(90)

Annamalainathan, K

NATIONAL CONFERENCE OF PLANT PHYSIOLOGY - 2016

Challenges in Crop Physiology Research : From Molecular to Whole Plant

8-10, December 2016

Organised by

Department of Crop Physiology
University of Agricultural Sciences, Bengaluru
and
Indian Society for Plant Physiology, New Delhi

PTO

SS39

Identification of a 23 kDa chloroplast stress protein as a marker for drought tolerance in *Hevea brasiliensis*

Annamalainathan K.*, Pramod S., Sumesh K.V. and James Jacob

Rubber Research Institute of India, Kottayam-686 009, Kerala, India
*Presenting author: annamalai@rubberboard.org.in

Ten different clones of *Hevea brasiliensis* were evaluated under soil moisture deficit condition for their relative drought tolerance potential. Physiological parameters such as leaf water potential, photosynthetic oxygen evolution rate of leaf, quantum yield of PSII activity (xPSII) and net CO_2 assimilation (A) rate were measured. The clones, RRIM 600, RRII 208 and RRII 430 recorded comparatively small decline in A and comparatively stable PS II activity upon exposure to soil moisture deficit stress. On the other hand, clones PB 260, RRII 105, RRII 414 and RRII 417 were found more susceptible in terms of severe inhibition of photosynthetic activities under moisture stress. Western blot analysis revealed consistent over-expression of a low molecular weight (23 kDa) chloroplast protein in the relatively drought tolerant clones, RRIM 600 and RRII 430. Further, this presence of this stress protein was validated in more number of clones of *Hevea*. It was observed that exposure to light was a pre-requisite for its over-expression under conditions of moisture stress. Together with other parameters, the relative over-expression of this protein is being used as screening tool for selecting drought tolerant clones of rubber.

SS40

Radiation processed carrageenan enhances essential oil yield and the active constituents of *Eucalyptus citriodora* Hook

Akbar Ali[1]*, Prem Kumar Dantu[1], M. Masroor A. Khan[2], M. Naeem[2], Moin Uddin[2] and Lalit Varshney[3]

[1]Department of Botany, Dayalbagh Educational Institute (Deemed University), Agra-282005, India
[2]Plant Physiology Laboratory, Department of Botany, Aligarh Muslim University, Aligarh 202002, India
[3]Head, RTDD, Isotope Group, Bhabha Atomic Research Centre, Mumbai -400085, India
*Presenting author: akbar.agra.alig@gmail.com

Eucalyptus citriodora is highly valued for its citronellal-rich essential oil (EO) extracted from its leaves. Citronellal i mainly used for synthetic production of menthol and citronellol. *Eucalyptus* oil is widely used in many perfumery an pharmaceutical formulations. Hence, escalated oil production of Eucalyptus is the need of hour. We developed a ne agricultural technique to achieve the goal. Application of biologically active oligosaccharides, derived from gamm irradiated polysaccharides, such as carrageenan (CR), proved to be potent plant growth promoters. Gel-Permeatior Chromatography of CR was performed after irradiating it using Co-60 gamma rays at 250KGy. A pot experiment we conducted to study the effect of foliar application of irradiated CR (ICR) on active constituents and growth, biochemic and yield parameters of *Eucalyptus*. ICR sprays were started at 6 months old plants. Totally, 5 sprays were carried o with an interval of ten days. The treatments were: deionized water (control), unirradiated CR 30, ICR 30, 60, 120 and 24 mg L^{-1}. Essential oil (EO) was extracted using Clevenger's apparatus and analyzed through Gas Chromatograph Treatment 60 mg L^{-1} (ICR-60) showed the highest value for most of the parameters studied. It increased the EO conte (28.7%), EO yield (72.4.5%), citronellal content (50.9%) and citronellal yield (159.7%) as compared to control.

J. Rubb. Res., **21(1)**, 46-61

Yield-Growth Dynamics of Hevea Hybrid Clones in Tripura

P.D. ANTONY[1#], P.M. PRIYADARSHAN[1], DAS K.[1] AND S. K. DEY[1]

Evaluation of growth and yield for twelve selected hybrids from two recombination breeding programmes was conducted in a clonal nursery trial at Tripura (North East India). Girth, increment in girth and yield based on test tapping as well as under ethephon stimulation were evaluated. Based on mean girth and girth increment, 99/5/9, 99/3/61, 99/1/15 and 98/46 were identified as vigorous clones. Test tap yield in the peak season was highest for reference clone RRIM 600 followed by 98/46. Hybrid clones 99/5/9, 99/3/61 and 99/5/35 also had test tap yield above the grand mean in both peak season and summer season. Assessment of intra-clonal variability through boxplot analysis revealed that among the promising clones 98/46, 99/3/61 and 99/5/9 had a lower range in girth, while 98/46 and 99/5/9 had better uniformity in yield. Significant yield-girth correlation was observed within clones in the second year of test tapping. Hybrid clones were classified based on mean and proportion of trees in the above average category. Clones 99/3/61, 99/5/9 and 98/46, belonging to the high girth and high yield categories, recorded higher mean yield than the grand mean over three years of test tapping, were comparable with RRIM 600 and identified as potential clones for further evaluation.

Keywords: clonal nursery evaluation; early selection; growth; hybrids; *Hevea*; yield

Derivation of climate resilient rubber clones (*Hevea brasiliensis* Muell. Arg.) for sub-optimal climatic conditions is prime, as rubber cultivation expands to newer areas worldwide. This involves screening of potential genotypes adaptable to new agro-climatic regions[1]. Breeding priorities in *Hevea* rubber include vigorous growth and high latex yield[2,3]. Vigorous growth is crucial for early attainment of tappability and the emerging demand for latex timber clones[4]. Although several studies have demonstrated the utility of girth[5], nursery yield[6], latex vessel density[6], plugging index[6], oil content[7], latex sugar[8], physiological and stomatal characteristics[9] *etc.*, as early selection criteria in *Hevea*, selection for yield and girth is widely adopted. High correlations between nursery yield at different growth stages and mature yield[10] suggests that nursery yield could be used to select at least a certain proportion of genetically high yielders[11]. Other parameters were found to be either inconsistent or could show only marginal improvement in selection efficiency based on yield. The only concern raised in early selection based on nursery yield is that non-precocious high yielders may often be eliminated[12]. However, selecting clones that perform better in later years of tapping is not favoured by several workers[13]. Considering rubber trees are now valued for latex as well as timber[14], recent emphasis has been on simultaneous selection for growth and rubber yield[4]. Striking a balancing point between girth and yield is arduous, but a challenge to the breeder.

[1] Hevea Breeding Substation, Rubber Board, Subrahmanya Road, Kadaba, Puttur Taluk, D.K. District, Karnataka-574221.
[#] Corresponding author (e-mail: deepthy@rubberboard.org.in)

Tripura of Northeast India, a non-traditional area for rubber cultivation offers a sub-optimal environment for rubber cultivation[15, 16]. Although the crop establishes well in this region, the average yield is lower than traditional regions. This disparity has been attributed to the sub-optimal environment[17, 18], the stress factors being low winter temperature, seasonal drought and strong winds, making derivation of adapted clones a top priority.

