal lands will be more preferable. Calvin (1977; 1979; 1980), Buchanan _et al_. (1978a, 1978b, 1979), Wang and Huffman (1981), Roth _et al_. (1984); Maxwell _et al_. (1985); Mechesney and Adams (1985); Carr _et al_. (1986); Carr and Bagby (1987), Marimuthu _et al_. (1989) and several other investigators have screened a large number of species for fuels, hydrocarbons, industrial oils and other energy sources. The most important source of NR is _H_. _brasiliensis_ for which a suitable successor or alternative species has not yet been identified to take over charge in the event of a catastrophe. An intensive search in this line resulted in the identification of a hitherto not cared species which can thrive under hostile environments. Thus Manihot glaziovii has been investigated to bring out its hidden qualities for enlisting it as a prospective alternative source of NR and its merits and rectifiable demerits are discussed.

5.2. Morphology, propagation and diseases

General growth and morphology of M. glaziovii varies with agroclimatic conditions and propagation methods. When propagated through cuttings, the trees takes its natural course of growth leading to slightly crooked stem. This is due to the early branching habit of the vegetative cuttings, which during subsequent growth undergo self pruning seasonally leaving a single leading stem. In such plants girthing of the stem was found to be more than in the seedlings of the same age. Dijkman (1951) has reported the same phenomena in Hevea, where the rate of girthing is more after the formation of branches and development of crown. However, for the ease of tapping low branching is not advisable and all branches should be pruned upto a height of about 2.5 m leaving a healthy and clean trunk (Radhakrishna

Pillai, 1980). The bole of such population in the natural habitat are mostly having stout and straight stem. Here the wild trees are having the light spread canopy, which is mostly restricted to the top. The leaves are palmately lobed, usually with 3-5 lobes. However in Location II where the tree has to face a hostile thermal stress, showed a further lobing from 2-7 in certain observed cases. This appears to be a xerothermic adaptation of the species to reduce the leaf area as in the case of other species growing in the arid regions.

Another peculiar habit of M. glaziovii is the shedding of shoot and buds. One of the most important drought resistance mechanisms of plants involves reduction in transpiring surface. Thus natural shedding of leaves and other plant parts reduces the transpiring surface area during a period of soil drying and prevents dehydration of plants to lethal levels. Seedlings of 1-2 years growth show symptoms of leaf shedding by the onset of summer. It takes about a month to shed the leaves and during that period the growth will be arrested. After complete shedding of leaves, the stem remains green for another period, of about a month. Then it starts slow drying from the tip to downwards. Along with this the axillary buds also will be shed. The slow drying proceeds downwards from internode to internode. The process is so slow that about 5-10 cm length of the shoot get dried in a month. When the season becomes favourable one of the dormant buds will sprout giving rise to a new shoot.

This natural adaptation of the tree is a continuous process through out the life span. Mature trees in both the locations also showed this character. The branchlets get slowly dried, after wintering. By self pruning the dried branchlets will be detached from the tree. The shedding of branches of plants of arid regions is a common drought resistance adaptation (Orshan, 1963, 1972). The tree is having a ramified canopy due to its repeated trichotomous branching. But through this self pruning mechanism, it is capable of maintaining an optimum canopy. Canopy control to an optimum level is a desirable character for a species exposed to hostile environments. Moreover the biomass deposits help to increase the fertility of the poor soil.

This is one of the characters which qualifies M. glaziovii as a suitable species for the dry regions.

Early flowering is considered to be a desirable character in crops which are meant for its seeds. Most of the tree species produce flowers after 3-5 years. From the breeders' side this is a very long time, so that various flower induction techniques has to be attempted. In *Hevea*, during the course of the crop improvement programmes different techniques like ring-barking and chemical sprayings were tried to induce early and off season flowering (Camacho and Jimenez, 1963; Cannel, 1971; Saraswathyamma, 1975; Premakumari and Nair, 1976). But the most attractive habit noted in *M. glaziovii* is its early natural flowering habit. Usually March-April is the flowring season and fruits are formed by May-June. This further enables the collection of fresh seeds for propagation during the preceeding planting season. Crop improvement through breeding can be achieved without waiting for a long period.

Leaves of most of the deciduous trees of the temperate zone are shed in the beginning of summer. Deciduous tree like *H. brasiliensis* sheds its leaves by January-February and refoliation takes place in a short period (George *et al*., 1967) even before the summer months are over. But in *M. glaziovii*, defoliation starts only by January-February and the trees remain leafless until the summer season is over. However early refoliation may occur if the plant receives sufficient pre-monsoon showers. There is considerable variation in annual leaf shedding in tropical climates because of variations in humidity and seasonal distribution of rainfall (Kozlowski, 1973). One of the most important drought resistance mechanism of plants involves reduction in transpiring surface, during the period of soil drying. In Brazil, where Ceara rubber is a native, the leaves of practically all deciduous trees abscise with the onset of a drought and are replaced when the drought ends (Alvim, 1964). Leaf shedding is an adaptation of the deciduous tropical perennials to overcome the thermal stress (Longman and Jenik, 1974). The considerable time gap between defoliation and refoliation exhibited by M. glaziovii is an adaptation of the plant to overcome drought stress.

In M. glaziovii the number of stomata per 1 mm^2 ranges from 510-660 and the average number observed is 593. The species shows a higher frequency of stomata compared to 411.69 in H. benthamiana, 447.76 in H. spruceanana and 465.17 in a clone of H. brasiliensis (Senanayake, 1969). Similarly the number of epidermal cells per 1 mm^2 also shows a higher average value of 3052.

The number of stomata per unit area varies not only between species, but also within any one species due to the influence of the environmental factors. It was reported that more cells per unit area and more

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).

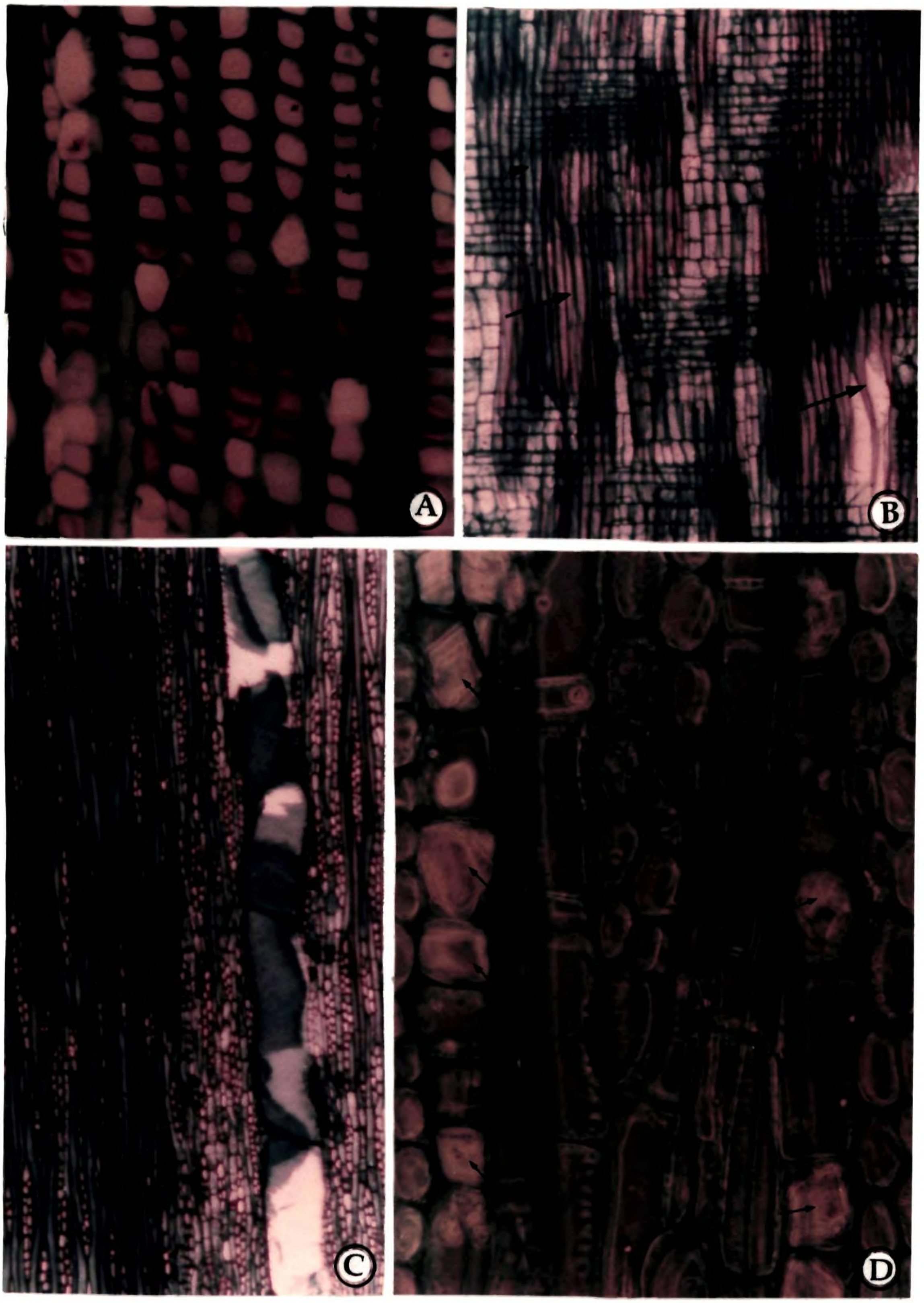


FIG. 23

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 $^{7}/_{10}$.

