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EVALUATION OF *HEVEA* CLONES IN A LARGE SCALE TRIAL IN INDIA WITH SPECIAL REFERENCE TO INTRODUCTIONS FROM MALAYSIA

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Twelve clones of *Hevea brasiliensis* including three clones of the RRIM 700 series introduced from Malaysia in 1993 were planted at the Central Experiment Station of the Rubber Research Institute of India in 1994. Yield of the clones in different tapping panels such as BO-1, BO-2, BI-1 and the pooled yield were analyzed for clonal and seasonal yield performance and stability. Stability of yield of clones over the years and different tapping panels were computed. Yield of the clones in low and high yielding seasons were calculated. Monthly yield contribution and yield trend were also recorded. In the BO-1 panel highest yield was recorded in the hybrid clone 86/44 followed by RRIM 722, 86/120, RRII 105 and RRIM 712. In the BO-2 panel, the top yielders were RRII 105, RRIM 722, 86/44 and 86/120 and their yields were on par. When the pooled yields of the BO-1 and BO-2 panels were analyzed, it was found that clones 86/44, RRII 105, 86/120 and RRIM 722 were the most promising clones in the trial. In the BI-1 panel, RRIM 722 recorded the highest yield. Clone 86/120 was the most stable clone in the high yielding and low yielding environments. Monthly yield contribution varied from four per cent (March and April) to eleven per cent in July, August and November. During the rest of the high yielding months, monthly yield contribution was ten per cent (September, October and December) and nine per cent (January and June). Monthly yield contribution varied from four to six per cent in the low yielding environment. There was a sharp decline in yield contribution in February (4%) from that of January (9%) and significant increase in June (9%) from that of May (6%). The high yielding season represented 81 per cent of the total annual yield and the low yielding season represented 19 per cent. Ranking based on yield and girth showed the hybrid clone 86/120 in rank one position followed by 86/44, RRII 105 and RRIM 722.

Key words: Girth, *Hevea* breeding, Introduced clones, Large scale evaluation, Season, Timber, Yield stability

INTRODUCTION

Economic and industrial importance of NR resulted in extensive cultivation of rubber in the southern and north-eastern states of India. A combination of area expansion under NR and generation of genetically improved planting materials forms the foundation of NR production and productivity. Crop improvement work in *Hevea* directed at yield increase achieved considerable improvement through various breeding methods such as ortet selection, hybridization and introduction. Hybridization is a major breeding program generally aimed at combining desirable

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traits using hand pollination followed by various stages of evaluations until the recommendation and release of clones for wide scale planting. Introduction of exotic clones and their evaluation in the local climate is also one of the methods of yield improvement and this also contributes to broadening of the genetic base. Introduction is a way to by-pass the initial stages of breeding work by way of utilizing clones exchanged among rubber growing countries. RRIM 700 series clones were released by the Rubber Research Institute of Malaysia during 1947-1958, and as part of a clone exchange program, India introduced RRIM 712, RRIM 722 and RRIM 728 in 1993. Prior to 1993 seventy-six clones were introduced from Malaysia in different years which included clones such as PB 86, RRIM 600 and PB 260 (Mydin and Saraswathyamma, 2005). Performance of the introduced Malaysian clones along with a few other Indian hybrids and ortets was evaluated in the trial in comparison with RRII 105 and RRIM 600 under Indian climatic conditions. The present study focuses on the long term yield performance of these rubber clones with special reference to the clones introduced from Malaysia.

MATERIALS AND METHODS

Twelve clones of *Hevea brasiliensis* were planted in a large scale trial (LST) in 1994 at the Central Experiment Station of the Rubber Research Institute of India at Chethackal, Pathanamthitta district of Kerala. The experimental station is situated at 44 to 188 m 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.

The trial was laid out in randomized block design (RBD) with twelve clones in three replications. Each of the thirty-six plots was planted with sixteen trees in 4.9 x 4.9 m spacing in an area of 1.5 hectare. The trial consisted of three Malaysian clones (RRIM 712, RRIM 722 and RRIM 728) introduced in 1993, three Indian hybrid selections (86/44, 86/120 and 55/180) from hand pollination (HP) programs, four primary clones (ortets) identified in India

Table 1. **Clones in the trial, their origin and parentage**

Clone	Origin	Parentage
RRIM 712	Hybrid - introduced from Malaysia	RRIM 605 x RRIM 71
RRIM 722	Hybrid - introduced from Malaysia	RRIM 600 x TK 4
RRIM 728	Hybrid - introduced from Malaysia	GT 1 x RRIM 623
55/180	Hybrid - 1955 HP program (India)	Tjir 1 x Gl 1
86/44	Hybrid - 1986 HP program (India)	PB 242 x RRII 105
86/120	Hybrid - 1986 HP program (India)	RRII 105 x RRII 118
O 65	Ortet - progeny of genetic variant (India)	Primary clone
O 70	Ortet - progeny of genetic variant (India)	Primary clone
RRII 50	Ortet - gamma ray irradiated progeny of Tjir 1 (India)	Primary clone
RRII 51	Ortet - gamma ray irradiated progeny of Tjir 2 (India)	Primary clone
RRIM 600	Check clone (Malaysian hybrid)	Tjir 1 x PB 86
RRII 105	Check clone (Indian hybrid)	Tjir 1 x Gl 1

(RRII 50, RRII 51, O 65 and O 70) and two check clones *viz.* RRII 105 and RRIM 600 (Table 1). All agricultural operations in the experimental area during the immature and mature phases were done as per the standard procedure prescribed by the Rubber Board.

Tapping was initiated in all clones in 2003 when the trees attained 50 cm girth at 150 cm height from the bud-union. Girth was recorded annually and yield was recorded at fort-nightly intervals in gram per tree per tap (g $t^{-1}t^{-1}$). Girth recorded in 2015 (12^{th} year of tapping) was used for analysis. Timber volume in cubic meter (m^3) was calculated using girth and first branching height following Chaturvedi and Khanna (1982). Recording of rubber yield was conducted as dry rubber from cup-coagulum collected from each tapping following S/2 d3 6d/7 tapping system. Dry rubber yields was recorded from BO-1 panel (first base panel of virgin bark), BO-2 panel (second base panel of virgin bark) and BI-1 panel (first renewed bark of BO-1). Dry rubber yields from the BO-1 panel (2003 to 2008), BO-2 panel (2009 to 2013), pooled yield of the first two panels (BO-1 and BO-2 combined), BI-1 panel (2014 to 2015) and overall yield for the period 2003 to 2015 were analyzed. Data on girth and yield were subjected to analysis of variance (Gomez and Gomez, 1989). Clonal average of yield was compared as per Duncan's multiple range test. Coefficient of variation (CV) and regression coefficient (*b*) were used as stability measures.