Recombination breeding through controlled hand pollination was adopted in *Hevea* for developing high yielding clones as early as 1930[19] and has led to the development of several high yielders like RRII 105[20, 21], RRIM 600[22], RRII 400 series clones[23, 24] *etc.* However, indigenous clones like RRII 105, RRII 414 and RRII 430 often exhibited lesser potential when grown in Tripura[25]. Development and identification of specifically adapted clones is the key for successful commercial cultivation. Accordingly, annual hybridisation programmes were initiated in Tripura, and hand pollination programmes of 1998 and 1999 yielded 717 hybrids. Based on mature yield of hybrids, selections were made and multiplied for further evaluation. The objective of the present study was to evaluate clones of selected hybrids for yield and growth in the nursery and to identify promising hybrid clones for multi-location on-farm trials that lead to clone recommendations.

EXPERIMENTAL

Materials and Methods

The clonal nursery for evaluation of selected hybrids was planted at a Research Farm in Taranagar, Agartala, Tripura (23°53'N; 91°15'E; 30m above msl).

Details of Hybrids Selected for Clonal Nursery Evaluation

The hybrid clones evaluated in the clonal nursery were selected from two seedling nurseries, planted with hybrid seedlings obtained from 1998 and 1999 hand pollination (HP) programmes (*Table 1*). Eight and twelve cross combinations were attempted in 1998 and 1999 hand pollinations, respectively. Seedlings were tapped at maturity and 18 superior genotypes were chosen in the first round of selection for further evaluation based on growth and yield (*Tables 2* and *3*), of which 12 hybrids were evaluated in the clonal nursery planted in 2008.

Field Planting and Evaluation

The selected hybrids (12) were multiplied by bud grafting and field planted in line RBD with three replications and five plants/ replication at a spacing of 2.5 m x 2.5 m in 2008. Clone RRIM 600, clone recommended for commercial cultivation in this region, was included as the local control clone. Quarterly recordings of girth was done at 30 cm height from the bud union from March 2010 to assess the seasonal growth increment. In Tripura, rubber clones are reported to have a definite peak yielding from October to January[26, 27]. Hence, for assessment of yield potential, test tapping was done at 30 cm height in November and May corresponding to peak and lean yielding periods, respectively. Test tapping was done under S/2 D3 6 d/7 system for three consecutive years from 2011 (third year after planting) onwards, following the modified Hamaker Morris-Mann method[28]. The first five tappings corresponding to panel opening were discarded and latex from ten consecutive tappings were coagulated. Dried cuplump weight was recorded and expressed as gram/tree/10 tappings ($gt^{-1}10t^{-1}$). To assess the amenability of the clones to low frequency

TABLE 1. PARENT COMBINATIONS AND SELECTIONS FROM 1998 AND 1999 HAND POLLINATION (HP) PROGRAMMES

	1998 HP	No. of progenies	No. of selections
1	RRIM 600 x RO 4616	24	
2	RRIM 600 x MT 4888	6	
3	RRIM 600 x RRII 208	2	1
4	RRII 105 x RRII 208	26	8
5	RRII 105 x Haiken 1	2	
6	RRII 105 x Juvenile Flower	2	1
7	PB 235 x RRII 208	7	
8	GT 1 x RRIM 600	6	1
	1999 HP		
1	RRIM 600 x RRII 208	298	2
2	RRIM 600 x Haiken 1	55	1
3	RRIM 600 x PB 235	95	1
4	RRIM 600 x PB 5/51	16	
5	GT 1 x RRIM 600	36	2
6	GT 1 x RRII 429	58	1
7	RRIM 600 x MT 4862	13	
8	RRIM 600 x MT 4888	18	
9	RRIM 600 x RO 4616	8	
10	GT 1 x RRII 208	2	
11	PB 235 x RRII 208	4	
12	GT 1 x PB 235	39	
	Total	717	18

TABLE 2. GROWTH AND YIELD PERFORMANCE OF SELECTED HYBRIDS FROM 1998 HP (SET I)

Sl No.	Identity	Parentage	Girth at 150 cm April 2003	Mean yield over 24 months from Nov 2004 ($g\ t^{-1} t^{-1}$)
1	98/33	RRII 105 x RRII 208	38.9	27.0
2	98/38	RRII 105 x RRII 208	33.4	24.2
3	98/46	RRII 105 x RRII 208	31.7	16.0
4	98/56	RRII 105 x RRII 208	-	24.8
5	98/61	RRII 105 x Juvenile Flower	32.7	18.9

TABLE 3. GROWTH AND YIELD PERFORMANCE OF SELECTED HYBRIDS FROM 1999 HP (SET II)

	Identity	Parentage	Girth at 150 cm April 2006	Mean yield over 21 months ($gt^{-1}t^{-1}$)
1	99/5/9	GT 1 x RRIM 600	43.3	18.62
2	99/5/35	GT 1 x RRIM 600	44.2	30.08
3	99/1/15	RRIM 600 x RRII 208	45.5	24.61
4	99/2/34	RRIM 600 x Haiken 1	44.6	37.68
5	99/3/61	RRIM 600 x PB 235	40.5	29.00
6	99/7/52	GT 1 x RRII 429	45.8	23.16
7	99/1/281	RRIM 600 x RRII 208	31.5	30.14

tapping under stimulation, response to stimulation was studied by test tapping the clones between July and August 2014 after panel application of 2.5% ethephon, followed by collection and recording of yield from ten tappings. Yield per girth was calculated based on the peak season test tap yield and girth recorded prior to commencement of tapping in the respective seasons. The clone performance was assessed based on the growth, test tap yield and yield/ girth. Statistical analysis was performed using Cropstat version 7.2 and box plot analysis was done in R statistical package[29].

RESULTS

Assessment of girth along with the increment in girth is used to determine the early performance of new planting materials[30]. In the present study, girth recorded annually did not reflect a significant difference between clones (*Table 4*). RRIM 600 (reference clone) recorded the highest girth in all the years (up to six years after planting). However, clones 99/5/9, 99/3/61, 99/1/15 and 98/46 had higher girth than the overall mean, and can be considered as promising clones in terms of growth. Seasonal and annual girth increment calculated from quarterly girth recordings revealed that differences were significant only in the mean summer girth increment of the clones (*Table 4*). Clone 99/5/9 recorded the highest mean summer girth increment (2.4 cm) followed by 99/3/61 and 98/46 (2.1 cm) and were higher than RRIM 600 (2.0 cm). Highest winter girth increment was recorded by the clones 99/3/61, 99/1/15 and 98/56 (1 cm) suggesting their cold tolerance potential (*Table 4*). Clones 99/5/9, 99/3/61, 99/1/15, 99/5/35, 98/46 and RRIM 600 had annual girth increment higher than the grand mean (6.4 cm).

