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CROP IMPROVEMENT IN THE NON-TRADITIONAL RUBBER GROWING AREAS IN INDIA

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Y. Annamma Varghese
Rubber Research Institute of India, Kottayam-686009, Kerala, India.

In India, the possibility of expansion of rubber in the traditional tract being extremely limited, increased attention has been given to the non-traditional areas from the 1960s onwards. The potential non-traditional areas, however, are confronted with different agroclimatic constraints. Regional Research Stations have been established in most of these places to give research back up for scientific rubber cultivation. Breeding and selection of location specific clones, evolving suitable planting and management techniques, irrigation schedules, fertilizer recommendation and exploitation systems are priority areas of research. The data generated so far in the regional stations have helped to address some of these constraints.

Among the research priorities, development of location specific clones is the most important one. The breeding programmes in the non traditional areas are streamlined to evaluate popular clones and polycross progenies in addition to conservation and evaluation of germplasm, hybridization and ortet selection aimed at development of clones for specific agroclimates. In the NE region, around 50 potential clones from the traditional region are being subjected to field evaluation in a phased manner. Growth reduction resulting in longer gestation period of 8-10 years has been observed as a result of high and low temperature and higher altitude situations.

The high yielding clones identified for NE India include PB 235, RRIM 600, RRII 208, RRII 203, RRII 118 and SCATC 88-13 for Tripura, RRIM 600, RRII 105, PB 235, RRII 208 and RRII 118 for Assam, RRIM 600, PB 311 and RRII 208 for Meghalaya and SCATC 88-13, RRIM 600, PB 311, PB 235 and RRII 208 for West Bengal. At Dapchari in North Konkan, the clones RRII 105, RRII 208 and PR 255 are observed to be high yielders. Among the pipe line clones RRII 429 and RRII 430 are found to be adaptable and stable in both traditional and non-traditional areas when initial growth is considered. In Dapchari the performance of polyclonal seedlings under unirrigated condition is quite promising indicating the usefulness of polyclonal seedlings in stressful areas. Evaluation of progeny derived from polyclonal seedlings is in progress in most of the regional research stations. Wild germplasm accessions resultant of the 1981 IRRDB expedition to the Amazon forests are being conserved at RRS Guwahati and Agartala and evaluated in order to select genotypes tolerant to specific stress situations. Recombination breeding initiated in Tripura has resulted in a total of 694 hybrids, which are in the early stages of evaluation.

INTRODUCTION

Natural rubber, *Hevea brasiliensis* being indigenous to the Amazonian rain forests of Brazil located at 5° longitude and an altitude below 200 m prefers a warm breezy humid weather and a fertile soil and hence its performance is best under tropical conditions. The region between 10^0 north and south of equator, suitable for rubber cultivation is known as the traditional rubber growing tract. In India the traditional rubber-growing region is a narrow tract of land in the Western Ghats situated between 8°-12° latitude including mostly Kerala and Kanyakumari District of Tamil Nadu and parts of Karnataka. However, this hardy perennial tree species can be grown in less ideal conditions also.

The possibility of expansion of rubber in the traditional tract being extremely limited, focus has been shifted to non-traditional areas in the country and steps taken to explore less congenial but potential areas like the north eastern states and certain locations in Western and Eastern India. However, local constraints often limit the growth and productivity in these areas. The package of practices applicable to the traditional areas, in most cases, had to be modified when the crop was grown under stress conditions.

Extending rubber cultivation to the non-traditional region posed various problems warranting R&D intervention and accordingly research activities were initiated during the late seventies. One of the thrust areas identified has been screening of various available clones for their adaptability for which clone evaluation trials were laid out from 1979 onwards in the none-traditional areas.

Valuable information on growth and productivity has been generated at the Regional Research Stations established in different states. Based on data and information available so far, it has been possible to draw certain guidelines for rubber cultivation under sub optimal conditions.

THE NON TRADITIONAL AREAS

Attempts to grow rubber at 20° to 28°N in India and at 18° to 24° N in China have been successful, in spite of the fact that in these areas the crop experiences various stress conditions.

The non-traditional rubber growing areas in India include Tripura, Assam, Meghalaya, Nagaland, Manipur, Mizoram and Arunachal Pradesh in the north eastern (NE) region, Maharashtra and Goa in the Konkan region of Western India and West Bengal, Orissa, Andhra Pradesh and Madhya Pradesh in the Eastern region.

