Cf. Annamma Varghese

Breeding for resistance to diseases and insect pests in plantation crops

Lecture Notes of the Winter School
held at
Central Plantation Crops Research Institute
Regional Station, Kayamkulam
(October 16 to November 6, 2006)

Editors

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(Indian Council of Agricultural Research)
KASARAGOD - 671 124, KERALA, INDIA

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Genetic improvement in rubber

Y. Annamma Varghese and Mercy Joseph
Rubber Research Institute of India, Kottayam

Introduction

Hevea brasiliensis, indigenous to the tropical Amazon rain forest was introduced to South East Asia by the British in the late 19th century. The Para rubber tree of commerce, produces around 99 % of the world's natural rubber (NR) produced mainly from the SE Asian countries. The NR industry owes its existence to the famous collection by Sir Henry Wickham from its native environment in the Amazon rain forests in 1876. Genetic improvement of *Hevea,* in spite of being a very elaborate time consuming procedure, has paid rich dividends in increasing yield by several folds and making available several high yielding clones, for commercial planting. During the first half of the century, the productivity of rubber plantations was as low as 300 kg/ha/year. The genetic improvement has resulted in a tremendous yield improvement of over ten-fold compared with that in the early years of rubber cultivation, thus making rubber breeding an outstanding success story.

Breeding and selection

The first steps in breeding were taken up by Dutch workers in Java and Sumatra. They showed that yields per tree were variable, that clonal propagation was possible and that individual clones differed in their genetic potential. With ordinary seeds as planting material in initial years of rubber research, productivity was only around 300 kg/ ha/ yr. Selection of high yielding mother trees and multiplication by budding resulted in early primary clones with improved yield potential. From 1920s onwards, budded clones and superior seedling populations progressively supplemented the random open pollinated seedlings. Subsequently, breeding new clones through hybridization resulted in a series of high yielding hybrid clones.

Breeding objectives in *Hevea* include developing clones with high production potential combined with desirable secondary attributes like initial vigor, smooth thick bark with a good latex vessel system, good bark renewal, high growth rate after opening, tolerance to major diseases, wind and TPD, good response to stimulation and low frequency tapping. Clones with early attainability of tapping girth and high initial yields are preferred over clones with higher yields in later phases of exploitation.

Breeding methods

The conventional breeding methods in *Hevea* are introduction, ortet selection and hybridization and clonal selection.

Introduction of clones

Introduction or exchange of available clones among the rubber growing countries in the early years constituted the original breeding pool in each country. Recent introductions under bilateral and multilateral clone exchange programmes organized by the International Rubber Research and Development Board (IRRDB) and Association of Natural Rubber Producing Countries (ANRPC) are confined to potential clones of good performance. In India, 127 Wickham clones evolved in countries like Malaysia, Indonesia, Sri Lanka, Thailand, China and Ivory Coast formed the exotic component of the gene pool, in addition to the recent introduction of over 5000 accessions of the wild Brazilian Germplasm (Varghese *et al.,* 2002).

Ortet selection

Ortet selection or mother tree selection is the oldest breeding method of systematic screening of outstanding seedling genotypes resulting from natural genetic recombination. Clones developed through ortet selection are called primary clones. Screening of extensive seedling plantations in Indonesia, Malaysia and Sri Lanka resulted in a number of early primary clones of importance like Tjir1, PR 107, GT 1, BD 10, AVROS 255, Gl 1, PB 28/59, Mil 3/2, Hil 28 of which clones like GT 1, PB 28/59 are still widely planted. In India earlier mother tree selections included 46 clones of which RRII 1, RRII 4, RRII 5, RRII 6, RRII 33, RRII 43, RRII 44 etc. are among the potential clones (Marattukalam *et al.,* 1980). Over 30 recent selections are under evaluation.