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

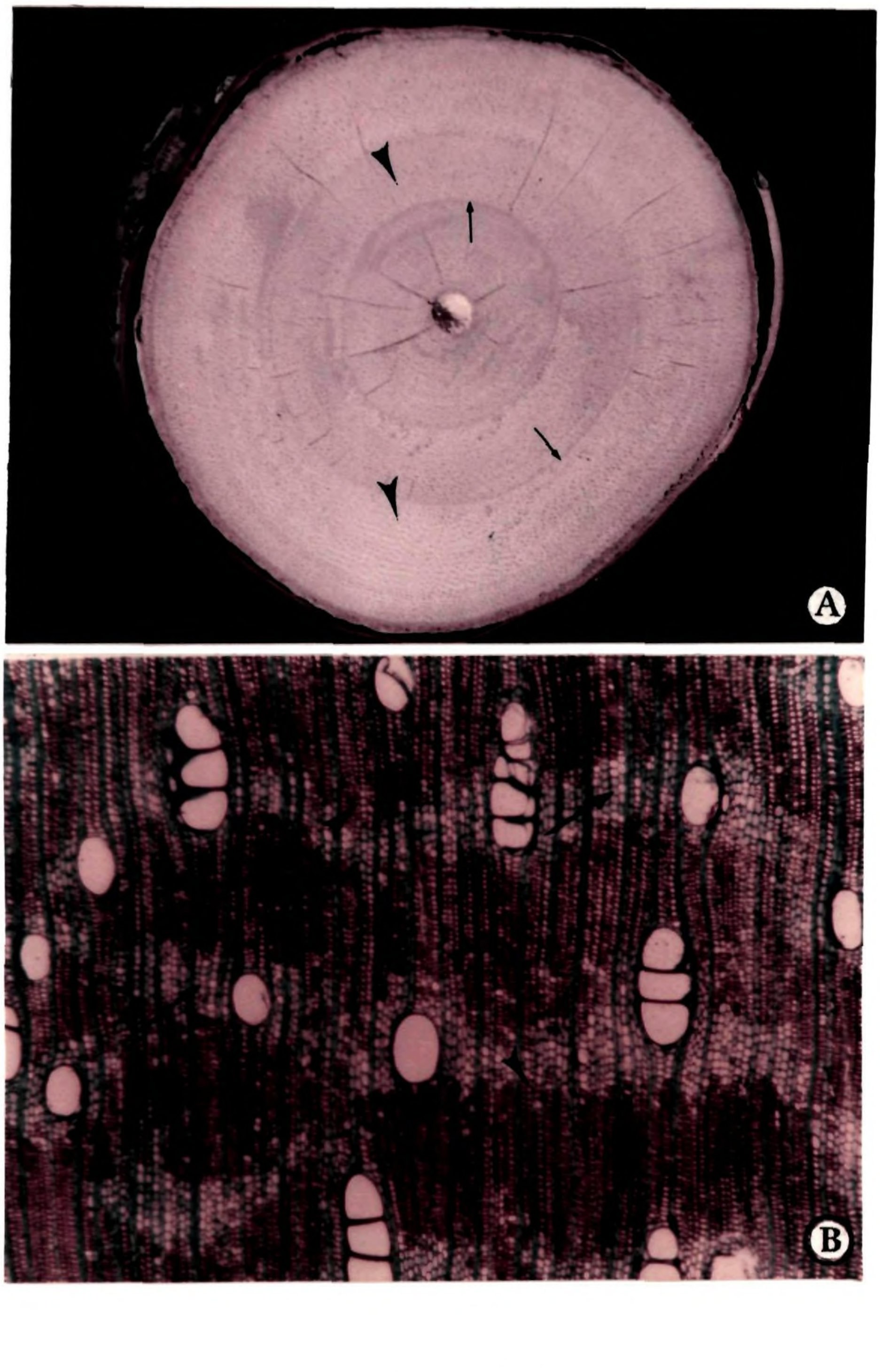


FIG. 22

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. 15

FIG. 12

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

B. Tangetial view of latex vessels with interconnetions (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.

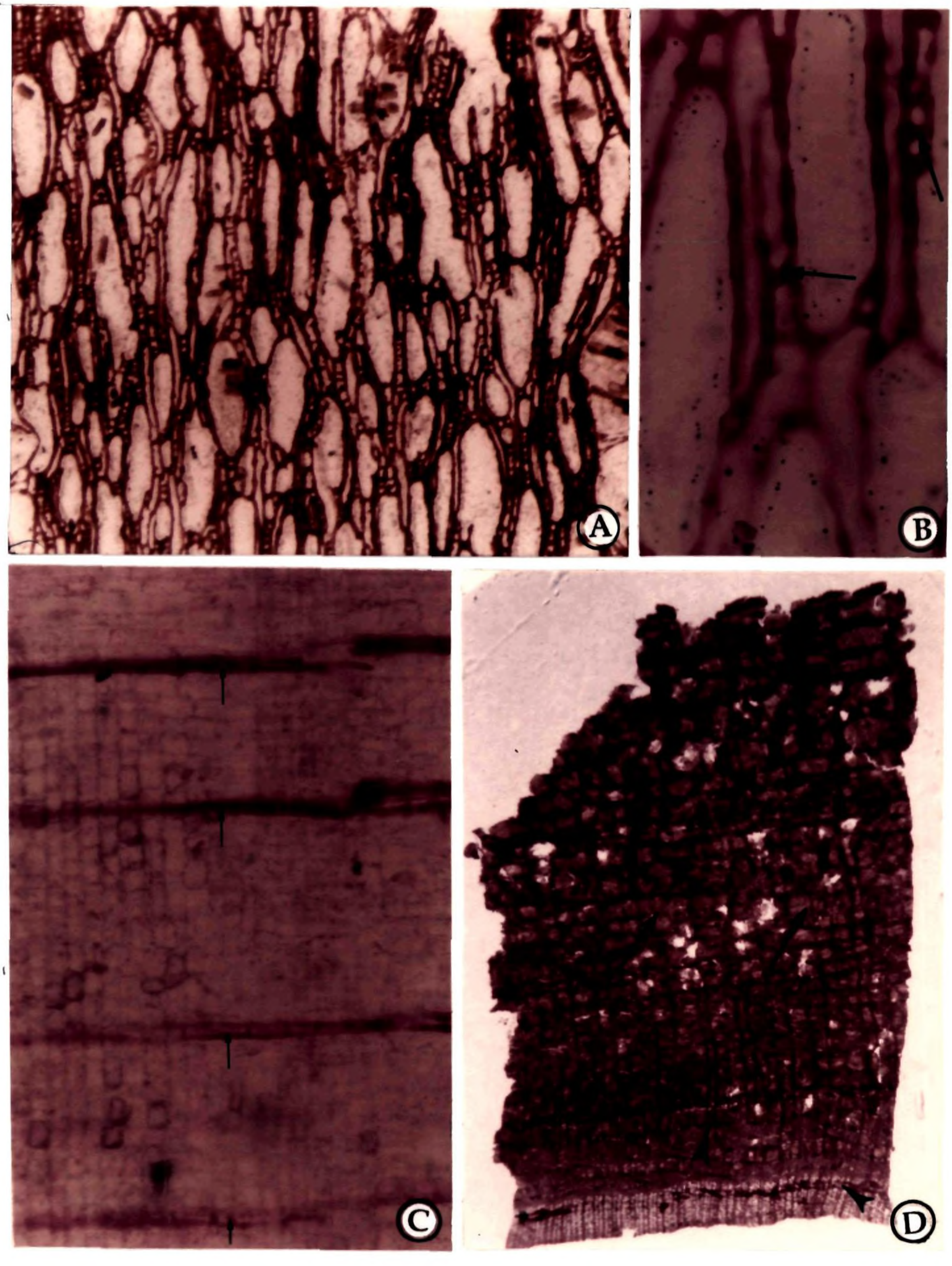


FIG. 12

FIG. 11

A. The bole showing flaky rhytidome.

B. Periderm with lenticels.
Stereophotomicrograph X 12.

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

D. Smooth, inner white bark.

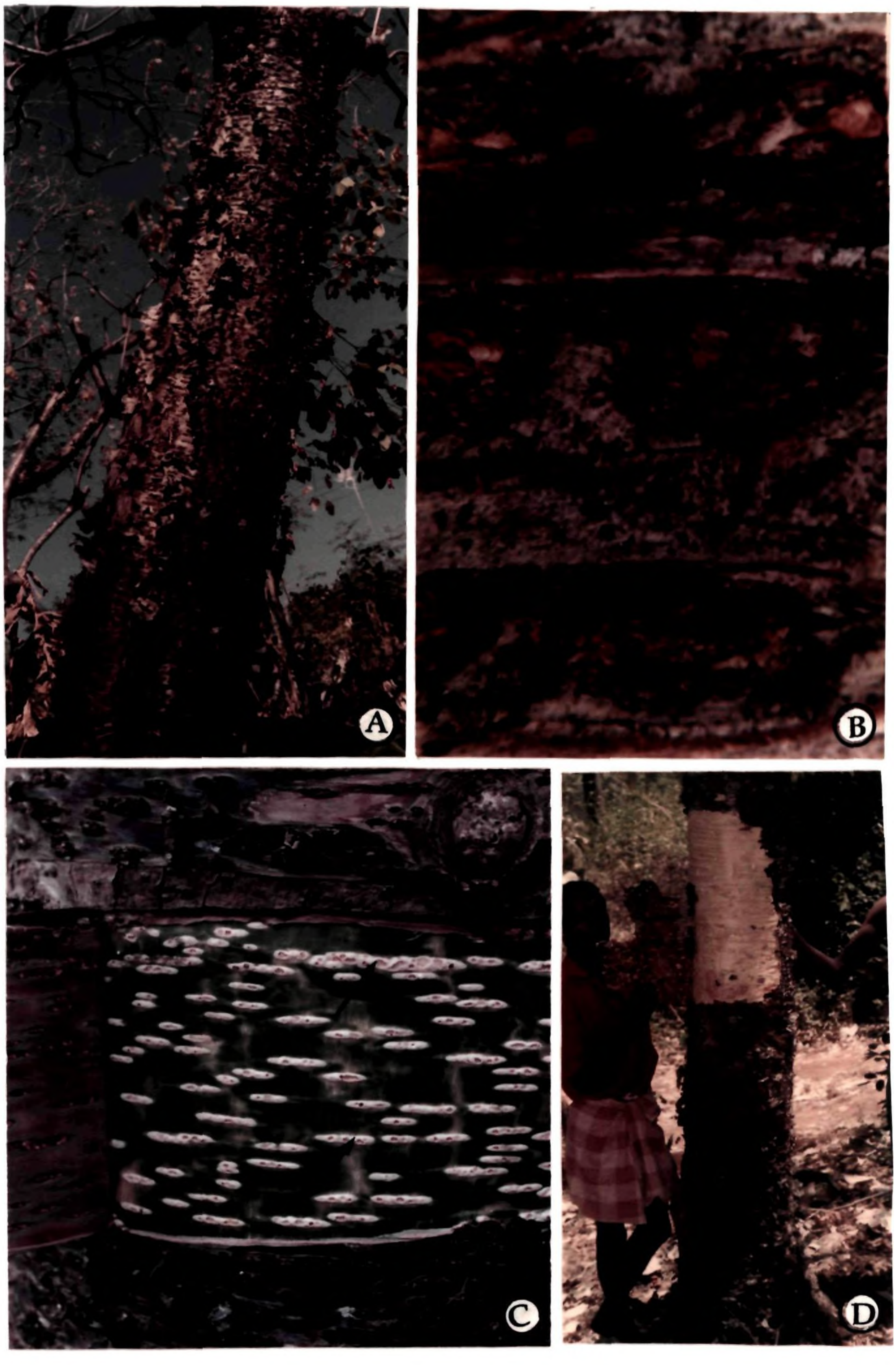


FIG. 11

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. 10

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).