RESULTS AND DISCUSSION

Girth in the opening year did not show significant differences among clones (Fig. 1a). Highest girth was recorded in clone 86/120 (60.9 cm) followed by O 65 (57.9 cm), 86/44 (56.9 cm), 55/180 (55.7 cm) and lowest girth was recorded in RRIM 728 (48.1 cm) followed by RRIM 600 (48.5 cm). Significant difference in girth was observed in the mature phase. Girth recorded in the 21^{st} year of planting was the highest in clones 86/120 (96.3 cm) and O 65 (93.4 cm). Girth of these two clones was superior to all other clones in the trial. Significant difference in girth was not observed among the rest of the clones. Average girth increment in the immature phase (5.6 cm $year^{-1}$) and in the mature phase (2.1 cm $year^{-1}$) was significantly different (Fig. 1b). Reduction in girth increment in the mature phase compared to the immature phase is attributed to competition between growth and rubber production process at the physiological level (Simmonds, 1982; Templeton, 1969).

Yield in the BO-1 panel was recorded from 2003 to 2008 (Table 2). Yield of clones ranged from 27.1 g $t^{-1}t^{-1}$ (O 70) to 74.5 g $t^{-1}t^{-1}$ (86/44). Yield of 86/44 was superior to both the check clones RRIM 600 (35.3 g $t^{-1}t^{-1}$) and RRII 105 (60.3 g $t^{-1}t^{-1}$). Clones 86/120 (60.9 g $t^{-1}t^{-1}$) and RRIM 722 (66.5 g $t^{-1}t^{-1}$) yielded on par with RRII 105. Apart from 86/44, four clones *viz.* RRIM 722, 86/120, RRII 105 and RRIM 712 recorded yields above the general mean (46.1 g $t^{-1}t^{-1}$) and yields of seven clones were below general mean (O 70, O 65, 55/180, RRIM 600, RRII 51, RRII 50 and RRIM 728) in the BO-1 panel. Poor yielders in the initial years of tapping are not generally considered for further evaluations for yield in the same region. However, their performance in the non-traditional rubber growing regions could be evaluated. Being a large scale trial (LST), which is the last evaluation stage next to the final on-farm trials, poor performers in the BO-1 panel in the LST could be eliminated from the final selections. Regarding the rest of the five clones in the trial, even though they recorded higher yields in the BO-1 panel, their superiority and consistency in yielding trend need further confirmation through the next tapping panel as there are

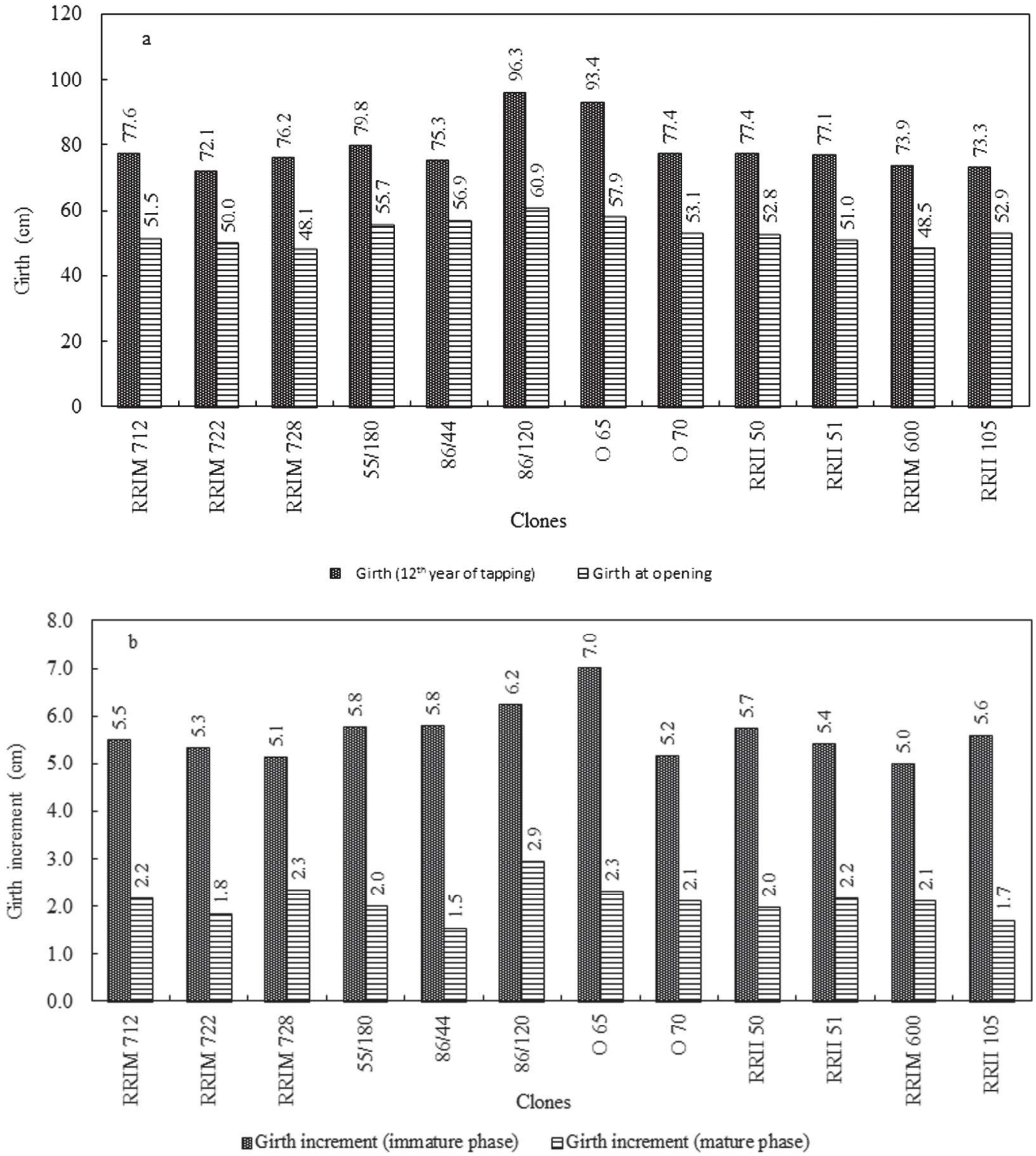


Fig. 1. Girth in the opening year and in the 21st year (a) and girth increment in the immature and mature phases (b)

chances for some of these clones to fail in the later years in the succeeding tapping panels.