Environmental constraints

The potential non-traditional areas, however, are confronted with different agroclimatic and socio - economic constraints. In the NE region, low temperature prevails during November to February with minimum around 10° C and occasionally coming down to 4-5° C. (Meenattoor *et al.*, 1989). Certain tracts of N.E. region also experience high velocity winds, occasional hailstorms and high altitude effect. (Meenattoor *et al.*, 1995). Similarly high temperature in association with low humidity and prolonged drought in the Konkan region and low rain fall and high temperature in Orissa are other unfavourable climatic factors. Moreover, locations like NE states and Orissa degraded with poor and depleted soils due to the primitive and unscientific practice of shifting cultivation ('jhumming') by the natives and the dry barren soils of North Konkan, are the other limiting factors for crop growth. The annual average range in temperature and the annual rainfall in the non-traditional rubber growing areas are given in Table 1.

Table 1. **Annual average minimum, maximum temperatures and rainfall of different stations of nontraditional areas**

Location	Temperatures (°C)			Annual rainfall (mm)
	Min.	Max.	Range	
Agartala	19.7	30.2	10.1-32.3	2043
Guwahati	18.7	30.5	10.0-32.8	1924
Tura	15.8	28.7	8.0-30.9	2607
Nagrakata	17.0	27.7	6.4-35.0	4066
Dhenkanal	20.8	31.8	9.9-39.7	882
Dapchari	20.5	32.9	13.9-36.7	2630

Drought/high temperature stress

The North Konkan region experiences severe and prolonged soil moisture deficit coupled with very high temperatures and solar radiation and low atmospheric relative humidity for about five to six months every year which inhibit the growth and productivity of *Hevea* (Sethuraj, 1984; Rao *et al.*, 1998). Under such stress situations, irrigation is essential for trees in the field to maintain optimum growth and with adequate irrigation during the summer months, *Hevea* can be successfully cultivated in this region (Sethuraj *et al.*, 1989; Vijayakumar *et al.*, 1998; Devakumar *et al.*, 1999). Immaturity period in the region can be reduced to even six years by providing irrigation. Adequate irrigation results in better growth performance in the dry season than in the wet season (Vijayakumar *et al.*, 1998). During severe drought, extreme soil and atmospheric moisture deficits result in very low plant moisture status leading to a high plugging index and consequently low and uneconomic yield (Chandrashekar *et al.*, 1993) which comes to only 10 per cent of the total yield obtained for the whole year (Chandrasekhar *et al.*, 1990). Hence tapping during the peak summer season is uneconomical and injurious to the trees if they are not irrigated.

Clonal variations exist in the degree of tolerance to drought (Chandrashekar, 1997) as well as in the response to irrigation. The clones RRIM 600, RRII 6 and RRII 208 show higher growth indicating better adaptability to stress in the North Konkan region than several other clones (Nazeer *et al.*, 1992, Chandrashekar *et al.*, 1994; Dey *et al.*, 1998). In a mature rubber plantation, the thick and luxuriant foliage intercepts solar radiation from reaching the soil surface, reducing the water requirement substantially. Similarly, mulching the open soil surface, particularly the plant basin of young plants and shading the plants helps to reduce moisture loss from the ground. (RRII, 1990, 1992).

Low temperature stress

Hevea, like other plants native of warm tropics suffer from chilling injury when exposed to low temperatures during winter (Long *et al.*, 1994). In winter, if temperature as low as 5^0 C persists, it can cause cold injury (Jiang, 1984). Chilling conditions set in by December and is at its peak by January. The low temperature hours are largely confined to the nights and early mornings. By early afternoon the days get warmer with high sun light intensity, which along with low temperature conditions can aggravate the stress injuries. (Oquist *et al.*, 1987, Jacob *et al.*, 1999). Physiographic features especially orientation of slope also result in temperature differences. In the hilly regions of Meghalaya, during winter months, perceptible difference between north and south facing slopes occurs, the latter being warme which favours growth while it is poor in the former (Saseendran *et al.*, 1993).

The severe winter conditions do not prolong for more than a month or so in the North East India as the weather warms up by February. During the other seasons of the year, congenial conditions exist, favouring the growth of *Hevea*. Some clones can grow here as well as in the traditional area (Sethuraj *et al.*, 1989). The survival of *Hevea* in cold conditions is largely dependent on the intrinsic cold tolerance characteristics of clones. Young plants are more vulnerable to cold injury than mature trees. Simple management practices like partial shading during winter months provides a conducive microclimate for young *Hevea* plants and thereby increases the growth substantially in the North East. Keeping budded stumps in polythene sheds increased the temperature in the immediate microenvironment and thus increased the sprouting of buds (RRII, 1992).

In general, the cool winter season of the NE region, favours latex flow by prolonging its duration (reduced plugging index) resulting in relatively high yield than in the non-winter period. The yield contribution during the entire cold season can be as large as 60 per cent of the total annual rubber yield (Vinod *et al.*, 1996). However, indiscriminate tapping during stressful winter season can be injurious to the trees, which can even result in tapping panel dryness syndrome (Das *et al.*, 1998, 2000).

