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GUAYULE: AN OVERVIEW

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Introduction

Natural rubber is commercially obtained from the para rubber tree (*Hevea brasiliensis* Muell Arg). Guayule (*Parthenium argentatum* Gray) has been considered a viable natural rubber source in U.S.A, and Mexico since the beginning of the century. It is reported that guayule rubber contributed 10-20 per cent of the total rubber consumption in the U.S.A. during the early part of the century (Naqvi, 1983). In 1910 it provided 10 per cent of the world's natural rubber (George *et al.* 1980). It is estimated that from 1905, when the first successful guayule processing factory was established in Mexico, till 1945, when commercial production from guayule ended, a total of 125 million kilograms of guayule rubber was produced (Anonymous, 1981). However, interest in guayule dwindled after world war II, when natural rubber from *Hevea* and elastomers of synthetic origin were available in plenty (Anonymous, 1977).

Following the oil embargo and price squeeze on petroleum feedstocks by OPEC during 1973, there had been a revival of interest in guayule as a source of elastomers. Due attention was also given to R & D efforts, especially in USA and Mexico where several institutions are currently working on different aspects to develop guayule as a commercial crop. The significance attached to this species is evident from the expenditure on R & D efforts, the outlay for which was 4 million $ in the United States during 1981 (Baird, 1981). The studies mainly pertain to domestication, cultural practices, plant improvement, extraction procedures and many other related basic problems.

History

The history of guayule dates back to 1500 AD. Conquering Spaniards were the first to discover Aztec youths in Mexico, playing with bouncing balls. The natives obtained rubber from guayule by chewing of the stems (Anonymous, 1977).

Public attention to the commercial use of guayule rubber in the U.S.A. was apparently directed for the first time in 1876 (Llyod, 1911; Hammond and Polhamus, 1965; Hanson *et al.* 1979a) which lead to the establishment of many factories later. However, by 1912 many of the guayule processing mills were closed down due to depletion of the raw material, as the wild stand was continuously exploited and there had been no attempt for fresh cultivation or replanting. Subsequently, the Mexican revolution also put the mills out of business.

Restriction of rubber supply from the plantations in Malaysia by the British government in 1920s gave a boost to guayule rubber. At that time 3,240 ha of guayule was planted in California which produced 1.4 million kg of rubber. In 1942 a massive "Emergency Rubber Project" (ERP) was launched, when Japanese invaded South East Asia and blocked 90 per cent of the rubber supply to U.S.A. During this time 13,000 ha of guayule was planted and 1.4 million kg of resinuous rubber was produced. However, in 1943 production of synthetic rubber commenced and by the end of the war, when *Hevea* rubber from South East Asia re-entered the market, guayule production began to dwindle. In 1946 11,000 ha of guayule was burnt in U.S.A. However, during this time the U. S Department of Agriculture continued the investigation on guayule, though in a limited scale. This resulted in the development of deresination techniques and experimental production of heavy truck tyres which were road tested in 1953 (Anonymous, 1977).

Besides the U. S. efforts, attempts to cultivate guayule were made in Australia, Argentina, Spain, Turkey, Soviet Union and Israel. At present there are no commercial plantations in the world, except experimental plots raised in Israel, Arizona and California. An estimated 4 million ha with 2.6 million tonnes of guayule shrub stand are available in various states of Mexico. This is estimated to yield 30,000 tonnes of deresinated guayule rubber. A pilot plant for extraction of rubber was established in 1976 and tyres were manufactured which are now undergoing road tests (Anonymous, 1977). Recently, Good year company has produced 16 aircraft tyres exclusively from guayule rubber and U. S. Navy has successfully tested it in F4J Phantom II jet fighters and found that the guayule tyre performed well, compared to those made from *Hevea* rubber (Anonymous, 1983).

Systematic Position and Distribution

Guayule (*Parthenium argentatum* Gray) belongs to the tribe Heliantheae of the family Asteraceae. The genus name *parthenium* originated with Linnaeus in Species Plantarum and was based on two species, *P. hysterophorus* and *P. integrifolium* (Rollins, 1950;