Yield potential of the clones was assessed based on the test tap yield ($gt^{-1}10t^{-1}$) and in response to stimulation. Analysis of peak season yield revealed that except in the first year of tapping there was no significant difference among the clones tested (*Table 5*). Control clone RRIM 600 recorded the highest yield over all three years. Clones 99/5/9 and 98/46 had higher yield than the grand mean yield throughout, while 99/3/61 had a higher yield than the grand mean in the second and third years of test tapping. Clone 99/5/35 also recorded high test tap yield in the third year of tapping. It was observed that, in the high yielding hybrid clones, the peak season

TABLE 4. GROWTH PERFORMANCE OF SELECTED HYBRID CLONES IN CLONAL NURSERY TRIAL

Sl. No.	Clone	Mean girth (cm)			Mean girth increment (cm)			
		2 YAP*	4 YAP*	6 YAP*	Monsoon	Winter	Summer	Annual
1	99/5/9	8.3	20.1	34.6	3.8	0.8	2.4	6.6
2	99/7/52	10.1	21.4	34.2	3.9	0.7	1.5	6.0
3	99/3/61	8.3	20.1	37.6	4.4	1.0	2.1	7.3
4	99/1/15	7.6	20.7	37.7	4.7	1.0	2.0	7.5
5	99/5/35	6.8	17.8	33.2	4.3	0.9	1.3	6.6
6	99/2/34	7.6	16.6	23.8	3.0	0.6	0.6	4.1
7	99/1/281	7.5	17.9	29.4	3.9	0.6	0.9	5.5
8	98/38	6.9	18.1	32.0	4.2	0.8	1.2	6.3
9	98/56	7.4	18.7	32.9	4.2	1.0	1.3	6.4
10	98/33	9.3	21.0	33.1	4.0	0.7	1.1	6.0
11	98/61	8.6	18.1	28.7	3.8	0.5	0.8	5.0
12	98/46	10.8	23.6	40.5	4.7	0.8	2.1	7.4
13	RRIM 600	13.8	27.6	47.8	5.7	0.9	2.0	8.5
	CD (0.05)	NS	NS	NS	NS	NS	0.9	NS
	GM*	8.7	20.1	34.3	4.2	0.8	1.5	6.4

*YAP- Year after planting, GM- Grand mean

TABLE 5. MEAN PEAK SEASON (NOVEMBER) TEST TAP YIELD OF SELECTED HYBRIDS OVER THREE YEARS

Sl No.	Clone	First year ($gt^{-1}10t^{-1}$)	Second year ($gt^{-1}10t^{-1}$)	Third year ($gt^{-1}10t^{-1}$)
1	99/5/9	51.33	156.81	186.97
2	99/3/61	48.19	125.28	189.03
3	98/46	68.51	154.66	189.75
4	99/5/35	41.53	108.30	188.66
5	98/56	41.68	106.29	159.20
6	98/38	42.78	115.94	114.30
7	99/2/34	65.42	122.45	123.00
8	98/33	31.64	94.88	121.62
9	98/61	31.34	91.26	155.27
10	99/7/52	41.16	88.42	138.42
11	99/1/15	35.69	78.20	100.27
12	99/1/281	17.79	44.54	88.44
13	RRIM 600	126.55	202.03	194.00
	CD (0.05)	34.08	NS	NS
	GM	49.51	114.54	149.92

yield showe
to third yeai
600 which s
second to t
yield was h
$^{1}10t^{-1}$) follo
(Table 6). C
also had m
mean of the

There w
the clones
season and
6). Clones
and RRIM
than the gr
was no sig
tested clon
years of tap
$gt^{-1}10t^{-1}$) re
yield over t
clones 99/5/

TABLE 6

Sl. No.	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	R
	C

yield showed an increasing trend in the first to third year of test tapping as against RRIM 600 which showed a slight decrease from the second to third year *(Table 5)*. Mean peak yield was highest for RRIM 600 (174.2 $gt^{-1}10t^{-1}$) followed by 98/46 (137.6 $gt^{-1}10t^{-1}$) *(Table 6)*. Clones 99/5/9, 99/3/61 and 99/5/35 also had mean peak yield above the grand mean of the trial (104.7 $gt^{-1}10t^{-1}$).

There was no significant difference among the clones in the test tap yield in summer season and in response to stimulation *(Table 6)*. Clones 99/5/9, 99/3/61, 99/5/35, 98/46 and RRIM 600 had a higher summer yield than the grand mean (78.9 $gt^{-1}10t^{-1}$). There was no significant difference between the tested clones in the mean yield over three years of tapping. Although RRIM 600 (152.1 $gt^{-1}10t^{-1}$) recorded the highest mean test tap yield over three years of test tapping, hybrid clones 99/5/9 (117.2 $gt^{-1}10t^{-1}$), 99/3/61 (110.2 $gt^{-1}10t^{-1}$), 98/46 (108.5 $gt^{-1}10t^{-1}$) and 99/5/35 (107.7 $gt^{-1}10t^{-1}$) recorded a mean yield higher than the grand mean of the trial (91.0 $gt^{-1}10t^{-1}$). Highest mean test tap yield in response to stimulation was recorded in clone 99/5/35 (277.2 $gt^{-1}10t^{-1}$) followed by 99/3/61 (223.5 $gt^{-1}10t^{-1}$). All other hybrid clones recorded lower yield under stimulation than the check clone RRIM 600 (218.1 $gt^{-1}10t^{-1}$).

Boxplot analysis of girth and yield of trees was done to understand the variability within the clones. Analysis of girth at three to five years after planting revealed that the clone 99/2/34 showed the maximum range (*Figures 1A, B* and *C*). Among the hybrid clones with a mean girth above the grand mean at five years after planting, 98/46, 99/3/61 and 99/5/9 had a lower range compared to other clones. Clones 98/33 and 98/46 had more than 50% trees in the above average girth category in all the years of test tapping. Despite having a

TABLE 6. MEAN YIELD OF SELECTED HYBRIDS OVER THREE YEARS OF TEST TAPPING

Sl. No.	Clone	Mean peak yield ($gt^{-1}10t^{-1}$) (3 rounds)	Mean summer yield ($gt^{-1}10t^{-1}$) (3 rounds)	Mean yield ($gt^{-1}10t^{-1}$)	Stimulated yield ($gt^{-1}10t^{-1}$)
1	99/5/9	131.7	102.7	117.2	149.8
2	99/7/52	89.3	62.7	76.0	125.2
3	99/3/61	120.8	99.7	110.2	223.5
4	99/1/15	71.4	43.3	57.3	129.9
5	99/5/35	112.8	102.6	107.7	277.2
6	99/2/34	103.7	62.0	71.9	138.1
7	99/1/281	50.3	47.7	49.0	88.8
8	98/38	91.0	73.6	82.3	154.1
9	98/56	102.4	72.0	87.2	153.7
10	98/33	82.7	77.8	80.3	157.1
11	98/61	92.6	72.9	82.7	157.2
12	98/46	137.6	79.3	108.5	132.9
13	RRIM 600	174.2	130.0	152.1	218.1
	GM	104.7	78.9	91.0	162.0
	CD (0.05)	NS	NS	NS	NS

