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HEVEA GERMPLASM AND IT'S POTENTIAL

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Rubber (*Hevea brasiliensis*) is the third largest plantation crop in Sri Lanka next to Tea and Coconut. For several years, Geneticists and Plant Breeders have emphasized the need to conserve *Hevea* genetic resources and to widen the genetic base of breeding populations used by the natural rubber producing countries. Rubber breeding in Sri Lanka is largely based on a small population of about 1919 seedlings introduced in 1876 from Wickham collection. It is believed that Sri Lanka was the centre of distribution of rubber plants to other South East Asian (SEA) countries. Further, introduction of new material from natural habitats has been restricted due to the fear of accidental introduction of South American Leaf Blight (SLAB) to this region. Therefore, the genetic base in the original population is narrow.

Directional selection during last 80 years of breeding for few economically important characters such as yield, growth, vigour and disease tolerance and also extensive use of clonal vegetative propagation has led to further erosion of genetic variability. Consequently, problems related to breeding and selection of *Hevea*, such as inbreeding depression which lead to declining yield response are becoming more apparent.

Most *Hevea* breeders believe that they have exploited the maximum genetic variability of Wickham's original introduction and have reached the threshold point with respect to economically important characters such as yield and vigour. *Hevea* breeders felt the need for exploration, collection and conservation of *Hevea* genetic material to widen the genetic base of present breeding populations. Necessity for such action becomes even more important as natural stands of *Hevea* in Amazon region are endangered by extensive felling of jungle land, for agricultural purposes.

What is germplasm of *Hevea*

The range of variability of genus *Hevea* found in it's natural habitats is the germplasm of *Hevea*. It is essential to conserve and maintain the germplasm in it's natural habitat (*in situ*) as well as the primitive agricultural systems (*ex situ*). For any plant breeding programme, it is necessary to maintain a constant flow of genes into the breeding population from other sources such as the germplasm collected, in order to prevent a decline in the efficiency of that programme.

The genus *Hevea*

Among the different cultivated sources of natural rubber (Gayule, Castella, Ficus, Funtumia, Landolphia, Manihot Taraxacum, Crypostegia.....) *Hevea*, is the commercially established rubber tree, and it contain 11 species which are rather difficult to distinguish from each other and natural hybridizations are very common

among them (Table 1). Because of its economic interest (quality and quantity) *Hevea brasiliensis* mainly located in the south of the river Amazon has become the most commonly used species for natural rubber in the Amazonian forest and apparently the sole species represented in the material introduced to Asia by Sir Henry Wickham in 1876. However, *Hevea benthamiana* and *H. guianensis* too were largely used in older times (Wycherley, 1977a).

Table 1. *Allied species of genus* Hevea – *Occurrence and their characteristics*

Species & Authority	Occurrence	Features*
H. benthamiana Muell. Arg.	North and West of Amazon forest basin, upper Orinoco basin (Brazil)	Complete defoliation of leaves. Medium size tree. Habitat: swamp forests.
H. brasiliensis (Willd. ex. A. de. Juss.) Muell. Arg.	South of Amazon river (Brazil, Bolivia, Ecuador, Peru)	Complete defoliation of leaves. From medium to big tree size. Habitat: well drained soils.
H. camargoana Pires	Restricted to Marajo island of Amazon river delta (Brazil)	Possibility of natural hybridization with *H. brasiliensis* From 2m to 25m tree height. Habitat: seasonally flooded swamps.
H. camporum Ducke	South of Amazon between Marmelos and Manicoré rivers tributaries of Madeira river.	Retains old leaves until new leaves appear. Maximum 2m tall. Habitat: dry savannahs.
H. guianensis Aublet	Throughout the geographic range of the genus (Brazil, Venezuela, Bolivia, French Guyana, Peru, Colombia, Surinam, Ecuador)	Retains old leaves until new leaves and inflorescences appear. Grows at higher altitudes (1100 m MSL) Medium size tree. Habitat: well drained soils.
H. microphylla Ule	Upper reaches of Negro river in Venezuela. It is not found in other region of geographic range of the genus	Complete defoliation of leaves. Small trees. They live on flooded areas (igapós). Habitat: sandy or lateritic soils.
H. nitida Mart. ex Muell. Arg	Between the rivers Uaupes and Icana tributaries of the upper Negro river (Brazil, Peru, Colombia).	Inflorescences appear when leaves are mature. Small to medium size trees (2m). Habitat: quartzitic soils.
H. paucíflora (Spr.ex Bth.) Muell. Arg	North and West of Amazon river (Brazil, Guyana, Peru). Distribution discontinuous due to habitat preferences.	Retains old leaves until new leaves and inflorescences appear. No wintering. Small to large trees. Habitat: well drained soils, rocky hill sides.