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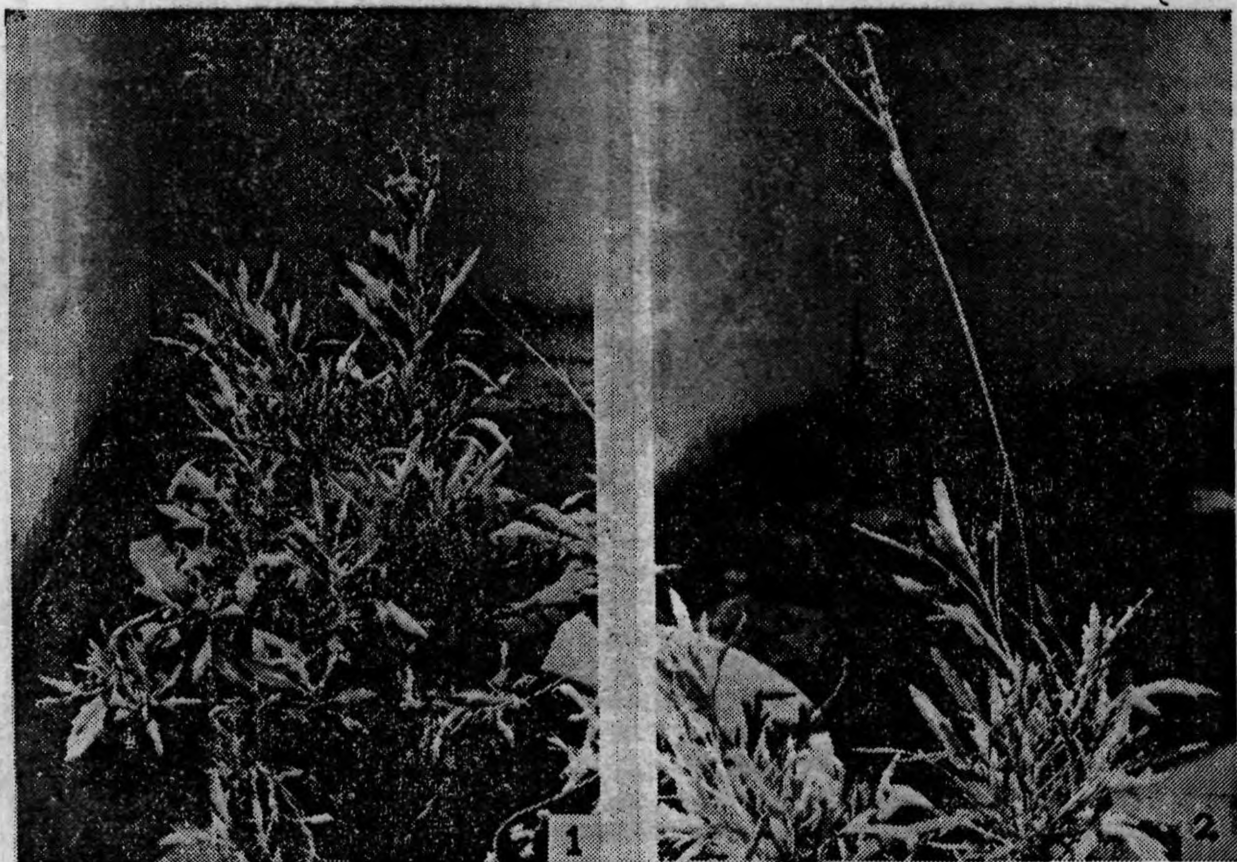
Polhamus, 1962). Guayule entered the formal literature of botany in 1852 when the famous physician and botanical explorer John Milton Beglow found it growing near Escondido Creek in Texas. Asa Gray, the distinguished Harvard botanist, gave the latin botanical name *P. argentatum* to this species, signifying the silvery sheen on the grey green leaves (Hanson *et al.* 1979 a). There are 16 species in the genus and *P. argentatum* is the only known species producing rubber. Several species cross freely with guayule and a few are employed in interspecific hybridization research.

According to Muller (1946) guayule is not a typical desert plant, but rather semi desert species. It is native to North Central Mexico and Southern Texas and is scattered through out 33,700 sq km of Chihuhuan desert. In the United States, the shrub is found wild in Transpecos area of Southwestern Texas at altitudes between 1,200 to 2,100 meters. The natural distribution of guayule is sporadic and patchy, generally restricted to calcareous slopes (Hanson *et al.* 1979 b; Naqvi and Hanson, 1980 a). The native habitat of guayule is classified as high desert (Hanson *et al.* 1979 b). However, the plant grows best in well drained soils and is adapted to a wide variety of shallow, stony, calcareous and friable soils (Anonymous, 1977).

Morphology

Guayule is a bushy perennial shrub, with narrow alternate leaves (Figs. 1 & 2). It attains a height of 30 to 90 cm, is hardy in nature and survives for 30 to 40 years under desert conditions where annual rainfall is less than 250 mm. (Anonymous, 1977). The plant develops a deep tap root, that may penetrate soil more than six metres, supplemented by extensive fibrous roots that may spread laterally upto three metres. This root net work allows guayule to absorb moisture from a large volume of desert soil and thus withstand periodic drought. (Anonymous, 1977).