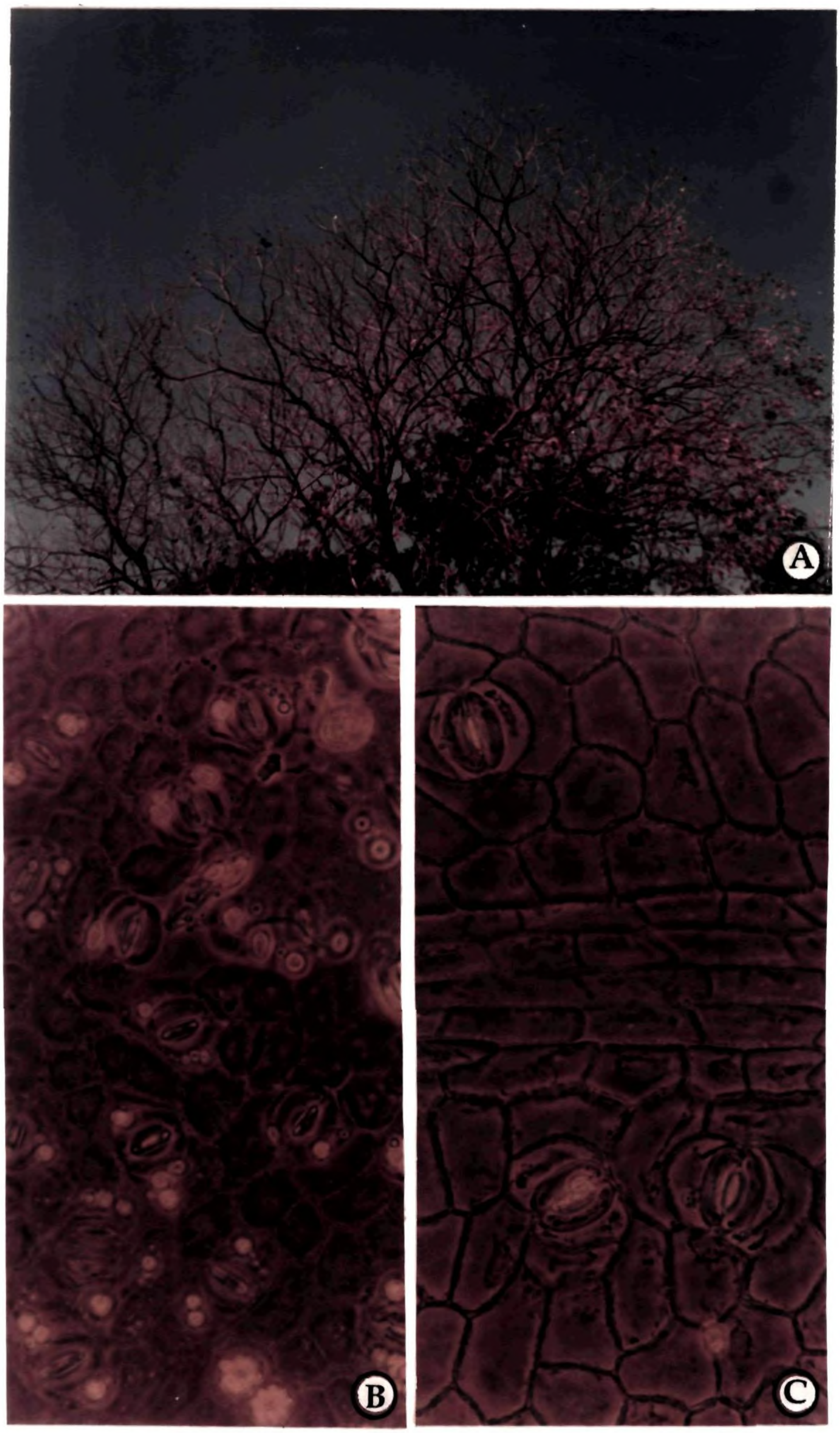


FIG. 9

FIG. 8

A. Shoot drying of young seedlings in natural habitat.

B. Different stages of shoot drying.

C. Shoot drying in the mature tree.

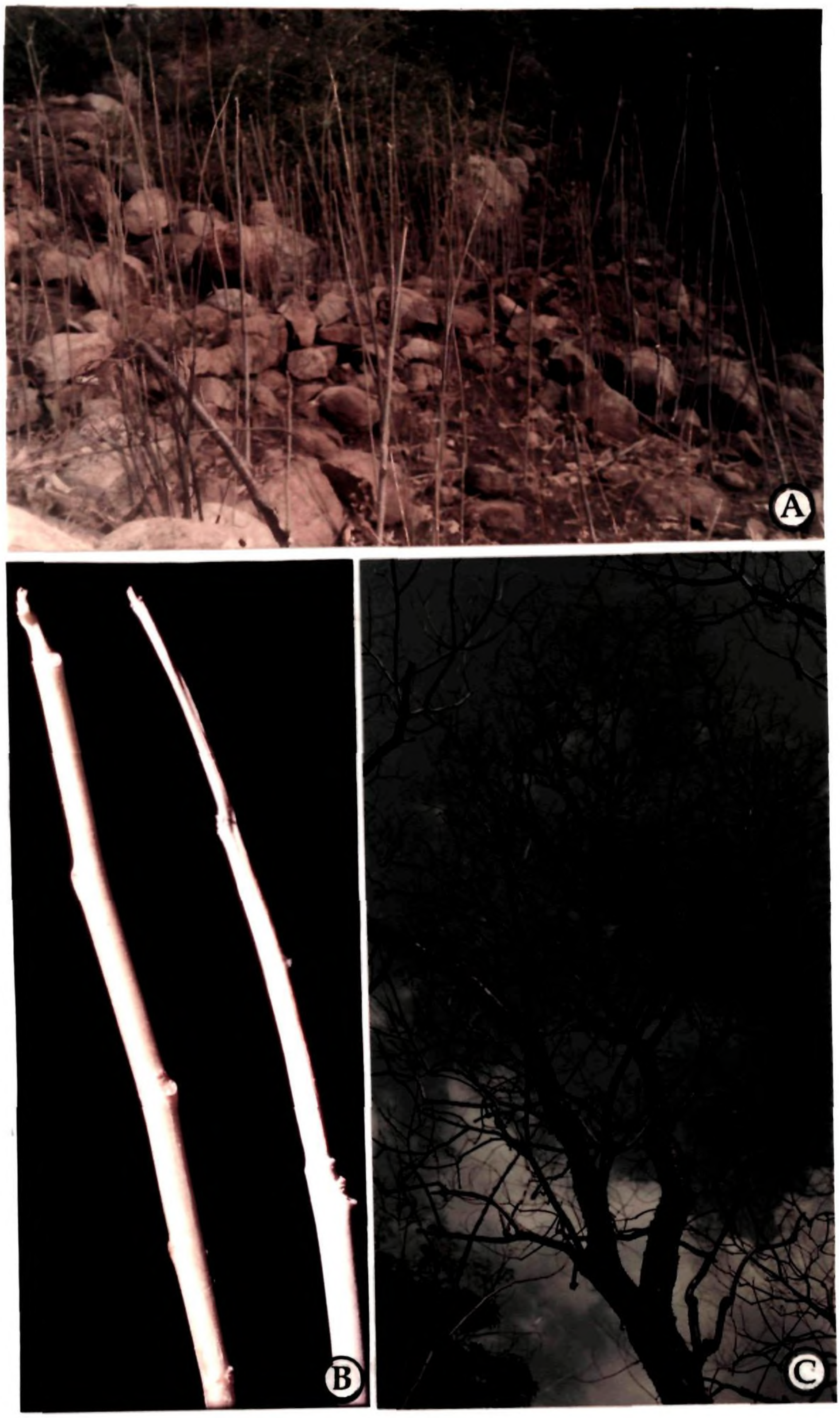


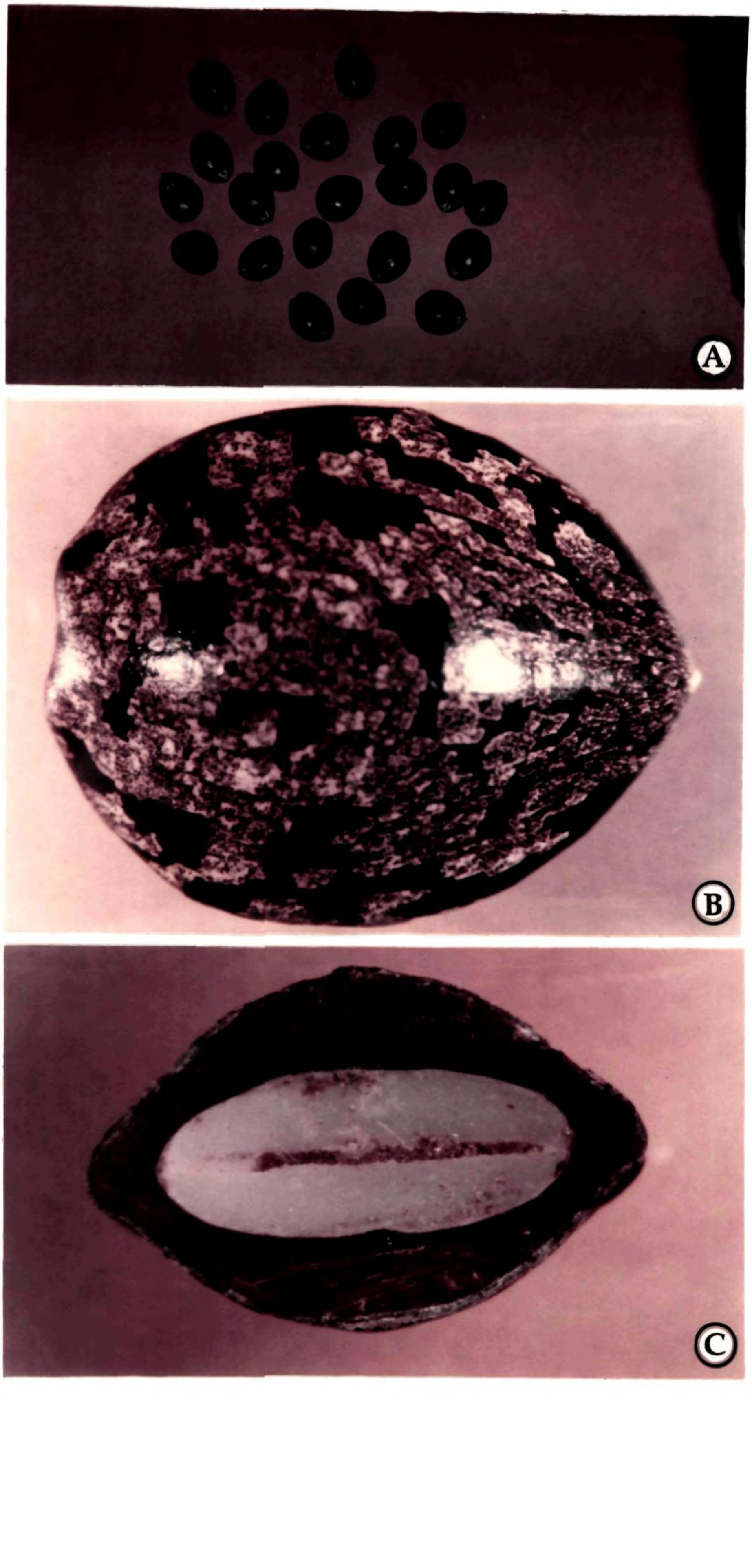
FIG. 8

FIG. 7

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.


A
B
C

stomata per unit area are seen in leaves of plants growing in dry soil and low humidity compared with those growing in moist soil and high humidity (Meidner and Mansfield, 1968).

Stomatal movements are closely affected by water supply to the plant. Stalfelt (1955) has reported that stomatal opening is closely dependent upon the hydrostatic pressure within the epidermium. During water deficit stomata gets closed due to hydroactive closure. Heath and Mansfield (1962) have found that the stomatal sensitivity to CO_2 increased enormously in leaves with a high water deficit. As the water deficit increased, the stomata became more closed and the CO_2 sensitivity increased progressively resulting in stomatal closure. This helps the plant to cutting down the transpirational water loss. In the case of M. glaziovii at the peak of water stress, the entire foliage is shed and the role of stomata seems to be of notmuch importance during the dry months. However, the high number of stomata present in the leaves of the refoliated tree, when sufficient water supply is regained, help the tree to start photosynthesis at a rapid rate, thereby to restore the carbohydrate reserves exhausted during the inactive summer season.

Propagation by seed is an important technique for raising agricultural crops worldwide. This method is of extreme importance to the propagation of woody plants, whether for forestry or plantation use. Seed is generally a low cost method of propagation, compared to vegetative propagation. Moreover, rate of growth and ability to establish following transplanting is very often faster due to seedling vigor. But there are certain limitations to propagation by seed. Genetic variation will be so high that uniformity in yield will be difficult. There will be difficulties in germination due to seed dormancy and hard seed coat. In such seeds it is necessary to carry out pre-sowing treatments to remove the hard or waxy seed coat for successful germination (Macdonald, 1986).

The seeds of M. glaziovii also need pre-treatment for efficient germination to remove a portion of the hard seed coat. Of the various techniques tried, grinding a portion of the seed coat was found to be the most reliable method giving 72% germination. Acid treatment is a usual method to soften the seed coat of similar type seeds. But the shell is having a thickness of about 1 to 1.5 mm (Fig. 7C). Due to this thickness, the common abrasion techniques also was found to be of no use. Among seed treatment techniques, light burning of the seeds was found to gain 11% germination. In this technique, though the method can accelerate germination, it was observed that about 10% of the seeds were killed due to over heat.

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 also showed much difference.

Since the seed is very small in size (Fig. 7A) and weigh only 0.50-0.60 g, it is very easy for storage and transportation. One kilogram seeds contain about 1750 numbers.

The seeds of M. glaziovii remain viable for a very long period.

M. glaziovii can be successfully propagated through vegetative cuttings also. This is a great advantage over the tedious budgrafting method adopted in the propagation of Hevea. Joseph and Saraswathy

(1992); Ooi *et al.*, (1976); RRIM (1964); and Webster (1989), have explained the various vegetative propagation techniques such as brown budding, green budding, benchgrafting, etc in *H. brasiliensis*. These techniques have got many disadvantages like stock-scion interaction (Abbas and Ginting, 1981) poor budding success, high maintenance cost, initial growth retardation, etc. In *M. glaziovii*, after the selection of a desirable genotype, cloning can be done quickly, without the intermediate stock plant. From the experiment it was found that brown wood cuttings taken from the mature trees are the best material for vegetative propagation. Though 20 cm log cuttings produced about 50% sprouts compared to 40 cm, most of them are shotlived. This may be due to the insufficiency of nutrition for the fast growing shoot. There is not much difference between the sprouting of brown and mature cuttings. However the only disadvantage observed in the experimental field is the early branching, which was discussed earlier. Cuttings develop trichotomous branches at an average height of about 150 cm. But this can be rectified by corrective pruning. Best result was obtained when cuttings are planted in punched polybags of 30 cm x 25 cm size. The sprouted (rooted) cuttings can thus be transplanted in the field without affecting the growth. This cheaper method of propagation is an added advantage of *M. glaziovii*.

In this context it is worth noting that the cost of raising a one year old polybag plant of *H. brasiliensis* will be about five times more than that of *M. glaziovii*.

Various fungal diseases and pests are reported to attack *M. glaziovii* in the wild stand as well as in the cultivated fields, causing severe defoliation, dry shoots and bark damage (Golato and Meossi, 1971; Teri, 1980; Teri and Keswani, 1981; Bastos and Magalhaes, 1981 ; Bastose *et al*., 1981 ; Bastose and Flechtmann, 1985; Serier, 1988). But none of these diseases and pests are reported so far in India.

Secondary leaffall (SLF) is common in the rubber plantations (*Hevea brasiliensis*) throughout South India during the months of April, May, September and October. Damp environments and high humidity are the pre-requisites for the spread of the disease (Ramakrishnan and Radhakrishna Pillai, 1961; Radhakrishna Pillai *et al*., 1980). This is the first report that *M. glaziovii* as an alternate host plant for the fungus *Gloeosporium* sp.

The symptoms of the disease was first observed in the mature trees in Location I. But the secondary leaffall was not so serious to warrant any plant protection operation. The disease is not observed in Ceara rubber trees or its samplings growing in Location II (Mettur Hills). This might be due to the dry atmosphere and scanty rainfall of locality. Such environment is unfavourable for the growth of the fungus. However, it is observed that the germplasm brought from Location II, which are being grown in Location I, are found affected by the disease. In Location I, the spores of the pathogen are plenty due to the extensive area planted with Hevea brasiliensis. This clearly shows that M. glaziovii can be grown in the dry regions without being affected by SLF caused by Gloeosporium.

The general habit and morphological features of the species are of a special nature, especially suited to the hostile environment. The morphological features of the bole give an appearence of a very rough bark, because of the flaky rhytidome. But this protective mechanism helps the tree a lot to escape from severe sunscorch. Most tree crop species need protective shading, white washing of the stem, thick mulching (Watson, 1989) and foliar sprays etc to overcome the summer season. But M. glaziovii never requires any protection against sunscorch.

The seasonal defoliation of the tree helps it to reduce excessive loss of water during summer. Such trees are grouped under 'summer deciduous' plants, where its abscission is correlated with moisture stress (Addicott and Lyon, 1973). However, the long time gap between defoliation and refoliation may affect the photosynthetic activity of the tree.

The drought survival adaptation of the seedlings also shows its self defensive ability. When the seedling nurseries of other important crop plants need careful shading, mulching and watering, in *M. glaziovii* the seedlings takes a fast growth during the favourable season and prepare itself to face the stress by shedding a portion of the shoot. Romberger (1963) has reported that a number of woody species terminate a flush of shoot growth by abortion and abscission of shoot tips rather than by formation of a terminal bud enclosed in bud scales. Thus it is evident that the cost of cultivation and maintenance of *M. glaziovii* trees will be considerably low, when compared to the expenses to be incurred for other crop species.

