PROSPECTS OF OPEN-POLLINATED PROGENIES IN *HEVEA* BREEDING

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Open-pollinated seeds are being used as supplementary genetic resources for Rubber Research Institute of Vietnam (RRIV) *Hevea* breeding program.These open-pollinated progenies over the years have shown good performance in small scale clone trials at different locations. In an attempt to enlarge genetic resources in *Hevea* breeding program, the open-pollination approach has been included in the RRIV's breeding program since 2008. High rubber yield combined with the acceptable growth of open-pollinated progenies in both early selection trials and small scale clonal trials at different locations suggested that these progenies would be potential genetic materials for *Hevea* breeding. The high genetic variance and high coefficient of heritability for studied characteristics indicated that good hybrids could be produced from high yielding and vigorous parents through open-pollination. In summary, the study establishes the prospects of open-pollinated progenies in *Hevea* breeding program.

Keywords: Broad-sense heritability, Hand-pollination, *Hevea brasiliensis*, Open-pollination, Selection, Variance

INTRODUCTION

Hand-pollination (HP) is the main method to produce genetic materials for *Hevea* breeding. However, low fruit set and subtle manipulation in the technique have become major limitations on genetic recombination. The problem for rubber breeders is how to take advantage of the large number of germplasm for *Hevea* breeding program. Low fruit set is a major limitation to genetic recombination in rubber breeding, (Tan, 1987; Clément Demange *et al*., 2007; Mydin *et al*., 2011). By contrast, open-pollinated progenies are diverse genetic resources because of varying recombination process due to outcrossing in *Hevea*. According to previous studies on biometrical genetics of *Hevea* (De Costa *et al*, 2000; Simmonds, 1986), this population had healthy growth and good yield due to the predominantly additive genetic control of growth vigor and yield. General combining ability (GCA) for these characteristics was recorded high (Mydin *et al*., 2010).

Since 1998, open-pollinated seeds have been initially collected as supplementary genetic resources for the RRIV's *Hevea*

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breeding program. These open-pollination progenies have exhibited good performance in small scale clonal trials (SSCT) at different locations. In an attempt to enlarge genetic resources for *Hevea* breeding, the open-pollination (OP) approach has been practised in the RRIV's breeding program since 2008. The open-pollinated seeds have been collected from promising female parents in the RRIV's Experimental Station at Lai Khe, Progenies of two sources, *i.e.* open-pollination and hand-pollination, were planted in Early Selection Trials (EST) as buddings every year. The aim of the paper is (i) to present agronomic performances of elite open-pollinated progenies in SSCTs at different locations; (ii) to review the results of recent ESTs planted from 2008 to 2010 at RRIV's Experimental Station and (iii) to estimate genetic parameters for main characteristics at the early stage.

MATERIALS AND METHODS

Early Selection Trials

In the study, data for 794 HP progenies and 458 OP progenies were collected from ESTs set up in the period of 2008 to 2010 at the RRIV's Lai Khe Experimental Station. Studied progenies were planted in fields of ESTs at 1.5 m x 1.5m spacing with four buddings per progeny. The experimental design for all trials was randomized complete block with two replications of two trees. These ESTs were established adjunctly in the same plot of flat and grey podzolic soil. Details of the crosses/female parents and their offspring are summarized in Table 1.

Girth measurement (cm) was taken at the height of 1 m above the ground before opening for tapping. Latex yield was recorded on a half spiral, third daily (S/2 d3) tapping system opened at the height of 60 cm above the ground, according to the modified Morris-Mann test. The first recording of latex yield was carried out at the end of dry season (October - December, 28 – 30 months after planting) and the second recording was at the beginning of rainy season (May - July, 36 – 38 months after planting). After discarding the first three tappings, two 5-tapping cycles were carried out for yield recording. The coagulated samples were air dried for at least one month until they gave the constant weight. The yield from each treatment was expressed in gram per tree per tapping (g $t^{-1}t^{-1}$).

Table 1. **Materials of early selection trials planted in 2008-2010**

Early selection trial	No. crosses (HP)/ No. female parents (OP)	No. progenies
Hand- pollination (HP)	150	794
EST 08	79	461
EST 09	46	262
EST 10	31	71
Open- pollination (OP)	45	458
EST 08	11	162
EST 09	17	220
EST 10	28	76

Oidium and *Corynespora* susceptibility

Severity of infection of leaf disease was graded from low susceptibility (1) to high susceptibility (5). Assessment of disease susceptibility was done according to the protocol by Crop Protection Division, RRIV. The assessment of all diseases was expressed as the percentage of infected progenies (Disease incidence, %).