REGIONAL RESEARCH STATIONS

In order to provide research support to overcome the climatic and environmental stresses experienced in the non-traditional rubber growing tracts, the Rubber Board has established Regional Research Stations (RRS) in different parts of the country. These include the RRS at Agartala in Tripura, Guwahati in Assam, Tura in Meghalaya in the North East, Dapchari in the Konkan region of Maharashtra and Dhenkanal in Orissa. (Table 2).

The research priorities identified in general are crop improvement and evolving suitable agromanagement practices such as planting technique, fertilizer management, diseases and pests management, exploitation systems and rubber-based sustainable cropping systems. The impact of rubber cultivation on the ecosystems is also under study. Location specific research aimed at developing appropriate package of practices for the respective area is carried out in each station and emphasis is given to problems, which require immediate attention.

The crop improvement programmes in the RSS are aimed at evaluation of potential clones, polyclonal seedling trees (polycross progeny) and fresh (wild) germplasm. In addition, the conventional breeding methods viz. ortet selection and clonal hybridization and selection are also being undertaken. A total of around 50 clones are being subjected to field evaluation in a phased manner. Available information on breeding and selection programmes undertaken in the different RRS is furnished below.

Regional Research Station, Agartala

Tripura of NE India, a non-traditional environment for *Hevea* with a physiographic predominance of hills (tillas) and valleys (lungas) offers an eco friendly system for rubber on the tillas and paddy or allied crops or fishery in the lungas which is a sustainable agro forestry system. .(Varghese *et al.*, 1998 b). Priyadarshan *et al.*, (1998 b) represented the optimum and stressful environment in an year as the low yielding Regime I (April - Sept.) and the period from October to January as the a high yielding Regime II. The general trend of rubber yield in Tripura shows a sudden rise

Table 2. **Regional research stations of RRII in the non traditional areas**

Station, State	Year of establishment	Longitude	Latitude	Altitude (m above MSL)
Agartala, Tripura	1979	91°E	23° N	30
Guwahati, Assam	1985	90 °E	26° N	105
Tura, Meghalaya	1985	90 °E	25° N	600
Nagrakata, West Bengal	1989	88 °E	26° N	68
Dhenkanal, Orissa	1987	85 °E	20 ° N	100
Dapchari, Maharashtra	1981	72 °E	20 ° N	48

in latex volume from early October, which reaches a peak in mid November and falls to the original level towards the end of January. The remaining part of the year is devoid of wide fluctuations. About 60% of the yield is realized during this short period (Vinod *et al.*, 1996a). The mechanism of a sudden jump in latex volume, prolonged flow, and latex dilution during the peak-yielding season in N.E. India, suggests that the trees experience a mechanism similar to stimulation, probably caused by lowering of temperature and the ongoing senescence process. It appears that this causes increased laticifer activity and higher sucrose loading resulting in drainage of excess unutilized sucrose through latex serum. (Vinod *et al.,* 2000).

Clone evaluation

The first clone trial in the NE region was laid out at the experiment station of RRS Agartala at Taranagar with 15 clones (RRII 5, RRII 105, RRII 118, RRII 203, Gl 1, RRIM 600, RRIM 605, RRIM 703, PB 5/51, PB 86, PB 235, GT 1, Harbel 1, RRIC 52 and RRIC 105), employing a completely randomized design with 40 replications in 1979 which was opened for tapping in 1989. Among the 15 clones RRIC 52, RRIC 105, RRII 118,RRII 203 and PB 235 were among the vigorous clones. (Table 3) Mean yield over eight years was the maximum in PB 235 (47.7g) followed by RRIM 600 (40g), RRII 203 (38.1g), RRII 118 (36.4g), RRIM 703 (34.3g) and RRII 105 (33.7g). (Priyadarshan *et.al.,* 2000). In terms of early yield and stability the clones RRIM 703, RRII 118, RRIC 105, RRII 203, RRII105, PB 235 and RRIM 600 were found promising.(Vinod *et al.,* 1996).

In another trial with 10 clones (RRII 105, RRII 118,RRII 208, RRIM 600,PB 5/51,PB 86, GT1, GL 1, PR 107,SCATC 88/13, SCATC 93-114 and Haiken 1) planted in 1987, RRII 208, SCATC 88/13, Haiken 1 and RRIM 600 are the selections considering both girth and yield (Priyadarshan, 2002, unpublished).