Early flowering habit, coupled with simple vegetative propagation facilities offer great chances to improve the productivity of the crop.

5.3. Bark structure

Bark anatomical investigations of a latex bearing tree is of much importance as the productivity is mainly based on the laticiferous system present in the bark. 'Bark' is a *non-technical term that describes all tissues* exterior to the vascular cambium (Esau, 1965; Srivastava, 1964), comprising of epidermis, cortex, primary phloem and the complex secondary phloem tissue (Kozlowski, 1971). The outer bark in a mature tree is an aggregation of dead tissues cut off by the periderm or rhytidome (Eames and Mc Daniels, 1947; Esau, 1965). The remaining living tissues of the bark, phloem and the phellogen and phelloderm, are collectively termed as inner bark (Eames and Mc Daniels, 1947; Whitmore, 1963). The functional laticiferous tissue of a latex bearing tree is concentrated in the inner living bark tissue in association with other secondary phloem elements.

Bark can be classified into smooth bark, furrowed bark, scale bark, ring bark and winged bark based on their appearance, texture and external morphology (Borger, 1973). M. glaziovii is a smooth barked tree characterised by a superficial periderm layer with flacky rhytidome and horizontally elongated lenticels. The hard and waxy analogue of the peelable periderm/rhytidome is an additional feature of Manihot bark which in turn protects the tree against intense evaporation and thereby helps to retain moisture content in the bark (George, 1993). The high moisture content of Manihot bark reported elsewhere confirms this, indicating the drought resistant adaptation of this tree species.

It has already been proved that majority of the species forming periderm also form lenticels (De Bary, 1984; Esau, 1965; Eames and Mc Daniels, 1947). Lenticels of Manihot bark are multi-layered and made up of loosely arranged complementary cells with intercellular spaces. Such numerous airfilled intercellular spaces associated with the lenticels in Manihot bark may provide thermal insulation and protect the cambial zone from rapid termperature changes as suggested by Cooke (1948), Hare (1965), Martin (1963) and Stickel (1941) in various smooth barked angiosperm species. This type of bark characteristics of Manihot glaziovii can also be considered as an adaptability of this tree species to drought and other hostile environments.

The internal structure of Manihot bark is more or less similar to that of Hevea bark. However, structural variation has been noticed with respect to certain characteristics.

The hardness of bark depends on the quantity of sclerified stone cells present in the outer bark zone and the nature and development of stone cells have been received much attention in relation to tapping (Bobilioff, 1919; Gomez, 1982). The less frequent stone cells in the outer bark zone of Manihot when compared to that of Hevea bark reveals that the former is softer than the latter whereby tapping can be done smoothly. Moreover, the alignment of stone cells, in the outer zone of Manihot bark is more or less in lines alternating with laticifers without disturbing the continuity of most of the laticifers unlike in Hevea bark where the stone cells are distributed randomly making the laticifers present in the outer zone of the bark discontinuous. Because of this feature more laticifers in Manihot glaziovii are functional in nature.

The quantity of laticiferous tissue produced by a tree depends not only on the number of laticifer rows but on the number (density) of latex vessels within a row also (Gomez, 1982). Mendonça and Maria Silvia de (1992) have reported that the distribution of laticiferous vessels and their density are greater in the liver bark (soft bark) of M. glaziovii. The present study also showed the maximum distribution of laticifers in the soft bark zone. In this study the total number of laticifer rows of Manihot bark is considerably lower than that of Hevea bark and the difference between them is more than 50%. Similarly the density of latex vessels per row per 1 mm circumference of the tree is also found to be lower (28.5) in Manihot bark in comparison with that of Hevea bark (33.72). The low mean values of these two characters in Manihot glaziovii may be some of the reasons for the low yield of this species. The lower mean values of the thickness of bark in Manihot also may be a factor which limits the number and density of laticifer tissue in the species.

The diameter of latex vessels plays a significant role on the rate of flow of latex during tapping (Frey-Wyssling, 1930; Riches and Gooding, 1952). Ashplant (1927, 1928) observed a good correlation between diameter of latex vessels and yield in Hevea brasiliensis. The mean diameter of latex vessels of Manihot glaziovii in the present study, is 14.15 μm indicating that the latex vessels are narrower in the former which in turn also results in low latex yield. However, the interaction of the physiology of latex flow, length of tapping cut, the rate of late flow etc. are considered to be the major factors directly or indirectly related to the latex yield suggested by De Jonge (1969a, b), Southorn and Gomez (1970) in *Hevea brasiliensis*. In this context, the results of the earlier studies conducted by Gomez *et al*. (1972), Narayanan *et al*. (1973, 1974); and Ho *et al*. (1973) in *Hevea brasiliensis* also deserves much attention and consideration. The bark anatomical traits which are contributing yield and productivity of *M. glaziovii* can be improved through crop improvement and breeding programmes. However, the relation between the anatomical parameters and latex flow and thereby latex yield needs further detailed investigations.

Considering the effeciency of tapping the distance between cambial zone and the inner row of secondary laticifers play a major role. The tapping is done in such a way that the tapping cut should not wound the cambial cells. Usually the tapper is advised to exploit the bark up to a depth leaving about 1 mm residual bark close to the cambium. In *Hevea brasiliensis* the residual bark left untapped during exploitation leaves about 40% of the laticifers left uncut. The efficiency of tapping and the desirable depth of tapping cut without wounding the cambium and the percentage of laticiferous tissue to be left uncut etc., have not been ascertained in *M. glaziovii* so far. However, these are vital aspects to be considered for commercial exploitation of the species. The present study on the structure of bark of this species reveals that the thickness of latex vessel free zone continuous to cambium in *M. glaziovii* is about 4.2% of the total thickness of bark whereas it is only about 3.06% in *Hevea brasiliensis*. This clearly indicates that the percentage of laticifers left uncut during tapping is minimal in *M. glaziovii* thereby maximum exploitation of latex is possible without wounding cambial layer. It has already been reported by De Jonge (1969 a, b) that deep tapping so as to severe maximum number of laticifers will be more effective for increasing yield in *Hevea*. In *Manihot* however, the situation need not held true as the residual bark will not contain many laticifers.

The study on the average of the distance between laticifer rows in *M. glaziovii* (0.327 mm) and that of *H. brasiliensis* (0.187 mm) indicated that the laticifer rows are less closer in the former. It has already been established that the formation of laticifers is a rhythmic process and are differentiated from the fusiform initials of the vascular cambium (Panikkar, 1974). The laticifer initials produced by the fusiform initials lead to laticifer formation, whereas other cells differentiated from fusiform initials lead to the formation of sieve elements and other phloic tissues. Hence the increase in the distance between laticifer rows in M. glaziovii may be due to the decrease in the rate of laticifer initial differentiation. The reduction in the number of laticifer rows in M. glaziovii also helps to confirm this result.

In drought affected regions many species shed their leaves when stressed for moisture as an adaptation to prevent water loss through transpiration.

M. glaziovii is a deciduous species, which shows a prolonged leafless period. The plant grows in the dry rocky areas where moisture stress will be very severe. Under such circumstance, the tree retains certain amount of water by means of moisture conservation in the bark.

M. glaziovii latex contains an average of 30% total solids. The remaining portion is mainly water. During tapping, along with each ml of latex 70% water is likely to drain from the trees. While in *H. brasiliensis* the latex contains about 60% of water. The summer yield of latex in *M. glaziovii* is comparatively more and the drainage was found not affecting the tree during the period of the experiment. This again gives a point for further investigation on the adaptation of the species against stress conditions. But after removing the periderm, the exposed bark dries quickly. Hence for tapping a careful removal of the periderm is needed (for which a special knife is required for the easy operation and it was designed and developed during the course of the investigation(Fig.3C).

The species *M. glaziovii* is highly tolerant to prolonged drought and thrives well at high elevations. Certain drought resistant adaptations of the tree have been discussed earlier. The soft bark beneath the periderm conserves considerable percentage of moisture. Another peculiarity observed is the presence of chlorophyll in the bark. Predominantly green and yellowish white are the two types of bark observed in *M. glaziovii*. In this study a 200 percent higher level of chlorophyll content was observed in the green bark of *M. glaziovii* (Table 7) compared to *Hevea* bark. The green bark is usually seen on the side of the stem facing sunlight. Appreciable photosynthesis of branches and bark often occurs in drought deciduous plants of arid regions (Jaezer, 1955; Pearson and Lowrence, 1958).

The pioneering work on the role of bark on photosynthate production was done in Aspen (Populus sp.) in the late 1950's (Jaeger, 1955; Pearson and Lowrence, 1958 and Edlin, 1975). They observed that the chlorophyll content in the bark start increasing at the onset of wintering. They also established the accumulation of photosynthate resultant of the activity of bark chloroplast. Some population of aspen have bark of yellow-green colour in content with the more familiar powdery white bark. Cottam (1954) has observed that the Aspen tree with greenish bark are found at high elevations and well adapted to the stress due to cold and summer.

The role of high percentage of chlorophyll in the bark needs further investigations.

5.4. Yield influencing factors and yield

Natural rubber is the most important economic product of the rubber yielding species. In species like Parathenium argentatum, the method followed for extraction and recovery of rubber is mechano-chemical. This method will have to be considered for extraction of rubber in laticiferous herbs also if and when such species are considered as potential alternative sources. In tree species, however, the latex is contained in the specialised tissue system mostly confined to the bark. Both in *H. brasiliensis* and in *M. glaziovii* where the rubber containing latex is synthesised in the specialised articulated anastomosing laticifers. Latex can be collected by different types of cuts and pricks. The widely adopted method of tapping in *H. brasiliensis*, consists of controlled wounding at specified intervals so as to open the latex vessels. This method is equally applicable in the case of *M. glaziovii*.

Duration of latex flow and total yield of latex collected on each tapping are influenced by various physiological and biochemical factors. In *H. brasiliensis* latex vessel turgor (P_{LV}) and latex vessel plugging (PI) are the two major factors reported to influence yield (Sethuraj, 1981).

Other factors like number and diameter of latex vessel rings are also influencing the yield. Since the anatomical features of the bark of *M. glaziovii* are more or less similar to those of *H. brasiliensis* the above factors may be of much relevance.

Turgor pressure of the laticifers is an important factor influencing the flow of latex. The laticifers are quite turgid in vivo, but keeping an equilibrium with the adjacent tissues. Opening of the laticifers results in the release of turgor pressure. Thus latex exudation is a pressure flow phenomenon. Gradually the flow stops because of the gradual reduction in pressure as well as flocculation and sealing of the cut ends of the laticifers. Boatman (1966) and Southorn (1969) have further explained the reasons for the cessation of latex flow in *Hevea*. When a cut is made on the bark of the laticiferous tree, latex flows out quite rapidly, because of the very high turgor pressure in the laticifers (Buttery and Boatman, 1964; Raghavendra *et al*., 1984). The rapid initial flow is also due to the elastic contraction of the walls, as the fluid cellsap of the laticifers is expelled after a sudden release in their turgor (Boatman, 1970; Buttery and Boatman, 1976; Gomez, 1983; Southorn, 1969). As the turgor pressure falls to low levels, further flow of latex will be slowly limited. The turgor pressure of various laticiferous plants were studied by different investigators (Table 10). The P_{LV} is very high (1.5 MPa) in H. brasiliensis and low (0.6 MPa) in Nerium oleander. M. glaziovii recorded a mean PLV of 1 MPa which is less than that in H. brasiliensis where the maximum P_{LV} reported is 1.5 MPa. Turgor pressure is an important factor which is easily influenced by the water relations of the plant (Buttery and Boatman, 1964; Gomez, 1983; Pakianathan et al., 1989). Though the initial flow rate is high in M. glaziovii it decreases rapidly and the flow ceases in about 10 to 20 minutes. While in H. brasiliensis the flow is prolonged to about 2-2.5 hours giving a high total volume. It is evident that the latex vessel turgor pressure is active only for a few minutes in M. glaziovii. Buttery and Boatman (1967) found that turgor pressure is a clonal character and varies from clone to clone. In the wild seedling trees of M. glaziovii this variation has been observed. hence there is scope for improving the duration of latex flow through breeding and clonal selection.