Hybridization

Hybridization and clonal selection, the most important conventional methods in *Hevea* offer scope for exploitation of heterosis in hybrid progeny of potential parent clones. Desirable recombinants once selected can be fixed easily through vegetative multiplication. As a result of hybridization and selection, a number of hybrid clones of commercial significance have been evolved. With the early primary clones as parents of the first hybridization series, resulted in early hybrid clones of commercial significance like RRIM 500 and 600 series, the yield levels of which were much superior to those of the parent clones. The best clones in each series were further used as parents in subsequent series. Rubber breeders followed this sort of cyclical generation-wise assortative mating (GAM) over the past years. In Malaysia, the Rubber Research Institute developed clones of RRIM 500 to 1000 series, while Prang Basar Institute in the private sector selected PB clones of commercial significance. The Indonesian Research Institute for estate crops in Java and Sumatra (BPPM) evolved PR, AVROS, BPM, LCB, PPN and RR clones. The RRIC clones originate from Sri Lanka, KRS clones from Thailand and Haiken, YRITC and SCATC clones from China.

In India, crop improvement programmes were initiated in 1954 and a large number of hybrid progenies were developed and evaluated for potential recombinants. In spite of the less favourable agro climatic conditions prevailing in the country, India could achieve the highest average productivity among the major rubber producing countries and is currently the fourth largest producer and consumer of NR. The early hybrid clones developed by the RRII include RRII 100,200 and 300 series with RRII 105, RRII 118, RRII 203, RRII 208, RRII 300 and RRII 308 (George *et al.*, 1980, Premakumari *et al.*, 1984 Saraswathy Amma *et al.*, 1987) of which RRII 105 is the most popular clone. The highest productivity achieved by India can be attributed to the high yielding hybrid clones of which the most popular clone is RRII 105. It has a production potential of over 2000 kg/ha/year in farmers' plots and enjoys the maximum popularity in the country. The latest contribution is the recommendation of five RRII 400 series clones *viz.* RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430 which recorded significant superiority in growth and yield over RRII 105 in small scale and large scale experimental evaluation trials (Licy *et al*,1992, Mydin *et al*,2005). Two of the best selections, RRII 414 and RRII 430 were upgraded to Category I and released to the nation for commercial cultivation by His Excellency, The President of India, Dr. A.P.J. Abdul Kalam in July 2005. Currently, over 100 clones superior to RRII 105 in rubber yield, timber yield potential and secondary attributes developed by hybridization, polycross breeding and ortet selection from polyclonal seedling plantations are in the pipe line and identified for farmer participatory clone evaluation and selection.

Crop improvement programmes in the non-traditional areas

Concerted efforts are in progress in developing location specific clones suitable for non-traditional rubber growing areas under sub optimal conditions. Growth and yield are highly variable under varying agro -climates. Growth reduction resulting in longer gestation period of 8-10 years has been observed as a result of high and low temperature and high altitude. Under North Eastern conditions, average growth is the lowest during cold season (Dec-Feb) ranging from 8.5 to 14.5% (of annual growth) in different locations, the variations attributed to latitudinal differences (Varghese, 2003).

The data available from the first sets of clone trials have revealed location specificity of clones. Among 25 clones in two clone trials at RRS Agartala, the high yielders include PB 235, RRIM 600, RRII 208, RRII 203, RRII 118 and SCATC/13.(Priyadarshan *et al.*, 1998; Priyadarshan, 2003).Under Assam conditions, RRIM 600, RRII 105, PB 235, RRII 208 and RRII 118 were the high yielders among 20 clones. (Mondal *et al.*, 1999). In the W.Garo hills of Meghalaya, at an elevation of 600 m, RRIM 600, PB 311,RRII 208 and RRII 118 recorded higher yield than RRII 105 in the early mature phase (Reju *et al.*, 2000).

In the northern part of W. Bengal at Nagrakatta, growth is comparable to that in the traditional area in spite of the slow growth during winter season, which seems to be compensated during the favorable season. Out of 18 clones, 14 clones attained tappable girth in the 7^{th} year. The early high yielders in Nagrakatta include SCATC 88/13, RRIM 600,PB 311, PB 235 and RRII 208 (Meti *et al.*, 1999; Varghese, 2003). Under the drought conditions at Dapchari, RRII 208, RRII 6, RRIC 100 are rated as more drought tolerant both in terms of girth and yield. (Chandrashekar *et al.*, 1998, RRII, 2002).

