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UTILIZATION OF WILD *HEVEA* GERMPLASM IN INDIA: LONG-TERM YIELD AND GROWTH OF CERTAIN W X A HYBRIDS

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One batch of 17 hybrids of Wickham (W) and Amazonian (A) parentage from six cross combinations were evaluated at the Central Experiment Station of the Rubber Research Institute of India. Yield of the clones in the BO-1 and BO-2 panels, combined yield from the two panels, summer yield, girth of the clones, biomass production and bole volume were evaluated. Heritability was moderate to high for both growth and yield parameters indicating scope for selection for the characters studied. Phenotypic variance and phenotypic coefficient of variation (PCV) showed values higher than the corresponding values for genotypic variance and genotypic coefficient of variation (GCV) for all the characters studied indicating the influence of environment on the characters. Secondary attributes like bole volume, biomass production and girth showed significant improvement in some of the hybrids (90/55, 90/109, 90/129 and 90/274) over the most popular and high yielding clone, RRII 105. Yield performance of these hybrids was on par with that of RRII 105. The hybrids which showed significantly improved bole volume and rubber yield comparable to RRII 105 may be designated as latex timber clones which could be utilized for further crop improvement programmes. Thus, without compromising on rubber yield it was possible to successfully develop W x A hybrids from divergent crosses in *Hevea brasiliensis*.

Keywords: *Hevea* breeding, Small-scale evaluation, Variability, W x A hybrids, Wild germplasm, Yield

INTRODUCTION

Hevea brasiliensis (Willd.ex Adr. de Juss.) Muell. Arg., is the major source of natural rubber (NR) of economic importance**.** In India, *Hevea* breeding assumes significance in the face of increasing demand of NR for the industrial sector. The demand for NR invariably resulted in the expansion of the rubber plantation sector into areas away from the traditional rubber growing regions of India which are sub-optimal for the commercial cultivation. Apart from NR, rubber wood also is in demand for commercial purposes. Breeding for clones adaptable to hot and cold weather conditions and biological stress conditions like incidence of various diseases are also priority areas in *Hevea* breeding. Both the demand for more NR and the challenges faced in the extension of rubber cultivation warrant intensive breeding programmes to meet the evolving scenarios in the rubber plantation industry.

The existing genetic base of the commercially cultivated *Hevea* clones in

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India, as in other rubber growing countries, is narrow. Hybridization involving selected parents through hand pollination, evaluation of the natural recombinants of poly-cross origin from specially designed poly-clonal seed gardens, introduced modern clones, and wild germplasm accessions are the major conventional *Hevea* breeding programs. Although yield improvement of clones is the primary objective of the conventional breeding programs, improvement of other secondary characters are also important. Incorporation of the wild Amazonian accessions in the *Hevea* breeding programs is in practice in India since 1990 which is mainly aimed at the improvement of secondary attributes of the existing modern clones without compromising the yielding potential. Introgression of desirable genes from the wild gene pool to the cultivated ones through such divergent cross-combinations will improve the genetic base of the existing *Hevea* gene pool. The first W x A (Wickham verses Amazonian accessions) hybridizations were undertaken in India in 1990 utilizing known high yielding clones as female parents and wild accessions with promising growth and test-tap yield in the first clonal nursery as male parents. From the seedling progeny thus produced, selections were cloned. This paper deals with the long term performance of such W x A hybrid clones in a small-scale evaluation trial.