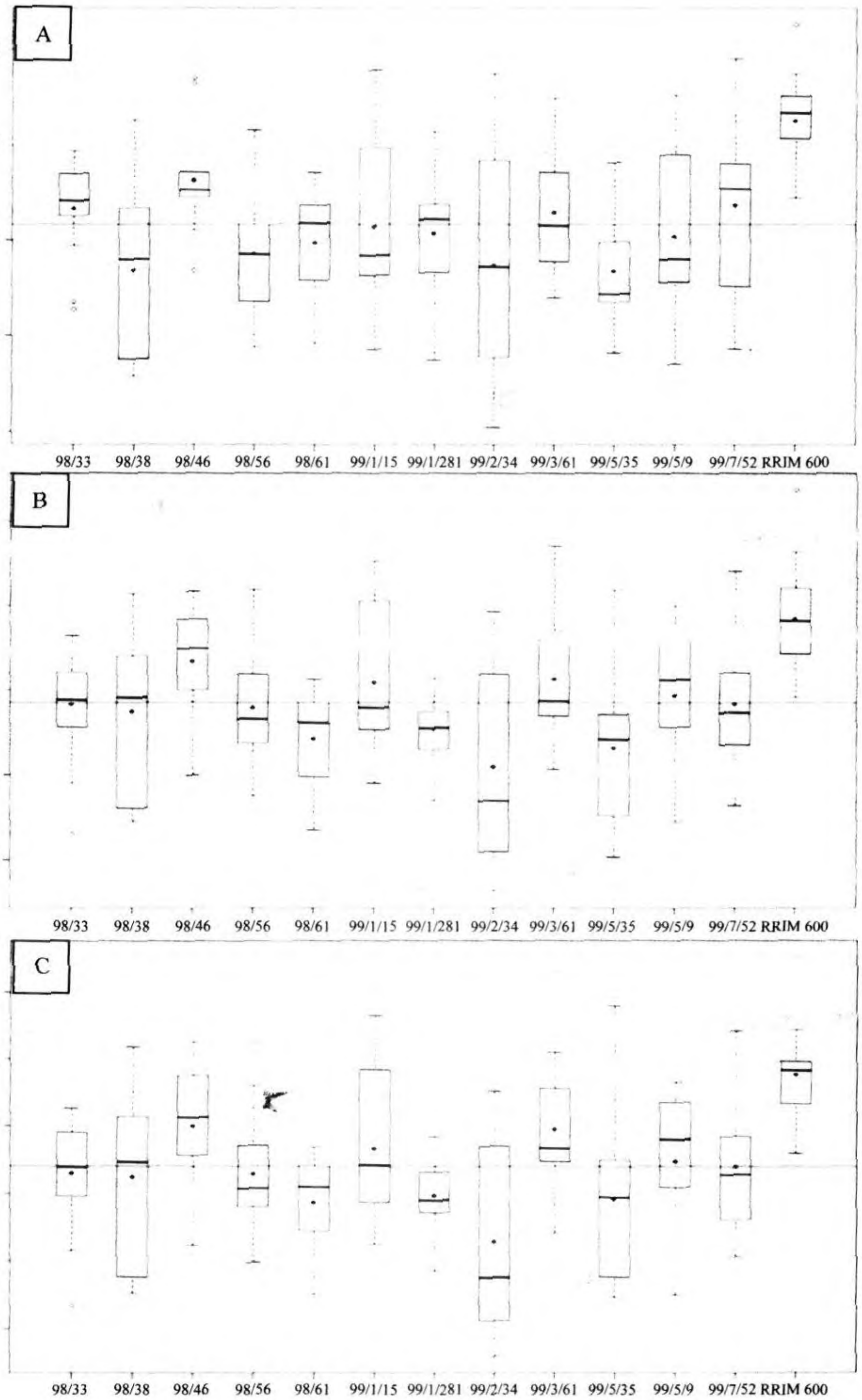

Figure 1. Boxplot of mean girth (cm) of clones over third (A), fourth (B) and fifth (C) year after planting.

high prop
98/33 fail
yield / girt
clones 9
first year;
year of te
to their lc
(*Figure 2*
clone RR
50% of th
all the ye
plot of y
three year
C), it is e
above ave
had a com
(IQR).

Signifi
with juven
others[3,31,3
irrespectiv
above ave
average g

TABLE 7

Sl. No.
1
2
3
4
5
6
7
8
9
10
11
12
13

high proportion trees of above average girth, 98/33 failed to give a high yield due to low yield / girth in all the years (*Table 7*). Similarly clones 99/1/281, 98/61 and 99/7/52 in the first year; and 98/38 and 99/1/15 in the third year of test tapping gave low yields owing to their low yield/girth. It was observed that (*Figure 2*) clones 98/46, 99/5/9 and control clone RRIM 600 consistently had more than 50% of the trees with above average yield in all the years of test tapping. From the box plot of yield performance of clones over three years of tapping (*Figures 2 A, B* and *C*), it is evident that among the clones with above average mean yield, 98/46 and 99/5/9 had a comparatively lower interquartile range (IQR).

Significant positive association of girth with juvenile yield was reported earlier by others[3,31,32]. In the first year of test tapping, irrespective of the clone, trees having above average yield (except two) had above average girth, but the reverse was not true. The number of trees with above average yield having below average girth increased to six and twelve in the second and third year of tapping, respectively. Significant correlation was observed between yield and girth on an individual tree basis and the correlation decreased from first to the third year of test tapping (*Figure 3*). The yield girth correlation within clones was significant (r) in all the clones in the second year of test tapping (0.66 to 0.99) (*Table 8*). However, in the third year of test tapping the correlation was insignificant for clones 99/7/52, 99/2/34, 99/1/281, 98/38 and 98/46, while it was negative for control clone RRIM 600.

Utility of test tap yield in the second year for identification of potential clones was advocated by several studies[5,32]. Hence, based on the mean and proportion of trees in the above average category in the second year of test tapping, the clones were classified into four categories (*Table 9*), as follows.

TABLE 7. YIELD/GIRTH OF HYBRID CLONES OVER THREE YEARS OF TEST TAPPING

Sl. No.	Clone	Mean yield/girth ($gt^{-1}10t^{-1}$)		
		1st year	2nd year	3rd year
1	99/5/9	2.3	4.7	4.9
2	99/7/52	1.6	2.8	4.2
3	99/3/61	2.1	3.9	4.9
4	99/1/15	1.4	2.3	2.5
5	99/5/35	1.9	3.5	4.8
6	99/2/34	2.9	4.5	4.0
7	9/1/281	0.9	1.7	3.0
8	98/38	1.9	3.7	3.4
9	98/56	1.7	3.7	5.2
10	98/33	1.4	3.3	3.5
11	98/61	1.6	3.5	5.0
12	98/46	2.7	4.5	4.6
13	RRIM 600	4.4	5.3	4.2
	GM	2.1	3.6	4.2

TABLE 8. CORRELATION (R) OF YIELD WITH GIRTH WITHIN CLONES OVER THREE YEARS OF TEST TAPPING

Sl. No.	Clone	1st year	2nd year	3rd year
1	99/5/9	0.877**	0.661*	0.790**
2	99/7/52	0.928**	0.941**	0.483
3	99/3/61	0.949**	0.987**	0.769**
4	99/1/15	0.938**	0.960**	0.801**
5	99/5/35	0.958**	0.978**	0.819**
6	99/2/34	0.845**	0.958**	0.698
7	99/1/281	0.653*	0.865**	0.483
8	98/38	0.966**	0.897**	0.538
9	98/56	0.762**	0.567*	0.568*
10	98/33	0.835**	0.857**	0.828**
11	98/61	0.893**	0.949**	0.946**
12	98/46	0.842**	0.905**	0.403
13	RRIM 600	0.927**	0.691**	-0.018