Small scale clone trial

The common experimental design for all SSCTs was randomized complete block with 2 – 3 replications of 7 – 8 trees. The planting spacing was 7 m x 2.5 m (571 trees ha^{-1}) for trials at Lai Khe (ST LK 03, ST LK 04,

ST LK 05, ST LK 06 and ST LK 07) and 6 m x 3 m (555 trees ha^{-1}) for trials at Dau Tieng and LocNinh (ST DT 07, ST LN 04 and ST LN 06). Details of all SSCTs in different locations are summarized in Table 2.

Girth measurements were taken once a year during the immature period as well as at the mature period at the height of 1m above the ground. The height of the cut was opened at 130 cm from the ground. The tapping system was S/2 d3 without stimulation for first two tapping years and with stimulation from the third tapping year onwards. Yield was recorded by cup-coagulation method, once a month. Latex was coagulated with acetic acid solution on a normal tapping day and collected on the same day. The samples were air-dried for a month after collection and weighed.

Statistical analysis

Simple statistics such as mean, minimum, maximum and coefficients of variation were computed for yield and girth.

As the ESTs were not initially designed for biometrical genetic studies, two assumptions were made for estimation of genetic parameters, *i.e.* absence of gene interactions ($\sigma^2_I = 0$) and no interaction between genotype and environment ($\sigma^2_{ExG} = 0$).

The analysis using the following statistical model considered all variables (except mean) as random effects (Gonalves *et al*., 2005):

$$Y_{ijkl} = \mu + f_i + c_j + r_k + d_{kl}$$

where

Y_{ijkl} = observed value of the l^{th} plant in the k^{th} replication within the j^{th} clone

μ = general mean

f_i = effect of the i^{th}family

c_j = effect of the j^{th}clone

r_k = effect of the k^{th} replication

d_{kl} = effect of the l^{th} plant within the k^{th} plot

The total genotypic variance (σ^2_G) and phenotypic variance (σ^2_P) were obtained using the expressions:

$$\sigma^2_G = \sigma^2_f + \sigma^2_c$$

$$\sigma^2_P = \sigma^2_f + \sigma^2_c + \sigma^2_E$$

Where, σ^2_f = genotypic variance due to differences among families, σ^2_c = genotypic variance due to differences among clones, σ^2_E= environmental variance.

For estimation of genetic parameters, the hand-pollination group was analysed on full-sib progenies and the open- pollination

Table 2. **Details of small scale clonal trials at different locations**

Trial	Location (Plantation, province)	Detail of trial			Year of planting	Year of opening
		No. clone	No. rep.	No. trees $plot^{-1}$		
ST LK 03	Lai Khe, Binh Duong*	72	3	8	2003	2009
ST LK 04	Lai Khe, Binh Duong	77	3	8	2004	2010
ST LK 05	Lai Khe, Binh Duong	127	3	7	2005	2011
ST LK 06	Lai Khe, Binh Duong	84	3	8	2006	2011
ST LK 07	Lai Khe, Binh Duong	120	3	8	2007	2012
ST DT 07	Dau Tieng, Binh Duong	66	2	8	2007	2012
ST LN 04	LocNinh, BinhPhuoc	44	3	8	2004	2010
ST LN 06	LocNinh, BinhPhuoc	60	3	8	2006	2012

(*) Lai Khe, Binh Duong: RRIV Experimental Station; Tapping system: S/2 d3

group was analysed on half-sib progenies (Tuy *et al.*, 2005).

The heritability in broad-sense is defined as the ratio of genetic variance to phenotypic variance (Falconer, 1989) and expressed as: $h^2 = \sigma^2 G / \sigma^2 P$

RESULTS AND DISCUSSION

Agronomic performances of two progeny groups in 2008-2010 EST

Yield and growth

The yield performances of two progeny groups in 2008-2010 ESTs are presented in Table 4. Results derived from various ESTs showed that performances of open-pollinated groups were slightly higher than that of hand-pollinated ones as displayed in higher values of mean, maximum and percent of the progenies exceeding the control clone PB 260. This finding implies the possibility in yield improvement of open-pollinated group. However, clear difference between two groups was not recorded for yield variability (Table 4). The results would give the chance for effective exploitation of open-pollinated progenies as supplementary genetic materials for *Hevea* breeding program regarding latex yield improvement.