MATERIALS AND METHODS

Selected progenies from the 1990 W x A hybridization programme were cloned by bud-grafting and planted in the Central Experimental Station, Chethackal, Pathanamthitta district, Kerala, India. The area of the experimental station is situated at 44 – 188m (above MSL) and the latitudes and longitudes of the area are 9°24′05.27" to 9°25′13.75" North and 76°48′22.94" to 76°50′22.54" East, respectively. Seventeen hybrids and their seven parents were evaluated in a small-scale trial (SST). The seventeen hybrids are the result of six cross-combinations involving seven parents. All the hybrids have RRII 105, one of the most popular and high yielding clone as the female parent. Amazonian accessions, namely, RO 24, RO 26, RO 34, RO 87, RO 132, and MT 196 were used as the male parents in the cross combinations. In the present study, fifteen clones were analyzed as there were high casualties in the plots of two hybrids (Table 1). The trial was laid out in a Randomized Block Design (RBD) with three replications in 1995. Four trees were planted in each of the plots with RRII 105 as a check clone in 4.9 m x 4.9 m spacing. Growth in terms of girth was recorded annually from the third year of planting. Tapping system adopted for crop harvest was S/2 d/3 6d/7. The rubber yield was recorded as dried rubber from the cup coagulum collected from each tapping. Experimental data collection on rubber yield was conducted at regular fortnight intervals in gram per tree per tap ($g\ t^{-1}t^{-1}$) basis. The dry rubber yield from the BO-1 panel (2003 - 2008), BO-2 panel (2009 - 2013), combined yield from 2003 - 2013 and yield during the low yielding summer months from February to May were analyzed to assess the yielding potential and pattern of the hybrid clones. Girth attained by the clones at 150 cm height from the bud-union, average bole volume of the clones ($m^3\ tree^{-1}$), and biomass production ($kg\ tree^{-1}$) were recorded. Coefficient of variation (CV) was used to assess the stability/uniformity attributes of the clones for certain parameters (Becker and Leon, 1988). Biomass production (Shorrocks *et al.*, 1965) and bole volume (Charurvedi *et al.*, 1982) of the trees were estimated for

Table 1. **Hybrids and their parentage**

Sl. no.	Hybrid	Parentage
1.	90/55	RRII 105 x RO 34
2.	90/277	RRII 105 x RO 34
3.	90/72	RRII 105 x RO 26
4.	90/104	RRII 105 x RO 87
5.	90/107	RRII 105 x RO 87
6.	90/109	RRII 105 x RO 87
7.	90/129	RRII 105 x RO 24
8.	90/130	RRII 105 x RO 24
9.	90/132	RRII 105 x RO 24
10.	90/136	RRII 105 x RO 24
11.	90/102	RRII 105 x RO 24
12.	90/140	RRII 105 x MT 196
13.	90/274	RRII 105 x MT 196
14.	90/92	RRII 105 x RO 132
15.	90/94	RRII 105 x RO 132

all the clones. The relationship between girth and biomass is expressed as shoot weight in kilogram. For the above-ground biomass estimation, girth of the trees was measured at 150 cm height from the bud-union. Bole volume of the main trunk was calculated as standing volume based on girth and first forking height. Data on growth and yield were subjected to analysis of variance (Singh and Chaudhary, 1985). Components of variance like genotypic variance (MSG - MSE / r), phenotypic variance (MSG/r) and error variance (MSE/r) were estimated (Wricke and Weber, 1986); where MSG, MSE and r are the mean squares of genotypes, mean squares of phenotypes, and number of replications, respectively (Baye, 2002). Genotypic coefficient of variation (GCV = (genotypic variance/mean) x 100), phenotypic coefficient of variation (PCV = (phenotypic variance/mean) x 100), and broad sense heritability (H^2) (genotypic variance / phenotypic variance) was also estimated (Singh and Chaudhary, 1985).

RESULTS AND DISCUSSION

The extent of clonal variations for the characters under study is very important for crop improvement in *Hevea*. The early performance of the W x A hybrids under study has already been reported (Sankariammal *et al*., 2011). Girth and yield performance of certain hybrid clones reported in the early study were found to be consistent in the present study also. Anatomical observations and various disease incidences were discussed in the earlier report. Certain additional traits like bole volume and biomass production of clones have been included in this study for further discussion. Of the five hybrids reported to be better in terms of girth and yield in the earlier report, three clones *viz*. 90/274, 90/55 and 90/109 maintained its performance in the present study also. The results showed different levels of genotypic and phenotypic variances in the clonal population studied. In all the characters, a major part of the phenotypic variance was due to the genetic component. In the present study, clonal variability for yield and growth characters was measured and computed mean, range, genotypic variance, phenotypic variance, genotypic and phenotypic coefficients of variation, and heritability in broad sense. Mean squares due to clones were significant (5% level) for all the growth and yield characters studied which showed the existence of genetic variation in the clonal population (Table 2). Impact of environmental factors on all the seven characters studied was manifested in the form of higher phenotypic variance than the corresponding values of genotypic variance. Phenotypic coefficients of variation (PCV) were also higher than the corresponding values of genotypic coefficients of variation (GCV) which also showed the influence of environment on the expression of the