*significant to 0.05 level ** significant to 0.01 level

TABLE 9. GROUPING OF CLONES BASED ON THEIR PERFORMANCE IN THE SECOND YEAR OF TAPPING

Yield	Girth	Above average		Below average	
	Proportion of trees with above average (Grand mean) performance (%)	25 – 75	>75	<25	25 – 75
Above average	25 – 75	99/3/61			99/2/34 98/38
	>75	99/5/9	98/46		
Below average	<25			99/5/35 99/1/281	
	25 – 75	98/33 99/7/52 99/1/15		98/61	98/56

In the pres
had the hig
the selectic
clone ranke
lowest mea
(Tables 4 a
and mean y
while its cl
mean peak
(Table 3),
(31.5 cm) r
respectivel
girth in the
and the clc
other clone
the Set II
mean yielc
$gt^{-1}t^{-1}$) reco
the clonal
recorded tl
clones of S

Clones
with high g
be conside
growth. Ea
during dro
the drougl
99/5/9 and
600 in su
their poter
winter girt
and 98/56 s
the clones
are reporte
above clon
climatic cc
although y
aim of any

Clones
high mean
as clones
with high t
99/5/9, 99/

In the present study, hybrid 98/33 (38.9 cm) had the highest girth and mean yield among the selections from Set I (*Table 2*) while its clone ranked second in girth and recorded the lowest mean yield among the clones from Set I (*Tables 4* and *6*). The hybrid with lowest girth and mean yield in set I was 98/46 (31.7 cm), while its clone exhibited the highest girth and mean peak yield. In the second set of hybrids (*Table 3*), 99/7/52 (45.8 cm) and 99/1/281 (31.5 cm) recorded highest and lowest girth, respectively. The clone 99/7/52 had highest girth in the initial years which later dropped and the clone 99/1/281 had lower girth than other clones of Set II except 99/2/34. Among the Set II hybrids, 99/2/34 recorded highest mean yield (37.7 $gt^{-1}t^{-1}$), while 99/5/9 (18.6 $gt^{-1}t^{-1}$) recorded the lowest. On the contrary, the clonal progeny of 99/5/9 (117.2 $gt^{-1}t^{-1}$) recorded the highest mean yield among the clones of Set II hybrids.

DISCUSSION

Clones 99/5/9, 99/3/61, 99/1/15 and 98/46 with high girth and annual girth increment can be considered as promising clones in terms of growth. Earlier studies have shown that girth during drought period can be used to assess the drought response of a clone[34]. Clones 99/5/9 and 99/3/61 were superior to RRIM 600 in summer girth increment indicating their potential for drought tolerance. High winter girth increment of 99/3/61, 99/1/15 and 98/56 suggests their cold tolerance. Since the clones that are more adaptable to a region are reported to show vigorous growth[35], the above clones are likely to be adapted to the climatic conditions prevailing in this region although yield improvement is the ultimate aim of any breeding programme.

Clones 99/5/9, 99/3/61 and 99/5/35 with high mean peak season yield were identified as clones with high yield potential. Clones with high test tap yield in summer season *viz.*, 99/5/9, 99/3/61, 99/5/35 and 98/46 are likely to have tolerance to summer stress. Stringent selection is not advocated in early evaluation stages in *Hevea* breeding and earlier reports have advocated the selection of moderate to high yielders for further evaluation[3]. Hence, hybrid clones 99/5/9, 99/3/61, 98/46 and 99/5/35 which recorded a mean yield higher than the grand mean were selected for further evaluation.

Narayanan and Ho[36] showed that in mature trees, more than half the variation in yield within clones was accounted for by the differences in girth. Hence, selection of high yielding clones exhibiting better uniformity in girth after budding will ensure better yield at maturity. Large range exhibited by the clone 99/2/34 in the boxplot analysis of girth indicates that the clone may not have much uniformity in terms of growth after budding. A lower range exhibited by vigorous clones *viz.*, 98/46, 99/3/61 and 99/5/9, compared to other clones indicates better uniformity. Earlier studies have shown that the uniformity of grafted plants depends on the graft stock family, the bud graft and the association between stock/bud subject to other factors being equal[37]. The observation that low yield/girth resulted in low yield in clones despite having a high proportion of trees in the high girth category indicates that relying on girth as the sole criterion for early selection may not be advisable. Futility of nursery selection based on juvenile vigour was reported earlier[3]. However, clones like 98/46, 99/3/61 and 99/5/9 with a high proportion of high girth trees, coupled with high yield / girth proved to be high yielders. Clones 98/46 and 99/5/9 had a comparatively lower interquartile range (IQR) and better uniformity in terms of test tap yield. Hence, based on the box plot, it can be concluded that 98/46 and 99/5/9 has better uniformity in yield and girth among the high yielding clones in the present study.

Significant positive association of girth with test tap yield was observed in the present