Table 3. **Mean girth, yield and yield attributes of 15 clones (1979 clone trial) at RRS Agartala**

Clone	Mean girth (cm)	Yield g/tree/tap) BO1	BO2	Mean yield over 8 years
Indian				
RRII 5	68.9	20.1	27.7	23.9
RRII 105	73.5	28.9	38.4	33.7
RRII 118	85.3*	27.5	45.3	36.4**
RRII 203	80.6*	32.5	43.7	38.1**
Malaysian				
Gl 1	61.2	15.2	17.1	16.3
RRIM 600	76.4	34.8	45.2	40.0**
RRIM 605	75.9	25.5	32.5	29.0
RRIM 703	69.0	29.3	39.2	34.3**
PB 5/51	66.2	19.7	28.1	23.9
PB 86	72.8	25.8	31.8	28.8
PB 235	80.0*	40.3	55.2	47.7**
Indonesian				
GT 1	70.1	20.5	30.4	25.4
Liberian				
Harbel 1	66.3	17.5	20.9	19.2
Sri Lankan				
RRIC 52	91.2*	19.6	26.6	23.1
RRIC 105	86.0*	25.4	30.3	27.8

* Vigorous clones
** High yielding clones
Source: Priyadarshan *et al.,* (2000)

Among the 10 clones viz. RRII 105, RRIM 600, RRIM 612, PB 217, PB 235, PB 260, PB 311, SCATC 88/13, SCATC 93-114 and Haiken 1 in the 1995 clone trial, in the immature phase, higher girth increment was recorded in PB 260, SCATC 88/13, PB 235 and SCATC 93 -114 (RRII, 2002).

Polyclonal seedling evaluation

A comparison of 361 polyclonal seedling trees with a multiclonal population of the same age revealed that polycross progenies were highly heterogeneous in growth, yield and other desirable characters

Table 4. Selections from polyclonal population at Agartala

Selection (code No.)	Girth (cm)	Annual girth increment (cm)	Mean yield over 3 years (g/tree/tap)
S1	87.5	9.9	70.30 (26.3)
S2	67.4	5.3	55.72 (25.8)
S3	93.1	7.8	54.53 (23.9)
S4	72.8	8.1	53.28 (40.4)
S5	78.5	6.0	51.59 (33.7)
S6	82.2	7.7	48.30 (24.6)
S7	70.4	5.3	44.08 (24.1)
S8	74.1	5.3	41.56 (36.7)
S9	75.3	7.9	40.52 (30.3)
S10	75.6	6.5	40.46 (26.3)
Mean *	68.7	4.8	21.11 (31.2)
Mean **	63.1	4.3	21.35 (53.3)

* Polyclonal seedlings ** Multiclonal population
Figures in parentheses are the coefficient of variation (CV) of yield over months
Source: Sasikumar *et al.*, (2001)

and attained early tappability, higher girth and girth increment on tapping. Data on the ten best polyclonal seedling selections are given in Table 4. The yield over three years (g/tree/tapping) ranged from 70.30 g (S1) to 40.46g (S10), in comparison to a population mean of 21.11 g for the poly clonal seedlings and 21.35 g for multiclone population.(Sasikumar *et al.*, 2001).

Hybridisation and selection programme

In general the climate in the non traditional areas is not very conducive for carrying out hybridization programmes, the conventional breeding programme adopted in *Hevea*. However attempts in this direction has been initiated at RRS, Agartala. Six cross combinations incorporating Wickham clones as parents during 1991-'93 period resulted in 52 hybrids of which, 26 selections are under small scale clone evaluation. Another seven combinations of the 1998 hybridization programme resulted in 75 hybrids. Both Wickham x Wickham and Wickham x Amazonian crosses were attempted in 13 different cross combinations during the 1999-2000 flowering season. which resulted in 642 hybrids.(RRII, 2002).

Low temperature affects the flowering behavior of *Hevea* clones (Meenatttoor *et al.*, 1989). Severe winter prolongs the flowering period beyond April and in general reduces the fruit set. A study on low fruit set revealed that pollen production in general was very less and ovule abortion occurred in 30-40 days after anthesis with the abortive ovules having a tendency to produce nucellar adventive embryos (Sudha sowmyalatha *et al.*, 1997).

Ortet selection

Hevea being a cross pollinated species, seedling plants are genetically heterogenous offering scope for selection of potential mother trees. Ortet selection or mother tree selection aimed at selection of potential natural recombinants from seedling plantations has also been done at Agartala. Consequently, 11 ortet clones preliminarily selected after screening 602 ha. of 30 year old seedling plantation of Sipahijala, of Tripura Forest Development Corporation Ltd. were established in an evaluation trial, and are in the early growth stage.

Germplasm conservation

Since rubber cultivation in India has been extended to marginal and non-traditional areas confronted with various agro climatic constraints limiting plant growth and productivity, development of location specific clones capable of withstanding specific stress situations has become a priority area of research. In this context, the wild germplasm collected by an expedition organized by the International Rubber Research and Development Board (IRRDB) in 1981 from the three provenances in Brazil viz. Acre (AC), Rondonia (RO) and Mato Grosso (MT) is a valuable raw material for achieving this objective and thereby gaining further genetic advance in crop improvement programmes.