Morphological studies were initiated at Los Angeles County Arboretum with the aim of identifying morphological characters which could be used as indicators of high rubber content of plants in native populations (Naqvi and Hanson, 1981). Mehta *et al.* (1979) studied over 75 native guayule plants and grouped them into three classes based on leaf trichome morphology. Rubber content in each group was also analysed. Group I plants have leaf margins entire to two-toothed. T-shaped trichomes were found with centrally attached stalk and cap cell with two blunt ends. Plants in this group contain 17 percent rubber. Group II plants have leaf margins entire to



four-toothed and T-shaped trichomes have an acentrally attached stalk and a cap cell with short end blunt, long end pointed and straight. Rubber content in these plants was 10 percent. Group III plants have leaf margins four to eight toothed. T-trichomes have an acentrally attached stalk and a cap cell with short end blunt, long end pointed end wavy or curved. These plants contain nearly six per cent rubber. Morphological as well as biochemical data indicated the presence of mariola genes in the last two groups of plants, which might had resulted in an increase in trichome length and a decrease in rubber content.

Anatomy

Anatomical criterion that has proved valuable for selecting plants with comparatively high rubber content is bark-to-wood ratio. Since most of the rubber is stored in phloem, selection for plants which have a high phloem-to wood ratio have yielded good results (Naqvi and Hanson, 1981). Most of the rubber in guayule is located in the vascular rays of the secondary phloem. In comparing the stem anatomy of the high and low rubber guayule plants many differences were observed. In high rubber guayule plants the ratio of secondary phloem produced in relation to that of the secondary xylem is higher, the vascular rays are entirely parenchymatous and the number of vascular rays is higher. It appears that plants with high rubber content have more parenchymatous tissues available for the storage of rubber as compared to those with low rubber (Naqvi and Hanson, 1981).

Mehta (1982) conducted a detailed study of stem anatomy of *P. argentutum* and *P. incanum* (mariola) and significant differences in structural details were found in these two species. As a result of introgression of mariola genes into guayule, three different forms of the latter exist in nature. The stem anatomy of these three groups of plants differ significantly. Group I plants have taller rays with cells of pith region and vascular rays parenchymatous. In group III plants a few to many cells of vascular rays and pith have lignified secondary walls and the rays are shorter. However, in group II plants the anatomical characters were intermediate between those in groups I and III. From this study, it was concluded that group I are the least introgressed by mariola, group III plants highly introgressed and Group II intermediate.

Ultrastructure

Gilliland and Van Staden (1983) observed one year old stem tissues of guayule under electron microscope and the rubber particles appeared electron opaque and membrane bound. They were abundant in the meristematic cells of bud and shoot primordia and in the epithelial cells of resin canals. Smaller vesicles filled with rubber was apparent in the parenchyma cells of cortex, pith and vascular rays. Chloroplasts were sparse in the stem tissue where most of the rubber occur. Backhaus and Walsh (1983) studied the ontogeny of rubber formation in guayule and found that rubber formation in stem first occurred in the cytoplasm of the epithelial cells surrounding the resin ducts and eventually in the cytoplasm of adjacent parenchyma cells. With age, rubber droplets appeared in the vacuole of both cell types. At maturity, rubber droplets increased in frequency and size, and most of the droplets occurred in each compartment-irregular or globoid in the cytoplasm and spherical in the vacuoles.

Rubber Content

Unlike in *Hevea*. rubber in guayule is contained in parehchymatous cells of the cortical tissues and medullary rays of stem and roots. There is no rubber present in the leaves. The rubber content is a measure of the total rubber present in a plant at any given time, being a measure of the amount of rubber that the plant has accumulated (Polhamus, 1962). Actively growing plants produce little rubber, but there is a gradual build up of rubber in the plant during the semi-dormant or apparently non-growing season. While all the factors which bring about this seasonal acceleration in rubber deposition are not known, it appears that the phenomenon is induced both by cool temperatures and high moisture stress. (Hall, 1981). This is supported by Goss Rachel *et al.* (1984) who found that there was two fold increase in rubber formation to that of control, in guayule plants exposed to a night temperature of 7°C over a period of 6 months. The control plants were maintained at 21-24°C night temperature,

Due to considerable genetic variability, rubber content varies within the species. Various strains cultivated in USA and Mexico were reported to have a potential of only 20% rubber after 4 years of growth, whereas those grown during 1940's had 26% rubber content (Naqvi, 1978; Mehta *et al.* 1979). Naqvi (1978) collected guayule samples from 53 locations in Mexico which showed a variability in rubber content from 9 to 19 per cent. Tipton and Gregg (1982) analysed 158 plants from ten native populations and found that their rubber content varied from 5 5 to 20.0% with a mean of 14.9 ± 2.4.

