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A Study on Nursery Selection in Hevea *Breeding*†

H TAN*

This paper describes a study on nursery selection carried out at the Rubber Research Institute of Malaysia. A sample of seedling progenies and their corresponding buddings (clones) of a family PB 5/51 × RRIM 600 was selected for this study. Nursery characters, namely nursery yield (NY), nursery yield per girth (NY/NG), nursery girth (NG), latex vessel density (LVD), plugging index (PI) and virgin bark thickness (VB), and mature yield over five years of tapping of the selected genotypes were investigated for their relationships and selection efficiencies.

Among the nursery characters, NY was positively correlated with NY/NG and LVD but was negatively correlated with PI. NY/NG was correlated with LVD and PI but not with NG. NG was also found correlated with LVD and VB. There was no correlation detected between the yield parameters (NY and NY/NG) and VB.

The nursery characters which were found to correlate with the mature yield included NY, NY/NG, LVD and PI. The three correlated characters (NY or NY/NG with LVD and PI) jointly accounted for 45% of the variations of the mature yield.

Comparison of selections based on single or a combination of two and three nursery characters for mature yield suggested that NY or NY/NG would be adequate and practical to be adopted as early yield selection criteria. LVD and PI could enhance the selection efficiency when considered together with the above parameters marginally. However, considering the extra efforts, costs and manpower and facilities required for the measurement of these two additional characters and the marginal gains in the selection efficiency, these two additional selection parameters were only recommended for the refinement of selection for top-yielders

The implication of the findings are discussed in relation to the early selection strategy for Hevea *improvement programme.*

The use of nursery information for the selection of progenies to be tested in small-scale clone trials started only after Phase III (1947–1958) of the breeding programme at the Rubber Research Institute of Malaysia (RRIM)[1]. During the early phases, Phase I (1928–1931) to Phase III, almost all the progenies produced were cloned for evaluation. In Phase IV (1959–1965),

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early selection was introduced and the selection criteria for cloning was primarily based on girth, height and branching habits. From Phase V (1966–1972) and onwards, nursery yield has been used as the main character in addition to the above characters, to select progenies for cloning. Other characters such as bark thickness, latex vessel number, latex vessel density, plugging index and disease tolerance were also considered. By applying nursery selection, the proportion of progenies selected for testing in the small-scale clone trial (SSCT) has been reduced from almost 100% to about 25% or less. This implies savings on large experimental areas, cost and labour in clonal evaluation. It also helps in the shortening of breeding and selection cycle.

This paper reports the results of a study using nursery characters for clonal selection. It also discusses the implications of the findings in relation to the early (nursery) selection strategy in *Hevea* improvement.

MATERIALS AND METHODS

The materials used for this study were selected progenies of a large family PB 5/51 × RRIM 600 produced in the 1966 RRIM breeding programme. About 250 were selected for test-tapping based on vigour of the 2000 progenies. From the result of the test-tapping, about 150 progenies were further selected for cloning in the SSCT. In the nursery trial, all the progenies were planted at 1.22 m × 1.22 m in a family block along with other families produced in the same batch of breeding programme. Test-tappings of the selected progenies were done at two years after planting on the S2/d3 tapping system according to the modified Haemaker - Morris - Mann technique. A total of 30 tappings were carried out and the nursery yield was expressed as g/tree/10 tappings. Diameters were measured at first and second year after planting. Nursery girth was measured before tapping commenced. Bark thickness, latex vessel number and density and plugging index were performed after the test-tapping.

In the SSCT, the 150 selected progenies along with other selected genotypes from the nursery were planted in single-row plots of eight trees each. A simple lattice design with two replications was used. Planting distance was 3.66 m × 7.62 m. Tapping was carried out five-and-a-half-years after planting.

The following characters were included in this study:

- Nursery characters: nursery yield (NY), nursery yield per girth (NY/NG), girth before tapping (NG), virgin bark thickness (VB), latex vessel density (LVD) and plugging index (PI).
- Mature character: mean yield over five years of tapping (MY 5).

Statistical Analyses

A simple correlation was used to study the relationship among characters. For yield prediction study, simple linear regression, multiple and stepwise multiple linear regression based on the least square method were carried out. These analyses were performed using the SPSS package.

RESULTS

To study the predictability of mature yields using nursery characters, the following approaches were used:

- Relationship studies between nursery characters to help identify characters useful for the prediction.

- Relationship studies between mature yield and nursery characters for identification of the associated nursery characters, and
- Comparison of common high yielding selections based on mature yield and nursery characters to illustrate the effectiveness of nursery selection.