In India, this new germplasm was imported from Malaysia during the period 1984 to 1990, both to the traditional and nontraditional regions. Currently, a total of 4548 wild *Hevea* germplasm accessions - 3975 in Kerala and 972 in the NE (some common in both locations) are being conserved (Varghese *et al.*, 2002b). From this collection, 246 wild accessions are being conserved in Tripura of which 89 are under field evaluation

Biotechnological investigations

Location specific programmes in biotechnology aimed at screening/ development of cold and *Oidium* tolerant genotypes have been initiated by establishing a tissue culture laboratory at Agartala. Studies on embryo rescue are in progress. Multiple shoots were obtained from immature embryos using MS medium supplemented with kinetin, NAA and GA3 (Das *et al.*, 1998).

Somatic embryogenesis was obtained after 5-7 weeks of culture of anthers on to modified MS medium. Clonal variation was observed on callus initiation and somatic embrogenesis with RRII 105 showing higher response than RRIM 600 and SCATC 93-114 selected for the study (RRII,2002).Use of DNA markers for screening/development of cold/ *Oidium* resistant genotypes from indigenous/exotic germplasm is a potential area deserving attention (Varghese, 1998, Varghese *et al.*, 2000a).

Regional Research Station, Guwahati

Growth and yield of clones were studied under the agroclimatic conditions of Assam. The first clone trial was established in 1985 at Sorutari, the experimental farm of RRS Guwahati. The 10 clones *viz.* RRII 105, RRII 118, RRII 203, RRIM 600, RRIM 605, PB 86, PB 235, PB 5 / 51, GT 1 and GL 1 planted in CRD with 40 replications were opened for tapping in the eighth year after planting.

Early data revealed that RRIM 600 exhibited the maximum girth in the juvenile stage closely followed by PB 235 and RRII 118. At the immature stage, PB 235 showed the highest girth closely followed by *RRIM 600* and *RRII 118*. *RRIM 600* showed the maximum girth after the commencement of tapping during mature stage also. Poor growth as well as low rubber yield was observed in all the ten clones during winter months characterized by low temperature from December to March combined with the

Table 5. **Girth and yield of 10 clones in the early mature phase at RRS Guwahati**

Clone	Girth (cm)	Girth increment (mean of 3 years) (cm)	Mean yield over the first 3 years (g/tree/tap)	Yield projected (kg/ha/ year)
RRII 105	50.26 (4)	1.37	27.25	1296.0 (2)
RRII 118	50.65 (3)	2.28	23.63	1139.0 (4)
RRII 203	49.32 (7)	2.58	19.70	962.0 (8)
RRIM 600	52.51 (2)	2.26	32.31	1554.0 (1)
RRIM 605	49.44 (6)	1.57	20.10	979.0 (7)
PB 86	50.23 (5)	2.72	19.40	936.0 (9)
PB 235	52.89 (1)	1.41	26.03	1249.0 (3)
PB 5 / 51	40.78 (9)	1.56	23.05	1112.0 (6)
GT 1	47.68 (8)	2.10	23.52	1133.0 (5)
Gl 1	40.18 (10)	2.05	17.67	853.0 (10)
CD at 5%		NS	8.55	247.89

* Yield based on 300 trees in 160 tapping days/ year/ha

* Figures in parentheses indicate the relative ranking of individual clone based on girth and yield performance

Source: Mondal *et al.*, 1999

wintering and defoliation stresses. High DRC of latex, low dry rubber yield and high plugging index were observed in all ten clones during May to August. An increasing trend in the yielding pattern was observed from August onwards in all the clones with a maximum in November. Among the 10 clones, RRIM 600 recorded the highest yield (32.31 g/tree/tap) for the first three years of tapping followed by RRII 105(27.25g) and PB 235(26.03g) with minimum in Gl 1 (Table 5). (Mondal *et al.,* 1999).

In the second clone trial planted in 1986 with 10 clones (RRII 5, RRII 105, RRII 118, RRII 208, PB 260, PB 310, PB 311, PR 255, PR 261 and RRIC 102) fourth year annual yield was the highest in PB 311 (30.3 g/tree/tap), followed by PB 310 (27.02 g) in comparison to RRII 105 (20.8 g) while RRIC 102, and RRII 118 were among the vigorous clones with girth values of 74 cm and 71 cm respectively in comparison to 60 cm for RRII 105 (RRII, 2002).