Table 2. **Estimates of variance components for important yield and growth characters**

Character	MST	MSE	Range	Mean	GV	PV	GCV (%)	PCV (%)	H^2
BO-1 panel yield (g $t^{-1}t^{-1}$)	293.4	46.6	7.9 - 47.6	21.0	82.8	97.8	43.3	47.1	0.85
BO-2 panel yield (g $t^{-1}t^{-1}$)	872.0	197.9	11.7 - 65.5	36.2	224.7	290.7	41.4	47.1	0.77
Mean yield over									
11 years (g $t^{-1}t^{-1}$)	677.3	157.5	10.9 - 59.7	32.5	173.3	225.8	40.5	46.2	0.77
Summer yield (g $t^{-1}t^{-1}$)	487.1	23.8	10.4 - 37.7	21.9	77.2	81.2	40.1	41.1	0.95
Biomass (kg $tree^{-1}$)	55511.4	26962.4	192.5 - 712.3	380.8	9516.3	18503.8	25.6	35.7	0.51
Girth (cm)	341.6	163.1	52.9 - 89.6	69.6	59.5	113.8	11.1	15.3	0.52
Bole volume (m^3 $tree^{-1}$)	0.40	0.17	0.09 - 1.47	0.68	0.08	0.13	40.2	53.1	0.57

MST (Mean Square Treatment), MSE (Mean Square Error), GV (Genotypic Variance), PV (Phenotypic Variance, GCV (Genotypic Coefficient of Variation), PCV (Phenotypic Coefficient of Variation), H^2 (Broad sense heritability)

characters under study. Effect of environment on the expression of characters is known in various crops (Mousmi *et al.,* 2013; Deebe *et al*., 2011). Very low differences between the PCV and GCV showed less influence of the environment and more contribution of the clone towards the characters. Phenotypic coefficient of variation ranged between 15.3 (girth) and 53.06 (bole volume). Values of PCV and GCV above 20 per cent were considered high, values between 10 per cent and 20 per cent as moderate and below 10 per cent as low (Sivasubramanian and Menon, 1973). Genotypic coefficient of variation ranged between 11.08 per cent (girth) and 43.33 per cent (BO-1 panel yield). The GCV was close to PCV for the summer yield, indicating a significant influence of genotype on phenotypic expression with little influence of the environment.

Heritability in broad sense varied from 0.51(biomass) to 0.95 (summer yield). Heritability may be classified in three groups, characters having heritability greater than 0.6 as high and characters having heritability between 0.6 and 0.3 as moderate and those with less than 0.3 as low (Robinson *et al.*, 1949). All the characters studied showed more than 0.5 heritability with the highest heritability recorded for summer yield which indicates that selection or improvement could be made on the basis of these characters. In general, heritability for rubber yield was at higher levels compared to the growth characters. In rubber, reports are available on narrow sense heritability for yield and other secondary characters (Alika, J.E., 1985; Narayanan *et al*., 2011). Analysis of genotypic coefficient of variation along with heritability studies could provide better information about the characters to be selected for improvement (Burton, 1952).