There was also no difference between two progeny groups in growth. The variability for growth was lower than that for yield. Both groups exhibited rather good growth with at least more than 50% of progenies having girth exceeding PB 260. The results indicated certain improvement in growth of both progeny groups (Table 5).

Oidium infection

In general, progenies of studied groups were not susceptible to *Oidium* (Fig. 2), most progenies in the trials had resistance *i.e.*low or very low infection with the disease. However, there was also difference between

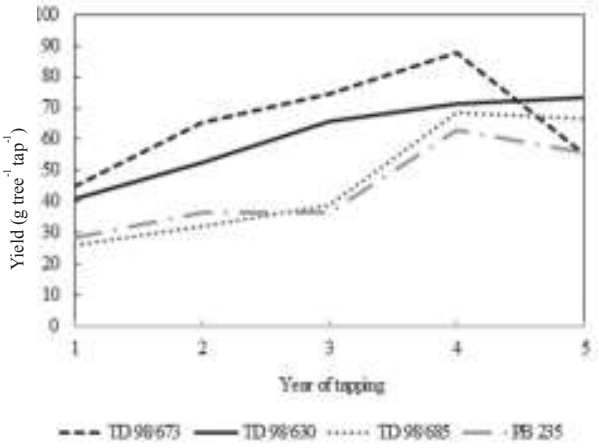

Fig. 1. Yield of promising open-pollinated progenies in ST LK 03 trial

two progeny groups for *Oidium* infection, the disease infection of the open-pollinated group was less than that of the hand-pollinated group. It could be due to the nature of higher genetic variation in the open-pollinated resource. However, this should be treated with caution because of the limitations by the ESTs.

Corynespora infection

Similar to *Oidium* infection, both progeny groups were not susceptible to *Corynespora* (Fig. 3), most progenies in the

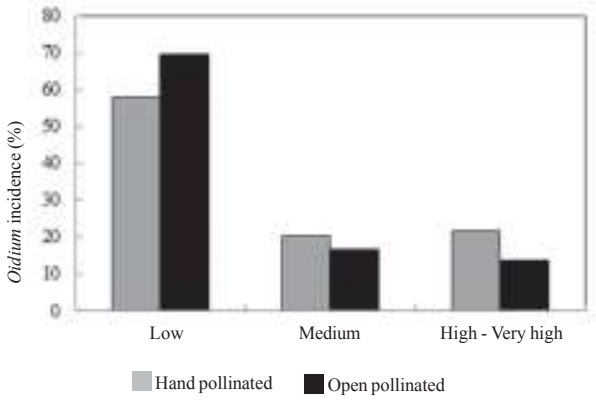

Fig. 2. *Oidium* incidence in two progeny groups in early selection trials
Resistance – Low infection (Grade of 0-2), Medium infection (Grade of 3), High – Very high infection(Grade of 4-5)

Table 3. **Rubber yield and growth of elite open-pollinated progenies in small scale clonal trials**