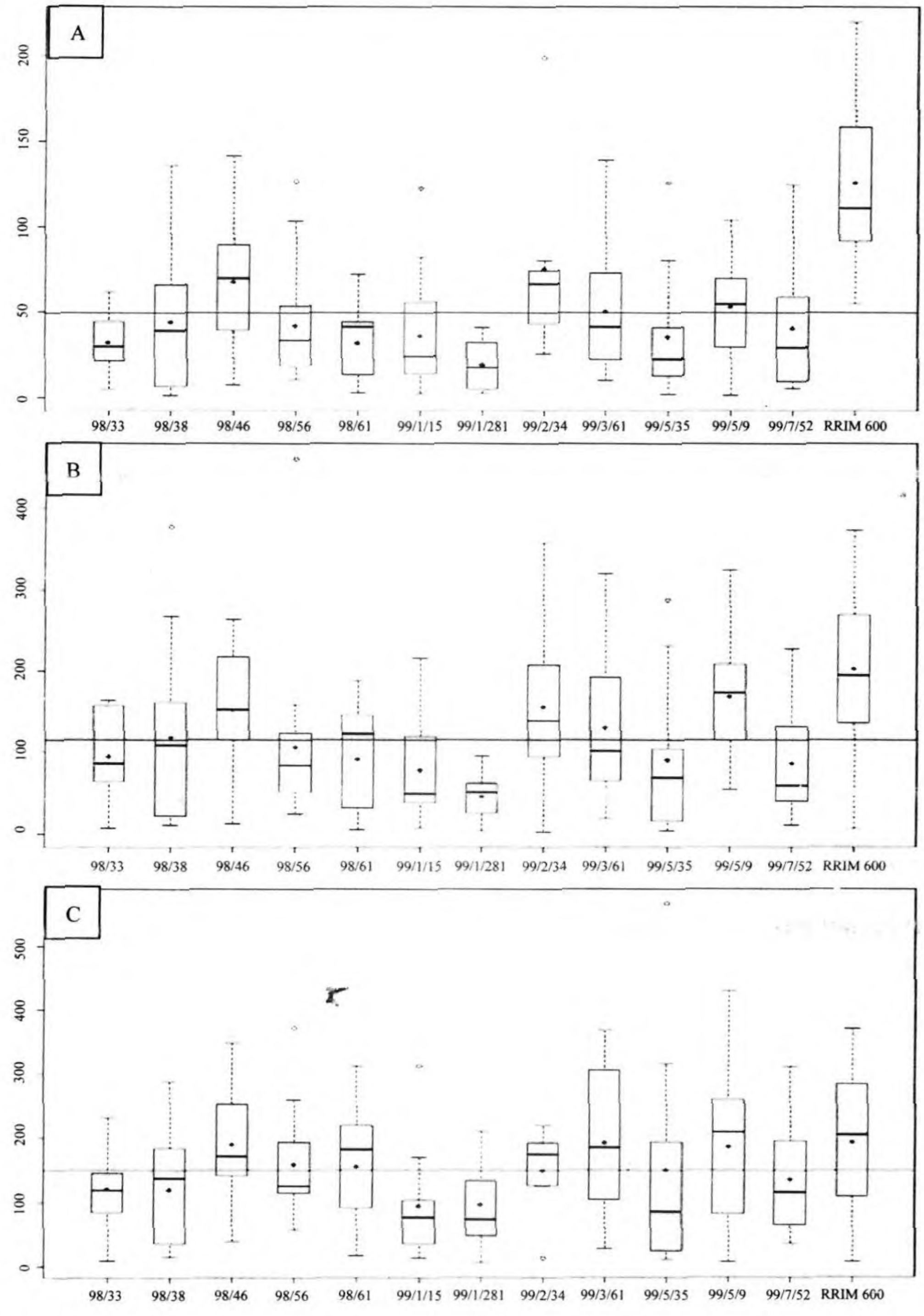

Figure 2. Boxplot of mean peak season yield ($gt^{-1}10t^{-1}$) of clones over first (A), second (B) and third (C) year of test tapping.

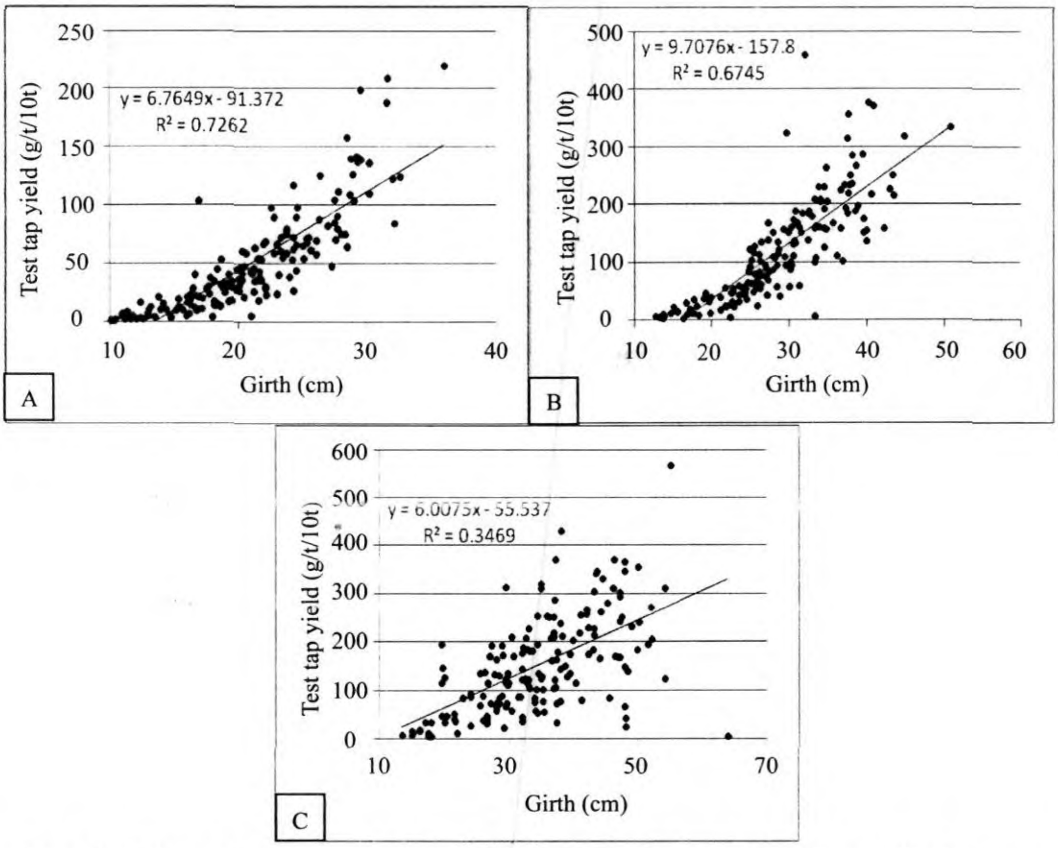

Figure 3. Yield - girth relation in trees in the first (A), second (B) and third (C) year of test tapping.

i) **High Girth and High Yield**

It was observed that hybrid clones 99/3/61, 99/5/9 and 98/46 belonged to this category of clones with above average mean girth and yield and can be considered as promising clones. Among these, 99/3/61 and 98/46 also had very strong yield-girth correlation indicating their girth dependence.

ii) **High Girth and Low Yield**

Hybrid clones 98/33, 99/7/52 and 99/1/15 recorded a low mean yield despite having a high mean girth.

iii) **Low Girth and High Yield**

99/2/34 and 98/38 of this category had a high mean yield/girth. Clone 98/38 had more than 50% trees with above average yield and the yield girth correlation was not high.

iv) **Low Girth and Low Yield**

Clones 99/5/35, 99/1/281, 98/61 and 98/56 belonged to this category.

Although several studies have explored the correlation between the ortets and their bud-grafts, results were mostly inconclusive[33].

study. Similarly, very high phenotypic and genotypic correlations were reported between girth at panel opening and rubber yield[2]. Girth of clones in the clonal nursery was also found to be positively correlated with yield at maturity[12]. Observation that trees with above average yield invariably had above average girth in the first year of test tapping indicates positive dependence of juvenile yield on girth. The increase in the number of trees with an above average yield despite having below average girth in the subsequent years may be due to reallocation of resources from vegetative growth to latex production. Earlier studies have also shown that in the first year of tapping girth and yield between clones are positively correlated. As tapping proceeds, this correlation disappears and may even become negative[38]. A similar trend was observed in the correlation between yield and girth on an individual tree basis with the correlation decreasing from first to the third year of test tapping. The yield girth correlation observed in this study was similar to the correlations (0.48 to 0.99) reported by Narayanan and Ho[39].

Mydin[3] reported the significant correlation of test tap yield of two year old nursery seedlings with the yield of resultant clones at maturity. Classifications of clones based on the means and proportion of trees in the above average category, in the second year of test tapping revealed that 99/3/61, 99/5/9 and 98/46 are promising as they had high girth and yield. Among these clones, 99/3/61 and 98/46 also had very strong yield girth correlation indicating their girth dependence. Hence the ability of these clones to have a higher proportion of high girth trees will be crucial in realising their yield potential. Further, the ability of 98/46 to retain more than 75% of the population in the above mean girth category when we go for large scale cultivation needs to be confirmed. Hybrid clones 98/33, 99/7/52 and 99/1/15 with low mean yield despite having high mean girth are not promising for further evaluation. Clones in the low girth and high yield category had a high mean yield / girth. However, 99/2/34 was found to have the maximum range among all the clones and the high mean yield was observed from only a few trees which attained tappable girth and hence, is not promising. Clone 98/38 can be selected for further evaluation as more than 50% trees had above average yield and the girth dependence of yield was not very high. Among the clones with low yield and girth, it was interesting to note that 99/5/35 had high mean yield over three years of tapping. On detailed examination, we can find that the high mean yield of 99/5/35 was due to a few trees (< 50%) giving above average yield in the third year of tapping and hence cannot be considered as a promising clone for further evaluation.