Correlation between Nursery Characters

The correlation coefficients among the selected nursery characters studied are given in *Table 1*. Nursery yield (NY) was positively correlated with the following characters in descending order of magnitude: nursery yield per girth (NY/NG), nursery girth (NG) and latex vessel density (LVD), but was negatively correlated with plugging index (PI). Similar to nursery yield, nursery yield per girth was also correlated with the above characters except nursery girth. In addition, the nursery girth was positively correlated with latex vessel density and bark thickness while the latter two characters were also correlated with each other. There was, however, no correlation between the yield parameters (NY, NY/NG) and bark thickness (VB).

Correlation between Nursery and Mature Characters

Two sets of analyses were carried out. The first set involved a larger sample size (n=127) with only a few nursery characters *viz.* nursery yield, nursery girth and nursery yield per girth (*Table 2*). The second set dealt with a smaller sample size (n=39) involving all the nursery characters mentioned earlier (*Table 3*).

In *Table 2*, among the three nursery characters studied, nursery yield per girth and nursery yield were positively correlated with mature yield. The degree of association of the nursery yield per girth appeared to be slightly stronger than nursery yield in relation with mature yield. No correlation was found between nursery girth and mature yield.

In *Table 3*, among all the nursery characters studied, nursery yield, nursery yield per girth and latex vessel density were positively correlated with mature yield. However, plugging index and mature yield was negatively correlated. In addition, there was no correlation between nursery girth and bark thickness with the mature yield.

Multiple Linear Regressions of Mature Yield on Nursery Characters

Simple and multiple linear regressions of mature yield over five years on nursery yield, nursery yield per girth, nursery girth and their combinations are presented in *Table 4*. It was shown that nursery yield and nursery yield per girth could account for about 6.7% and 11 5% of yield variations in the mature stage, respectively. Nursery girth alone, however, was a very poor predictor for mature yield. However, when nursery girth combined with nursery yield, they were able to account for about 10.1% of the variations in the mature yield. The magnitude of R^2 for this combination (nursery yield and nursery girth) was higher than that for nursery yield alone, but close to that for nursery yield per girth. Nursery girth did not give additional predictive power, when considered together with nursery yield per girth.

In another study, stepwise regressions were performed for mature yield (MY 5) on correlated nursery characters *i.e.* NY, NY/NG, PI and LVD (*Table 5*). This was aimed to study the

TABLE 1. CORRELATION AMONG NURSERY CHARACTERS OF SELECTED PROGENIES (N=39) OF PB 5/51 × RRIM 600

Characters	Nursery yield	Nursery yield per girth	Nursery girth	Latex vessel density	Plugging index
Nursery yield per girth	0.89***				
Nursery girth	0.60***	0.24^{NS}			
Latex vessel density	0.57***	0.46**	0.46**		
Plugging index	–0 50**	–0 56***	-0.10^{NS}	$-0\ 14^{NS}$	
Bark thickness	0.17^{NS}	0.05^{NS}	0.32*	0.37*	0.32*

*, ** and ***· P<0 05, 0.01 and 0.001, respectively
NS: Not significant at P<0.05

TABLE 2 CORRELATION COEFFICIENT BETWEEN NURSERY AND MATURE YIELD OVER FIVE YEARS FOR SELECTED PROGENIES (N=127) OF PB 5/51 × RRIM 600

Characters	Mature yield
Nursery yield per girth	0.34***
Nursery yield	0.26**
Nursery girth	-0.05^{NS}

**, *** P<0.01 and 0.001, respectively
NS Not significant at P<0.05

relative importance and magnitude of the independent variables (the nursery characters) in accounting for the variation of the dependent variable, MY 5. In Group A equations, NY/NG was used first in the equation followed by PI and then LVD. NY/NG accounted for 31.8% while PI and LVD contributed additional 8.7% and 4.4%, respectively for the variation of the mature yield in subsequent stepwise regression equations. The three nursery characters (NY/NG, PI and LVD) jointly accounted for 45% of the mature yield variation. In Group B equation, NY, PI and LVD were considered for predicting MY 5. In this case, PI was used at the first step of the equation followed by LVD and NY. PI accounted for 30.9% followed by additional 11.0% and 1.6% for LVD and NY, respectively in accounting for MY 5 variation. The three characters, when taken together, accounted for 43.5% of the mature yield variation.