A general concept on latex flow was proposed by Ariz (1928), Frey-Wyssling (1932) and Gooding (1952 a and b) on the basis of their studies conducted in Hevea. It was further modified with the evidence that latex flow is blocked by plugging of latex vessels after tapping (Boatman, 1966; Buttery and Boatman, 1967). A physical plug forms near the cut end of the latex vessel and blocks further flow of latex and finally the exudation completely stops (Boatman, 1966; Southorn, 1969). The total yield of a latex yielding tree is thus determined by the initial rate of flow and the rate of plugging. The PI may be changed by environmental stresses, especially water stress and exploitation techniques (Raghavendra, 1991). In M. glaziovii a high plugging index is recorded in the location where soil moisture was more due to distributed annual rainfall. Ideal soil and good rainfall are totally unsuitable to ceara rubber (Wickham, 1908). Whereas Hevea performs well only in such conditions. Prolonged severe soil moisture stress and high summer temperature are the major environmental constraints for growth and productivity of para rubber. Effects of these adverse conditions on growth of Hevea (Sethuraj et al., 1989; Bhaskar et al., 1990) and effects of extreme stress conditions on yield and yield components etc. are well studied (Gururaja Rao et al., 1988; Devakumar et al., 1988; Vijayakumar et al., 1988). Though the initial flow rate is satisfactory for the first five minutes in M. glaziovii, it contributes little to the total volume of latex. In M. glaziovii unlike in Hevea the flow stops within 10 to 20 minutes and spontaneous coagulation takes place blocking the latex vessels. This flow restriction mechanism is due to certain particles contained in the latex, which in turn influence plugging. Detailed investigations on the physiology of latex flow in *M. glaziovii* are needed to find out the components responsible for high latex vessel plugging and spontaneous coagulation.

The physiological basis of yield potential of high yielding and low yielding clones of *Hevea* had been studied by Sethuraj *et al*. (1973). It was found that the initial flow rate was positively correlated with yield and the plugging index was negatively correlated. With this view point the high PI and low yield of *M. glaziovii* can be interpreted in another way. When tapping is done, the flow of latex is rapid, but the latex on contact with the humid air, starts forming a film of coagulated latex. This film formation continues resulting in total coagulation of the naturally thick latex. This peculiarity was observed in the latex collected. That the latex in *M. glaziovii* coagulates on adding water strongly indicates that water or humidity play major role in the spontaneous coagulation. This is in sharp contrast to the nature of latex in H. brasiliensis where coagulation takes place only with the help of a coagulating agent, the commonly used ones in commercial practice being dilute formic acid or acetic acid.

The latex vessel rows also influence yield. In Hevea, the correlation analysis between the rows of latex vessels and yield and between the rows of latex vessels and initial flow rate, showed that the number and rows of latex vessels were positively correlated with both yield and the initial flow rate. In M. glaziovii however the latex vessels apparently are not influencing PI, but contributes towards initial flow rate.

Beaufils (1957) and d'Auzac (1960) have investigated the reasons for premature coagulation of latex at the tapping panel and reported that it is associated with high magnesium content and Mg/P ratio. It has been observed that Hevea clones with low P/Mg ratios in latex have a tendency for higher plugging index (Yip and Gomez, 1980). Magnesium content of 2280 ppm estimated in the fresh latex of M. glaziovii may be one of the major reasons for the spontaneous coagulation and low yield.

Yield

The dry rubber recovered from the latex exuding out on tapping is the true measure of the productivity. In the ceara rubber tree, productivity is dependent on many factors. Of the several factors influencing the total quantity of dry rubber, volume of latex obtained on tapping, the dry rubber content of the latex, girth and bark thickness of the tree and the environmental condition to which the tree is exposed to are important. Above all, the genetic constitution of each individual genotype is all the more important. The extent and nature of the laticiferous tissue, especially of the bark, are also factors which govern productivity.

The data generated from the present study bear ample testimony to the potentialities of M. glaziovii as an alternative source of NR and also point out to the vast scope for productivity improvement through conventional genetic recombination and selection. It has to be remembered in this context that almost exclusively NR of commerce is obtained from a single species, H. brasiliensis and also that little attention has been given to M. glaziovii either in India or abroad. As such the stage which M. glaziovii now has can be compared with the pre-commercialisation status which H. brasiliensis had during the latter half of the 19th Century.

That vegetative means as can be assumed, is an effective method of propagation and establishment of a more or less uniform population of *M. glaziovii*, has immense significance and potentialities. The mean monthly yield of the trees, in Location I, which are resultant of propagation through cuttings exhibited only a narrow range from 4.19 to 5.59 g per tree per tap. The coefficient of variation in yield between plants is low (7.8 to 16.4 per cent) which indicates that the tree to tree variation in yield is negligible. Monthly variation in yield also followed the same trend. The mean yield ranged from 2.58 g recorded during the month of July to 5.76 g per tree per tap obtained during March. The quarter June to August showed the period of lowest production, the yield of rubber per tree per tap being only 3.47 g. The period December to March was the high yielding season, the mean yield per tree being 5.49 g per tap (Table 14). The quarter June to August, which recorded considerably low yield, enjoyed maximum precipitation. The total rainfall obtained during this period was 2563 mm, distributed in 82 raining days. The relative humidity was also high during this period.

In the case of *M. glaziovii* only July, June, August and May recorded in order; a production less than that of the mean monthly production during the year. This is in sharp contrast to the situation in the para rubber tree H. brasiliensis, where all the months from February to August recorded a production less than that of the monthly average (Rubber Board, 1993). The production was minimum during February followed by March, June, July, April, August and May in order. The monthly contribution trends towards annual dry rubber yield in M. glaziovii and H. brasiliensis are presented in Fig. 14 and Fig.24 respectively. NR being a vitally strategic industrial raw material, steady assured supply round the year is always welcome. In a situation where proper package of practices for M. glaziovii is developed and the species cultivated on a commercial scale, the low production from one during a particular part of the year can be compensated by the comparatively high production from the other on a complementary basis.

Compared to the more or less uniform population in Location I, the standing trees in Location II were highly variable in nature. M. glaziovii is a cross fertilised species, with a long life cycle. The species is thus highly heterozygous because of the breeding behaviour and seed propagation under natural

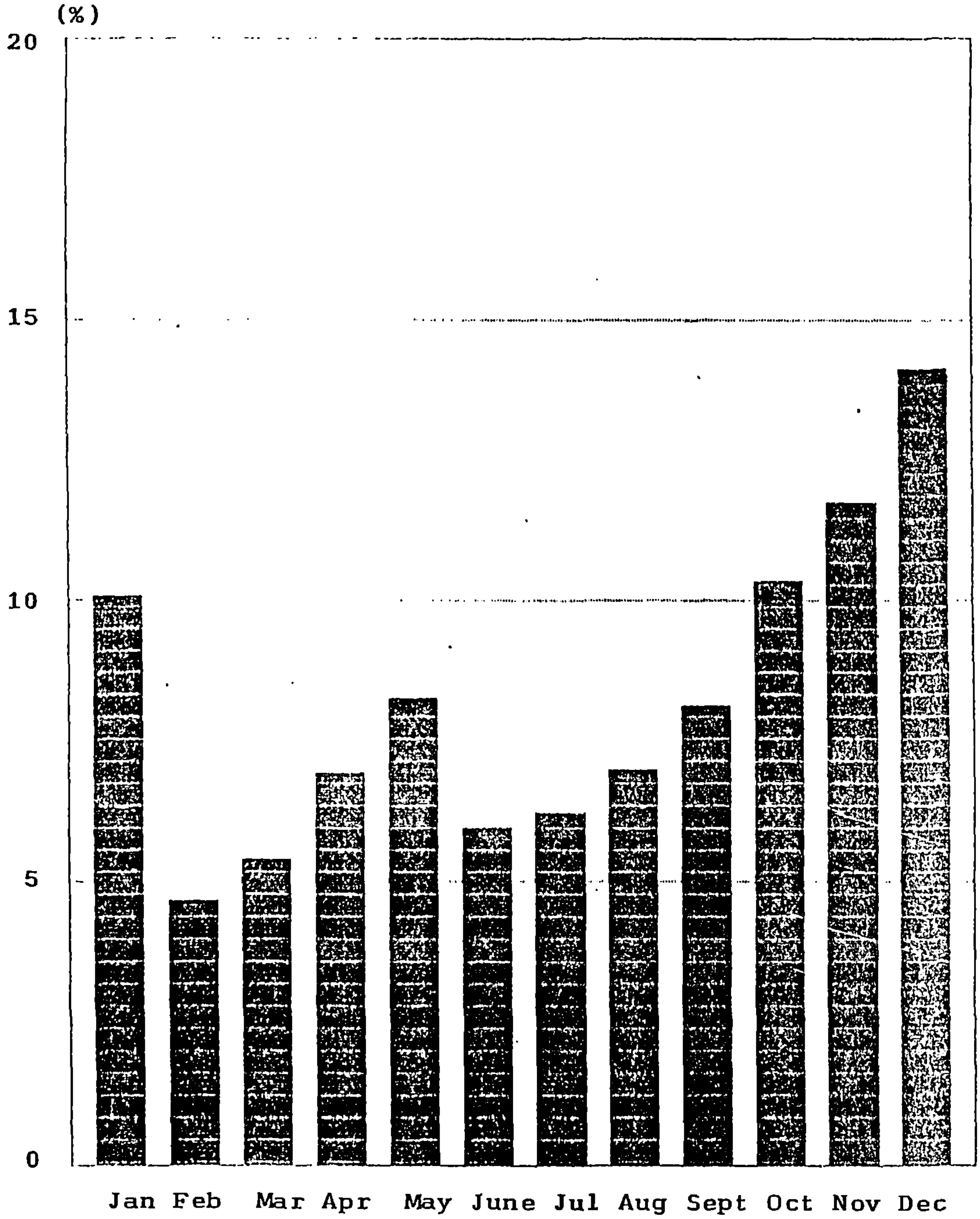


Fig. 24. Monthly contribution (%) towards annual dry rubber yield in H. brasiliensis

condition. While the mean DRC of the latex from the trees of Location I and II did not differ much, being 23.6% in the former and 23.44% in the latter tree to the variation was very vide in Location II. Variation in DRC ranged from 21.7 to 25.7 in the first Location. Compared to this variation in the other location was from 15.0% to 33.1% with 60% of the trees having a DRC less than the mean of the population. Dry rubber yield and volume yield of latex also showed the same trend. These observations clearly show that the population of M. glaziovii in Location II are having high genetic variation. Compared to the limited germplasm resources available in H. brasiliensis in the early part of genetic improvement programmes (Schultz, 1977; Swaminathan, 1977; Panikkar et al., 1980 and Annamma, 1992), the germplasm resources of M. glaziovii available within the country at present is very rich. Volume of latex and the dry rubber it contains are important factors governing dry rubber yield (Sethuraj, 1968, 1977, 1992; Sethuraj and Usha, 1980). In Location II, 2% of the population contributed to 27.8% of the total rubber yield of the population. Serier (1988) has reported that 1% of the trees in a population of M glaziovii was outstanding. These observations open out the immense scope for genetic improvement in *M. glaziovii* by judicious planning of parental combinations and vegetative propagation of the highly promising recombinants.

The average productivity of the *M. glaziovii* population in Location I was estimated to be 701.19 g per tree per year (Table 15). Considering a stand of 450 trees per hectare, this works out to an estimated productivity of 315 kg dry rubber per hectare. Genetic improvement of the species and adoption of scientific methods of cultivation can improve productivity substantially has been clearly established in the case of *H. brasiliensis*. The productivity was only 284 kg per hectare per year in 1950-51, which improved to 1154 kg during 1992-93 (Rubber Board, 1994) during a span of less than 50 years. Carefully planned tree improvement programme, if implemented scientifically, can be expected to result in the identification of superior genotypes in *M. glaziovii* as well in a reasonable span of time.

The uncared seedling genotypes of *M. glaziovii* in Location II amounts to around 2000 seedling trees. Even the observations of a few randomly selected seedling trees have indicated an yield variation from 4.21 g per tree per tap to 10.55 g tree per tap. In the case of volume yield the range has been from a lowest of 15 ml per tap to 47 ml. In the case of drc the minimum recorded was 15.0%, the maximum being 35.5 percent. Systematic observations of the population, based on factors like total volume, dry rubber content, tree girth, etc, which directly influence yield can be thought of as a means of identifying superior genotypes in this wide range of genetically different tree population. That propagation by cuttings can easily be adopted, the time involved in bringing out potentially promising selections can be drastically brought down. During the early phase of the cultivation of the para rubber tree, identification of elite trees form among genetically divergent seedling populations and establishment of primary clones had paid rich dividents (Dijkman, 1951). In fact this method of ortet selection is even now adopted for establishment of location specific cultivars in H. brasiliensis in almost all NR research institutions.

5.5. Characterisation of latex and rubber

Properties of latex

Like most colloids latex from glaziovii is white in colour and its general appearance is similar to that of Hevea latex. At least in the latex stage the non-rubber constituents in Manihot latex are not found influencing its colour. No significant variation in colour was observed among the individual trees.

The viscosity of a liquid is a measure of its resistance to flow. *Manihot* latex is having a viscosity in the same range as that of *Hevea* latex. Generally viscosity of a rubber latex increases with its rubber content (Blackley, 1966). However, in the present case *Manihot* latex is found having a slightly higher viscosity in spite of a lower rubber content. It is believed that the comparatively higher viscosity of *Manihot* latex is contributed mostly by its higher non-rubber content.

Specific gravity of *Manihot* latex is very nearly unity. However, compared to *Hevea* latex this is slightly higher, in spite of the fact that the specific gravity of dry sheet rubber prepared from *Manihot* latex is very close to that of *Hevea* rubber. It may also be noted that the drc of *Manihot* latex is lower. It is therefore inferred that the higher specific gravity of *Manihot* latex is contributed by the presence of non-rubber constituents.