At Dhenkanal in Orissa, RRIM 600 and SCATC/13 are the high yielders in the early mature phase (Gupta and Edathil, 2001). Evaluation of progeny derived from polyclonal seedlings revealed that the seedling population is highly heterogenous with respect to growth, yield and desirable secondary characters and offer considerable scope for selection (Varghese, 2003).

Classification of recommended varieties

Clones are usually named after the estates, institute or station from which they have originated and such names are abbreviated to serve as identifying codes prefixed to the clone number. Some examples include **India:** RRII (Rubber Research Institute of India); **Malaysia:** RRIM (Rubber Research Institute of Malaysia), PB (Prang Basar), Pil Pilmoor, Malaysia, ᵔ¹ Glenshiel, Malaysia; **Indonesia:** GT Gondang Tapen, ..⁷ROS (Alegemene Verneitging Rubber Planters Oostkust Sumatra,.), Tjir (Tjirandji), **SriLanka:** RRIC/ RRISL Rubber Research Institute of Ceylon/ SriLanka, Hil (Hilcroft), Mil Milakande; **Thailand:** KRS Kohong Rubber Estate; **China:** SCATC South China Academy of Tropical Crops; **Ivory Coast** IRCA Institute des Recherches sur le Caoutchouc and **Brazil:** IAN Institute Agronomico du Norte.

Planting recommendation in India

In India a multi-clone planting is recommended with the cultivars grouped into three different categories as given below (Rubber Board, 2006).

Category I: 4 Clones *viz.* RRII 105,PB 260, RRII 414 and RRII 430. (for large scale planting, covering upto 50% of the total rubber area in a holding):

Category II: 8 clones *viz.* RRIM 600, GT 1, RRII 5, RRII 203, PB 28/59, PB 217, RRII 417 and RRII 422. (clones with consistent performance in India over a long term in any one of the evaluation trials. Three or more of these cultivars may be used to plant upto 50% of the total area of any holding.)

Category III: 34 Clones *viz.* RRII 50, RRII 51,RRII 52,RRII 118,RRII 176, RRII208,RRII 300, RRII 429, PR 107,PR 255, PR 261, PB 86, PB 5/51 PB 235, PB 255, PB 280,PB 311, PB 312, PB 314, PB 330,RRIM 605, RRIM 701, RRIM 703, RRIM 712, RRIC 100,RRIC 102, RRIC 130, KRS 163, IRCA 111, IRCA130,SCATC 88-13,SCATC 93-114, Haiken 1, BPM 24 and polyclonal seeds. (Clones having limited data recommended for only small scale planting not exceeding 15% of the area.)

Important characters of certain popular cultivars are provided in Appendix 1.

Broadening the genetic base

The genetic base of *Hevea* in the east is reported to be very narrow, limited to a few seedlings originally collected by Sir Henry Wickham, referred to as the 'Wickham base' (Simmonds, 1989), collected from a miniscule of the genetic range of the species in Boim, near the Tapajos River in Brazil (Wycherley, 1968). Added to this, there was a further narrowing down of the original 'Wickham gene pool' due to a number of factors, like directional selection for yield, cyclical generation wise assortative breeding pattern and a wider adoption of clonal propagation by budding. The parentage of popular clones bred in various rubber-growing countries including India can be traced back to a handful of parent clones (Tan 1987; Varghese, 1992). *Hevea* breeders across the world had realized the need for broadening the narrow genetic base which resulted in a major collection expedition organized by the International Rubber Research and Development Board (IRRDB) and Brazilian Government to the Amazon rain forests in 1981 (Ong *et al.*, 1983). In India, a total of 4548 accessions including 126 ortet clones received from the Malaysian center, have been established in traditional and non- traditional areas for conservation, characterization, evaluation and utilization. Studies for screening of wild germplasm for resistance to major diseases, drought and cold conditions have revealed wide variability for most of traits. Field observations have identified a general field tolerance of the wild germplasm belonging to Mato Grosso provenance to shoot rot disease (Mercy *et al.*, 1995). Early data from the evaluation trials has revealed wide variability in growth, yield, yield related traits (Annamma *et al.*, 1989, Abraham *et al.*, 1992, 1994). A good number of accessions with desirable traits have been short listed for further confirmation and incorporation in the breeding programmes (Varghese *et al.*, 2005).