Species & Authority	Occurrence	Features*
H. rigidifolia (Spr. ex Bth.) Muell. Arg	Among Negro river and its affluents. Uaupes and Içana rivers (Brazil, Colombia and Venezuela).	Retains old leaves even after inflorescences appear. Small tree from savannahs. Sometimes tall, with small crown on the top. Habitat: well drained soils
H. spruceana (Bth.) Muell. Arg.	Banks of Amazon, Rio Negro and lower Madeira (Brazil)	Retains old leaves until new leaves and inflorescences appear. Flowers reddish purple. Medium size tree. Habitat : muddy soils of islands
H. paludosa Ule	Marshy areas of Iquitos, Peru	Small leaflets, narrow and thin in the fertile branches; up to-30 m. height. Habitat: marshy areas.

(Source - http://www.ecoport/Interactivetable. htm)

Center of diversity of *Hevea*

Geo-morphologically the centre of diversity is near the northern margin of the Amazon basin where the upland of Guyana shield rise. The approximate limits of distribution of the species are given in Fig. 1. Within these limits, all of them are

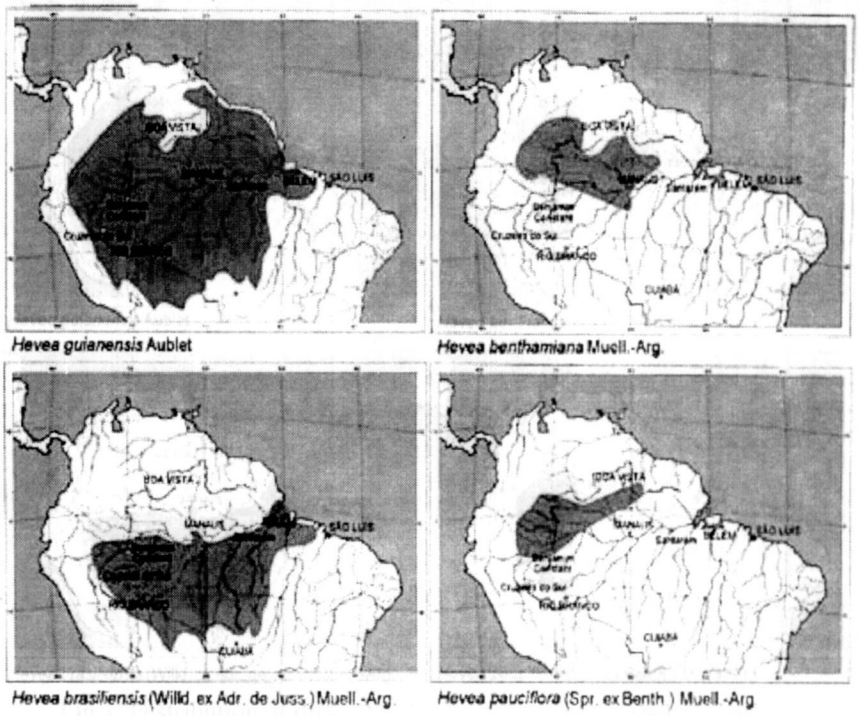


Fig 1. Distribution of different *Hevea* species in the Amazon valley
(Source - http://www.ecoport/Picture2.htm)