Both total solids content and dry rubber content are found to be lower in the case of *Manihot* latex. However, it may be noted that the *Manihot* trees were tapped almost daily during 1993 for these investigations, while the *Hevea* trees were tapped only on alternate days. Tapping intensity has been reported to be one of the important factors contributing to the solids content of *Hevea* latex (Jacob *et al*., 1989). One of the most significant differences between latex from *Hevea* and *Manihot* is the markedly higher non-rubber solids content in the latter. This is found to be more than double the value obtained in the case of *Hevea*. It must be pointed out here that the actual non-rubber solids content of the latex is much higher than the values shown in Table 18, as the drc film obtained from the latex still contains substantial quantities of non-rubber constituents.

The non-rubber solids content of the *Manihot* latex comprises mostly proteins, resins and minerals.. Proteins and resins are associated more with the rubber particles as is indicated by the substantially higher protein and acetone extractable content of the sheet rubber (Table 20). The size of rubber particles in *Manihot* latex has been reported to be in the range of 600-1800 A as against 1000-15000 in the case of *Hevea* (Stavely *et al*., 1961). The lower average particle size causes association of a higher non-rubber content with the rubber phase as the non-rubber solids are forming a protective layer over the particle surface.

Although _Manihot_ latex is coagulated by formic acid and acetic acid, coagulation is not found complete, with the serum remaining slightly turbid. It is probable that the higher protein content of the latex is responsible for the incomplete coagulation by acids. It is also probable that the isoelectric point of the proteins in _Manihot_ latex is lower than that of the proteins in _Hevea_ latex. As the latex is coagulated by acids, it is inferred that the particles in _Manihot_ latex are negatively charged.

Manihot latex is found to undergo spontaneous coagulation as in the case of _Hevea_ latex. Spontaneous coagulation is caused by the action of bacteria on the carbohydrates in latex. It is found that spontaneous coagulation takes place in _Manihot_ latex almost at the same rate as in _Hevea_ latex. Spontaneous coagulation of latex could be followed by changes in viscosity. Figures 16 and 17 show the changes in viscosity during storage of _Manihot_ and _Hevea_ latices respectively. The figures indicate that spontaneous coagulation is a slow process and takes place over a period of 7-8 h.

A very significant observation is the coagulation of _Manihot_ latex upon dilution with water. Diluted latex, upon storage, rapidly thickens and finally forms of a lump of coagulum. In the case of

Hevea latex also dilution with water causes an increase in viscosity initially which disappears on further dilution. It is known that when latex is diluted, the lutoids burst releasing their content (B-Serum) which consists of an acid serum enriched with divalent cations (Ca^{++} and Mg^{++}) and cationic proteins. B-serum is thus capable of provoking formation of microflocs of rubber particles (Southorn and Yip, 1968) causing the viscosity of latex to increase. It is probable that the lutoid content of *Manihot* latex is much higher and that its B-serum contains sufficient cationic proteins and divalent cations to cause complete coagulation of latex. The fact that *Manihot* latex contains a substantially higher magnesium and calcium supports this. It is also seen from Table 20 that the concentration of magnesium and calcium in the dry sheet rubber from *Manihot* latex is very close to those of the total solids film. This clearly indicates that both magnesium and calcium are getting chemically linked to the rubber particles on coagulation, further supporting the conclusion that coagulation of *Manihot* latex is resulting from the action of divalent metal ions released into it by the bursting of the lutoid particles on dilution.

Properties of total solids film from latex

The total solids film, prepared by drying the latex, is the right material for studying the chemical composition of latex. The film obtained from Manihot latex is found to be coherent, as in the case of Hevea latex. The colour of the film was, however, found to be much darker in the case of Manihot. It was also found to be less transparent. Both these differences are contributed by the higher non-rubber content of Manihot latex.

The chemical composition of Manihot latex is significantly different from that of Hevea latex. The difference is clearly observed with respect to the protein and resin contents. The total mineral content of Manihot latex also is higher than that of Hevea latex. The mineral composition is also different. One of the important observations is that copper content is much lower in Manihot. This might be caused by the fact that no copper based fungicide was applied for Manihot. The most significant difference between the two latices is the concentration of magnesium, which is almost four times its concentration in Hevea latex.

Properties of dry rubber

Table 20 summarises the properties of sheet rubber prepared from the two latices. When graded by the visual grading system the sheet prepared from Manihot latex was found to belong to RMA 3 while that from Hevea latex RMA 2. The difference in the grade was mostly due to its darker colour and lower transparency. Thus the presence of higher non-rubber constituents causes downgrading of Manihot rubber, unless adequate precautions are taken to remove most of the non-rubber constituents while preparing sheet. Dirt content was found to be slightly higher in Manihot rubber. As both the sheets were prepared under identical conditions of sieving and sedimentation, the higher dirt content could be resulting from the higher viscosity of the latex after dilution which causes the sedimentation process slower. It is also possible that some of the proteins and resins in the rubber get precipitated and form part of the dirt content.

The appearance of an off-white powdery deposit on the surface of sheet, subjected to stretching, is also caused by the non-rubber constituents in the Manihot rubber. This fact is confirmed by the fact that the intensity of the deposit decreases with higher dilution of latex before coagulation and thorough washing of the wet sheet.

A substantial portion of the proteins in the latex is associated with the rubber particles and hence even after conversion of latex into sheet through coagulation, about 45 percent of the original protein content is found retained in the rubber. This is found to be to the same extent in both the rubbers. However, as the original protein content in Manihot latex is much higher, a proportionately higher protein content is observed in the sheet prepared from it.

Ash content of Manihot rubber is found to be higher than that of Hevea rubber. But it is substantially lower than that of the total solids film. This shows that a major portion of the mineral matter is remaining dissolved in the serum and are removed during preparation of sheet rubber. A closer examination of the results indicate that the percentage retention of ash in the sheet rubber (compared to that of the total solids film) is higher in Manihot (26 percent) than in Hevea (12.8 percent). This indicates that more mineral constituents are associated with the coagulum in the former than in the latter.

PRI is a measure of the resistance to oxidation and this is found to be significantly lower in the case of Manihot rubber. Lower PRI is usually attributed to the presence of proxidants like copper, manganese and iron (Watson, 1969). The lower PRI of

Manihot rubber is believed to be due to the higher manganese and iron contents. It is also possible that the natural antioxidants are less in *Manihot* rubber or those which are present, are less effective.

Results from the accelerated storage hardening test indicate that *Manihot* rubber possesses constant viscosity character. When *Hevea* rubber is stored, its viscosity is found to be increasing. This phenomenon of storage hardening is known to involve carbonyl groups in rubber, since hardening is almost fully suppressed by the addition of reagents that could block carbonyl groups (Wood, 1953; Sekhar, 1962). The fact that the plasticity of *Manihot* rubber does not increase significantly during accelerated storage suggests that carbonyl groups are less in *Manihot* rubber. This is a striking superiority of *Manihot* rubber. In the case of *Hevea* rubber, in order to achieve stable viscosity, it is necessary to add special reagents like hydroxylamine salts into latex before coagulation. The results indicate that this is not necessary in the case of *Manihot* rubber.

The FT-IR spectra of both the rubbers are shown in Figures 20 and 21. The spectra are very much identical. Therefore, it is concluded that the chemical structure of *Manihot* rubber is identical to that of *Hevea* rubber. The viscosity average molecular weight of *Manihot* rubber is also found to be very close to that of *Hevea* rubber.

Processing properties

Mooney viscosity values of the mixes from *Manihot* rubber are found to be slightly lower than that of the corresponding mixes from *Hevea* rubber, in spite of the fact that the former had a higher Mooney viscosity in the raw stage. This suggests that the rate of mill breakdown is higher in *Manihot* rubber. The vulcanization behaviour, including scorch time and optimum cure time are more or less identical in both the rubbers.

Physical properties of vulcanizates

The gum vulcanizates of *Manihot* rubber were found having higher modulus and hardness. This is believed to be due to the presence of higher concentration of non-rubber constituents like proteins.

With the addition of carbon black, the difference in the modulus and hardness of the vulcanizates was found to be disappearing. Tensile strength was found to be lower in the case of *Manihot* rubber. The addition of black did not cause any significant increase in tensile strength. The reasonably high tensile strength of the gum vulcanizate indicates that Manihot rubber also is capable of undergoing strain crystallisation as in the case of Hevea rubber.

Manihot rubber has been found to be slightly inferior to Hevea rubber with respect to tear resistance, resilience, heat build-up and abrasion resistance. The lower resilience and the higher heat build up might be resulting from the higher protein content of Manihot rubber. Crack growth resistance was found to be higher for this rubber. Resistance to Ozone and thermo-oxidative ageing have been found to be more or less identical in both the rubbers.

5.6. Ceara rubber wood and seed oil

The survey of literature reveals that the information on the structural features and utilization of ceara wood is still obscure. Hence the present study also aims at the understanding of certain physical properties, anatomical features and the capacity of wood for chemical impregnation of water borne wood preservatives.

Ceara wood is diffuse porous. It is a very light hard wood according to the classification suggested by Findlay (1975) and Bhat (1985) based on the basic density values of wood. In comparison to Hevea wood, which also is a light hard wood, the basic density is lower in ceara wood. The attractive white yellowish colour, medium coarse texture and straight grains of ceara wood, similar to that of Hevea wood, indicate its potentialities for various end uses.

The fibers are long and broad in ceara wood with an average value of 1577 µm and 30 µm respectively which are higher than that of Hevea wood. The fiber length of H. brasiliensis wood varies from 1189 µm to 1500 µm (Guha and Negi, 1969; Silva, 1970; Bhat et al., 1984; Reghu et al., 1989) with an average width of 27 µm (Reghu et al., 1989). This dimensional feature of ceara wood may be attributed to its potential use as a raw material for pulp industry.

Unlike Hevea wood, the wood of M. glaziovii is characterised by the absence or rare occurrence of tyloses in the vessel lumen. This special feature of ceara wood indicates its premeability and penetration capacity of wood preservatives during chemical impregnation. It has been reported that the presence of numerous tyloses in the vessel lumen usually makes the wood less permeable to liquids and preservatives (Kramer and Kozllowiski, 1960; Akachuku, 1985). The chemical impregnation of water borne boron compounds by vacuum pressure method done in the present study also justifies the high 'through and through' penetration capacity of ceara wood.

The major demerits of ceara wood noted from the present study is its susceptibility to fungus and insect attack and the occurrence of tension wood similar to that of Hevea wood. The susceptibility to fungus and insect attack may be due to the presence of high soluble sugar and starch contents and also due to the absence of heart wood formation. This defect can be rectified by means of chemical impregnation of wood preservatives. Tension wood formation is a common natural defect of various hard wood species which ultimately affects the seasoning property of wood during drying and the intensity of this defect can be minimised up to a certain extent by adopting controlled seasoning schedules during the course of wood drying.

In this context it may be recalled that during 1950's Hevea wood has been considered unimportant in the replantation scheme (Silva, 1970) and were being used only as fuel wood. But in recent years, it has been well proved that Hevea wood could be upgraded as a substitute for quality timber after appropriate preservative treatments and seasoning (Teik, 1982;

Gnanaharan and George Mathew, 1982; Hedley, 1987; Hon *et al*., 1982; Tisseverasinghe, 1969; Sonti *et al*., 1982). Now-a-days, though *Hevea* wood is a light hard wood, it is being used as a potential raw material for various wood based industries such as match industry, packing cases, plywood, composite wood, furniture, textile accessories and even for building constructions (Todd, 1970; Sekhar, 1989).

The inadequate availability of good quality timber and its ever increasing demand will always necessitate search for alternative source of timber. Ceara wood may be a potential timber for various wood based industries, if and when available on a large scale, after adopting appropriate prophylactic and preservative treatments.

Seed oil

M. glaziovii flowers profusely and sets seeds. *Manihot* seed is a potential source of oil. It was observed that one tree gives about 250 g of seeds per annum. Assuming a stand of 400 trees per hectare about 100 kg of seeds could be expected from 1 hectare of *M. glaziovii* plantation.

The average seed weight is 0.57 g. The kernel accounts for around 20 percent of the weight of seed.

Thus, the yield of kernel is estimated to be in the range of 20 kg per annum. The oil content of the kernel has been tested and found to be 40.88 percent by weight. Therefore, 20 kg of kernel may give an yield of about 8 kg of seed oil. The annual yield of oil from one hectare of *Manihot* plantation is thus estimated to be approximately 8 kg.

The important physical properties of the seed oil are given in Table 26. Properties of the seed oil from *Hevea* have been reported by Pushpadas *et al.* (1980) and are reproduced in the same table for comparison. Iodine value and sopanification value of the *Manihot* seed oil are found to be very close to those of *Hevea* seed oil. The high iodine value indicates that the oil is a semidrying one and hence could find applications in paints and also in the plastics industry. The acid value of the oil is found to be much lower compared to that of *Hevea* seed oil. However, it must be pointed out here that the *Manihot* seed oil was tested immediately after extraction, which could be one of the reasons for the low acid value obtained.