Out of 266 polyclonal seedling trees screened, in the 1986 polycross progeny evaluation, 10 seedlings with high yield potential were preliminarily selected, the yield potential of which (6^{th} year) ranged from 60-122 g/t/t (RRII, 2002). 534 wild germplasm accessions are being conserved in the station. Seventy of these were screened for *Oidium* resistance, which showed a wide range in the levels of resistance indicating scope for selection (RRII, 2002).

Regional Research Station, Tura

In the West Garo Hills of Meghalaya at Tura, the experimental farm is located at an elevation of 600m above MSL, where the immaturity period of 10 years is required for the trees to attain tappable size. (Reju *et al.,* 2000). Reju *et al.,* (2001) defined 4 different seasons – Winter (Dec.-Feb.), Summer (March-May), Monsoon (June – August) and post monsoon (Sept.-Nov.). Data from a clone trial with 10 clones showed that the proportion of growth and yield in different seasons vary. The maximum growth occurred during monsoon (44%) and post monsoon (40%) seasons with the least in winter (5%) followed by summer (11%). On the other hand, the proportion of yield is the maximum (36%) during the post monsoon months with more or less equal proportion in monsoon (23%) and winter (22%) periods and the minimum (19%) in the summer season.

In the first clone trial planted in 1985 with 10 clones (RRII 105, RRII 118, RRII 203, RRIM 600, RRIM 605, PB 5/51, PB 86, PB 2235, GT1 and GL 1) in CRD with 40 replications, the vigorous clones include RRIM 600 (79.65cm) followed by PB 235 (77.46) and RRII 203(76.57).Highest annual yield in gram per tree per tap was recorded for RRIM 600 (31.2g) followed by PB 235 (31.9g), RRII 203 (31.2g) and RRII 105 (30.4g) (RRII, 2002).

In the second clone trial with another set of 10 clones, girth after tapping was the

Table 6. **Performance of 10 *Hevea* clones in Tura (1986 clone trial)**

Clone	Tappability (%) at 10 years	Yield (g/tree/tap)	Girth (cm)
PB 311	96	36.8 (1)	72.9 (2)
RRII 208	73	30.9 (2)	68.5 (5)
RRII 118	83	28.7 (3)	71.6 (3)
PB 310	70	26.8 (4)	71.6 (3)
RRII 105	43	25.3 (5)	63.3 (7)
PB 260	50	22.5 (6)	61.5 (8)
RRII 5	44	21.8 (7)	57.7 (9)
PB 255	41	21.4 (8)	65.0 (6)
RRIC 102	73	20.3 (9)	69.1 (4)
RRIC 105	85	18.8 (10)	74.4 (1)
Mean	65.8	25.3	67.6
SE	6.3	1.8	1.7
CD ($P \leq 0.05$)		6.9	1.1
CD ($P \leq 0.01$)		9	1.4

Source: Reju *et al.,* 2001

highest in RRIC 105 followed by PB 311, RRII 118 and PB 310. These three clones recorded high tappability percentage too (Table 6). Mean yield over two years was the maximum in PB 311 (36.8g). Other high yielders include RRII 208 (30.9g), RRII 118 (28.7g), PB 310 (26.8) and RRII 105 (25.3g) (Reju *et al.*, 2001).

Evaluation of polycross progeny is also being undertaken. Data from a population of 190 polyclonal seedlings planted in 1987 has revealed high variability in growth and early mature yield. The range in 4th year yield was 8.80 to 40.4 g/tree/tap which indicate the scope for selection of potential genotypes.

Under the ortet selection programme, screening of 2500 seedling trees from Bagmara and Tebrongre plantations of the Soil Conservation Department resulted in selection of 9 mother trees with high yield potential, which have been established for further evaluation and confirmation of the genetic potential.

Regional Research Station, Nagrakata

The northern part of West Bengal, located in the sub Himalayan region , has been identified as a marginally suitable zone for rubber cultivation (Rao *et al.*, 1993). In the Regional Experiment Station at Nagrakatta, in Dooars area of West Bengal, clone evaluation trials have been laid out from 1990 onwards in order to study the growth and yield of different clones.

During 1990, 18 clones were planted in two evaluation trials in a randomised block design with three replications. These include clones developed in India (RRII 105, RRII 118, RRII 203, RRII 208, RRII 300), Malaysia (Gl 1, RRIM 600, RRIM 612, RRIM 703, PB 5/51, PB 86, PB 235, PB 311), Indonesia (PR 107, GT 1) and China (SCATC 88-13, SCATC- 93-114, Haiken 1).