Biotechnological interventions in crop improvement

Advances in rubber biotechnology in India include development of protocols for the micropropagation of *Hevea* through somatic embryogenesis using immature anther and inflorescence explants (Kumari Jayashree *et al.*, 1999). Transgenic plants integrated with SOD gene for environmental stress and TPD tolerance were developed with CaMV 35S and FMV34S promoters while transgenic *Hevea* tissues integrated with the gene coding for sorbitol-6-phosphate dehydrogenase (for drought), isopentenyl transferase and antisense ACC (for TPD) and are under different developmental stages (Thulaseedharan, 2003). β-1,3 -glucanase gene involved in defense to fungal infection in *Hevea* has been cloned and characterized and its involvement in defense against *Phytophthora* infection was studied. It was observed that faster, higher and prolonged expression of this gene during pathogen is involved in disease tolerance (Thanseem, 2005.)

Research initiated on molecular markers in *Hevea* indicated the potential of RAPD markers in various applications in genetic improvement like assay of genetic diversity and genetic analysis (Varghese *et al.*, 1997). 59 microsatellites were developed for genomic characterization of *Hevea* germplasm (Roy *et al.*, 2004). Species-specific SCAR markers (Sequence Characterized Amplified Region) have been developed for identification of the fungal pathogen, *Colletotrichum* (Saha *et al.*, 2002). Studies aimed at identification of molecular markers linked to resistance/tolerance to biotic and abiotic stresses in *Hevea* with an ultimate objective to clone and characterize the respective genes are in progress.

Breeding for resistance to diseases

In the different rubber producing countries, where any particular disease poses serious problems, some efforts in breeding for resistance have been made with varying degrees of success. In general, three leaf diseases *viz.*, abnormal leaf fall (*Phytophthora* spp.), powdery mildew (*Oidium heveae*) and secondary leaf spot (*Colletotrichum gloeosporoides*) cause serious problems in *Hevea*. In India, abnormal leaf fall and powdery mildew results in varying degrees of yield drop. In Sri Lanka also *Phytophthora* and *Oidium* cause severe damage (Baptiste, 1961), while in Indonesia, *Oidium* is a major problem. Birds eye spot (*Drechslera heveae*) is reported from Ghana. White root disease is a serious problem in Nigeria. In RRIM nursery also, incidence of root disease has been reported. Breeding for *Colletotrichum* and *Oidium* resistance are priorities in Malaysia and Indonesia, respectively.

In India, the two major leaf diseases viz. abnormal leaf fall disease (*Phytophthora* sp.) and powdery mildew (*Oidium* sp.) cause considerable crop loss. Recent reports on the incidence of *Corynespora cassiicola* leaf spot observed in the popular clones RRII 105 and RRIM 600, in the rubber growing tracts of Karnataka and certain parts of North Kerala (Jacob, 1996), has caused serious concern. In the case of the emergence of a virulent strain of a particular pathogen in favorable environmental conditions, the disease will spread and cause serious damage, if sufficient genetic variability is not available in the population. Wild germplasm being a rich source of genes conferring resistance to stresses, screening of the accessions for major diseases is a priority area. An on - going interdisciplinary programme of screening wild genotypes for resistance to *Phytophthora, Oidium and Corynespora* leaf diseases at RRII has so far led to identification of a good number of tolerant accessions.