CHAPTER 6

SUMMARY AND FUTURE PROSPECTS

6. Summary and future prospects

Natural rubber is one of the most important raw materials of plant origin. Statistics reveal that during 1992 the country's consumption was 414,105 metric tons of NR, while the production was only 393,490 metric tons, creating a gap which demanded import. The only species cultivated for NR is *Hevea brasiliensis*, a tree native to the Amazon rain forests. Scarcity of suitable land and the peculiar agro-climatic preference of the species limits its cultivation. More over the crop is being threatened by various diseases and environmental stresses.

Under such a situation, the search for a potential alternative source was carried out and *Manihot glaziovii*, a species belonging to Euphorbiaceae has been sorted out after screening a number of laticiferous species and detailed observations were carried out on its potentialities as an alternative source of NR.

The main reasons for the selection of *M. glaziovii* (Ceara rubber) for this study are its (1) early introduction (1902) and acclamatisation, (2) adaptability to the most harsh drought affected marginal lands, (3) simple and inexpensive cultivation and maintenance, (4) easy exploitation facility, (5) cis-poly isoprene rubber content in the latex, (6) afforestation and biomass deposits, (7) xerothermic habit and (8) it fulfills the requirements for a 'life support species' for para rubber.

The yield data collected from the ceara rubber trees selected for the study, showed that the intrinsic potential is about 310 kg per hectare per year. This is comparable to the yield of H. brasiliensis of the pre-crop improvement stage of 250 kg per hectare. Rubber yield has increased ten times during the last 35 years. The studies on M. glaziovii reveal that the species is amenable to genetic improvement for various yield contributing factors.

The thermotolerance of M. glaziovii is the most attractive character to propose it for the semi-arid regions. Even under such environment the tree retains life saving moisture and produces latex.

The biomass production of the species throughits shoot and leaf shedding habit enriches the degraded soil.

The bark of M. glaziovii is smooth and soft and thereby exploitation can be done easily. The number, density and diameter, etc. of laticifers have influence on yield and can be improved through breeding.

The waxy analogue of the hard and peelable periderm and flaky rhytidome, large and elongated lenticells, high bark moisture percentage, etc. in *M. glaziovii* are certain important characters revealing its xerothermic habit.

Investigations on the yield influencing factors have revealed that *M. glaziovii* has high plugging of latex vessels, short duration flow, high magnesium content in the latex, lesser number of latex vessels, slightly higher level of non-rubber constituents in the latex etc. These characters show genetic variability and offer scope for genetic improvement.

The species can be propagated both through seeds and by vegetative means. Pests and diseases are comparatively few that it warrants no expensive plant protection operations.

Exploitation of the tree also is comparatively easy, that no mechano-chemical methods are needed. By simple tools latex can be collected.

Rubber obtained from *M. glaziovii* is structurally comparable to the rubber from *H.*

brasiliensis. Appearance of the rubber also is very similar to that of Hevea rubber. The main differences are the higher non-rubber constituents and the consequent influence on properties like modulus, resilience and heat build-up. The rubber does not undergo any significant level of hardening during storage and in this respect it is found to be similar to the viscosity stabilised grades of Hevea rubber. Latex of M. glaziovii is found to undergo coagulation on dilution with water. This could be advantageously used for the production of sheet rubber. In general it is revealed that the rubber from M. glaziovii could very well be used as a substitute for Hevea rubber.

M. glaziovii being a species which thrives well under semi-arid and marginal situation, is particularly important for a country like India. One third of the area in the country is subjected to characteristic features of aridity (Fig.25) and it is (CAZRI, 1979) estimated that 956,750 sq. km. enjoys semi-arid conditions (Bhandari, 1991). Quite a good portion of this area could be brought under crops specifically adapted to these zones with appropriate package of practices. Even then a substantial portion could be left uncovered. Even if it is assumed that only one percent of this could be brought under ceara

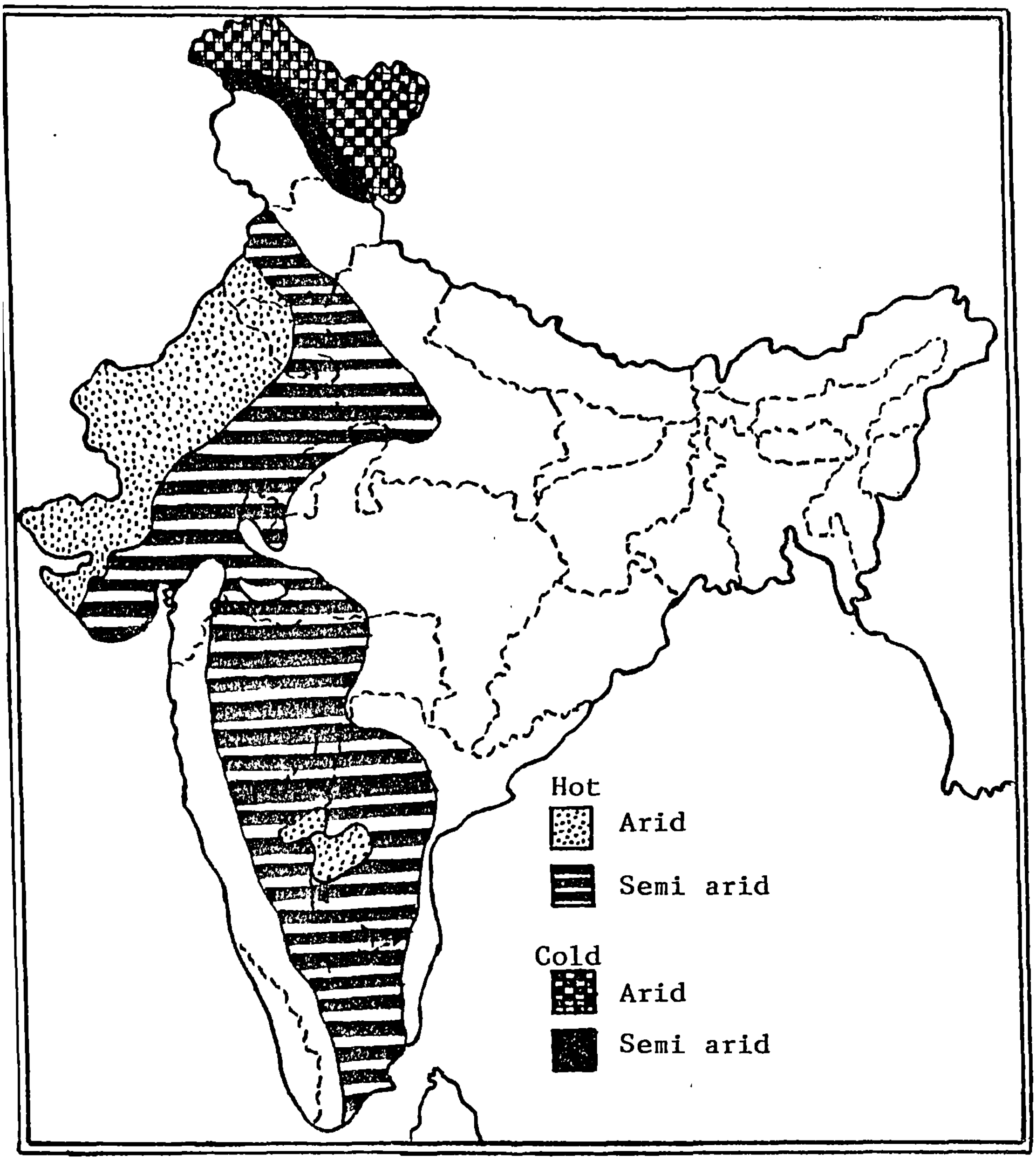


Fig. 25. Extent of semi arid zones in India

rubber, the extent is enormous being 9,567.5 sq. km or over 9.5 lakh hectares. This is substantial considering that the present area under the para rubber in the country is only just 5 lakh hectares (Rubber Board, 1994).

It is possible that M. glaziovii could be bred for improved rubber yields and quality. If this were done using the available genetic resources, ceara rubber could provide a part of the country's rubber requirement, without encroaching the fertile land occupied by other crops or causing any change in the land use pattern.

A major source of hydrocarbon whether it is low molecular weight or high molecular, is petroleum, which is now widely believed to run out within few decades. Exploitation of this source also affects the environment in different ways. So a plant, that produces hydrocarbon warrants immediate attention.

As an alternative source of natural rubber M. glaziovii thus holds bright potential in view of its adaptability to semi-arid and marginal situations, easy exploitation, non-cumbersome post harvest technology and immense scope for genetic improvement in yield and yield contributing factors.

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APPENDIX I

Authors publications on *M. glaziovii* (Ceara rubber)

George,P.J., Panikkar,A.O.N. and Joseph,G.M. (1980). *Manihot glaziovii*: Rubber yielding plants other than *Hevea brasiliensis*. In: *handbook of Natural Rubber Production in India*. Rubber Research Institute of India, Kottayam, India.

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CEARA RUBBER (Manihot glaziovii) : A DROUGHT RESISTANT TREE FOR SEMI ARID AND MARGINAL AREAS

(P.J.George, Deputy Director, Germplasm Division)

The Ceara rubber tree (*Manihot glaziovii* Mull. Arg.) is a native of the Brazilian province Ceara, was one of the source of natural rubber in the early part of the Century. The tree was exploited in Brazil as wild rubber for a long period, even before it was botanically identified.[14] The species was discovered by Dr.Glaziovii, a French Botanist, in the neighbourhood of Rio de Janeiro, and was described and named after him by Mueller.

M. glaziovii is a member of the family Euphorbiaceae to which the *Hevea* rubber tree belongs. Though the origin of the genus *Manihot* is in the Ceara Province and the nearly provinces of Piavi and Bahia of North-East Brazil, its geographical distribution extends from California Bay up to Peru[15]. The best known species of the genus is *Manihot esculenta*, otherwise known as Cassava or tapioca. Though the earlier investigation, reported that there are 200 species under the genus[12], Rogers and Appan (1970) reported that there are only 98 species under the genus *Manihot*.

The certain regions of the north-east Brazil, to which *Manihot* belongs are characterised by irregular rainfall and very harsh climate. The annual average rainfall of this region is 600-700 mm with the extremes ranging from 0-1400 mm. The altitude goes up to 1000 m MSL.

Manihot grows well in dry rocky ground, and so can be cultivated in areas unsuitable for most other crops[5]. In the province of Ceara, it is reported that the plant thrives well in semi arid regions and even in granitic rocky areas. The plant resists the driest weather, and when every other form of vegetation is destroyed under the influence of the scorching wind, it thrives and yields generously a profitable quantity of latex[14].

Manihot glaziovii has been introduced to India during 1877-78. It was brought to Kew in 1876 by Robert Cross, and later in 1877, the plants were sent to Singapore, Calcutta and Ceylon. Again in 1878, planting materials were brought from Kew to Madras and Calcutta[15]. The quick growth and easy propagation of ceara rubber attracted the attention of many. The only literature available on its cultivation in India is the reports appeared in the Bulletin of the Imperial Institute[1]. The report contains the analytical results of ceara rubber samples collected from Kallar and Burliar Estates in the Nilgiris.

Certain drawbacks of ceara rubber compared to the advantages of para rubber pushed aside its cultivation and caused gradual disappearence from the scene. Though the plant thrives well, the humid climate is unfavourable for rubber production, while under the same climate *Hevea* gives more rubber. The spontaneous coagulation of the latex is another drawback. In this context, it is worth mentioning the opinion of Sir Henry Wickham, "the Ceara, named after the Brazilian province of that name, is a tree of quite different character. Its native locality is high, stony, arid and in places almost semi desert," scrub" covered country. The latex from ceara rubber tree is like that of *Hevea*, and if properly cured, the rubber resultant therefrom is remarkable for its strength and tenacity. In the East, it has never, as yet, I think, had justice done by it. It has too often been set out on land, and under rainfall, totally unsuited to it. In Ceylon especially, there are large areas of dry forest lands, which should be admirably adapted to this tree, and considering the high quality of the rubber when well cured, it would, surely, better planted out in such districts, closely resembling as thereby do the natural requirements and conditions of this tree, rather than to try to plant the *Hevea*, a tree native to the heavy rainfall of the Amazon Valley"[17].

During 1903 to 1912 a considerable quality of ceara rubber had been exported from Brazil.. This was mainly due to the attention given to Ceara rubber, when the *Hevea* plantations were badly affected by SALB (South American Leaf Blight).

Manihot glaziovii, Muell. Arg. is a tall tree attains a height of 10 to 15 m, with a ramified branches and branchlets. The leaves are palmately lobed with three lobes, rarely 2-7 lobes of oblong oval shape, glabrous and light green in colour. It produces profuse flowers in about 1½ years. Flowering is usually seen after the prolonged wintering period. Flowering commences by June, after the full refoliation. Flowers are unisexual with the male flowers clustered at the top of the panicle. The fruit is a three lobed globular capsule distinguished by six grooves. The seeds are comparatively small, oval plano-convex about 12-15 mm long and 7-8 mm broad, with a tough, brilliant, mottled integument.