Yield in the BO-2 panel was recorded from 2009 to 2013 (Table 2) which ranged from 39.5 g $t^{-1}t^{-1}$ (O 70) to 90.1 g $t^{-1}t^{-1}$ (RRII 105). Yield of RRIM 722 (77.3 g $t^{-1}t^{-1}$), 86/44 (78.4 g $t^{-1}t^{-1}$) and 86/120 (86.4 g $t^{-1}t^{-1}$) were on par with RRII 105. In the BO-2 panel,

Table 2. **Panel-wise yield and clear bole volume of clones**

Clone	Yield ($gt^{-1}tap^{-1}$)					
	BO-1	BO-2	BO-1 and BO-2	BI-1 (2 years)	Overall	Clear bole volume (m^3)
RRIM 712	47.4 c	60.2 b	53.2 b	60.8 a	55.3 b	0.1 cde
RRIM 722	66.5 ab	77.3 a	71.4 a	62.9 a	69.1 a	0.08 de
RRIM 728	42.1 cd	55.4 b	48.1 bc	35.3 c	45.9 bc	0.09 cde
55/180	31.7 de	51.3 bc	40.6 cd	36.4 c	39.4 cd	0.1 cde
86/44	74.5 a	78.4 a	76.2 a	56.2 ab	72.5 a	0.12 bc
86/120	60.9 b	86.4 a	72.5 a	58.4 ab	70.0 a	0.18 a
O 65	30.9 de	53.2 bc	41.0 cd	53.5 ab	42.8 c	0.14 ab
O 70	27.1 e	39.5 c	32.7 d	27.9 c	31.9 d	0.09 cde
RRII 50	39.5 cd	51.5 bc	45.0 bc	28.8 c	42.2 c	0.09 cde
RRII 51	36.4 cd	61.4 b	47.7 bc	41.2 bc	46.2 bc	0.11b cd
RRIM 600	35.3 de	56.4 b	44.9 bc	35.8 c	43.2 c	0.1cd e
RRII 105	60.3 b	90.1 a	73.8 a	54.7 ab	70.1 a	0.08 e
General Mean	46.1	63.5	54.0	46.0	52.4	
CV%	13.7	12.5	11.2	20.2	10.4	
*T-Statistic	-7.9					
T-Table (5%)	2.2					

Means followed by the same letters do not differ significantly.
*Significantly different at 5% level of significance.

only four clones (RRII 105, 86/120, 86/44 and RRIM 722) recorded yield above the general mean (63.5 g $t^{-1}t^{-1}$) and the remaining eight clones showed yield below the general mean. The four clones which showed above average yield in the BO-2 panel were also higher yielders in the BO-1 panel which proved the consistency in yielding trend and superiority of these clones in the trial. One Malaysian clone *viz.* RRIM 712 which performed better in the BO-1 panel failed to keep up its performance in the succeeding BO-2 panel. Panel shift from BO-1 to BO-2 was associated with an increase in the yield. Average yield in BO-1 panel was 46.1 g $t^{-1}t^{-1}$ and that in the BO-2 panel was 63.5 g $t^{-1}t^{-1}$. The yield difference was significant as shown by the t-test. Yield increase associated with panel change from BO-1 to BO-2 has been reported from other trials as well (Mydin *et.al.*, 2011).

When yields in the BO-1 and BO-2 panels were combined and analyzed, top yielders identified were 86/44 (76.2 g $t^{-1}t^{-1}$), RRII 105 (73.8 g $t^{-1}t^{-1}$), 86/120 (72.5 g $t^{-1}t^{-1}$) and RRIM 722 (71.4 g $t^{-1}t^{-1}$) and these four clones recorded yields above the general mean (54.0 g $t^{-1}t^{-1}$) (Table 2). Yield ranged from 32.7 g $t^{-1}t^{-1}$ (O 70) to 76.2 g $t^{-1}t^{-1}$ (86/44). Three clones in the trial *viz.* 86/44, 86/120 and RRIM 722 showed superior performance to the check clone RRIM 600 and their yield was on par with RRII 105. Average yield of these three clones *viz.* 86/44 (76.2 g $t^{-1}t^{-1}$), 86/120 (72.5 g $t^{-1}t^{-1}$) and RRIM 722 (71.4 g $t^{-1}t^{-1}$) in the first eleven years of tapping would give an estimated yield of 3048 kg ha^{-1} $year^{-1}$, 2900 kg ha^{-1} $year^{-1}$ and 2856 kg ha^{-1} $year^{-1}$, respectively. Among the three Malaysian clones introduced in 1993, RRIM 722 yielded on par with RRII 105 in both BO-1 and BO-2 panels under Indian conditions. RRII 105 was the highest yielding clone in India when this trial was laid out. According to the reports available from Malaysia, RRIM 712 yielded 44.8 g $t^{-1}t^{-1}$ over the first ten years of tapping, RRIM 722 recorded 28.2 g $t^{-1}t^{-1}$ over thirteen years of tapping and RRIM 728 recorded 36.9 g $t^{-1}t^{-1}$ over ten years of tapping (Anonymous, 1981; 1987; 1998). The RRIM 700 series clones introduced from Malaysia (RRIM 712, RRIM 722 and RRIM 728) showed better performance than in Malaysia. The two ortet clones (O 65 and O 70) in the trial were low yielders in both the panels.

Yield in the BI-1 panel was recorded for two years (2014 and 2015) (Table 2). Yield ranged from 27.9 g $t^{-1}t^{-1}$ (O 70) to 62.9 g $t^{-1}t^{-1}$ (RRIM 722) with a general mean of 46.0 g $t^{-1}t^{-1}$. RRIM 722, RRIM 712, 86/120, 86/44, and O 65 recorded yields on par with RRII 105 in the BI-1 panel. Yield performance of clones in the BI-1 panel, which comes up after eleven years of tapping in the preceding panels, is useful only for confirmation of yield performance of those clones which recorded higher yields in the virgin panels. Clones that show up only in the BI-1 panel are generally not considered for further evaluations as they are clearly late yielders and not qualified for planting recommendations. Even though RRIM 712 showed above average yield in the BO-1 panel, it was a low yielder in the BO-2 panel and again showed good yield in the BI-1 panel; hence the performance of this clone was not reliable. Likewise O 65 was a low yielder in both the virgin panels and yielded on par with RRII 105 in the BI-1 panel; hence a late yielder. Higher yield of RRIM 712 and O 65 in the BI-1 panel showed the yielding potential of these clones in the latter years of tapping, which is not a desirable attribute with regard to screening of clones for higher yield.