Earlier workers related rubber content to morphology of the plants. Artschwagar (1943) had shown that the rubber content of the plant is determined at least in part by the amount of parenchymatous tissue available within which rubber is stored. Aizpurua (1958) found that highly branched shrub types had higher rubber than the less branched tree types.

The rubber percentage in guayule stem at any one time depends upon temperature, light intensity, water availability, nutrition and any other factors which influence the growth rate and metabolic activities of the plant (Hanson *et al.* 1979 b). Growth analysis over a period of three years had shown that the rate of increase in rubber content was high in fall and winter than in spring and summer. It was further noticed that the onset of flowering period for the second year was marked by a decline in the rubber percentage of the plant (Naqvi and Hanson, 1981). Yokoyama (1977) found that specific bio-regulators when sprayed on guayule plant cause a dramatic increase in the rubber percentages of the stem and root tissues. He showed that 2-(3, 4, dichlorophenoxy-triethylamine) when sprayed to the growing plants at a concentration of 500 ppm, caused 2.2-6 fold increase in the amount of rubber present.

Rubber analysis

Analysis of rubber content is a very important aspect in guayule research. A modified procedure based on Traub's photometric analysis is followed at Los Angeles County Arboretum (Naqvi and Hanson, 1981). Other popular methods are C-13 NMR analsyis, the soxhlet extraction methods, blender analysis etc. In gravimetric assay, retention of resin in "deresinated" guayule tissues can lead to false high rubber value. Verbisacr *et al.* (1982) developed a faster and more complete extraction procedure employing solvents of enhanced selectivity. This provides a higher purity for isolated rubber for quantitation. Lorriane and Downes (1983) found that low-resolution proton magnetic resonance could be used as a rapid procedure for determination of rubber content in guayule.

Cultivation

(i) Soil and climate

Though guayule is native to calcareous soils it grows well on a range of soil types, provided they are permeable, well-drained and reasonable moisture content is available. Guayule grows well in soil pH ranging from 6.0 to 8.5 but growth is stunted at pH 4.5 or 10.5. Guayule does not appear to be very salt tolerant and it can stand only up to 0.3 per cent salt (Srivastava and Subrahmanyam, 1983).

Warm dry summers are conducive to growing guayule with a high rubber content. Moisture is perhaps the most important factor affecting guayule growth and an annual rainfall of 280-640 mm is needed for commercial production. Highest yield is obtained when guayule is grown under irrigated conditions. However, to meet the particular stress requirements for good rubber synthesis, dry season also appears necessary (Anonymous, 1977).

(ii) Propagation

Guayule is propagated mainly through seeds, though propagation through cuttings is also possible. seeds, are spread in flat trays filled with a mixture of peatmoss and vermiculite The Seeds germinate in two days and are ready for transplanting into small containers in eight days. Although guayule seeds can be planted directly in the field, production of seedlings first and further transplanting is preferred.

(iii) Green house management

Under green house conditions the germinated seedlings are transplanted first in 5 cm pots. For optimum growth, the seedlings require well-drained soils, fortified with essential nutrients and lime Both liquid and slow-release fertilizers are used (Naqvi and Hanson, 1980 b). For liquid fertilization, the media should contain sand and peat and 500g of superphosphate per cum of the media. Best growth is obtained when a modified Hoagland's solution is added.

Under proper green house conditions, the seedlings will be ready for field transplanting in 6-8 weeks (Naqvi and Hanson, 1980 b).

(iv) Flowering and fruiting

The capitula are borne on long stalks (fig. 2) and each head contains five fertile ray florets. Flowers and seeds are produced as early as six months after germination. Vigorously growing plants bloom and set seed continuously, throughout summer. It is estimated that guayule under irrigated conditions yield 1.5 x 10^8 achenes/ha (Hammond and Polhamus, 1965).

(v) Harvesting and seed storage

Harvesting of seed can be done by hand as well as by mechanical means. A method of mechanised harvesting, cleaning and pre-treatment of guayule seeds was devised by Tipton *et al.* (1981). Achenes are harvested with a vacuum insect net and cleaned by a series of screening, threshing and forced air separation. Seeds are treated with 0.5% sodium hypochlorite (Naocl) solution in a semi automatic system and finally dried and stored. Whitworth (1983) recovered 90% seeds with a germination percentage of 70-95 by simple mechanical means. Achenes are then treated with 0.53% Naocl solution, washed, dried and stored. It is mentioned that good viability can be retained for one year in this way. If the seeds are stored carefully in sealed containers, viability could be retained for several years. The seeds collected during ERP in late 1940's were successfully germinated recently at Los Angeles County Arboretum (Anderson, 1983). In Israel, over 90 per cent germination was obtained from 20 year old seeds (Anonymous, 1977).