Trial	Progeny	Mean yield of the first tapping years			Girth at opening		Girth increment on tapping	
		g $t^{-1}t^{-1}$	Check clone (%)	Rank	cm	Check clone (%)	cm	Check clone (%)
ST LK 03 (5 years)	TD 98/673	65.7	149.3	1/72	47.7	105.2	1.7	56.2
	TD 98/630	60.9	138.4	4/72	45.3	99.8	1.9	99.9
	TD 98/685	46.3	105.2	13/72	48.0	105.8	2.4	124.1
ST LK 04 (4 years)	TD 98/517	60.3	163.2	2/77	41.4	96.8	2.4	98.9
	TD 98/1149	55.4	150.0	3/77	44.8	104.8	1.9	75.9
	TD 98/40	43.8	118.5	16/77	43.3	101.4	2.8	114.0
ST LK 05 (3 years)	TD 00/469	64.2	175.7	2/127	44.2	94.6	1.9	110.6
	TD 00/360	51.1	139.9	10/127	49.6	106.3	1.4	79.5
ST LK 06 (3 years)	TD 00/469	58.2	162.1	1/84	38.7	95.0	3.1	116.5
	TD 98/298	55.4	154.1	2/84	44.0	107.9	2.7	101.9
	TD 98/370	55.1	153.4	3/84	35.3	86.6	4.0	151.2
ST LK 07 (2 years; 63/120 clones under tapping)								
	TD 02/501	44.6	196.3	1/120	41.7	107.5	3.6	102.1
	TD 02/516	44.4	195.8	2/120	44.3	113.9	4.0	113.2
	TD 02/2054	44.1	194.3	3/120	41.1	105.7	3.9	110.3
	TD 02/80	42.4	186.9	4/120	39.9	102.8	3.1	89.0
	TD 02/1106	39.8	175.5	5/120	40.8	105.0	3.5	99.0
	TD 02/2161	39.5	174.2	6/120	40.2	103.4	3.5	100.6
ST LN 04 (4 years)	TD 98/517	57.5	134.2	2/44	50.5	103.1	2.1	145.2
ST LN 06 (3 years)	TD 00/469	55.0	154.0	1/60	50.4	102.1	1.3	129.6
	TD 00/439	49.8	139.6	2/60	53.8	108.9	1.5	145.5
	TD 00/678	43.4	121.6	8/60	50.7	102.8	1.9	179.8
ST DT 07 (2 years)	TD 98/298	41.6	159.0	4/66	48.5	104.7	2.3	108.0

Rank of the treatment/Total of treatments in the same trial

Check clones: PB 260 (ST DT 07); RRIV 106 (STLK 07); PB 235 for other trials.

trials had resistance or low infection with the disease. In general, there was difference between two progeny groups for *Corynespora* infection.

Performance of elite open-pollinated progenies in various SSCTs at different locations is presented in Table 3. They gave high to very high latex yield, ranging from 105.2 to 196.3 per cent that of the control clone for the first 2 to 5 tapping years. The good yield performance of several progenies, namely TD 98/298 and TD 00/469 and TD 98/571, was also repeated in the second trials at other locations (Table 3). This suggested these progenies would have stable yielding capability in different

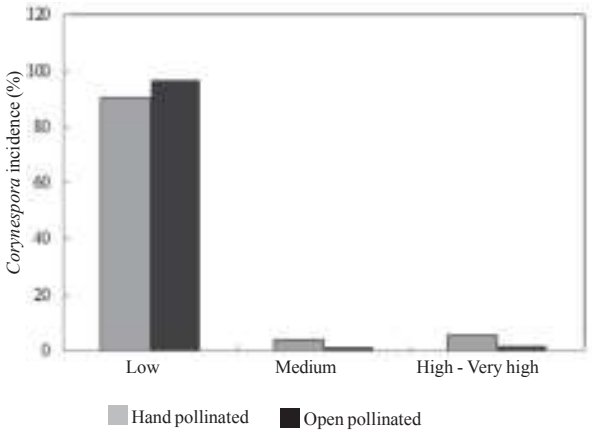

Fig. 3. *Corynespora* incidence in two progeny groups in early selection trials
Resistance – Low infection (Grade of 0-2), Medium infection (Grade of 3), High –Very high infection (Grade of 4-5)

environments, which could be promising for further selection of rubber clones for various rubber growing regions in the country.

The yield trends for elite clones on ST LK 03 trial are shown in Figure 1. In general, yield of these progenies tends to increase and stabilize with increase in the age of tree although there was a small drop in yield at the fifth year of tapping. At the fourth year of tapping, yield of these progenies increased significantly due to stimulation. Yield of TD 98/673 declined strongly at the fifth tapping year due to the high rate of tapping panel dryness.

Above findings show that the open-pollinated progenies have potential yield and respond to stimulation from the early years of tapping. Along with yield performances, open-pollinated progenies also have acceptable growth with girth at opening and girth increment per year of tapping slightly exceeding or equivalent to that of control clone (Table 3). The high yield combined with the acceptable growth of open-pollinated progenies suggested that these progenies are potential genetic resources for *Hevea* breeding program as also suggested in earlier reports from India (Mydin *et al.,* 1996; Mydin *et al*., 2010).