When the overall yield of clones across panels was pooled and analyzed, three clones *viz*. 86/44 (72.5 g $t^{-1}t^{-1}$), 86/120 (70.0 g $t^{-1}t^{-1}$) and RRIM 722 (69.1 g $t^{-1}t^{-1}$) performed on par with RRII 105 (70.1 g $t^{-1}t^{-1}$) (Table 2). Since RRII 105 is the highest yielding Indian clone in the trial, other clones, yielding on par with RRII 105 in the trial such as the introduced Malaysian clone RRIM 722 and locally bred hybrids like 86/44 and 86/120, can be considered as high yielding clones in the region. Mean timber volumes of the introduced clones were on par with RRII 105 (0.08 m^3) (Table 2). Highest bole volume was recorded in 86/120 (0.18 m^3). Bole volumes of 86/44 (0.12 m^3) and O 65 (0.14 m^3) were superior to that of RRII 105.

Rubber yield is a known polygenically controlled trait (Simmods, 1982; 1989; Clement *et al*., 2007). Moreover, rubber yield is also significantly influenced by environment, and the existence of the genotype interaction with environment (G x E interaction) has already been reported (Costa *et al*., 2000; Goncalves *et al*., 1998; 2003; Meenakumari *et al*., 2011; Tan, 1995). Higher yield from the initial years of tapping, and maintaining the same yield trend with consistency throughout the economic life span is an important breeding objective and a highly desirable trait. Clones with higher yield in the initial years and yield drop in the subsequent years, as well as late yielders with low initial yields are undesirable selections. Such clones need to be checked from entry into the list of selected clones for commercial planting by subjecting yield data to stability analysis for different tapping panels and over years.

The concept of yield stability was used to determine the consistency of clonal yield performance across years, over seasons, and in different tapping panels. The interaction of genotype with year (G x Y interaction) reflects the temporal stability for consistency over years (Barah *et al.*, 1981). Static and dynamic concept of yield stability developed by Becker and Leon (1988) was used by Lin and Binns (1988) to define stability of genotypes based on static concept to assess yield stability across years within same locations. Various methods have been proposed by different authors for stability analysis. Regression coefficient and mean square deviations from linear regressions have been suggested by Singh and Chaudhary (1977). Regression coefficient was also suggested by Finlay and Wilkinson (1963). CV is also a measure of stability (Francis and Kannenberg, 1978). In this study, regression coefficient (*b*) and CV were used for stability analyses.

Linear regressions of individual clonal mean yields on the mean yield of all clones were computed. Mean yield of all clones, which is the seasonal yield, was used as the independent variable and individual mean yield as the dependent variable. It was also suggested that while regression coefficient serves as a stability parameter, relative mean yield represents adaptability. A clone with regression coefficient (*b*) closer to 1.0 shows average stability. When the regression coefficient is above 1.0, stability of the clone is below average, and when the regression coefficient is below 1.0, stability of the clone is above average. Stability alone cannot be a criterion for clone selection; rather a stability-adaptability association is required for selection. Clones with above average yield associated with regression coefficient closer to unity have general adaptability. A clone with regression coefficient closer to unity and yield below average are poorly adapted. Since below average yields are not desirable, above average yields associated lesser or greater regression coefficients are considered adaptable to favourable environments.

Out of the twelve clones tested, only three clones showed regression coefficients significantly different from unity (RRIM 712, 86/44 and O 70) (Table 3). All other clones showed general stability. Only five clones showed mean yield above general mean (52.4 g $t^{-1}t^{-1}$). They are RRIM 712 (55.3 g $t^{-1}t^{-1}$), RRIM 722 (69.1 g $t^{-1}t^{-1}$), 86/120 (70.0 g $t^{-1}t^{-1}$), RRII 105 (70.1 g $t^{-1}t^{-1}$) and 86/44 (72.5 g $t^{-1}t^{-1}$). Among the five clones with above average yield, three clones (RRIM 712, 86/120 and RRII 105) showed regression coefficient not significantly different from unity, hence exhibited general adaptability. The other two clones (RRIM 722 and 86/44) showed regression coefficients different from unity

Table 3. **Stability parameters and average yield of clones**

Clone	Yield (g $t^{1}t^{-1}$)	Regression coefficient (*b*)	CV (%)
RRIM 712	55.3 b	0.95	28.3
RRIM 722	69.1 a	1.61 *	40.0
RRIM 728	45.9 bc	0.79	28.6
55/180	39.4 cd	0.81	33.6
86/44	72.5 a	1.65 *	36.5
86/120	70.0 a	1.04	25.5
O 65	42.8 c	0.70	29.7
O 70	31.9 d	0.51 *	27.6
RRII 50	42.2 c	0.86	35.3
RRII 51	46.2b c	0.91	34.5
RRIM 600	43.2 c	0.73	29.1
RRII 105	70.1 a	1.44	34.8
Average	52.4		31.94

*Means followed by the same letters do not differ significantly.