Biomass estimation is part of crop response studies and biomass estimation for various clones has already been carried out from different regions in India (Chaudhuri *et al*., 1995; Dey *et al*., 1996). Variability for biomass ranged from 192.5 kg $tree^{-1}$ in hybrid clone 90/136 to 712.3 kg $tree^{-1}$ in clone 90/55 with a mean value of 380.82 kg $tree^{-1}$. Biomass estimated for the popular clone RRII 105 was only 245.3 kg $tree^{-1}$. Hybrid clones 90/55 (712.3 kg $tree^{-1}$), 90/129 (566.7 kg $tree^{-1}$), 90/277 (528.5 kg $tree^{-}$), 90/130 (512.3 kg tree^{-1}), 90/274 (508.6 kg tree^{-1}) and 90/132 (495.6 kg tree^{-1}) recorded significantly superior biomass over the popular clone RRII 105.

Bole volume is an important economic character like rubber yield in *Hevea* and represents overall growth of the tree because the computations of the bole volume takes into account both girth and height of the tree. Bole volume ranged from 0.093 m^3 tree^{-1} in wild accession RO 132 to1.473 m^3 tree^{-1} in hybrid clone 90/55 and the mean value was 0.684 m^3 tree^{-1}. Clones 90/55 (1.48 m^3 tree^{-1}), 90/277 (1.11 m^3 tree^{-1}), 90/129 (1.09 m^3 tree^{-1}), 90/130 (1.00 m^3 tree^{-1}), 90/132 (0.96 m^3 tree^{-1}) and, 90/140 (0.85 m^3 tree^{-1}) showed significantly superior bole volume over RRII 105 (0.28 m^3 tree^{-1}) (Table 3). Highly improved bole volume of the hybrids showed scope for selection of latex timber clones (Fig. 3). Importance of timber yield of rubber has already been reported from various clone trials (Mydin *et al*., 2005). Girth is a very important character as far as *Hevea* clones are concerned. Early attainment of the required girth for the initiation of crop harvest is a significant economic trait in *Hevea*. In the present study, seven clones showed significantly superior girth compared to the popular clone RRII 105 (58.1 cm) in the 18th year of growth. Highest girth was recorded in 90/55 (89.6 cm) followed by 90/109 (82.5 cm), 90/129 (81.2 cm), 90/130 (80.0 cm), 90/277 (79.2 cm), 90/132 (77.6 cm), and 90/274 (75.8 cm). Stability in attainment of girth of the clones across replications in terms of coefficient of variation (CV %) was computed. High girth hybrid clones like 90/109 (7.2%), 90/55 (7.6%), and 90/130 (9.2%) showed better stability leading to greater tree to tree uniformity in these clones than RRII 105 (31.5%).

Table 3. **Growth performance of the hybrid clones**

Clone	Girth (cm) (18th year)	CV (%)	Biomass (kg tree^{-1})	Bole volume (m^3 tree^{-1}) (18th year)
90/55	89.6	7.6	712.3	1.47
90/277	79.2	18.9	528.5	1.11
90/72	70.8	12.2	374.5	0.77
90/104	69.7	10.7	357.1	0.54
90/107	69.7	8.4	354.5	0.70
90/109	82.5	7.2	565.0	1.42
90/129	81.2	18.4	566.7	1.09
90/130	80.0	9.2	521.3	1.00
90/132	77.6	17.4	495.6	0.96
90/136	52.9	32.9	192.5	0.32
90/102	64.7	7.5	287.6	0.44
90/140	65.5	4.9	295.5	0.85
90/274	75.8	30.6	508.6	0.41
90/92	64.7	13.8	294.1	0.70
90/94	70.1	16.3	371.3	0.30
RO 34	61.5	27.7	277.9	0.38
RO 26	60.7	22.6	269.6	0.59
RO 87	66.6	21.9	313.7	0.48
RO 24	61.0	13.9	265.4	0.51
MT 196	68.3	32.2	331.8	0.55
RO 132	61.3	19.8	249.4	0.17
RRII 105	58.1	31.5	245.3	0.28
Mean	69.6		380.8	0.68
SD	10.7		136.0	0.35
CD (5%)	11.3		155.0	0.56