Meti *et al.*, (1999) defined four different seasons *viz*. hot (March-May), monsoon (June–September), cool (October–November) and cold (December-February). Growth was more in monsoon and cool (post monsoon) seasons and less in summer season with only negligible growth in the cold season. Highest rate of growth was observed in the cool season (1.13 cm/month) followed by monsoon (1.02 cm), hot (0.24 cm) and cold (-0.01cm) season. A stability analysis indicated that among the 18 clones GT 1, RRII 118, SCATC 88/13, SCATC 93/114 and Gl 1 showed comparatively more stability for growth. Except the clones PB 5/51, RRII 300, PR 107 and GT 1, all others recorded significantly higher girth during immaturity period and attained tappable girth by the seventh year. Growth in the immature phase in terms of girth over seven years was the highest in RRIM 612 (52.2 cm) followed by RRII 118 (52.1cm), RRII 203 (51.5), RRIM 703 (51.7 cm), and PB 235 (50.8 cm). Initial (first year) yield was the highest in SCATC 88-13 (Meti *et al*, 1999). Same trend continued in the early mature phase also. Mean yield over the first three years of tapping was the highest in SCATC 88-13, followed by PB 311, RRII 208, and PB 235 (Meti *et al.*, 2002, unpublished).

Another clone trial with 11 clones planted in 1991 also employing RBD with three replications is in the early mature phase (Table 7). Both the Chinese clones Haiken 1 and SCATC 93-114 as well as PB 235 and RRIM 600 are among the vigorous clones. First year yield was high in Haiken 1, RRII 300, RRIM 600 and PB 235 (RRII, 2002).

Table 7. **Performance of 11 clones in Nagrakata (1991 clone trial)**

Clone	Girth (cm)	Annual girth increment (cm)	Mean yield-first year (g/tree/tap)
RRIM 612	52.34	2.09	17.50
RRII 208	51.97	2.24	26.43
PR 107	49.24	2.80	13.53
PB 310	51.33	1.54	23.66
SCATC 93-114	54.27	2.28	9.30
PB 260	51.26	2.42	12.64
RRIC 102	53.90	2.73	16.70
PB 86	52.53	2.51	16.95
RRIM 600	53.72	1.99	23.84
Haiken 1	56.01	2.13	26.45
PB 235	57.53	2.67	23.30
SE±	1.92	0.34	2.74
CD (P=0.05)	NS	NS	NS

Source: RRII (2002)

With the objective of screening of fresh wild germplasm for cold tolerance, two evaluation trials of 49 and 22 accessions each were laid out in 2000 in simple lattice and RBD designs respectively. Early growth data has revealed wide variability indicating scope for selection of cold tolerant genotypes.

Regional Research Station, Dapchari

This research station is situated in the Thane district of North Konkan region of Maharashtra which experiences prolonged drought for about seven rainless months. Although there is an annual rainfall of about 2000-3000 mm, distribution is confined to mid June-mid September. Rao *et al.*, (1993) using a climatic index classified this region as conditionally suitable for rubber cultivation. Based on rainfall pattern and moisture availability Chandrashekar *et al.*, (1998) divided the year in to three seasons viz. wet (June- September) with excess soil moisture, mid (October-January) with good residual soil moisture and dry (February-May) with very low soil moisture levels. According to a generalized growth pattern for *Hevea* in North Konkan under rainfed condition, 76.1% of growth takes place in the wet season followed by 23.4 % in the mid season with a negligible proportion (0.5%) in the dry season (Chandrashekar *et al.*, 1998).

Major research activities include development of suitable planting materials and agrotechnology for this drought prone region. The first clone evaluation trial was planted in 1985 incorporating 15 clones in an RBD with three replications consisting of 36 plants each, with the objective of selection of high yielding and drought tolerant clones. Among the 15 clones (RRII 5, RRII 6, RRII 105, RRII 208, RRII 308, RRIM 605, PB 260, PB 310, PB 311, RRIC 52, RRIC 100, RRIC 102, RRIC 105, PR 255 and PR 261), in terms of immature growth, RRII 208, RRIC 52, RRII 6, RRIC 102 and RRIC 100 are rated as more drought tolerant than the other clones. (Chandrashekar *et al.*, 1998). This trend was continued in the mature phase too with RRII 208 performing well both in terms of girth and yield. (Table 8).

Table 8. **Performance of 15 clones at RRS Dapchari (1985 clone trial)**

Clone	Mean girth (cm)	Mean annual yield (g/tree/tap)
RRII 5	55.0	29.1
RRII 6	58.4	39.9
RRII 105	54.0	33.5
RRII 208	60.9	39.0
RRII 308	52.4	24.8
RRIM 605	53.7	22.7
PB 260	54.6	24.5
PB 310	55.6	29.1
PB 311	53.4	29.5
RRIC 52	60.3	19.8
RRIC 100	56.1	30.7
RRIC 102	56.7	28.4
RRIC 105	54.0	20.3
PR 255	53.1	27.9
PR 261	52.6	24.3
CD (%)	4.7	17.5

Source: RRII (2002)

Evaluation of polycross progenies was done using data on yield over seven years (4^{th} to 10^{th} year of tapping) from two blocks of seedling trees. Block 1 yielded 997.8 kg / ha with a CV of 49%, while Block II yielded 609.4 kg /ha with a CV of 64 %. The pooled mean yield of polyclonal seedling trees in the drought prone non traditional Konkan area under unirrigated condition was 803.6 kg/ha (RRII, 2002). The yield realized is very promising indicating the significance of planting polyclonal seedlings in stress prone areas.