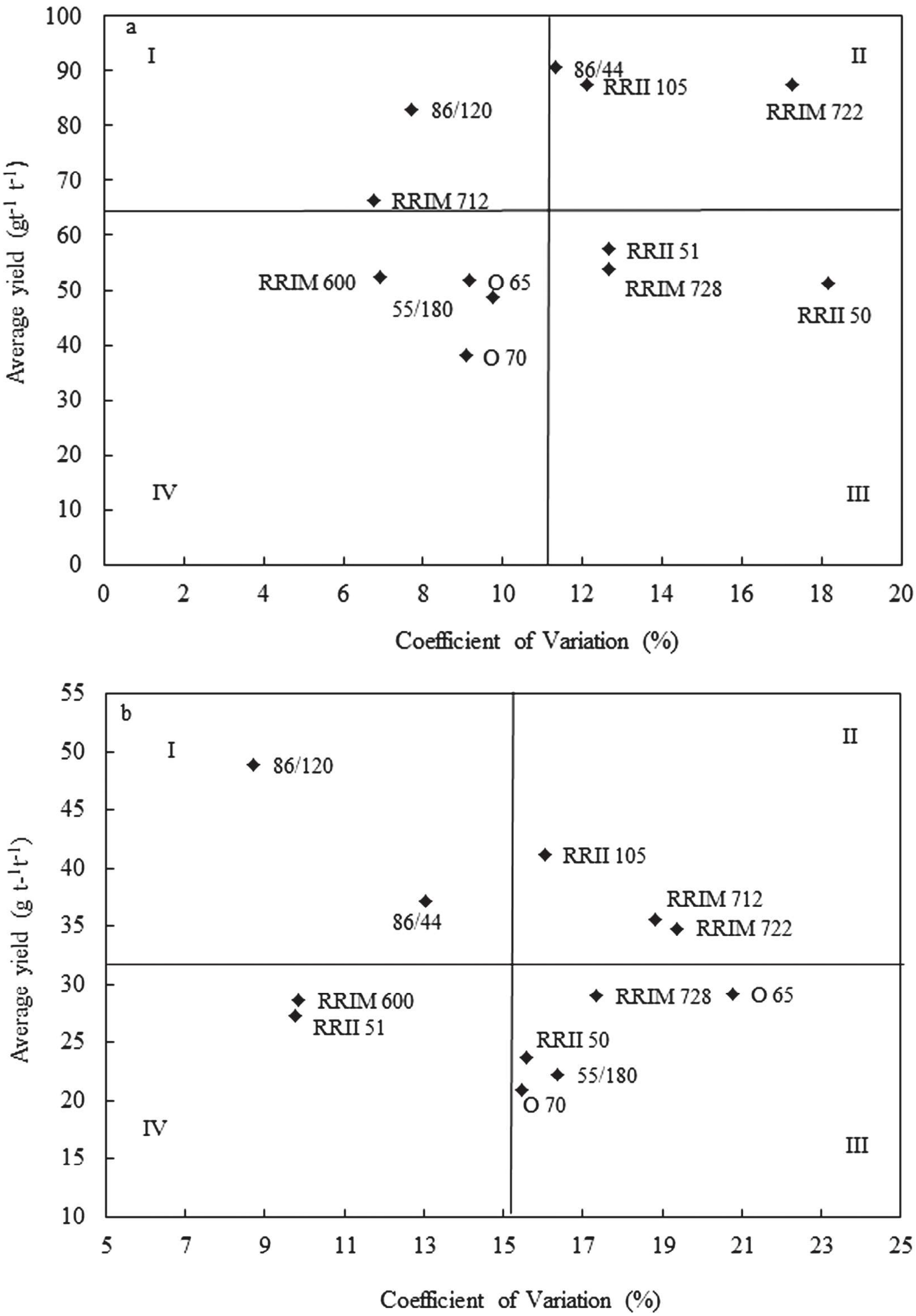


Fig. 2. Rubber yield *vs* CV per cent in (a) high yield season and (b) low yield season

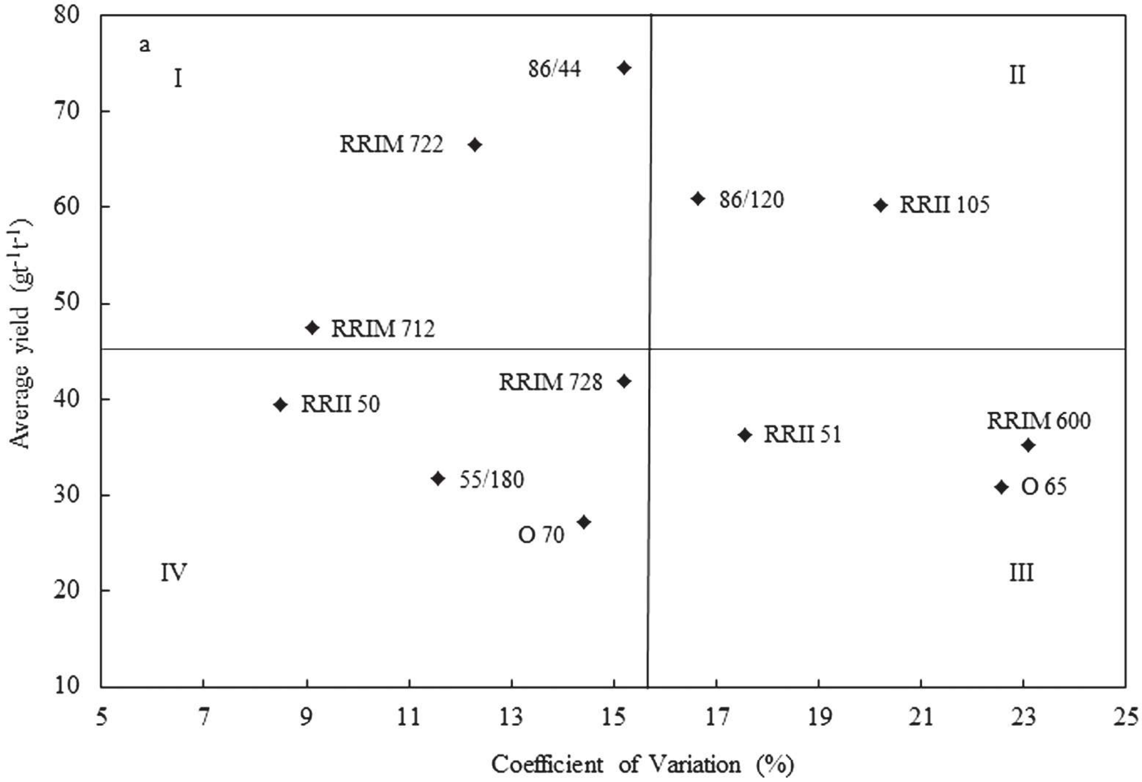
and hence these clones displayed sensitivity in annual yield fluctuations. CV for yield was also high in these clones compared to other clones. The rest of the clones, though they were generally stable or more stable, cannot be considered for selection on account of their below average yield.

Clones with low CV values across years are stable ones. Clones that combine high yield and lower CV values are the most desirable. Clonal differences in stability for yield can be determined by plotting individual average yield of clones against CV for each clone (Asante and Dixon, 2002). A horizontal line through the average clonal yield and a vertical line through the grand mean of the CV made four quadrants. In this study, such quadrants have been depicted by plotting average yield of individual clones against CV for different yielding phases such as high and low yielding seasons BO-1 panel, BO-2 panel, combined yield on BO-1 and BO-2 panels, and the overall yield.

Clones showing low CV and above average yields were the most desirable ones which are high-yielding with high stability (quadrant I). Clones with CV beyond mean CV and above average yield were considered as high yielding with low stability (quadrant II). Yield and CV of clones in the high yielding season are given in Figure 2a. Of the high yielding clones, two clones (86/120 and RRIM 712) fell into quadrant 1 of high-yielding and high stable clones in the high yielding seasons. The other three high yielding clones (86/44, RRIM 722 and RRII 105) were in quadrant II, indicating high-yield with low stability. The rest of the clones were poor yielders with varying levels of stability in the high yielding season. All the five high-yielding clones in the high-yielding season also showed high-yielding trend in the low yielding season; however, with stability levels shifted in a couple of clones (Fig. 2b). In the low yielding season, clone 86/120 remained in quadrant I of clones with high yield and stability. Another high yielding hybrid clone *viz.*, 86/44 got shifted from the high yielding but less stable quadrant II to high yielding and high stable quadrant I while RRIM 712 moved to quadrant II from quadrant I. In both high yielding and low yielding seasons RRIM 722 and RRII 105 remained in the high yielding but less stable quadrant II and the rest of the clones being low yielding; their stability levels offer less scope for discussion.