Among the high yielders, not much correlation existed in the ranking of the selected ortets and their respective bud-grafts. Variation in the growth pattern of genotypes consequent to bud-grafting is reported in earlier studies and was mainly attributed to stock scion interactions[30]. The rootstock is reported to have a significant effect on the growth, yield and growth physiology of rubber tree scions[40].

CONCLUSIONS

Based on the overall performance, hybrid clones 99/5/9, 98/46 and 99/3/61 with high yield and girth were identified as promising clones in the early evaluation. It is crucial to select clones with better vigour and yield from early sorting trials like clonal nursery evaluations for further evaluation in on-farm trials. The present study emphasises the need for taking into account the uniformity in yield and girth of clones along with their mean performance. The selected clones have to be evaluated further in on-farm trials under

normal spac
control clor
performanc
can also be
other locati

A

We wish to
and Dr. K
(Crop Imp
encourage

1. PRIYA
Hevea
Constra

2. GONÇ
GOUV
(2006)
and Ru
Agri. (

3. MYDI
Correla
Rubber
Brasili

4. GOUV
BOME
OLIVE
P DE
Rubbe
Rubbe
43.

5. VARG
PREM
AND
Evalua
the Juv
6 (1&

normal spacing and tapping systems along with control clones to ascertain the long term yield performance in Tripura. The selected clones can also be evaluated for their adaptation at other locations in northeast India.

ACKNOWLEDGEMENT

We wish to thank Dr. James Jacob, Director and Dr. Kavitha K. Mydin, Joint Director (Crop Improvement), RRII for their constant encouragement and support.

Date of receipt: April 2017
Date of acceptance: July 2017

REFERENCES

1. PRIYADARSHAN, P.M. (2003) Breeding *Hevea Brasiliensis* for Environmental Constraints. *Adv. Agron.*, **79**, 351 – 400.

2. GONÇALVES, P DE S. , SILVA, M. D., GOUVEA, L.R.L. AND SCALOPPI, E.J.J. (2006) Genetic Variability for Girth Growth and Rubber Yield in *Hevea Brasiliensis. Sci. Agri. (Piracicaba, Braz.)*, **63(3)**, 246 – 254.

3. MYDIN, K.K. (2012) Juvenile Mature Correlations and Associations Among Rubber Yield and Yield Attributes in *Hevea Brasiliensis*. *Nat. Rub. Res.*, **25 (1)**, 1 – 12.

4. GOUVEA, L.R.L., SILVA, G.A.P., BOMBONATO, A.L., VERARDI, C.K., OLIVEIRA, L.B. AND GONCALVES, P. P DE S. (2013) Simultaneous Selection of Rubber Yield and Girth Growth in Young Rubber Trees. *Ind. Crops and Prod.*, **50**, 39 – 43.

5. VARGHESE, Y.A., JOHN, A., PREMAKUMARI, D., PANIKKAR A.O.N. AND SETHURAJ, M.R. (1993) Early Evaluation in *Hevea* : Growth and Yield at the Juvenile Phase. *Indian J. Nat. Rubb. Res.*, **6 (1&2)**, 19 – 23.

6. TAN, H. (1998) A Study of Nursery Selection in *Hevea* Breeding. *J. Rubb. Res.*, **1(4)**, 253 – 262.

7. FERNANDO, D.M. AND DESILVA, M.S.C. (1971) A New Basis for the Selection of *Hevea* Seedlings. *Quarterly J. Rubb. Res Inst. Ceylon*, **48**, 19 – 30.

8. GOHET, E., CHANTUMA, P., LACOTE, R., OBOUAYEBA, S., DIAN, K., CLEMENT-DEMANGE, A., KURNIA, D. AND ESCHBACH, J. M. (2003) Latex Clonal Typology of *Hevea Brasiliensis*: Physiological Modeling of Yield Potential and Clonal Response to Ethylene Stimulation. *Proceedings of the International Workshop on Exploitation Technology*, India 2003, 199 – 216.

9. AHMAD, B., IDRIS, H. AND SULONG, S.H. (2009) Early Selection of Promising High Yielding *Hevea* Progenies Based on Selected Physiological and Stomatal Characteristics. *J. Rubb. Res.*, **12 (3)**,140 – 150.

10. HO, C.Y. (1976) Clonal Characters Determining the Yield of *Hevea Brasiliensis*. *Proc. Int. Rubb. Conf., 1975*, Kuala Lumpur, Malaysia, **2**, 17 – 38.

11. TAN, H. (1987) Strategies in Rubber Tree Breeding., In: Improving Vegetatively Propagated Crops. Abbott, A.J. and Atkin, R.K. (Eds) London: Academic Press. 27 – 62.

12. MYDIN, K.K., LICY, J., VARGHESE, Y.A., JOHN, A., NAIR, R.B. AND SARASWATHYAMMA, C.K. (2004) Clonal Nursery Evaluation for Shortening the Breeding Cycle in *Hevea Brasiliensis*. *Nat. Rubb. Res.*, **17 (1)**, 60 – 66.

13. CHANDRASEKHAR, T.R., MARATTUKULAM, J.G., MERCYKUTTY, V.C. AND PRIYADARSAN, P.M. (2007) Age of Yield Stabilization and Its Implications for

Optimizing Selection and Shortening Breeding Cycle In Rubber (*Hevea Brasiliensis* Muell Arg.). *Euphytica,* **156**, 67 – 75.

14. SILPI, U., THALER, P., KASEMSAP, P., LACOINTE, A., CHANTUMA, A., ADAM, B., GOHET, E., THANISAWANYANGKURA, S. AND AMEGLIO, T. (2006) Effect of Tapping Activity on the Dynamics of Radial Growth of *Hevea Brasiliensis* Trees. *Tree Physiol.*, **26**, 1579 – 1587.

15. VIJAYAKUMAR, K. R., CHANDRASHEKHAR, T. R. AND PHILIP, V. (2000) Agroclimate. In: *Natural Rubber: Agromanagement and Crop Processing. P.J.George and C. Kuruvilla Jacob (Eds.).* Kottayam: Rubber Research Institute of India, 97 – 116.

16. PRIYADARSHAN, P.M., SASIKUMAR, S. AND GONCALVES, P DE S. (2001) Phenological Changes in *Hevea Brasiliensis* Under Differential Geo-Climates. *The Planter (Malaysia),* **77**, 447 – 459.

17. PRIYADARSHAN, P.M., HOA, T.T.T., HUASUN, H. AND GONCALVES, P DE S. (2005) Yielding Potential of Rubber Tree (*Hevea Brasiliensis*) Clones in Sub-Optimal Environments. In: Genetic and Production Innovation in Field Crop Technology: New Developments in Theory and Practice. M.S. Kang (Ed.). J. *Crop Improv.*, (Special issue) **14 (1/2)**, 221 – 247.