Regional Research Station, Dhenkanal

The regional research station at Dhenkanal District was established in 1987 to undertake location specific research so as to develop a package suited for this drought prone region. The first clone evaluation trial was planted in 1987 with three elite clones RRII 105, RRIM 600 and GT 1. Of the three clones, RRIM 600 recorded the highest average annual yield of 25.8 g/tree /tap followed by RRII 105 (21.8g) and the lowest was in GT 1 (RRII, 2002).

The second clone evaluation trial was planted in 1990 with ten clones *viz.* RRII 5, RRII 208, RRII 300, RRIM 600, RRIM 701, PB 310, PR 255, SCATC 88 -13, SCATC 93- 114 and Haiken 1. An analysis of growth data in the immature phase revealed higher growth indices in RRIM 600, SCATC 93-114, RRII 208 and RRII 5 in comparison with the other clones. The first year yield was the highest in RRIM 600 (20.5g.) followed by SCATC 88-13 with 19.5 g/t/t. (Gupta and Edathil, 2001).

The 1991 clone trial consists of nine clones (RRII 5, RRII 105, RRII 208, RRII 300, RRIC 102, RRIM 600, GT 1, PR 255, PR 261) and polyclonal seedlings. In this trial in the immature phase, the polyclonal seedlings recorded significantly higher girth (63.2 cm) than the most vigorous clone RRIC 102 (58.9cm). An on-farm trial of 11 clones (RRII 51, RRII 105, RRII 208, RRII 300, RRII 351, RRII 352, RRII 357, RRIM 600, PB 28/59, IRCA 109, IRCA 111) was planted in 1999 and the girth in the juvenile phase was the highest in RRII 357 followed by RRII 352 and PB 28/59 (RRII, 2002).

Multilocational clone evaluation

Performance of clones varies in different agro climatic zones due to Genotype x Environment interaction. Therefore Genotype x Environment Interaction studies are essential for identifying clones with good adaptability and stability over different environments. Multilocational evaluation of clones was taken up with 12 potential clones planted in 1996 in four different agro climates representing both traditional and non traditional areas at Kanyakumari and Padiyoor (Traditional), Agartala, Nagrakatta and Bubaneshwar (Nontraditional). The 12 clones are RRII 105, RRII 203, RRII 51, RRII 176, RRIM 600, PB 217, RRII 414, RRII 417, RRII 422, RRII 429 and RRII 430.

Based on early data, stable and adaptable clones include RRII 430, RRII 5 and RRII 417. In the Kanyakumari and the Bubaneshwar regions, highest growth was recorded in PB 217 while in the cold prone Agartala and Nagrakatta, RRII 429 recorded maximum growth. Though good growth was observed for RRIC 100 in the first two locations, the performance was poor at Nagrakatta and Agartala due to its susceptibility to cold weather (Meenattoor *et al.*, 2000).

CONCLUDING OBSERVATIONS

Crop improvement programmes viz. breeding and selection including evaluation of potential clones and polyclonal seedlings were carried out in the different Regional Research Stations of RRII. Data available so far has helped to identify a few clones suitable for different locations, the commercial performance of which need to be confirmed in further experiments.

RRIM 600 proved to be the most suitable clone in terms of growth and yield in Assam and Meghalaya. In Tripura, PB 235 consistently gave high yield and in RRII 203 the yield increased steadily over the years. Based on experimental yield data from the station, the high yielding clones in the order of hierarchy are PB 235, RRII 203, RRIM 600, RRIM 703 and RRII 105 (RRII, 2002). The Chinese clones, in general, revealed promising performance under Nagrakatta conditions. In the drought prone North Konkan, RRII 208 recorded good girth and yield in the early mature phase.

It is well established that, in general, polycross progenies are better adapted for stress conditions than clones. In all the stations where the polyclonal seedling progenies were evaluated, performance was promising. These expressed wide variability for growth and early yield indicating scope for selection of promising genotypes. Ortet selection programmes for development of potential clones from seedling plantations also appear to be promising. The fresh germplasm resultant of the 1981 IRRDB expedition is expected to contain genes conferring tolerance to different biotic and abiotic stresses which, when incorporated in to the breeding pool will help development of stable location specific clones resulting in further genetic improvement and higher production and productivity.

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