As in the case of high yielding and low yielding seasons, in the BO-1 panel also high yield was recorded in clones 86/44 and 86/120, two of the Malaysian clones (RRIM 712 and RRIM 722) and in the popular Indian clone RRII 105 (Fig. 3a). Three of these clones (86/44, RRIM 722 and RRIM 712) were stable performers also. The remaining two high yielding clones (86/120 and RRII 105) were less stable. In the BO-1 panel, RRIM 728, RRII 50, 55/180 and O 70 were stable but low yielding while RRIM 600, RRII 51 and O 65 were sensitive to annual yield fluctuations. In the BO-2 panel, only four clones were in the high yielding category (RRII 105, 86/120, 86/44 and RRIM 722), of these, RRII 105 and 86/120 were in the stable quadrant I while 84/44 and RRIM 722 showed less stability (Fig. 3b). The remaining clones in the BO-2 panel were low yielding, of which RRIM712, RRIM 728, RRII 50 and O 70 were less stable. Although RRII 51, RRIM 600, 55/180 and O 65 were stable, they were low yielding.

When yield and stability of the clones were considered after combining BO-1 and BO-2 panels, three clones (86/44, 86/120 and RRIM 722) were found stable and high yielding (Fig. 4a). RRII 105 alone was in quadrant II of high yield but less stable. Three clones *viz.* RRIM 712, RRIM 728 and RRII 50 were stable but low yielding while