100 gm of seeds contain about 175 nos. of fresh seeds. Manihot can be propagated through seeds and vegetative cuttings.

The tree attains an average girth of about 50 cm within a period of around 4 years. The bark of the mature trunk is covered by a peelable rhytidome, which is thin and leathery. Beneath the rhytidome, the smooth and soft bark appears with scattered lenticells.

The rhytidome helps the tree to retain moisture in the bark, even during the hottest weather. The bark is sufficiently thick that tapping cut can be done easily. Though the trees were exploited long back, there is no record of a proper tapping system followed for ceara rubber. However it withstands a 'V' cut and gives a quick flow of latex but coagulates within few minutes. The response of the tree to different tapping intensities and stimulation is yet to be studied in detail.

The latex is white, thick with an average drc of 30. For processing, no need of adding acid. Just bulk the latex with sufficient water and keep in a dish for overnight, and the latex coagulates perfectly. Preliminary studies and previous reports [1,8] showed that the dry rubber is exactly similar to

Hevea rubber in its properties.

M. glaziovii gives only a very low quantity of latex per tree per tapping. The earlier report gives an indication that its potential is 415 Kg per hectare per year. Unlike in *Hevea* and Guayule, there are only wild trees in *Manihot*. No high yielding strain is developed through breeding and selection or as vitroplants.

But during our exploration to the Mettur forests, we come across wild trees with yield variation from 8 gm to 10 gm per tap. This preliminary survey indicates that there are genetic materials having a potential of around 500 kgs/ha/year. Five hundred kilograms potential exhibited by stray trees growing in a drought affected granitic hill of 3500 ft., with scanty rainfall, without undergoing any crop improvement attempts, points to the chances of giving more economic yield if proper crop improvement programmes are attempted.

Besides rubber, the wood also is good for similar uses as that of *Hevea*. The seeds contain more than 40% oil, which once used as fuel for the Brazilian motor vehicles. The leaves of ceara rubber contain 25-30% protein in dry matter, which after the removal of hydrocyanic acid, is considered to be a good cattle fodder[15].

M. glaziovii is now being used in India by the Tuber Crops Scientists as a source of Cassava Mossaic Virus (CMV) resistance [6,11] and as an alternate host-plant for honey-bee, at the Rubber Research Institute of India[10].

The once discarded guayule (*Parthenium argentatum*) with all its low production potential and cumbersome process of extraction is now gaining attention in the USA, with huge research backing[3], as an alternative source of natural rubber. Why not we too have an alternative source for NR? The accidental introduction of a spore of *Microcyclus ulei* (SALB) can easily bring down out rubber production from *Hevea* plantations[2,162] to the lowest level. This is evident from the report that the *Hevea* plantations of Amazon basin, even up to 1978 gave only 250 kg/ha due to the infection of SALB[15]. We have not reserved any life support plant to overcome such situations[4].

The xerothermic character of *M. glaziovii* is well evident from reports and from the experience we had during our exploration. If one could pinpoint the gene responsible for the 'xerothermic' character in such plant species, it may be a valuable tool for the genetic engineering in the field of gene transfer technology to synthesise transgenic plants adapted to environmental stress including green house effect[9].

The tree needs the immediate attention of the rubber researchers to investigate the possibilities in the following fields:

1. Selection of plus trees from the available semi-wild seedling population located in Tamil Nadu.
2. Breeding value of the plant and its multiplication techniques.
3. Suitable tapping method and stimulants.
4. Investigations to overcome the problem of spontaneous coagulation, rubber synthesis, etc.
5. Testing the selected genotypes in the drought prone marginal lands.
6. Technological properties of the rubber.
7. Economic utilisation of the bye-products like wood and seed oil.

The vast stretches of semi-arid barren land with its thousands of starving human population, is waiting for a suitable parasol. It may be rewarding if selected strains of M. glaziovii is planted and evaluated in such locations.

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COLLECTING CEARA RUBBER (*Manihot glaziovii* Muell. Arg.) AND ITS POTENTIALITIES

P.J.George* and C.P.Reghu**
Rubber Research Institute of India, Kottayam - 686 009

ABSTRACT

The restricted cultivation of *Hevea brasiliensis* in the tropical zones due to its agroclimatic preference, necessitates an alternative source of natural rubber for the semi-arid marginal lands. Preliminary studies showed that *Manihot glazio*[illegible] known as ceara rubber, is a potential plant [illegible] such semi-arid marginal lands. The plant was introduced to India in 1902 during the regime of the British. It is well adapted to the dry granitic high lands with scanty rainfall. Under such stress affected conditions the unselected wild plants yield an appreciable quantity of latex containing more than 80% rubber. Since there is no organised cultivation of *M. glaziovii* in India genetic materials are not commonly available An exploration to the semi-arid hill tracts of Tamil Nadu resulted in the discovery of a large semi-wild seedling population. Mature trees were tapped at random and on the basis of the preliminary observations on the bark characteristics, latex flow pattern and morphological variation germplasm of ten genotypes were collected and brought to the Rubber Research Institute of In[illegible] for

* Deputy Director, Germplasm Division, RRII
** Botanist, Germplasm Division, RRII

multiplication and further studies.

Natural rubber is one of the most important raw materials obtained from plant sources. Among the 35000 laticiferous species reported, only 2000 contain rubber hydrocarbon in their latex (Pradhan, 1982). Natural rubber is used as an industrial raw material for manufacturing more than 30,000 various products. The most important economic source of natural rubber is Hevea brasiliensis (Para rubber) which is a crop adapted to specific agroclimatic conditions and hence its cultivation is restricted to certain regions in the tropical zone.

The demand for natural rubber is ever increasing, while the production is not in proportion to it. Average production of natural rubber in India during 1992-93 was 394000 metric tonnes against the domestic consumption of 414000 metric tonnes (estimated). India is ranked fourth among the natural rubber producing countries.

For every crop an alternative source or life support species is highly necessary. Moreover it is today's need to cultivate the marginal lands and upgrade the poor soil with those species adapted to the extreme hostile environment. Such species could be utilised in times of need (Randhawa 1987, Paroda 1987, Smith 1987). The major rubber yielding crop *Hevea* is under a potential threat from South American Leaf Blight (SALB caused by *Microcyclus ulei* (Thomson 1986, National Acad. Sci. 1977). The increasing demand for natural rubber and paucity of suitable areas, warrants the identification of a suitable stress tolerant species adapted to the drought prone semi-arid marginal lands (Menon 1983).

Under this circumstances, *Manihot glaziovii* (ceara rubber was examined as the potential alternative rubber yielding plant with certain extent of drought tolerance. *M. glaziovii* was one of the sources of natural rubber in the early part of the Century (Seeligman, 1910, Polhamus, 1962). It is a native of the Central regions of NE Brazil and introduced to India in 1902 (Serrier, 1988).

There are reports on the occurrence of few trees of *M. glaziovii* in different parts of South India (Umrao, 1983). It is also grown in the Central Tuber Crops Research Institute, Trivandrum for cassava breeding purpose. Two other species viz., *M. dichotoma* ule and *M. piuhyensis* ule are also reported to be available in the Botanical Gardens at Calcutta and Bangalore (CSIR 1962).

EXPLORATION AND COLLECTION

We explored a large seedling population of *M. glaziovii* growing in a semi-arid condition, varying from huge trees to small seedlings, in the Mettur Hills of Tamil Nadu. This hill station is situated about 60 km from Salem District and is a continuation of the Yercaud-Shevroy Hill tract. We identified 50 seedling trees and conducted a preliminary screening. Out of this 10 genotypes were tentatively selected on the basis of certain attributes, and collected germplasm.

COLLECTOR'S SHEET

Expedition	:	Indigenous
Team/collector's name	:	P.J.George and C.P.Reghu
Date of collection	:	March 1993
Species name	:	*Manihot glaziovii* Muell. Arg.
Common name/local name	:	Ceara rubber Manicoba rubber Komputhookki (Tamil)
Locality	:	Mettur Hills, Salem District Tamil Nadu
Altitude	:	1100 m. MSL
Rainfall	:	1133 mm
Soil type	:	Granitic

Material/samples collected	:	Vegetative cuttings, seeds, Flowers, bark, latex coagulum, wood.
Status	:	Wild
Accessions collected	:	IC 101, 102, 103, 104, 105, 106, 107, 108, 109, 110.

02, 103, 1(

RESULTS AND DISCUSSION

M. glaziovii is a quick growing tree belongs to the family Euphorbiaceae. It thrives well in areas where soil is degraded and rocky. Adversities like low rainfall, low humidity, drought and other stress environments seldom affect the survival of the plant. It can grow well at high altitude up to 1800 m MSL.

The tree grows to a height of 8-12 m with ramified trichotomous branches and canopy. Girthing of the trunk is fast that it attains 40-50 cm at 4th year. It can be propagated through seeds as well as through vegetative cuttings. Wintering starts from January to April and flowering follows after refoliation. Flowering has also been observed (George 1993). The trunk of the trees is almost straight, covered by a leathery, peelable rhytidome under which the smooth bark is visible with numerous lenticels.

Leaves are alternate, oblong-oval and palmately lobed. Leaf lobes vary from 2-7. Flower are monoceious and unisexual. Male flowers are seen at the top of the panicles. Female flowers are located at the lower pedicels. Flower colour varies from white to violet. Flowering starts at the age of 18 months.

Fruit is a capsule with three locules. Seeds are small, plano-convex, with mottled tough tegument. Each seed weighs about 0.58 gm. The endosperm contains about 40.88% oil.

Bark of M. glaziovii is smooth and soft beneath the rhytidome. Bark colour varies from white to green. The green bark contains chlorophyll. Bark retains moisture during drought season (George, 1993).

The laticifers in M. glaziovii are compound, articulated and anastomosing as in Hevea. The inter-connected latex tubes are sandwiched with secondary phloem elements (Scoor 1884, George 1993). Table 1 depicts the variation in the girth, bark thickness and bark anatomical traits of samples collected from Mettur hills.

The trees can be tapped for latex collection, when they attain a girth of 40-50 cm at a height of 100 cm from ground level. The rhytidome has to be removed prior to tapping from the portion of the trunk marked for opening the channel. The tapping channel may be opened at a slope of 30°, using a Jebong knife. Half spiral cut and 'V' shaped cuts also can be tried. During every latex collection operation, the channels are to be reopened by shaving off a thin layer of bark. Tapping may be done on alternate days. The latex thus oozing out will be directed through a spout to the collection cups.

Table 1. Variation in the girth, bark thickness and bark anatomical traits

Tree No.	Girth (cm)	Bark thickness (mm)	No. of latex vessel rows	Density of latex vessel/ mm circumference of the plant	Diameter
1	112	15	19.7	34.0	17.39
2	107	16	29.7	36.0	16.45
3	130	18	10.0	35.4	18.36
4	112	16	25.5	32.6	13.79
5	115	16	11.6	36.0	14.[illegible]
6	142	15	24.5	47.4	14.40
7	140	16	8.0	39.4	16.20

The wild population of *M. glaziovii* showed wide variation in their various characteristics like bark colour, latex flow duration, volume of latex, rubber content etc. Dry rubber yield varies from 4.6 g to 10 g per tree per tap. The estimated potential yield is 276 to 600 kg/hectare per year.

Latex is milky white and thick. Unlike in *Hevea,* the latex flow is affected by spontaneous coagulation. Preliminary studies showed that low latex vessel turgor and high plugging index (PI) are certain prominent adverse characters present in the species.

Table 2. Latex flow characteristics of *M. glaziovii*

Tree No.	Initial vol. of latex ml (5 mts)	Total vol. of latex (mm)	Plugging index	Dry rubber
1	7	15	9.33	7.97
2	22	32	13.75	9.04
3	23	47	9.78	. 10.55
4	11	22	10.00	7.81
5	11	30	7.33	7.37
6	24	33	14.55	6.92
7	20	34	11.76	7.78

It has also been observed that upon dilution with water the viscosity of latex increases significantly eventually resulting in coagulation.

Properties of air dried sheet prepared from *Manihot* latex have been assessed in comparison with that of *Hevea* latex. The appearance of sheet rubber is similar to that of *Hevea*. However, ash content (1.18%) and nitrogen content (0.99%) of *Manihot* rubber are higher than that of *Hevea* rubber. Acetone extract is significantly higher (5.64%) in the case of the former indicating a higher concentration of resins.

M. glaziovii can be listed as a potential alternative source of natural rubber. Ceara rubber plantation will be a solution for the afforestation of marginal lands with degraded soil unsuitable for other crops. The drawbacks experienced in latex production can be eleminated through breeding and selection. No crop improvement attempt has so far been made with a view to increasing rubber production in *M. glaziovii*. Genetic resources available at stray locations have to be collected and conserved before they are destroyed. Breeding cycle and selection constraints can be reduced considerably due to the early flowering habit and vegetative propagation facilities.

It may also provide employment and earnings to the marginal land dwellers. Important technological properties of *Manihot* rubber is comparable with that of *Hevea* rubber. In addition to rubber, the tree yields wood and seed oil. Ceara rubber Garden is the most ideal place for bee-keeping (Nehru, 1989).

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