Comparisons of Selections in Nursery and Mature Stages

To demonstrate the effectiveness of nursery selection using nursery yield, nursery yield per

TABLE 3 CORRELATION COEFFICIENT BETWEEN NURSERY CHARACTERS AND MATURE YIELD OVER FIVE YEARS FOR SELECTED PROGENIES (N=39) OF PB 5/51 × RRIM 600

Characters	Mature yield
Nursery yield	0 52***
Nursery yield per girth	0 56***
Plugging index	–0 58***
Latex vessel density	0 40**
Nursery girth	0 08^{NS}
Bark thickness	0 06^{NS}

*,*** P<0 05 and 0 001, respectively
NS Not significant at P<0 05

TABLE 4 LINEAR REGRESSION OF MATURE YIELD OVER FIVE YEARS (MY 5) ON NURSERY CHARACTER(S) FOR SELECTED PROGENIES (N=127) OF PB 5/51 × RRIM 600

Equation	Dependent variable	Regression coefficient of independent variable: Nursery yield/girth	Nursery yield	Nursery girth	Intercept	R^2(%)
1	MY 5	24 79** (6 153)			22 07	11 5
2	MY 5		0 62** (0 208)		27 15	6 7
3	MY 5			–0 18^{NS} (0 342)	42 75	0 2
4	MY 5	24 75*** (6 171)		–0 17^{NS} (0 323)	26 74	11 7
5	MY 5		0 84*** (0 229)	–0 78* (0 363)	44 37	10 1
6	MY 5	42 01^{NS} (25 289)	–0 65^{NS} (0 929)	+0 30^{NS} (0 744)	14 32	12 1

Figures in bracket refer to standard error for the corresponding regression or partial regression coefficients
*, **, *** P≤0 05, 0 01 and 0 001, respectively
NS Not significant at P≤0 05

TABLE 5. STEPWISE MULTIPLE REGRESSION OF MATURE YIELD (MY 5) ON CORRELATED NURSERY CHARACTERS FOR SELECTED PROGENIES (N=40) OF PB 5/51 × RRIM 600

Step/Group	Dependent variable	Regression coefficient of independent variable			Intercept	Proportion reduced	R^2 (%)	DF
		Nursery yield/girth (NY/NG)	Plugging index (PI)	Latex vessel density (LVD)				
Group A								
Step								
1	MY 5	44 47*** (10 561)			9.96	31.8	31.8	38
2	MY 5	29.23* (11 940)	−2.91* (1.247)		28 95	8.7	40.6	37
3	MY 5	18 77^{NS} (13 157)	−3 23* (1 230)	+0 03^{+} (0 019)	27 82	4 4	45.0	36
Group B								
Step		PI	LVD	NY	Intercept	Proportion reduced	R^2 (%)	DF
1	MY 5	−4.58*** (1 110)			52.12	30.9	30.9	38
2	MY 5	−4 19** (1.042)	+0 044* (0.017)		39 02	11 0	41.9	37
3	MY 5	−3.59*** (1 202)	+0.03^{NS} (0 021)	+0.41^{NS} (0.402)	33 43	1.6	43 5	36

Figures in bracket were standard errors of corresponding regression or partial regression coefficients

+, *. **, *** P≤0 10, 0 05, 0 01 and 0 001, respectively

girth and nursery girth, comparisons of progenies selected from a sample of 127 progenies in the nursery and mature stages were made. *Table 6* summarises the results based on three arbitrary selection pressures (10%, 20% and 30%). Among the three nursery characters used as selection criteria, nursery yield and nursery yield per girth were found to be more useful than nursery girth in predicting mature yield performance as expected from correlation studies. There were relatively more common selections in using yield and nursery yield per girth than nursery girth when compared with selections based on mature yield under the three selection pressures.

In a similar study (*Table 7*), which involved NY, NY/NG, PI, LVD and mature yield a

TABLE 6. NUMBER AND PERCENTAGE OF COMMON SELECTIONS BASED ON NURSERY CHARACTERS AND MATURE YIELD (MY 5) OF PROGENIES (N=127) FROM FAMILY PB 5/51 × RRIM 600

Selection criteria	Proportion selected (%)	Number in each fraction	Common selection for MY 5 Number	%
Nursery yield/girth	10	13	2	15
	20	25	6	24
	30	38	13	34
Nursery yield	10	13	3	23
	20	25	8	32
	30	38	14	37
Nursery girth	10	13	1	8
	20	25	4	16
	30	38	8	21

TABLE 7 NUMBER AND PERCENTAGE OF COMMON SELECTIONS BASED ON NURSERY CHARACTERS AND MATURE YIELD (MY 5) OF PROGENIES (N=40) FROM FAMILY PB 5/51 × RRIM 600