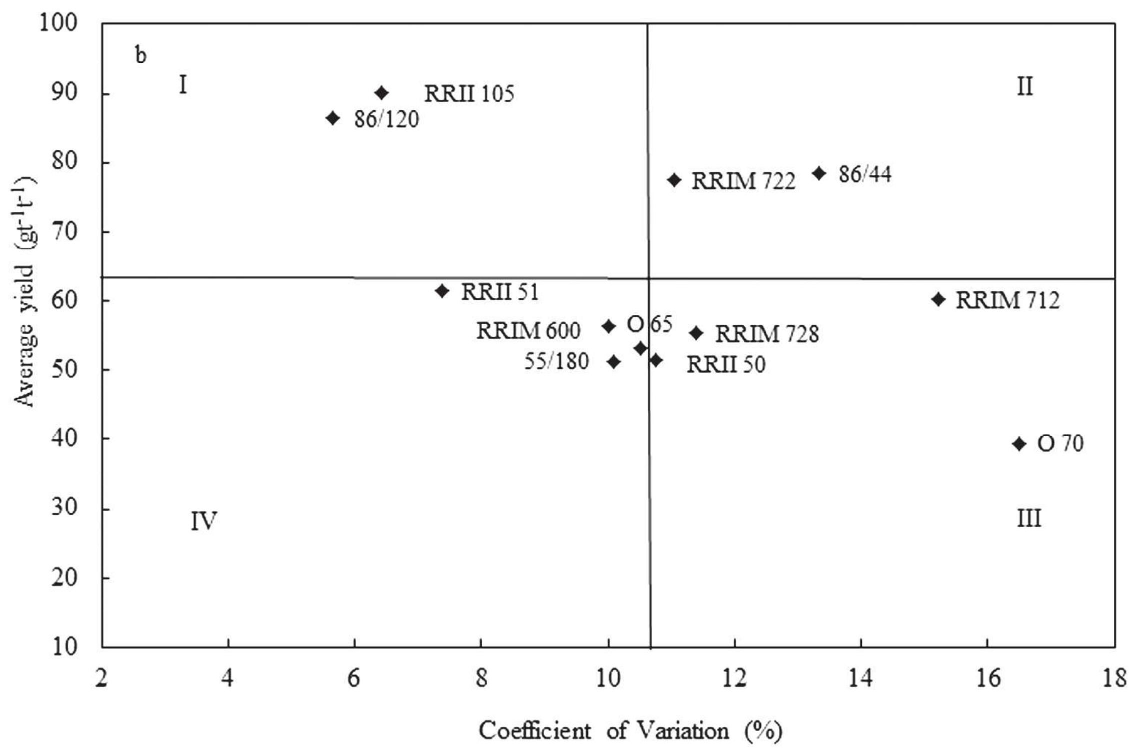


Fig. 3. Rubber yield *vs* CV in the (a) BO-1 panel and (b) BO-2 panel

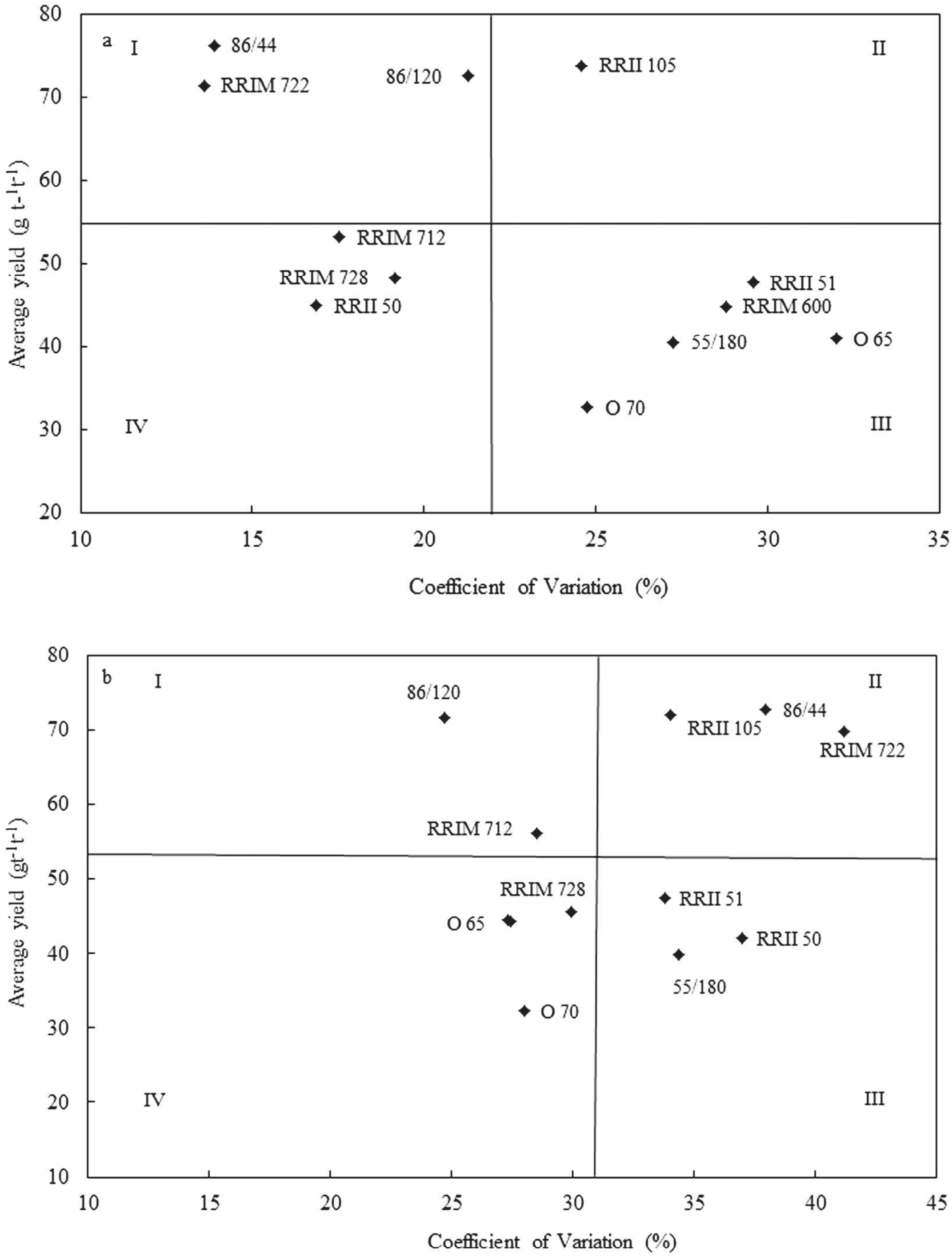


Fig. 4. Rubber yield *vs* CV in the (a) BO-1 & BO-2 panels combined and (b) overall yield

RRII 51, RRIM 600, 55/180, O 65 and O 70 were both low yielding and less stable. When the overall yield of thirteen years analysed, clone 86/120 retained the high yielding and high stable trait (Fig. 4b). The other high yielding clones were 86/44, RRII 105 and RRIM 722 but in quadrant II of less stability. The rest of the seven clones were low yielding of which RRIM 728, O 65, RRIM 600 and O 70 were stable clones while RRII 51, RRII 50 and 55/180 were less stable.

Seasonal mean of monthly yields were recorded (Table 4). Yield from February to May was below monthly average (53.2 g $t^{-1}t^{-1}$). From January to February, there was a significant reduction in yield. The lowest yield was in March (27.9 g $t^{-1}t^{-1}$) followed by April (28.5 g $t^{-1}t^{-1}$). There was a significant gain in yield in June (57.3 g $t^{-1}t^{-1}$) compared to the preceding month of May (35.6 g $t^{-1}t^{-1}$). There was a significant drop in yield in February, and continued to be low yielding until May. Yield significantly increased in June. Thus, two clear yielding seasons were observed, a high yielding season beginning with June and ending with January and a low yielding season, beginning with February and ending with May (Fig. 5a). The highest yield was recorded in July,

Table 4. **Yield in the low and high yield seasons, and monthly yield**

Clone	Yield (g $t^{-1}t^{-1}$)		Month	Yield (g $t^{-1}t^{-1}$)
	Low yield season (February - May)	High yield season (June - January)		
RRIM 712	35.5 bc	66.4 b	Jan	56.2 d
RRIM 722	34.8 bc	87.4 a	Feb	34.3 e
RRIM 728	29.1 cd	53.9 c	Mar	27.9 f
55/180	22.2 ef	48.6 cd	Apr	28.5 f
86/44	37.2 b	90.5 a	May	35.6 e
86/120	48.9 a	83.0 a	Jun	57.3 cd
O 65	29.2 cd	51.7 c	Jul	67.5 a
O 70	20.9 f	38.0 d	Aug	69.4 a
RRII 50	23.7 de	51.2 c	Sep	64.7 ab
RRII 51	27.3 de	57.4 bc	Oct	61.1 bc
RRIM 600	28.7 cd	52.4 c	Nov	68.9 a
RRII 105	41.2 b	87.4 a	Dec	66.9 a
Average	31.6	64.0	Average	53.2
CV	11.63	10.4	CV	4.91
SD	8.28	18.26		
SE	2.4	5.3		
Variance	68.401	333.868		
*T-Statistic	-9.401			
T-Table (5%)	2.201			

Means followed by the same letters do not differ significantly.
*significantly different at 5% level of significance