South American Leaf Blight (SALB) caused by *Mycrocyclus ulei*, the most devastating disease of rubber, fortunately still confined to tropical Americas, also poses threat to the rubber plantations in the SE Asian countries. Promising clones (Fx 25, Fx 3899 and Fx 3164) were bred by Ford Motor Company in Brazil and by Fire Stone Rubber Company (MDF and MDx series) in Liberia and Guatemala. Subsequently a large number of resistant clones were bred in Brazil, of which only six (Fx 25, 3810, 3899, 3925, IAN 710 and IAN 717) seem to be commercially acceptable (Chee and Holliday, 1986). However, in many cases, the resistant clones selected were pathotype specific and break down of resistance due to physiologic races (Langdon, 1965) is a serious problem. Simmonds (1989) stressed the need of breeding for horizontal resistance in contrast to vertical resistance to SALB. In *Hevea* available results indicate polygenic inheritance, implying chances of obtaining horizontal resistance, which is more stable and durable. Fortunately for the plantation rubber industry of the old world producing over 90 % of the world's natural rubber requirement, this disease is still confined to the tropical Americas. However, in spite of the stringent quarantine measures adopted, the chances of the spread of this disease to the eastern hemisphere cannot be completely ruled out. Hence, breeding for SALB resistance should be given priority not only in Brazil, but also in other rubber producing countries.

and refoliation are early and partial. It is a medium vigorous clone. Both virgin and renewed bark thickness is average. The clone is invariably an high yielding cultivar with an average yield obtained over the first 15 years of tapping in on farm trials being 2210 kg/ha/yr. To manage the high intensity of Tapping Panel Dryness in this clone adherence to half spiral, once in three days tapping is strongly recommended.

PB 260: This hybrid developed by the Prang Basar Estates Ltd. in Malaysia, from the parents PB 5/51 and PB 49 is also a high yielder. Trees have tall and straight trunk with light branching balanced with a strong union. The clone has a dense canopy with a pale green foliage. Highly vigorous clone before tapping commences, and after commencement of tapping is an average vigour clone. Thickness of virgin and renewed bark is below average. On farm trials recorded a mean yield of 1631 kg/ha/yr over the first five years of tapping. This cultivar has a high incidence of tapping panel dryness.

RRII 414: The parents of this clone are RRII 105 & RRIC 100. Trunk is tall, straight and cylindrical with open, broad, heavy canopy of dark green leaves, restricted to the top. Girth at opening is high and girth increment on tapping average. Mean yield over 11 years of tapping in the small scale trial is 74.02 g/ tree/ tap and in the large scale trial over four years of tapping is 56.68 g/ tree/ tap. Incidence of *Oidium* is high. Incidence of pink disease and abnormal leaf fall are moderate while it is relatively tolerant to *Corynespora.*

RRII 430: Parents are RRII 105 & RRIC 100. The clone has above average girth at opening. Canopy is open, broad and heavy with broad glossy leaves. Virgin bark is of average thickness, renewed bark thickness is high. Mean yield over 11 years of tapping in the small scale trial is 63.37 g/ tree/ and in the large scale trial over four years of tapping is 61.09 g/ tree/ tap. Incidence of *Oidium* is very high while incidence of abnormal leaf fall, pink disease and *Corynespora* leaf fall are low.

RRIM 600: Another very popular clone in India, especially in the non-traditional rubber growing tracts in North Eastern states of India, was evolved by the Rubber Research Institute of Malaysia. It is a hybrid from a cross between Tjir 1 X PB 86. The clone has a tall straight growing trunk with moderate to heavy branching but with weak branch unions. Narrow broom shaped crown, with sparse foliage and small yellowish green leaves with a normal wintering and refoliation pattern. Girth increment after the commencement of tapping is high and the virgin bark thickness is low and that of renewed bark is high. Average annual yield in estates over the first 20 years is 1349 kg/ha/yr . Latex of this cultivar is unsuitable for concentration.