restricted to some degree by habitat preferences. Therefore, *Hevea* appears to have evolved under almost constant humid climate, but where edaphic and topographic conditions give rise to some variety at soils and ecological habitats. The constant humid climate means that new foliage will almost certainly be borne under conditions favoring attack by fungal diseases and some degree of resistance would seem essential for survival. The species extending beyond the region surrounding the centre of diversity have adapted progressively to more seasonal conditions and a long dry period each year. Seasonality may coordinate change of foliage and flowering (Wycherley, 1977b).

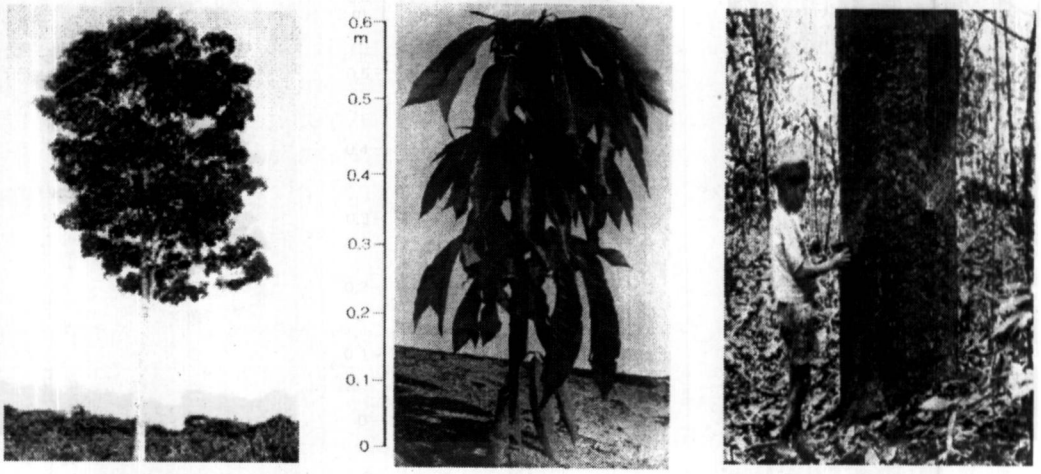
Growth forms of *Hevea*

When the growth form is considered, there is considerable variation in height and inter node lengths within the species. There are genotypes of very tall (up to 40m), dwarf and semi-dwarf characteristics (Fig. 2).

In general, the different species and varieties have preserved their relative growth forms in cultivation. It has been indicated that if these variants were used as root-stock, they would induce similar growth forms in scions. But, some characteristics such as swollen trunk, shown by some species are not induced by rootstocks in nature, as they normally happen in response to environmental conditions such as flooding.

As far as the pattern of growth is considered, the occurrence of short shoot or spur type growth in *Hevea* is seen in which the internodes were strongly compressed and marked by scale leaves. This feature is not conspicuously developed in the best known species *H. brasiliensis*. It appears that generally in those species in which short shoots are transient, poorly developed and inconspicuous, the trees "winter" that is, all the foliage falls and the trees are bare for a brief period before new shoots extend bearing young foliage distally and scale leaves proximally, the later often bearing flowers in their axils. Whereas in those species in which short shoots are well developed and obvious, the new shoots emerge bearing flowers and foliage before the old leaves fall. However, some time the old foliage falls before the new shoots emerge even in some trees displaying conspicuous short shoot development. This may be expected to enhance "disease-escape" in the case of SALB or other leaf diseases.

All species of *Hevea* have trifoliate leaves which are folded back at emergence. Subsequently, the leaves assume various positions, shapes and some features. The shape of leaf varied from long narrow tapering convex to broad convex. Other shapes such as oval-shape, pear-shape, boat-shape and elliptical-shape were also discerned (Fig. 3). Leaf margins of the leaves were from smooth to wavy. The length of petioles also differed considerably; they could be long, medium or short. The leaf-stalks range from well distributed to cluster. Some other features like reddish brown pubescence underside of leaflets, glabrous beneath leaflets, leathery leaflets *etc.* are also present.