Yield of the clones in the present batch of hybrids on the BO-1 (2003 – 08) panel, BO-2 (2009 – 13) panel, combined yield from both the panels (2003 – 2013) and yield during the summer months were analyzed. Average dry rubber yield on the BO-1 panel was 21.0 g t^{-1}t^{-1} and yield of clones ranged from 7.9 g t^{-1}t^{-1} (RO 34) to 47.6 g t^{-1}t^{-1} (RRII 105) (Table 4). One hybrid clone 90/274 recorded yield on par (43.0 g t^{-1}t^{-1} with RRII 105. Average yield on the BO-2 panel was 36.2 g t^{-1}t^{-1}. Dry rubber yield on

Table 4. **Yield performance of the hybrid clones**

Clone	BO-1 panel ($g\ t^{-1}t^{-1}$) (over 5 years)	BO-2 panel ($g\ t^{-1}t^{-1}$) (over 5 years)	Mean yield ($g\ t^{-1}t^{-1}$) (over 11 years)	CV (%)	Summer yield ($g\ t^{-1}t^{-1}$)	CV (%)
90/55	26.0	52.0	52.6	12.4	32.5	7.6
90/277	19.9	27.7	35.1	45.6	21.4	3.3
90/72	9.9	14.7	14.7	12.9	10.4	3.9
90/104	20.3	23.3	26.2	8.8	18.4	5.0
90/107	14.5	23.1	22.1	18.2	18.9	3.9
90/109	27.8	65.5	54.1	17.3	37.5	3.9
90/129	22.5	47.0	47.8	24.8	31.1	7.7
90/130	24.1	46.5	43.2	39.6	26.2	5.8
90/132	27.8	44.8	43.8	18.6	25.8	7.1
90/136	22.6	38.1	38.1	42.4	19.8	3.8
90/102	31.1	43.3	32.1	28.2	24.5	6.5
90/140	25.6	27.0	27.7	25.4	15.8	5.3
90/274	43.0	57.3	59.7	54.0	37.7	9.6
90/92	18.7	24.0	25.1	23.0	16.2	6.1
90/94	19.4	40.2	17.6	23.9	24.6	4.5
RO 34	7.9	17.9	16.5	5.5	12.0	3.3
RO 26	11.1	11.7	10.9	35.3	10.4	6.5
RO 87	9.4	18.8	21.0	67.2	15.6	2.9
RO 24	15.1	29.7	29.1	8.7	16.3	12.9
MT 196	17.0	21.1	20.7	14.5	17.8	3.3
RO 132	8.6	21.9	19.3	16.7	14.4	5.3
RRII 105	47.6	64.4	58.3	17.4	35.3	9.0
Mean	21.0	36.2	32.5		21.9	
SD	9.89	17.1	15.0		8.6	
CD (5%)	11.3	13.0	11.6		2.3	

the BO-2 panel was higher than the BO-1 panel as expected. Yield on the BO-2 panel ranged from 11.7 $g\ t^{-1}t^{-1}$ (RO 26) to 65.5 $g\ t^{-1}t^{-1}$ (90/109). Three hybrid clones showed yield on par with RRII 105 in panel BO-2 *viz.*, 90/109 (65.5 $g\ t^{-1}t^{-1}$), 90/274 (57.3 $g\ t^{-1}t^{-1}$) and 90/55 (52 $g\ t^{-1}t^{-1}$). Average yield over eleven years from 2003 to 2013 was 32.5 $g\ t^{-1}t^{-1}$. Yield ranged from 14.7 $g\ t^{-1}t^{-1}$ (90/72) to 59.7 $g\ t^{-1}t^{-1}$ (90/274). Three hybrid clones *viz.*, 90/274 (59.7 $g\ t^{-1}t^{-1}$), 90/109 (54.1 $g\ t^{-1}t^{-1}$) and 90/55 (52.6 $g\ t^{-1}t^{-1}$) showed yield on par with RRII 105 (58.3 $g\ t^{-1}t^{-1}$). The yield of these clones was comparable to that of RRII 105 in the BO-2 panel too.