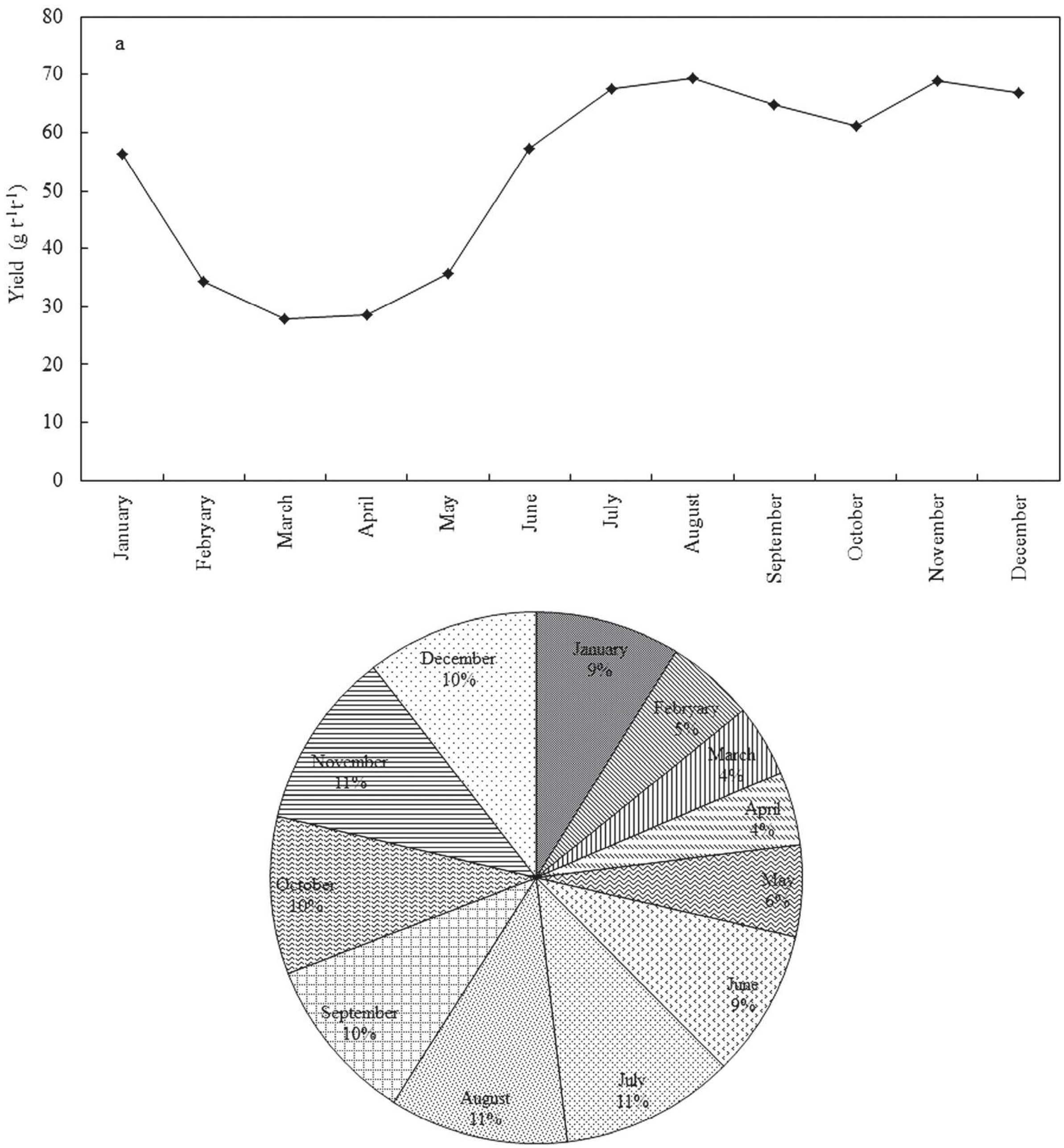


Fig. 5. (a) Pattern of average monthly yield and (b) per cent share of monthly yield in the total annual year

August, November and December months, indicating the necessity the use of rain-guarding of the tapping trees during rainy season.

Monthly yield contribution during July, August and November was eleven per cent each. During the rest of the high yielding months, monthly yield contribution was ten per cent (September, October and December) and nine per cent (January and June). Monthly yield contribution varied from four to six per cent in the low yielding months. March and April contributed four per cent each, and five per cent in February and six per cent in May. The sharp decline in yield contribution in February (4%) from January (9%) and significant increase in June (9%) from May (6%) is clearly evident from the pie chart (Fig. 5b). The high yielding season represented 81 per cent of the total annual yield and the low yielding environment represented 19 per cent.

Yields during the two seasons were subjected to t-test and found that the two seasons were significantly different (Table 4). The low yielding season coincides with the summer season, characterized by low rainfall, high temperatures, and emergence of new flushes. Leaf maturation also takes place during this period following wintering. In the low yielding season, March and April recorded significantly lower yield compared to February and May. Hence it may be advisable to impose tapping break for these two months especially in the initial years of tapping considering the biotic and abiotic stresses the trees undergo during this low yielding season.

Performance of the individual clones during the two yielding seasons was also recorded (Table 4). During the low yielding season maximum yield was recorded in 86/120 (48.9 g $t^{-1}t^{-1}$) followed by RRII 105 (41.2 g $t^{-1}t^{-1}$) and 86/44 (37.2 g $t^{-1}t^{-1}$), and the lowest was in O 70 (20.9 g $t^{-1}t^{-1}$). Yield of 86/120 was superior to RRII 105 and RRIM 600 during the low yielding season. High yield of 86/120 during the low yielding season showed tolerance of this clone to the biotic and abiotic factors prevailing in the low yield season. During the high yielding season, highest yield was recorded in 86/44 (90.5 g $t^{-1}t^{-1}$), RRIM 722 (87.4 g $t^{-1}t^{-1}$), RRII 105 (87.4 g $t^{-1}t^{-1}$) and 86/120 (83.0 g $t^{-1}t^{-1}$) and the lowest yield was recorded in O 70 (38.0 g $t^{-1}t^{-1}$).

Significant monthly yield variations, suggests the need to develop season specific approach to crop extraction, and selection of clones that perform well in all seasons.

Rank sum based ranking was carried out for all the clones (Table 5). Ranking of clones

Table 5. **Ranking of clones based on growth and yield**

Clone	Girth (cm)	Yield (g $t^{-1}t^{-1}$) Overall yield	High yield season	Low yield season	BO-1	BO-2	BO-1 & BO-2	B1-1 Panel (2014- 2015)	Rank sum	Rank
RRIM 712	77.6	55.3	66.4	35.5	47.4	60.2	53.2	60.8	36	5
RRIM 722	72.1	69.1	87.4	34.8	66.5	77.3	71.4	62.9	34	4
RRIM 728	76.2	45.9	53.9	29.1	42.1	55.4	48.1	35.3	59	7
55/180	79.8	39.4	48.6	22.2	31.7	51.3	40.6	36.4	76	11
86/44	75.2	72.5	90.5	37.2	74.5	78.4	76.2	56.2	23	2
86/120	96.3	70.0	83.0	48.9	60.9	86.4	72.5	58.4	20	1
O 65	93.3	42.8	51.7	29.2	30.9	53.2	41.0	53.5	62	8
O 70	77.4	31.9	38.0	20.9	27.1	39.5	32.7	27.9	90	12
RRII 50	77.4	42.2	51.2	23.7	39.5	51.5	45.0	28.8	71	10
RRII 51	77.1	46.2	57.4	27.3	36.4	61.4	47.7	41.2	55	6
RRIM 600	73.9	43.2	52.4	28.7	35.3	56.4	44.9	35.8	68	9
RRII 105	73.3	70.1	87.4	41.2	60.3	90.1	73.8	54.7	29	3

for each yielding phase such as BO-1 panel, BO-2 panel, combined yield in the two panels, yield in the BI-1 panel and long tern overall yield was done. Girth of the clones was also ranked. Ranking based on yield and girth showed the pipeline clone 86/120 in rank one followed by another pipeline clone 86/44. RRII 105 was in rank three followed by two of the Malaysian clones RRIM 722 in rank four and RRIM 712 in rank five.

CONCLUSIONS

Clones evaluated in the trial, both introduced exotic clones and indigenous clones, revealed their potential in BO-1, BO-2 and BI-1 panels, and overall yield. In the mature phase highest girth was recorded in the hybrid pipeline clone 86/120. Highest yield in the BO-1 panel was recorded in the pipeline clones 86/44, 86/120 and RRIM 722. In the BO-2 panel, clones 86/44, 86/120 and RRIM 722 were top yielders and were on par with RRII 105. The same trend was observed in the yield pattern after the completion of the first two panels and the overall yield after thirteen years of tapping. These three clones also showed a stable performance across years. Two distinct yield seasons were seen in the study. Decline in yield from February to May was significant compared to the yield from June to January as evidenced in the yield shift in the preceding month of February and succeeding month of May. During the stressful low yielding season highest yield was recorded in 86/120 which was superior to RRII 105. Yielding potential of clones in different tapping panels, and their stability over years combined with vigorous growth have revealed the superior performance of clones 86/120, 86/44 and RRIM 722, of which 86/120 is also performing as a latex timber clone.

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