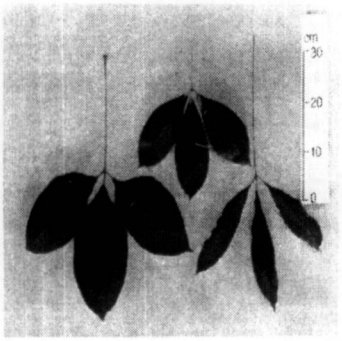


Tall form (40m)

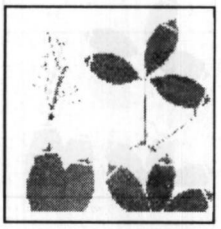
Compact dwarf form (0.6m)

H. brasiliensis var. *subconcolor* (diameter is about 4 ft)

Fig. 2. Some growth variations of the genus *Hevea*



Three examples of variation in leaf shape and size from the germplasm collection



H. brasiliensis

H. guianensis

H. pauciflora

Fig. 3. Variation of the leaves of different species of *Hevea*

Floral biology of the species

In all species of *Hevea* there are separate male and female flowers borne in the same inflorescence, the latter terminating the main branches of the panicle (Fig. 4).

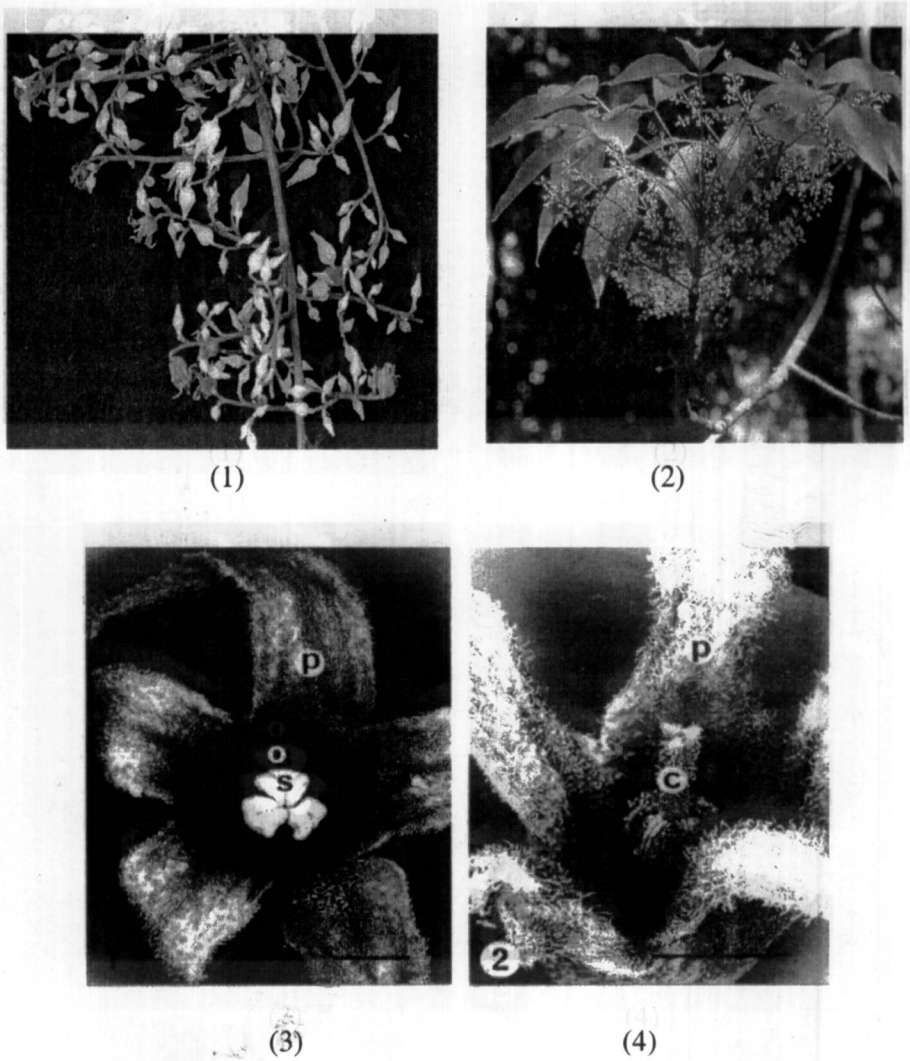


Fig. 4. Floral characteristics of *Hevea* **1 & 2.** Inflorescence of both male and female flowers are present, **3.** Enlarged photograph of male flower **4.** Enlarged photograph of female flower

The un-opened buds, open flowers and central axes of the two sexes are together distinctive of each species (Fig. 5). In both sexes of all species there are five perianth lobes. The central axis of male flowers is occupied by the staminal column and in female flowers the pistil is in this position. A disk is found at the base of the

central axis. The disk may be strongly or weakly developed. Among the largest flowers in the genus are those of *H. spruceana*, whose flowers are moreover purplish in colour, unique in the genus. The flowers of other species are green or yellow. The number of anthers range from 5 to 10 in one regular or irregular whorls or two regular or irregular whorls. In *H. brasiliensis* there are normally 10 anthers in two whorls, which may be regular or irregular.