The summer months (February to May) are characterized by low rainfall and relatively high air temperature. During the initial days of the summer months, the trees undergo the process of re-foliation and leaf

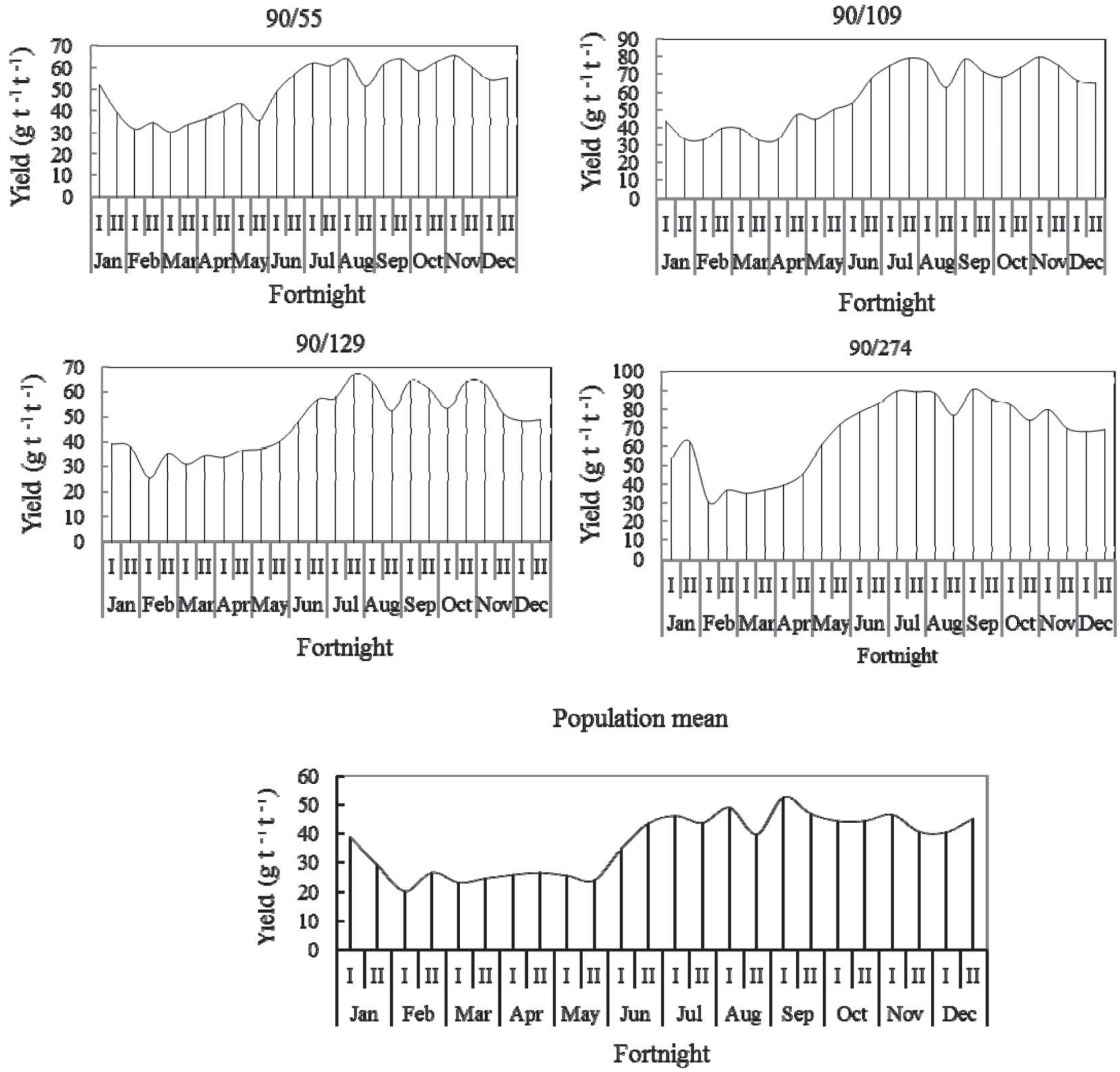

Fig. 1. Seasonal trends in yield over eleven years in four promising W x A hybrids and the population mean