Selection criteria	Common selections for MY 5 under three selection pressures					
	10%		20%		30%	
	Number	%	Number	%	Number	%
NY	1	25	4	50	7	58
NY/NG	1	25	3	38	6	50
PI	2	50	4	50	8	67
LVD	2	50	5	63	5	42
NY, PI	1	25	4	50	9	75
NY/NG, PI	1	25	4	50	7	58
NY, LVD	2	50	4	50	6	50
NY/NG, LVD	1	25	4	50	7	58
PI, LVD	3	75	6	75	9	75
NY, PI, LVD	3	75	5	63	9	75
NY/NG, PI, LVD	2	50	5	63	7	58

Number in each fraction for 10%, 20% and 30% selection pressures were 4, 8 and 12, respectively reasonable proportion of the high yielding selections in the mature stage could be found in the selections using the individual nursery characters as early selection criteria. PI and LVD, independently, appeared to be better nursery predictors for mature yield than NY or NY/NG. Under 10% selection, they were able to select two out of four top-yielders in the mature stage as compared to one out of four by using NY or NY/NG. However, this predictive advantage could not be maintained under 20%–30% selection pressure. The number of top selections common to the mature stage have increased by about two times and the selection efficiencies of all the individual correlated nursery characters were fairly close.

When joint selections were made using a combination of these three nursery characters, the selection efficiency did not show significant improvement in most cases. The joint selection which deserved attention, perhaps, was the use of nursery yield, plugging index and latex vessel density together in selecting future high yielders under 10% selection criteria.

DISCUSSION AND CONCLUSION

Among the three nursery characters studied, nursery yield and nursery yield per girth were significantly correlated with mature yield over five years of tapping. This suggests that these two characters, could be satisfactory predictors for mature yield. Nursery girth was not correlated with mature yield but it could play a significant role when considered together with nursery yield for selection. The significant negative partial regression coefficient for nursery girth and positive partial regression coefficient for nursery yield in the multiple linear regression for predicting mature yield imply a preference of selecting progenies with smaller girth among those having similar nursery yield. The character, nursery yield per girth which takes yield and girth into consideration, appears to be a slightly better predictor compared to nursery yield alone. However, comparing the selections *using nursery yield per girth and nursery yield* as predictors for mature yield, the apparent advantage of the former character was not evident. There were almost equal number of common progenies selected as high yielders (based on five years' yield) in the mature stage using these two nursery characters separately.

To be effective in nursery selection for mature yield prediction, *Hevea* breeders would have to choose one or more nursery characters showing very high correlations with mature yield. Although a significant positive correlation was obtained for nursery yield per girth and nursery yield with mature yield, the degrees of association were relatively low. Thus, only a fraction of the high yielders in the mature stage would be included by using nursery yields (NY and NY/NG) as selection criteria. The other nursery characters (PI and LVD) which were correlated to the mature yield did not contribute to the efficiency of selection for mature yield to any great extent. The two characters, however, were only able to provide some improvement in terms of selection efficiency when combined jointly with nursery yield. This is perhaps not surprising, because both the nursery characters (PI and LVD) were components contributing to nursery yield.

There were several studies on yield prediction and early selections as shown by Tan[2]. Among these characters considered were nursery yield[3], latex vessel system in the bark[3] and leaf as revealed by Huang *et al.*[4], physiological characters: plugging index[3] or bursting index[5] and photosynthetic rates according to Samsuddin *et al.*[6]; biochemical attributes such as rubber hydrocarbon in petiole and leaf[7], nucleic acids[8], cotyledon oil[9], and pH[5]; chemical attributes: latex constituents such as N, P, K *etc*[3]; and morphological characters: leaf venation (Testam method of Amand)[10] and stomata number[11]. Among these parameters, only nursery yield, plugging index and latex vessel number or density were found to show consistent significant correlations with yield of the mature trees[4,12].

While considerable future achievements could be anticipated from research on assisted selection using molecular markers, rubber breeders have to make use of the available information to formulate their selection strategy.

In some research institutions, early nursery selection has been adopted in their *Hevea* improvement programme. It is prudent to practise a mild selection on the large number of seedling progenies using nursery yield initially to retain about 20%–30% of the seedling progenies in view of the low correlation between the nursery yield and the mature yield. Another round of selections based on other nursery characters, such as nursery vigour, bark thickness, disease tolerance, branching habit and tree forms, could be carried out to cull out trees with undesirable secondary characteristics. The more promising progenies could then be selected for plugging index and latex vessel density measurements, for further refinement in selection. These promising genotypes with favourable yield and secondary characteristics from the second round of selection would be retained for testing in small-scale clone trial while a few of the most promising genotypes in the final stage of selection would be tested on the promotion plots or large blocks to shorten the clonal testing cycle.

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