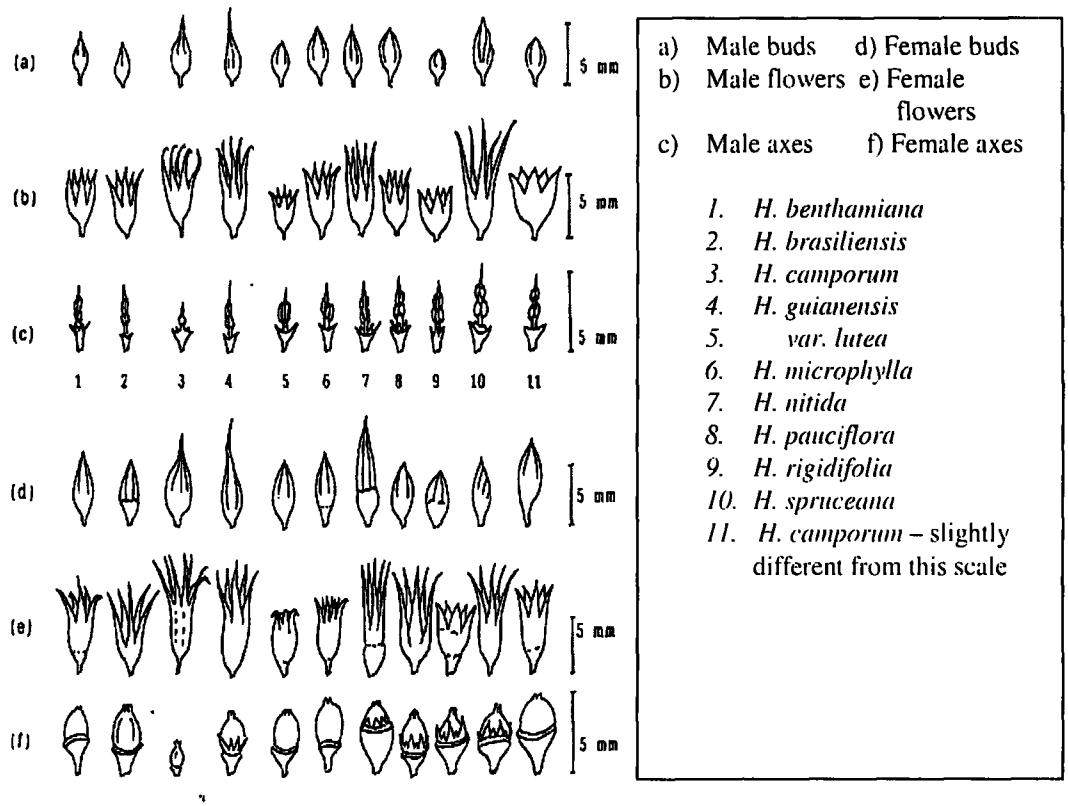


Fig. 5. Un-opened buds, open flowers and central axes of the two sexes of *Hevea* flowers

(Source - http://www.ecoport/picture1.htm)

The fruit in all species is a trilocular capsule which usually contains three seeds (Figure 6). The fruit is explosively dehiscent in all except two species. The woody valves twist on drying and throw the seeds far out. The first exception is *H. spruceana* in which although the valves are woody, they do not twist strongly enough to throw the seed far. The other exception is *H. microphylla* which has thin leathery valves which open slowly. (http://www.PlantNationaldatabase/plant_profile.htm)

The shape of the seed in transverse cross section also vary

H. benthamiana - Rounded
H. brasiliensis - Rounded
H. camporum -
H. guianensis - Kite-shape
H. microphylla - Triangular-ovate
H. nitida - Kite-round (Kite shape in one end and rounded at the other)
H. pauciflora - Hexagonal
H. rigidifolia - Hexagonal
H. spruceana - Lozenge

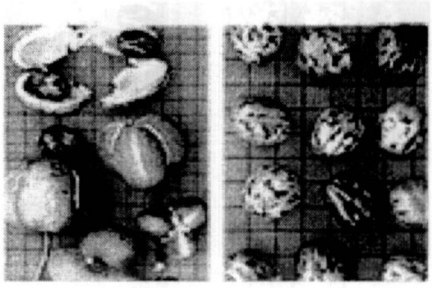


Fig 6. Variations of the fruit and seeds of *Hevea* species

Commercially accepted latex and rubber have been obtained from *H. brasiliensis*, *H. benthamiana* and *H. guianensis* in descending order of quality. The latex and rubber from *H. nitida* var. *toxicodendroides* is reported to be satisfactory in quality although the quality that could be harvested is less. Whereas, *H. nitida* itself yields latex which are not coagulated (anti-coagulant) and weak, poor rubber. *H. spruceana* and *H. pauciflora* produce latex with high proportion of resin giving poor quality. *H. microphylla* and *H. rigidifolia* latex also have a poor reputation and *H. camporum* does not seem to have ever been tapped. Within *H. brasiliensis wild trees*, we can observe variation in the colour of the bark *i.e.* black barked, red barked and white barked trees. A considerable variability has been reported in yields among them, blacked barked trees are reported more favorably yielded than red and white barked trees (Wycherley, 1977a) & (Schultes R.E. 1945).

Germplasm collection in Sri Lanka

The member countries of the International Rubber Research and Development Board (IRRDB) realized the importance of collection and preservation of a range of genus *Hevea* found in its natural habitats. In 1981, a team of scientists collected wild *Hevea* germplasm from Acre, Matto Grosso and Rodonia States of Brazil. Bud wood from this collection was distributed among the member countries of IRRDB. The accession numbers for theses collection were given based on the Estate

name and its District name which they were collected with some reference number (Table 2). Sri Lanka received around 10,000 accessions from this collection and they are planted in Nuechattle Estate of Kalutara District. The acquisition and the judicial use of the new germplasm in breeding programs had broadened the genetic base of *Hevea* breeding material.