(vi) Seed dormancy and germination

A major problem in guayule propagation is seed dormancy.

The delayed germination is attributed to an embryo dormancy of two months and the longer lasting action of seed coat. The delayed germination was partially overcome by various earlier workers using Naocl containing 1.5% available chlorine (Mc Callum, (1929) or storing the seeds for six months or treating the seeds 2-6 months after collection, with a solution of Naocl containing 5% available chlorine (Benedict and Robinson,

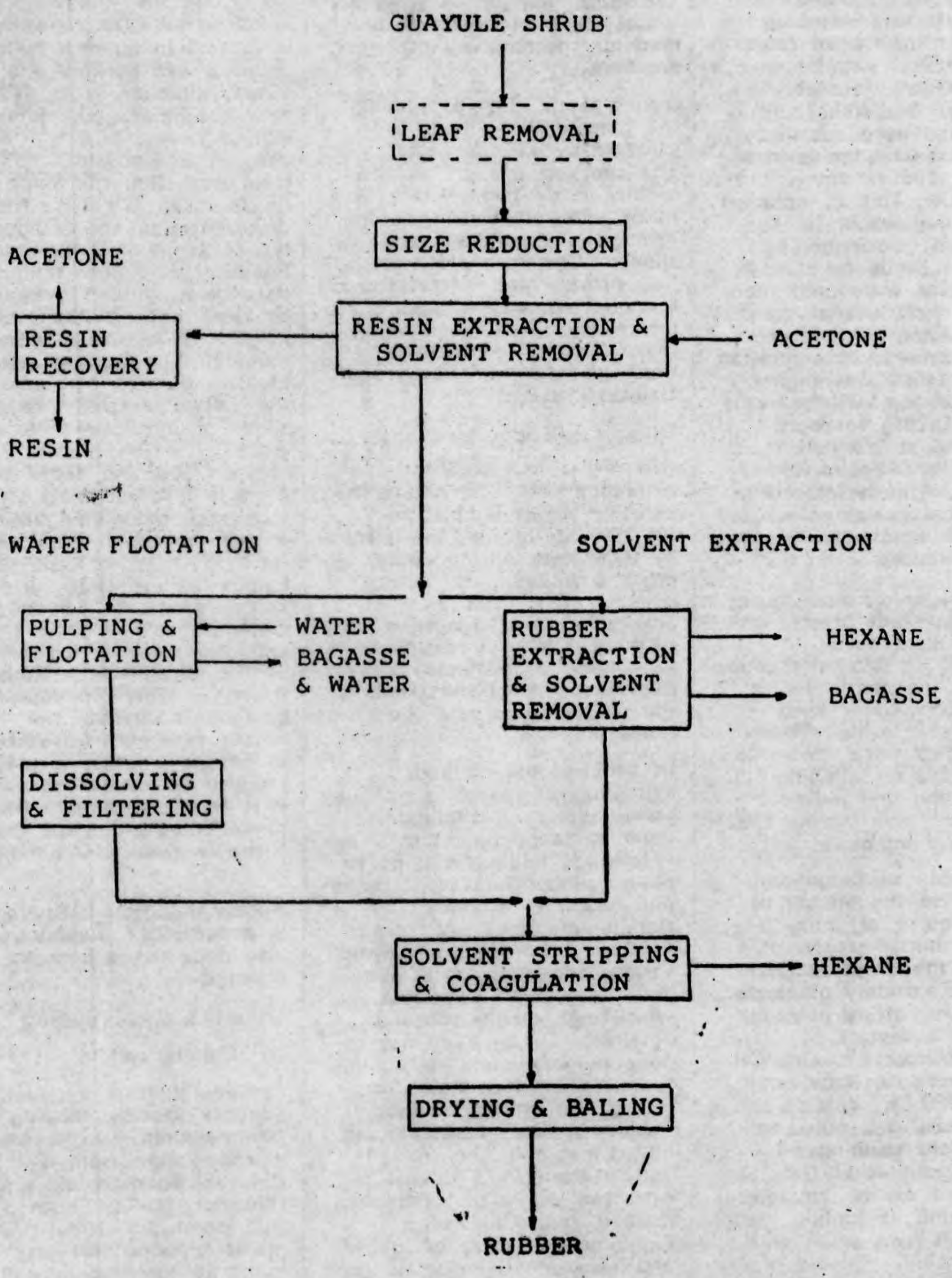


Fig. 3. The processing sequence, from shrub to the final product (from European Rubber Journal 1981).