maturation. All these factors together place trees under a stressful environment. Hybrids that can perform relatively well under such conditions may be adaptable to such stress situations. Highest yield during this period was recorded in the hybrid clone 90/274 which was significantly superior to RRII 105. Summer yield of clones 90/109 (37.5 g $t^{-1}t^{-1}$) and 90/55 (32.5 g $t^{-1}t^{-1}$) were on par with RRII 105 (35.3 g $t^{-1}t^{-1}$). Coefficient of variation was low for all the clones during the summer months compared to the rest of the yield regimes. Fortnightly yield trends over seasons during eleven years of tapping were shown for both population mean yield and the yield of promising hybrids (Fig. 1). In general there was a decline in the quantum of yield from the second half of

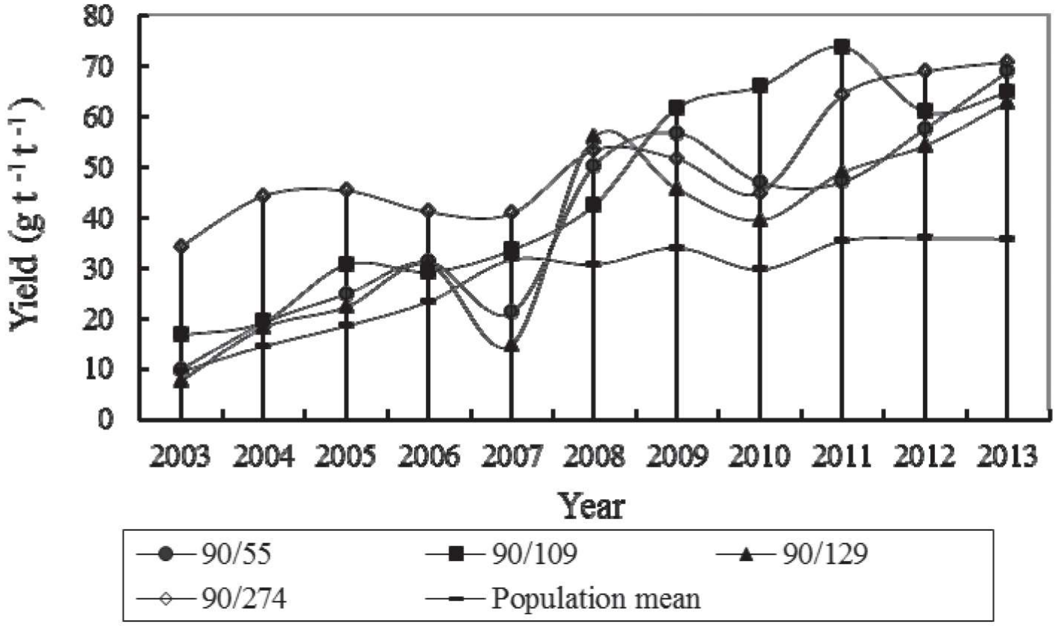

Fig. 2. Trend in annual yield over eleven years of tapping in the promising W x A hybrids and the population mean

January, and continued to be yielding low until the second half of May. Hybrid clones 90/55, 90/109, 90/129, and 90/274 showed increasing yield trend from the second half of April onwards whereas the population mean yield remained low until the second half of May. The low yielding trend of the clones during this period could be attributed to the summer weather conditions prevailing in the region coupled with the process of emergence of new flushes after wintering and the leaf maturation processes. Yield began to increase from the first half of June and remained at a higher level for the rest of the year except during the peak rainy season. As evident from Figure 1, the hybrid clone 90/274 attained the highest peak (89.7 g $t^{-1}t^{-1}$) in July followed by 90/109 (77.0 g $t^{-1}t^{-1}$) in July and November. The hybrid 90/274 is also promising in respect of precocity in terms of early high yields from the very initiation of tapping (Fig. 2). The graph also indicates stability in yield over eleven years in this hybrid. The scatter diagram (Fig. 3) depicts the latex timber hybrids that resulted from the W x A hybridization. Hybrids 90/274, 90/109, 90/55, and 90/129 in quadrant I were promising in terms of both rubber yield and timber yield while the check clone RRII 105 in quadrant II was a high rubber yielder but low in timber volume. A large number of hybrids and some of the parental wild accessions in quadrant III, though low rubber yielders, they were promising timber clones.