Variance components of two progeny groups for yield and girth

Analysis of variance components of two progeny groups for yield and girth are illustrated in Table 6. The magnitude of genetic variance as expressed by heritability coefficient varied according to the experimental populations, mating systems and the experimental design. In general, the studied progenies were high

Table 4. **Rubber yield of two progeny groups from early selection trials**

Early Selection Trial	Yield				
	Mean ($gt^{-1}t^{-1}$)	CV (%)	Max ($gt^{-1}t^{-1}$)	Min ($gt^{-1}t^{-1}$)	Progenies over PB 260 (%)
Hand-pollinated					
EST 08	2.0	62.3	6.33	0.01	19.9
EST 09	1.7	43.0	4.4	0.01	16.4
EST 10	2.2	63.4	6.6	0.01	62.9
Open-pollinated					
EST 08	2.1	58.6	6.8	0.01	28.2
EST 09	1.8	43.1	4.9	0.01	29.0
EST 10	2.8	57.4	9.4	0.01	84.0

Table 5. **Girth of two progeny groups in early selection trials**

Early Selection Trial	Girth				
	Mean (cm)	CV (%)	Max (cm)	Min (cm)	Progenies over PB 260 (%)
Hand-pollinated					
EST 08	15.0	11.9	20.1	9.3	60.2
EST 09	12.9	13.6	19.0	9.1	80.1
EST 10	15.4	15.6	20.2	8.4	84.0
Open-pollinated					
EST 08	14.8	11.8	20.3	10.6	51.6
EST 09	12.7	14.5	19.0	8.7	74.8
EST 10	15.4	17.5	21.1	7.2	92.08

in genetic variability which was mainly governed by the variation due to family. The variation due to family accounted for 43.3 to 47.1 per cent and 41.7 to 47.1 per cent of the total variability for yield and girth, respectively. This finding would indicate that it is possible to use nursery characteristics for genetic study to identify good parents and to accelerate their use.

Genotypic and phenotypic variations and broad-sense heritability for yield and girth

Values of genotypic, phenotypic variations and broad-sense heritability for yield and girth in ESTs are presented in Table 7. The genetic variation accounted for 65.2 to 68.3 per cent and 58.6 to 60.4 per cent of the total variability for yield and girth, respectively. The high genetic variation in the progenies population showed the possibility in early selection for studied characteristics of both progeny groups.

In general, the coefficients of broad-sense heritability for studied characteristics were rather high, ranging from 0.65 to 0.68 and 0.59 to 0.60 for yield and girth, respectively. The results suggested that good hybrids could be produced from high yielding and vigorous parents. Higher estimates of

Table 6. **Variance component (%) of two progeny groups for yield and girth**

Progeny group	Variation source	Yield		Girth	
		Mean of square	(%)	Mean of square	(%)
Hand-pollinated	Families (F)	93,955.71 **	43.30	10.73 **	41.71
	Clones (C)	47,546.65 *	21.91	4.34 *	16.86
	Errors (E)	75,468.77	34.78	10.65	41.43
Open-pollinated	Families (F)	187,786.86 **	47.08	18.39 **	47.13
	Clones (C)	84,498.98 *	21.19	5.18 *	13.26
	Errors (E)	126,543.76	31.73	15.46	39.61

*Significant at P≤ 0.01; **Significant at P ≤ 0.001

Table 7. **Genotypic and phenotypic variations and broad-sense heritability for yield and girth**

Progeny group	Yield		Girth	
	Mean of square	%	Mean of square	%
Hand-pollinated				
1^2	141,502.35	65.2	15.06	58.6
1^{2G}	75,468.77	34.8	10.65	41.4
1^{2E}	216,971.12	100.0	25.72	100.0
h^{2P}	0.65		0.59	
Open-pollinated				
1^2	272,285.84	68.3	23.57	60.4
1^{2G}	126,543.76	31.7	15.46	39.6
1^{2E}	398,829.60	100.0	39.02	100.0
h^{2P}	0.68		0.60	

heritability for rubber yield have been reported earlier too (Simmonds, 1989 ; Mydin *et al*.,2011) and this is supposed to be a reflection of the youth of the crop which has not reached the advanced generations of selection compared to the original population of *Hevea* that was introduced to South East Asia.

CONCLUSION

The high yield combined with acceptable growth of open-pollinated progenies in both ESTs and SSCTs at different locations suggested that these progenies are potential genetic resources for *Hevea* breeding program, in addition to the resource created by the conventional approach, the hand-pollination. The high genetic variance and rather high coefficient of heritability for studied characteristics indicated that good hybrids could be produced from high yielding and vigorous parents through open-pollination. In summary, the study showed the prospects of open-pollinated progenies for polycross breeding in *Hevea*.

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