1946). Federer (1946) reported that Naocl treatment sometimes retarded the emergence of guayule seedlings. Emparan and Tysdal (1957) and Hammond (1959) emphasised the importance of light as a factor in breaking the dormancy of freshly harvested seeds. Treatment with Nacol containing 0.75% available chlorine and Gibberelic acid (GA 3) acted as a substitute for light in breaking the dormancy (Hammond, 1959). Naqvi and Hanson (1979, 1980 c) obtained effective improvement in guayule seed germination by washing the seeds for at least eight hours in water and then soaking in a mixture of equal parts Naocl and GA3 for two hours. The optimum concentration of Naocl needed was higher for fresh seeds (1.0% for fresh seeds and 0.25% for older seeds). GA3 at 200 ppm served best for stored as well as fresh seeds. With this procedure, freshly harvested seeds germinated 100% under light and 75% in complete darkness.

Recent experiments had shown that guayule chaff present on seed, influenced seed germination. Bioassay of aqueous extracts of the chaff and seed coat showed at least seven phenolic acids. These phenolic acids were shown to be responsible for inhibition of germination and radicle growth (Naqvi and Hanson, 1982)

(vii) Disease and pests

Young guayule seedlings are susceptible to the attack of various damping off fungi during the initial stages of growth in the green house. The fungi commonly associated with damping off of guayule seedlings are species of *Pythium, Rhizoctonia, Fusarium* and *Phytophthora* (Naqvi and Hanson, 1980 b). Witch's broom disease was noted in three year old seedlings of guayule (Tipton *et al.* 1982) The affected plants, though showed prolific blooming, had seeds which were small with low percent fill. The use of sterilized media, washing of pots with chlorox, treatment of seeds with Naocl and other precautions prevented the attack of fungi (Naqvi and Hanson, 1980 b). Various fungicides like Turban, in combination with Terrachlor may be used as a broad spectrum treatment for most of the damping off problems.

During warm, humid weather, the green house plants are attacked by various pests. The common one are aphids, moths, mealy bugs, white flies, thrips, mites etc. causing severe damage to the foliage and shoots. Chemical pesticides like 'Orthene' and 'Metasystox R' are effective against aphids, mealy bugs, thrips, and white flies. 'Comite' is effectively used against mites (Naqvi and Hanson, 1980 b)

Rubber Extraction

Guayule is harvested for extraction either by cutting the plant at about 5 cm above the ground, leaving the stem to regenerate or the entire plant is pulled out. Since guayule plant lacks an antioxidant, the processing may be done as early as possible. As rubber is restricted to individual cells of the plant, the whole shrub must be processed.

In conventional methods, extraction of rubber is done by various steps. Parboiling is done to coagulate rubber. Afterwards, milling is done to release rubber from plant tissues and rubber is separated by flotation in large slurry tanks. Budiman *et el* (1981) reviewed various extraction procedures and deresination techniques, by which high quality rubber is obtained. Deresination may be done by subjecting fresh plants to microbial degradation or retting. In another method, freshly harvested plants are cut into pieces and then treated with acetone in a tubular extractor. By a still different method, guayule "worms" (agglomerated mass of rubber and resin) are deresinated using acetone. Recent researches at Firestone company has shown that 90% of the resins could be extracted as a by-product along with rubber (Anonymous, 1981). The various steps involved in the processing are shown in Fig. 3. In the first step, resin is recovered. Defoliated guayule is ground in hammer mills to about 3 mm particle size. Resin extraction is carried out in a continuous percolation extraction system similar to that used in oil industry. Following resin extraction the shrub is desolvenised. Acetone from desolvenisation and resin recovery is condensed and recycled. Recovery of rubber from the deresinated ground material can be done either by the flotation process or by solvent extraction method. The flotation process involves pulping and passing the pulped material through a series of mixing and flotation steps by which rubber agglomerates and floats, while bagasse or residue sinks. Rubber thus recovered is then dissolved in hexane and filtered to remove entrapped cork. Wet bagasse is recovered, dried and used as fuel. In the second method involving solvent extraction, continuous extraction of the deresinated material with hexane is done. The final rubber solution is filtered prior to rubber recovery. The rubber in hexane solution is steam stripped to remove the solvent. It is then coagulated, dried in tunnel driers and bailed. Bagasse is desolvenised, dried and used as fuel.

Rubber yield from both processes is about 90%. Rubber quality also does not appear to be affected.