Table 2. *Collection sites of* Hevea *germplasm and their acquisition numbers*

State	District	Acquisition number
1. Acre	1. Brasileia 2. Feijo 3. Sena Madureira 4. Tarauaca 5. Xapuri	1. AC/B/..... 2. AC/F/..... 3. AC/S/..... 4. AC/T/..... 5. AC/X/.....
2. Mato Grosso	1. Aracotuba 2. Cartriquacu 3. Itauba 4. Vila Bela	1. MT/A/..... 2. MT/C/..... 3. MT/IT/..... 4. MT/VB/....
3. Rodonia	1. Ariquemes 2. Calama 3. Costa Marques 4. Jaru 5. Jiparana 6. Ouro Preto 7. Pimenta Bueno	1. RO/AB/... 2. RO/C/..... 3. RO/CM/.... 4. RO/J/..... 5. RO/JP/..... 6. RO/OP/..... 7. RO/PB/..... 8.

(Western states of Brazil – Acre, Rodonia and Mato Grosso***)

*** Reason for selecting the these states –

1. The two states, Rodonia and Acre, are known to have vigorous and high yielding rubber trees and also reports indicate that Acre-rubber trees produce better quality rubber. Additionally, considerable variation in the species *H. brasiliensis* prevail in the forest of these states.

2. Accessibility to wild rubber trees, growing in these states is feasible since most of the forest areas are within reach of small towns and villages and are serviced by aerotaxis, boats and passable jungle tracks.

3. Ecological differences are also prevalent in the collection areas and the effects of these are considered important to plant breeders for their future work (Ong *et al.*, 1983).

Importance of having germplasm collection

To-date, we have achieved 5-6 fold increase in rubber yield by breeding and selection through existing Wickham collection. As a result of directional selection for a few economical important characters, the genetic base of the present rubber population has become very narrow. Therefore it is very important to incorporate wild genetic resources to the existing population to widen the genetic base.

Fig.7. Hand pollination; the way of improving existing *Hevea* gene pool

Hevea breeding programmes for disease resistant is one example of the importance of germplasm collecton. Some trees of *Hevea* displayed characters which are expected to enhance "disease-escape" in the case of SALB or other leaf diseases. Most of the natural rubber producing countries have serious disease problems which requires incorporation of disease resistant characters to the present breeding populations. Resistance may also found to be important in various insect pests such as Thrips and Mites.

So far, resistance has not yet been found against termites and root diseases. Among the wild relatives of *Hevea,* there may be some rootstocks which are resistant to root diseases and termites or plants which can withstand such damages. Therefore, it is very important to select suitable rootstock materials to present breeding population which are easily propagated and secure throughout the life of the plantation,

Some morphological characters of germplasm materials, such as dwarf or dumpy forms can be used to change the tree architecture suitable to plant them in high windy and hilly areas.

The potentiality of rubber timber for various industrial applications has been well established. However, the major limitation preventing the wide utilization of rubber wood is the formation of high proportion of unlignified or partially lignified tension wood fibers. In addition, low level of lignification of normal fibers and high susceptibility to biological deterioration due to low level of phenolic conversion of reserve metabolites into extractives are also reduce the quality of wood. As a result,

wood surface become lustrous, wooly and rough and it also reduces the physical, mechanical and strength properties (Reghu *et al.*, 2005). The process of tension wood formation is genetically controlled activity and therefore, there is some variation of wood quality among the plants of germplasm due to continuous exposure of high wind, prolong drought conditions and prolong flooded condition *etc.* Therefore it is necessary to explore such plant among the germplasm and incorporated in to present breeding population.

Among the *Hevea* germplasm collected, there is the possibility of having some genetic materials which can withstand adverse environmental conditions such as drought, extreme temperatures (high and low), high light intensities and high saline conditions *etc.* Therefore screening of germplam materials to find out such plants and incorporation of them in to present breeding population is of great importance. It will also help us in our attempts to expand the rubber cultivation into areas having such adverse environmental conditions.

Some physiological variations also, can be incorporated to the present breeding population from the wild relatives. For example; species where lattices are seems to be anticoagulant which indicates the possibilities of continuous flow exploitation, can be incorporated, if the tree can sustain such changes (Ong *et al.*, 1983).

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