18. SASIKUMAR, S., PRIYADARSHAN, P. M., DEY, S.K. AND VARGHESE, Y.A. (2001) Evaluation of Polyclonal Seedling Population of *Hevea (Wild. Ex. Adr. De Juss. Muell. Arg.)* in Tripura. *Indian J. Nat. Rubb. Res.*, **14(2)**,125 – 130.

19. PRIYADARSHAN, P.M. AND CLÉMENT-DEMANGE, A. (2004) Breeding *Hevea* Rubber: Formal and Molecular Genetics. *Adv. Genet.*, **52**, 51 – 115.

20. NAIR, V.K.B. AND GEORGE , P.J. (1968) The Indian Clones RRII 100 series. *Rubber Board Bulletin*. **10**, 115 – 140.

21. NAZEER, M.A., MARKOSE, V.C., GEORGE, P.J. AND PANIKKAR, A.O.N. (1986) Performance of a Few *Hevea* Clones from the RRII 100 Series in Large Scale Trial. *J. Plant. Crops*, **14(2)**, 99 – 104.

22. CHAN, W.H. (1984) A review of RRIM [Rubber Research Inst. of Malaysia] 600 in a Large Group of Rubber Estates in Peninsular Malaysia [Hevea Clones]. *Planter* (Malaysia), **60(696)**, 95 – 110.

23. LICY, J., SARASWATHYAMMA, C. K., PREMAKUMARI, D., MEENAKUMARI, T., MEENATTOOR, J. R. AND NAZEER, M. A. (2003) Genetic Parameters and Heterosis in Rubber (Hevea Brasiliensis Muell. Arg.): V. Hybrid Vigour for Yield and Yield Components Among the RRII 400 Series Clones in Small Scale Evaluation. *Indian J. Nat. Rubb. Res.*, **16 (1&2)**, 75 – 80.

24. MYDIN, K.K., MERCYKUTTY, V.C. AND SARASWATHYAMMA, C.K. (2005) Clonal Selection for High Yield and Precocity in Rubber (*Hevea Brasiliensis* Willd. Ex. Adr. De Juss. Muell. Arg.) Early Results of Large Scale Evaluation of the RRII 400 Series. *Proc. Int. Rubb. Conf., India*, pp 27 – 36.

25. ANTONY, P. D., DEY, S.K. AND MEENAKUMARI, T. (2010) Comparative Growth and Yield Performance of *Hevea* Clones Under the Agro-Climatic Conditions of Tripura. *Nat. Rubb. Res.*, **23(1&2)**, 12 – 19.

26. PRIYADARSHAN, P.M., SUDHASOWMYALATHA, M.K., SASIKUMAR. S., VARGHESE, Y.A. AND DEY, S.K. (1998) Relative Performance of Six *Hevea Brasiliensis* Clones During Two Yielding Regimes in Tripura. *Indian J. Nat. Rubb. Res.*, **11(1&2)**, 67 – 72.

27. VINOD, K.K. (2001) Studies on Divergence of *Hevea Brasiliensis* Clones for Yield and Related Traits During Peak Yielding Seasons in Tripura. *Indian J. Nat. Rubb. Res.*,**14 (1)**, 36 – 42.

28. TAN, I
A Five
Certain
Proc. I
Malays

29. R COR
Enviro
R Fou
Vienna

30. CHAN
K.K., .
SARA
Intracl
(*Hevea*
Res., **1**

31. LICY,
Associ
Progen
Adr. D
Rubb.

32. ABRA
MYDI
Evalua
Differe
29 (3),

33. BOME
VERA
GONC
Ortet-I
Selecti
Breedi
855 –

28. TAN, H. AND SUBRAMANIAM, S. (1976) A Five Parent Diallele Cross Analysis of Certain Characters of Young *Hevea* Seedlings. *Proc. Int. Rubb. Conf., 1975,* Kuala Lumpur, Malaysia, **2**, 13 – 16.

29. R CORE TEAM (2016) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna: Austria. https://www.R-project.org/

30. CHANDRASHEKAR, T.R., MYDIN, K.K., ALICE, J., VARGHESE, Y.A. AND SARASWATHYAMMA, C.K. (1997) Intraclonal Variability for Yield in Rubber (*Hevea Brasiliensis*). *Indian J. Nat. Rubb. Res.*, **10 (1&2),** 43 – 47.

31. LICY, J. AND PREMAKUMARI, D. (1998) Association of Characters in Hand Pollinated Progenies of *Hevea Brasiliensis* (Willd. ex. Adr. De Juss.) Muell. Arg. *Indian J. Nat. Rubb. Res.*, **1(1)**, 18 – 21.

32. ABRAHAM, T., AJITHKUMAR, E. AND MYDIN, K.K. (2016) Clonal Nursery Evaluation of Half-Sib Progenies in Two Different Agro-Climatic Regions. *Rubb. Sci.*, **29 (3),** 264 – 276.

33. BOMBONATO, A.L., GOUVEA, L.R.L., VERARDI, C.K., SILVA, G.A.P. AND GONCALVES, P. DE S. (2015) Rubber Tree Ortet-Ramet Genetic Correlation and Early Selection Efficiency to Reduce Rubber Tree Breeding Cycle. *Ind. Crops and Prod.*, **77**, 855 – 860.

34. MERCY, M. A., SINGH, M., REGHU, C. P. AND VARGHESE, Y. A. (2010) Preliminary Field Screening of Wild *Hevea* Germplasm for Tolerance to Drought. *J. Nat. Rubb. Res.*, **23(1/2)**, 71 – 79.

35. VINOD, K.K., SURYAKUMAR, M., NAZEER, M.A., SULOCHANAMMA, S., THOMAS, K.U., VIJAYAKUMAR, K.R. AND SARASWATHYAMMA, C.K. (2003) Growth Analysis of *Hevea Brasiliensis* Clones in Coastal Karnataka Region. *Indian J. Nat. Rubb. Res.*, **16 (1&2)**, 35 – 40.

36. NARAYANAN, R. AND HO C. Y. (1970) Yield Girth Relationship Studies on *Hevea. J. Rubb. Res. Inst. Malaya,* **23(1)**, 23 – 31.

37. GENER, P. (1977) Growth And Uniformity of Grafted *Hevea* Plants with Various Preparation and Planting Techniques. *J. Rubb. Res. Inst. Srilanka.* **54(1)**, 70 – 82.

38. WYCHERLEY, P.R. (1969) Breeding of *Hevea. J. Rubb. Res. Inst. Malaya,* **21(1)**, 38.

39. NARAYANAN, R. AND HO C. Y. (1973) Clonal Nursery Studies in *Hevea* II. Relationship Between Yield and Girth. *J. Rubb. Res. Inst. Malaya*, **23 (5)**, 332 – 338.

40. CARDINAL, A. B. B., GONCALVES, P. DES. AND MARTINS, A. L. M. (2007) Stock-Scion Interactions on Growth and Rubber Yield of *Hevea Brasiliensis*. *Sci. Agric. (Piracicaba, Braz.)*, **64 (3)**, 235 – 240.