Genetics and breeding

(i) Genetic system

P. argentatum is a genetically complex species, forming a polyaneuploid system comprising a wide range from diploid ($2n=36$) to octoploid ($2n=144$) (Khoshoo, 1982; Khoshoo and Subrahmanyam, 1984). Guayule plants growing in India were found to vary cytologically from $2n=54(3x)$ to $2n=74(4x+2)$ with two to four B-chromosomes

(Srivastava and Subrahmanyam, 1983). Cytologically, they are classified into three groups viz. diploids (2n = 36), triploids (2n = 54) and tetraploids (2n = 72) based on x = 18 (Bergner, 1946; Stebbins and Kodani, 1944). While the diploids are sexual, all the polyploids are pseudogamous facultative apomicts (Powers, 1945; Esau, 1946). The species is self-incompatible with a sporophytic control (Gerstel, 1950). The evolution of apomixis in guayule could probably be due to failure of chromosome reduction, failure of fertilization and development of non-reduced egg cells without fertilization. It is reported that apomixis and polyploidy evolved together in guayule with hybridization playing an important role (Powers, 1945). The genetic system has potentialities to conserve and preserve heterozygosity through agamospermy, provided the genotype has adaptive value (Khoshoo and Subrahmanyam, 1984).

(ii) Genetic markers

In guayule, plants with purple flower colour were identified among polyploid and diploid strains (Estilai and Tysdal, 1981). Purple flower colour was used as a genetic marker in hybridization studies. Diploid guayules with purple and white flower colour were crossed in all possible combinations Crosses among white parents produced only white progenies. Reciprocal crosses between two purple parents produce fifty purple and one white. Crosses between purple and white parents produced either all white or white and purple progenies in 1:1 ratio. It was suggested that purple flower colour is a recessive trait, controlled by one pair of genes (Estilai, 1984).

The isozyme variation in guayule and allied *Parthenium* species like *P. incanum*, *P. tomentosum*, *P. fruticosm* and *P. confertum* were investigated by Radin *et al.* (1980) to help identifying genetic markers. The enzymes chiefly studied were peroxidases and esterases. Inter and intraspecific variations were observed in the case of peroxidase isozyme. Based on banding patterns, three groups of peroxidases were recognizable. The upper group-I, showed considerable variations and were subdivided into Ia and Ib. In *P. argentatum* Ia bands were present. *P. incanum* contained a different banding pattern and was classified as group II. However in *P.confertum*, a third type of banding (group III) appeared. Esterase isozyme patterns were found to be simple, and not much variable as that of the peroxidase. No esterase isozyme was located in *P. confertum*. Inheritance studies of peroxidase and esterase isozymes in F1 hybrid and back cross progenies showed extensive recombination patterns. Segregation data revealed the presence of three genetic loci corresponding to peroxidase, and two for esterase.

(iii) Germplasm

In 1910 W. B. Mc clung, a botanist, started domestication and cultural experiments on guayule in Torreon, by gathering seeds from native plants in many parts of Mexico and continued the work until 1942. As a result a number of superior lines were produced of which the strain N 593 was the standard variety during the ERP (Rubis, 1978). In 1948 B. L. Hammond made extensive collection of guayule seeds and was successful in obtaining lines with high rubber yield. Hewit Tysdal, who started systematic breeding work during 1949, developed a superior strain 11605. In 1959 seeds of 23 of the highest rubber yielding lines was sent to National Seed Storage Laboratory at Fort Collins (Rubis, 1978). Later, in 1976 guayule breeding programme was started at Arizona and 25 lines were obtained from National Seed Storage Laboratory. Reed Rollins and co-workers made an extensive germplasm collection (114 collections from 45 localities) in September 1976 (Rubis, 1978). George Hanson and associates at the Los Angeles County Arboretum selected a superior variety N 575, while Davis Rubis at University of Arizona obtained a top yielding strain 11591 (Baird, 1981).

An extensive germplasm bank has been established in the University of California, Riverside which includes the 26 U.S.D.A lines and selection from new accessions collected in Mexico; selections from Los Angeles County Arboretum and collections of North and Central American species. Besides, a number of hybrids between guayule and several other species are also maintained (Youngner, 1982). Recently four guayule genotypes were developed jointly by California Department of Agriculture and University of California, Davis and released in 1982 (Estilai, 1983; Tysdal *et al.* 1983). They are: Cal-1 and 2- developed from open pollinated seeds collected from F2 and BC1 plants of interspecific crosses between guayule and *P. tomentosum* and *P. fruticosum* respectively. Both strains showed good vigour and increased biomass production Cal-3 resulted from intercrossing 12 diploid plants with high rubber content. This variety is a source of diploid genotypes. Cal-4 was developed as a composite of open-pollinated seeds from disease resistant diploid plants. It is a source of resistance to *Verticillum* wilt- The rubber content of these varieties varied from 1.49 to 3.5 per cent (Tysdal *et al.* 1983)

(iv) Hybridization

Guayule is very compatible with its related species. It often crosses naturally, offering opportunities to the plant breeder to add desirable features without losing rubber producing capacity (Mc Ginnies, 1978). Mariola (*Parthenium incanum* HBK) is the closest relative and normally guayule and mariola are found in the same habitat. Natural interspecific hybrids between these species are often found in wild stands and there is tremendous introgression of mariola genes (Rollins, 1975). Mariola has winter hardiness, which could be transferred to guayule. A new population of diploid maniola was located by Behl *et al.* (1982), trichome studies of which showed no introgression from guayule.