GT 1: This is a primary clone developed in Indonesia with an upright but slightly kinked trunk. Main branches are long and acute angled, with light secondary branches. It has a narrow globular crown, dense dark green glossy foliage with medium to high girth at opening, Virgin and renewed bark thickness is medium. The summer yield is fairly high with an average annual yield of 1420 kg/ha in estates for 19 years. Only mild incidence of tapping panel dryness syndrome is observed in this cultivar.

RRII 417: The parentage of this clone is RRII 105 & RRIC 100. Trunk is tall and straight. Canopy is broad, open and heavy with semi-glossy leaves. Thickness of virgin bark is average and renewed bark is high. This clone has above average tolerance to wind and is moderately susceptible to pink disease. Incidence of abnormal leaf fall is low to moderate while incidence of powdery mildew is very high. It is moderately susceptible to *Corynespora.* The mean yield over 11 years in the small scale trial is 70.52 g/ tree/ tap and over four years of tapping in the large scale trial is 53.06 g/ tree/ tap.

RRII 422: Parents of this clone are RRII 105 & RRIC 100. Girth at opening is above average. Stem is crooked with high branching. Canopy is open, narrow with dark green glossy leaves. This clone has recorded 64.94 g/ tree/ tap in the small scale trial during 11years of tapping and 61.16 g/ tree/ tap in the large scale trial over four years. Incidence of abnormal leaf fall and pink disease is low, *Oidium* is high and *Corynespora,* moderate.

RRII 429: Parents are RRII 105 & RRIC 100. This clone with tall, straight and cylindrical trunk has a dense, heavy canopy with dark green leaves. Girth at opening is high and girth increment on tapping average. This clone shows low incidence of abnormal leaf fall diseases and *Corynespora* leaf fall. Highly susceptible to pink and powdery mildew. TPD occurrence was found to be above average. The mean yield over 11 years in small scale trial was 77.82 g/ tree/ tap, while it was only 49.42 g/ tree/ tap in the large scale trial over four years of tapping.

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Appendix 1

Important characters of certain popular cultivars

RRII 105: This is the most popular clone currently cultivated in India. The clone was developed by the Rubber Research Institute of India through hybridization between the clones Tjir 1 and Gl-1. The clone has characteristic features like tall trunk, presence of more than one leader, good branching habit, dense canopy and dark green foliage with glossy leaflets. Wintering

Future prospects

Rubber, one of the youngest of the major domesticated crops of the world, is a success story among the plantation crops. Systematic breeding and selection over the years, utilizing the original gene pool collected from a miniscule of the genetic range of *Hevea* in the centre of origin in the Amazon rain forests, has resulted in significant improvement in production and productivity in *Hevea.* However, the genetic base of the crop got narrowed down during this process of unidirectional selection, where yield was the primary concern. In *Hevea,* reports indicate instances of less serious diseases becoming more severe and erosion of genes controlling major leaf diseases including SALB, tl ost devastating disease of rubber, in the original g pool. In the present day context of extension of rubber cultivation to marginal and non-traditional areas, the breeding priorities include development of location specific clones with resistance to major diseases, drought, cold, high elevation, wind etc. for which the base material should contain ample genetic variability and a broad genetic base. In this context, the collection of wild germplasm by the IRRDB sponsored expedition to the Amazon basin in 1981 and sharing of the germplasm, among the member countries was a significant leap in enriching the original narrow gene pool. Fresh germplasm serves as a potential source of many valuable and novel genes for many of the desired characters. The challenge before the breeder lies in evolving strategies for identifying these genes a ncorporation into high yielding clones.

Confronted with the long breeding and selection cycle and the heterozygous nature of the crop, it has become essential to improve the potential clones through modern biotechnological interventions. Success has been met with, in perfecting protocols for genetic transformation and developing plantlets with agronomically desirable genes. Further concerted efforts are essential to perfect these systems on a commercial level.

In the present global scenario, Natural rubber stands to gain from high demand of rubber in the expanding automobile industry besides a host of other industries using different forms of rubber. The Rubber Research Institute of India and rubber plantation sector is committed to meet the forthcoming challenges in the Natural Rubber sector.

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