CONCLUSION

Analysis of the data collected from the small scale evaluation trial at the mature stage over eleven years of tapping revealed that incorporation of wild Amazonian accessions into the *Hevea* breeding program in India has been successful in production of improved genotypes (clones). Secondary attributes like girth, bole volume and

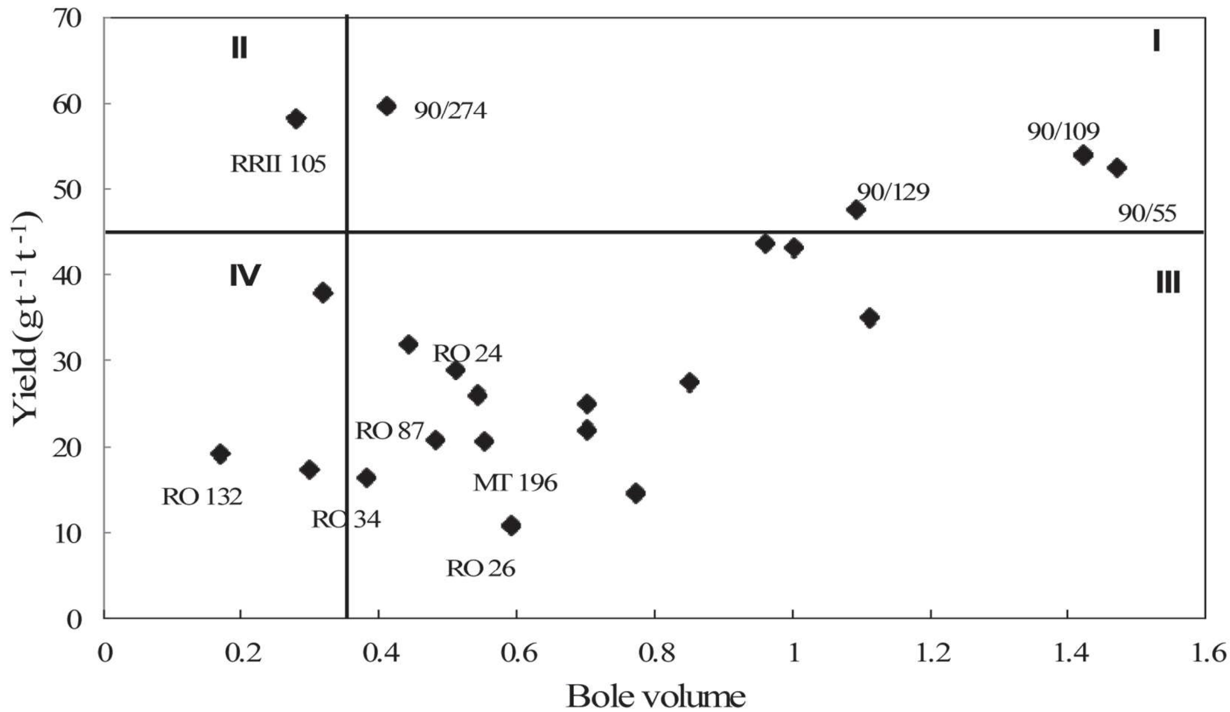

Fig. 3. Yield and bole volume of clones

biomass production could be improved without compromising the yield potential of the genotypes. Hybrid clones of W x A origin like 90/55, 90/109, 90/129 and 90/274 are potential latex timber clones. These clones, along with some of the superior timber yielders could be utilized in further *Hevea* breeding programs.

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