Desirable qualities from related *Parthenium* species could be incorporated into guayule through interspecific hybridization. Increased vigour and biomass, cold and disease resistance and increased adaptability to diverse horticultural practices and agronomic conditions are some of the traits with potential for improvement. Successful interspecific crosses have been obtained with *P. incanum, P. tomentosum* and *P. fruiticosum* and the F1 hybrids were found to produce rubber. Other species that are being crossed include *P. confertum, P. hysterophorus, P. bipinnatifidum, P. schottii* and *P. integrifolium*. Back crossing with high rubber guayule is also being attempted to increase rubber yields (Naqvi and Hanson, 1981).

Tissue culture

Radin *et al.* (1982) initiated callus cultures in leaf and inflorescence from mature guayule plants. Initial cultures were morphologically heterogeneous and contained leaf and shoot primordia. These structures were substantially eliminated by serially culturing only the least organized callus like tissues. The selected calli from inflorescence have exhibited stable morphogenetic properties and growth rates for over one year. These cultures produced chlorophyll when grown under illumination and chemical analysis of both light and dark grown calli showed the presence of cis, 1-4 polyisoprene, besides various other compounds like alleanes sesquiterpenoids, guayulin etc. Staba and Nygaard (1983) established nine different guayule strains in tissue culture using shoot and root meristems, on static or liquid medium containing various growth regulators. Culture medium containing 6-benzyl aminopurine was best suited for callus growth and development. Smith (1983) devised a rapid invitro propagation method using excised buds, on a medium containing benzyl adenine (BA). Shoot proliferation was achieved with a concentration of 1.0 mg l^{-1}BA and root initiation, with 0.5 mg l^{-1} BA. Plantlets could be developed and grown in green house, by this way.

Research in India

Work on guayule has been taken up at the National Botanical Research Institute, Lucknow since 1978. The plant has been successfully grown from seed to seed for three generations. Standardization of propagation and cultivation techniques, cytogenetic studies and improvement by selection and breeding are being attempted (Srivastava and Subrahmanyam, 1983). Other centres involved in guayule research are Biocentre, Ahemadabad, Central Salt and Marine Chemicals Research Institute, Bhavanagar and Central Arid Zone Research Institute, Jodhpur. The Rubber Research Institute of India is also a member of the co-ordinating group for guayule research in India.

Future Research Needs

Considerable research and development efforts must be put in to place guayule among plants of commercial importance. Sizeable extend of land is available in the arid and semi-arid regions which could be considered for guayule cultivation. Studies on the adaptability of different strains to various agroclimatic regions and soil types will be of prime importance. Economic feasibility of commercial cultivation remains to be investigated. Another major problem with regard to commercial production of guayule is the low rubber productivity of the strains available in India It is necessary to introduce improved strains and test its performance. Further improvement through breeding and selection is also necessary. It will be interesting to investigate the use of bio-regulators for increasing rubber production. Development of a quick and efficient method for estimation of rubber content or identifying certain morphological markers related with productivity are also essential

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TRAINING PROGRAMME INAUGURATION

The various branches of Canara Bank in Kerala had disbursed an amount of Rs. 188.64 lakhs as loan during 1984 under the rubber plantation development scheme for newplanting and replanting of rubber. Though the achievement is only 50% of the target, the Bank's performance is outstanding among all other Commercial Banks in Kerala State. This was disclosed by Shri. TR Subramoniam, Deputy General Manager of the Bank at the inaugural session of a training programme organised by the Rubber Board for a group of Branch Managers at the Rubber Research Institute of India. He attributed several reasons for the poor off take of credit. He said that farmers are not willing to mortgage their property for fifteen years.

In most of the cases where replanting is undertaken the planters do not need bank finance since the income from slaughter tapping/sale of trees along with the subsidy from the Board would be adequate to meet the replanting expenses.

The subsidy is not linked to institutional finance. Shri. Subramoniam also claimed that the Canara Bank had conducted a series of extension programmes in different parts of the state to promote the scheme.

Shri PJ Thomas, Chairman, Rubber Board inaugurated the programme. Shri. P Mukundan Menon, Rubber Production Commissioner, Dr. MR Sethuraj, Director, Rubber Research Institute of India and Shri. George, Project Officer spoke on the occasion.